Threatened ecosystems of Myanmar

An IUCN Red List of Ecosystems Assessment

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2020 | Version 1.0

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Citation:
Murray, N.J., Keith, D.A., Tizard, R., Duncan, A., Htut, W.T., Hlaing, N., Oo, A.H., Ya, K.Z., Grantham, H. (2020) *Threatened Ecosystems of Myanmar. An IUCN Red List of Ecosystems Assessment. Version 1.0.* Wildlife Conservation Society. ISBN: 978-0-9903852-5-7

DOI
10.19121/2019.Report.37457

ISBN
978-0-9903852-5-7

Cover photos: © Nicholas J. Murray, Hedley Grantham, Robert Tizard

Numerous experts from around the world participated in the development of the IUCN Red List of Ecosystems of Myanmar. The complete list of contributors is located in Appendix 1. Please refer to the website for any recent updates: https://www.myanmar-ecosystems.org

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Foreword

Myanmar has always benefitted from our ecosystems for our wellbeing, our livelihoods and our economy. The Ministry of Natural Resources and Environmental Conservation (MONREC) strives for managing the natural resources including its forests and minerals as well as natural ecosystems for the benefit of both current and future generations. To ensure this future we must embrace Nature-based solutions (NBS). These solutions are actions to protect, sustainably manage, and restore our natural and modified ecosystems. That is why it is my pleasure to welcome Myanmar's first Red List of Ecosystems. Our red list will be a valuable tool to support our decisions and investments that simultaneously provide human well-being and biodiversity benefits.

Myanmar's Red List of Ecosystems has recognized and evaluated 64 ecosystem types. We now understand that almost half of our ecosystems are not threatened, and their intactness is clearly an important asset for Myanmar's future. Unfortunately, we also recognize that three of our ecosystems have changed so drastically that they could be very close to collapse; and can understand that eight of our ecosystems are Critically Endangered, nine are Endangered and twelve are Vulnerable so we need to ensure that these ecosystems are protected, restored and never lost.

In understanding these ecosystems, we have a much finer view of the incredible diversity Myanmar supports and how we can work towards reaching our Forest Policy (1995), our 30-year National Forestry Master Plan targets and the fulfilment of international commitments including Nationally Determined Contributions (NDCs), Sustainable Development Goals (SDGs), Aichi Biodiversity Targets, etc. MONREC also has a responsibility to manage our freshwater and saline wetlands and the marine realm. In protecting all of our natural resources we recognize the Sustainable Development Goals specially to conserve and sustainably use our oceans and marine resources as well as protecting, restoring and sustainably using our terrestrial ecosystems.

In Myanmar's Sustainable Development Plan (2018 - 2030), we clearly recognize the importance of natural resources and the environment for the posterity of the nation. Under this plan MONREC will ensure a clean environment together with healthy and functioning ecosystems as well as improving land governance and sustainable management of resource-based industries ensuring our natural resources dividend benefits all our people.

Myanmar's Red List of Ecosystems, our understanding of threats and this newly developed spatial information will strengthen the implementation of our plans and strategies and ensure a sustainable future for all of Myanmar.

H. E. U Ohn Winn
Union Minister
Ministry of Natural Resources and Environmental Conservation

Preface

Myanmar's Red List of Ecosystems is a tool to understand our threats and plan for conservation and sustainable management. Forests constitute the dominant ecosystems in Myanmar, and we are blessed with high forest cover (42.92%) and diversity, with 36 of our 64 ecosystems identified as forest and mangrove. These forests and biodiversity underpin a range of ecosystem services which are central to Myanmar's sustainable development, supporting human and resource needs, and contributing to a more stable climate. The loss of forests and our biodiversity leads to degradation and deterioration of ecosystem services and threatens Myanmar's irreplaceable ecological heritage.

We often discuss ecosystem services but this study documents Myanmar's terrestrial ecosystem typology and spatial distribution for the first time. This is one of the first ecosystem red lists developed within ASEAN and this will inform our implementation for decades to come to inform legislation, land-use planning, protected area expansion, monitoring and reporting, and ecosystem management. To sustain our forests and our biodiversity we need to sustainably manage all of these incredible ecosystems.

This report has supported Myanmar to reach Aichi Biodiversity Target 14: Ecosystems and essential services safeguarded under Myanmar's National Biodiversity Strategy and Action Plan (2015-2020); especially Target 14.1: By 2020, a rapid national ecosystem assessment has been carried out, identifying the status, values and trends of key ecosystems and the services they provide; Action 14.1.1: Quantify trends and pressures in the status of ecosystems and species populations that provide key ecosystem services, including distinct ecological and hydrological units such as the Ayeyarwady River Basin; and Action 14.1.2: Identify and map (using GIS) key ecosystem services through desktop analyses and participatory consultations involving multiple stakeholder groups, including, marginalized poor and vulnerable groups. These actions will support the Forest Department to reduce loss and restore degraded natural habitats, through sustained land use management and take action against those committing unlawful environmental damage to conserve and protect terrestrial, freshwater, coastal and marine areas through integrated resources planning and effective and equitable management.

Myanmar will use the Red List of Ecosystems to mainstream the protection of our environmental and biodiversity dividend into a range of planning and decision making. Whether on land, above ground or under water, a range of policy safeguards, legal protections and enforcement mechanisms will be deployed to ensure that unsuitable and destructive practices are phased out and replaced with more environmentally conscious approaches. Myanmar will also ensure that individuals and communities, including those most vulnerable, are included in decision-making processes at all levels.

This book will build a stronger foundation for achieving our Forest Policy and Sustainable Development Plan by 2030 and inform our actions for the post-2020 Global Biodiversity Framework for the Convention on Biological Diversity.

Nyi Nyi Kyaw, PhD
Director General
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Acknowledgements

We gratefully acknowledge the efforts of hundreds of scientists and practitioners who have contributed to the understanding of Myanmar's terrestrial ecosystems over the past two centuries. Our work is largely a synthesis exercise that would not have been possible without the dedication and contributions of those before us.

We also acknowledge all contributors to this project, particularly those who attended workshops in Myanmar over the last three years. Without input from a large and diverse expert group, the development of the Myanmar Ecosystem Typology, the ecosystem descriptions and application of the criteria would not have been possible. We also acknowledge the crucial support of field and GIS staff at WCS Myanmar. Contributors to this assessment are listed within each ecosystem assessment and in Appendix 1.

The work to develop an IUCN Red List of Ecosystems of Myanmar was made possible through the funding and support of Global Environment Facility *Strengthening Sustainability of Protected Area Management in Myanmar* (GEF #5159, UNDP #5162) implemented by United Nations Development Program and executed by the Myanmar Forestry Department and Wildlife Conservation Society.

Coordinating Organisations

Wildlife Conservation Society

The Wildlife Conservation Society is a globally distributed science-based conservation organization, producing and disseminating the information and knowledge necessary to inform and improve conservation and management action in wild places. With field conservation operations in nearly 60 nations and all of the world's oceans, WCS has supported governments and communities in the creation or expansion of 245 protected areas. WCS employs more than 170 PhD and DVM scientists and have trained and funded generations of field and zoo colleagues, many of whom are now leaders in conservation science, wildlife veterinary medicine, and curatorial research around the world.

Centre for Ecosystem Science, University of New South Wales

The University of New South Wales (UNSW) is a focal point for environmental research, and has research strengths that include conservation biology, environmental risk management and coastal and estuarine ecology. Hosted at UNSW, the Centre for Ecosystem Science (CES) is a world leader in ecosystem research, its application and communication of environmental change. It has well-established research strengths in environmental risk assessment, and has deep involvement in award winning ecosystem management programs such as the IUCN Red List of Ecosystems initiative. The CES has five major programs focused on biodiversity of ecosystems: wetlands and rivers; terrestrial ecosystems; marine ecosystems; remote sensing and GIS, and conservation policy and management.

အကျဉ်းချုပ်

နိုင်ငံအဆင့် မြန်မာ့ဂေဟစနစ် အကဲဖြတ်မှုစစ်တမ်းသည် ကမ္ဘာ့ပတ်ဝန်းကျင်ဆိုင်ရာ ရန်ပုံငွေအဖွဲ့ (GEF) ၏ ရန်ပုံငွေပံ့ပိုးမှုဖြင့် အကောင်အထည်ဖော်ဆောင်ရွက်နေသည့် "မြန်မာနိုင်ငံရှိ သဘာဝနယ်မြေများ စီမံအုပ်ချုပ်မှု ရေရှည်တည်တံ့စေရေးအား မြှင့်တင်ခြင်းစီမံကိန်း" ၏ လုပ်ငန်းရလဒ်တစ်ခု ဖြစ်ပါသည်။ မြန်မာ့ဂေဟစနစ် အကဲဖြတ်မှုစစ်တမ်းအတွက် အပြည်ပြည်ဆိုင်ရာ သဘာဝ ထိန်းသိမ်းရေးအဖွဲ့ (IUCN) အနီရောင်စာရင်း၏ ဂေဟစနစ်အမျိုးအစားများနှင့် စံနှုန်းသတ်မှတ်ချက်များဖြင့် မြန်မာ့ကုန်းတွင်းပိုင်းရှိ ဂေဟစနစ်များကို အကဲဖြတ်ဆန်းစစ်ခဲ့ပါသည်။ ယခု အစီရင်ခံစာတွင် မြန်မာ့ဂေဟစနစ် အမျိုးအစား (၆၄) ခု၏ ဂေဟစနစ်ဆိုင်ရာ သတင်းအချက်အလက်များ၊ အကဲဖြတ်ပုံ နည်းစနစ်များ၊ ဖော်ထုတ်တွေ့ရှိရမှုများကို အကျဉ်းချုပ် တင်ပြထားပါသည်။

ဂေဟစနစ်ပေါင်း ၆၄ ခုကို IUCN အနီရောင်စာရင်း ဂေဟစနစ် အမျိုးအစားများနှင့် စံသတ်မှတ်ချက်အရ အမျိုးအစားခွဲခြားကာ အကဲဖြတ် သုံးသပ်ခဲ့ပါသည်။ ပျက်သုဉ်း လုနီးပါး ဂေဟစနစ် (Critically Endangered Ecosystem Type) ၈ ခု (၁၂.၅%)၊ ပျက်သုဉ်းရန် အန္တရာယ်ရှိသော ဂေဟစနစ် (Endangered Ecosystem Type) ၉ ခု (၁၄.၁%) နှင့် ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်နိုင်သော ဂေဟစနစ် (Vulnerable Ecosystem Type) ၁၂ ခု (၁၈.၈%) တို့ပါဝင်သော ဂေဟစနစ် စုစုပေါင်း ၂၉ ခု (၄၅.၃%) ကို ပျက်သုဉ်းရန် ခြိမ်းခြောက်ခံနေရသော အခြေအနေ (Threatened Status) တွင် သတ်မှတ်ခဲ့ပါသည်။ သတင်းအချက်အလက် သေချာမှုမရှိသည့် အကဲဖြတ်ချက် ရလဒ်အချို့ကိုပါ ထည့်သွင်းစဉ်းစားခဲ့ရာ မြန်မာနိုင်ငံတစ်ဝှမ်း ဂေဟစနစ် ၄၅.၃% (၄၂.၂% - ၅၀.၀%) သည် ပျက်သုဉ်းရန် ခြိမ်းခြောက်ခံနေရသော အခြေအနေ(Threatened Status) ရှိကြောင်း သိရှိနိုင်ပါသည်။ ဂေဟစနစ်တစ်ခုဖြစ်သော ဧရာဝတီအလယ်ပိုင်း ရေလွှမ်းလွင်ပြင် မြက်ခင်းတော များကို ပျက်သုဉ်းပြီးဟု အတည်ပြုနိုင်ခဲ့ပါသည်။ ထပ်မံ၍ ဧရာဝတီ ကနစိုစိမ့်တောနှင့် တောင်ပိုင်း ရခိုင်ကုန်းမြင့် အမြဲစိမ်းမိုးသစ်တော ဂေဟစနစ်နှစ်ခုကို နောက်ဆုံး အကဲဖြတ်ချက် ရလဒ်အရ ပျက်သုဉ်းရန်အန္တရာယ်ရှိဟု သတ်မှတ်ခဲ့သော်လည်း ပျက်သုဉ်းခြင်းအဆင့် (Collapsed) ထိပင် သတ်မှတ်နိုင်ကြောင်း အကဲဖြတ်ထားပါသည်။

ဂေဟစနစ် ၂၈ ခု (၄၃.၈%) ကို ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး (Nearly Threatened or Least Concern) ဟု အကဲဖြတ် သတ်မှတ်ခဲ့ပါသည်။ သို့ရာတွင် ဂေဟစနစ် ၂၅ ခု (၄၄ %) အနက် ၁၁ ခုကို အချက်အလက်များ လုံလောက်စွာ ရရှိပါက ယခင်အကဲဖြတ်မှုအရ ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါးသည့် အဆင့် ကို တိုးမြှင့်နိုင်သည်။ ယင်း ၁၁ ခုကို အချက်အလက် ပြည့်စုံမှုမရှိ (Data Deficient) ဟု ပြန်လည် သတ်မှတ်ခဲ့ပါသည်။

မြန်မာနိုင်ငံ၏ ဂေဟစနစ် ၁၇ ခု (၂၆.၆%) ကို အချက်အလက် ပြည့်စုံမှုမရှိ (Data Deficient) ဟု သတ်မှတ်ခဲ့ပါသည်။ အချက်အလက် ပြည့်စုံမှုမရှိသည့် ဂေဟစနစ်အမျိုးအစားများဆိုသည်မှာ ယခင်သမိုင်း

မှတ်တမ်းများတွင် ဖော်ပြထားမှုများ ရှိခဲ့သော်လည်း လက်ရှိအကဲဖြတ်ဆန်းစစ်ရာတွင် သတင်းအချက်အလက် မလုံလောက်သော နေရာများ (ဥပမာ- ကျောက်ဆောင်ပေါ်သော တနင်္သာရီ ထုံးကျောက်ဂူများ) ကို ဆိုလိုပါသည်။ တစ်နည်းအားဖြင့် စံနှုန်း A နှင့် B ၏ အကဲဖြတ်ချက်များအထိ လုပ်ဆောင်နိုင်ရန် မြေပုံဖော်ထုတ်ရာတွင် အသုံးချနိုင်သည့် လုံလောက်သော ပျံ့နှံ့တည်ရှိမှု မှတ်တမ်းများ မရှိသေးသည့်နေရာများ (ဥပမာ - ဒီရေလွှမ်း မြက်ခင်းတောများ) ဖြစ်သည်။ ထို့အပြင် သတင်းအချက်အလက် မလုံလောက်သောကြောင့် ကွင်းဆင်းသုတေသန အဖွဲ့များ သွားရောက် လေ့လာအကဲဖြတ်ရန် အကန့်အသတ်ရှိသည့်နေရာများ (ဥပမာ - ရှမ်းကုန်းပြင်မြင့် မြက်ခင်း တောများ) ဖြစ်ပါသည်။ သို့ဖြစ်၍ သတင်းအချက်အလက် မလုံလောက်သော ဂေဟစနစ်များ ပျံ့နှံ့တည်ရှိမှုများကို အတည်ပြုရေးနှင့် အကဲဖြတ်ရေးလုပ်ငန်းများ ပိုမိုလုပ်ဆောင်ရန်လည်း အကြံပြုအပ်ပါသည်။

ယခု IUCN အကဲဖြတ်မှုစစ်တမ်းအရ မြန်မာ့ဂေဟစနစ်များသည် ပျက်သုဉ်းပျောက်ကွယ် သွားနိုင်သည့် စိုးရိမ်ဖွယ် အခြေအနေကို ရင်ဆိုင်နေရကြောင်း သုံးသပ်နိုင်ပါသည်။ အကဲဖြတ်ပြီးသည့် ဧရိယာများမှ သုံးပုံနှစ်ပုံနီးပါး (၆၄%) ကို သဘာဝဂေဟစနစ် အမျိုးအစားအဖြစ် မြေပုံရေးဆွဲ ခဲ့သော်လည်း ၎င်း၏ ထက်ဝက်ခန့် (၅၇.၈ %၊ ၂၄၇၅၀ စတုရန်း ကီလိုမီတာ) သည် ခြိမ်းခြောက် ခံနေရသော ဂေဟစနစ်အမျိုးအစားများ (ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ၊ ပျက်သုဉ်းရန်အန္တရာယ်ရှိနှင့် ပျက်သုဉ်းရန်အန္တရာယ်ကျရောက်နိုင်သည့် အဆင့်များ) တွင် ပါဝင်နေပါသည်။ ဆိုလိုသည်မှာ မြန်မာ့ ဂေဟစနစ်၏ သုံးပုံတစ်ပုံကျော်သည် ပျက်သုဉ်းမှုအတွက် ခြိမ်းခြောက်ခံနေရသည့် နေရာများထဲတွင် ပါဝင်နေခြင်းပင်ဖြစ်သည်။ ထို့အပြင် ယခု အကဲဖြတ်မှုအရ ခြိမ်းခြောက် ခံနေရသော ဂေဟစနစ် အမျိုးအစားများ ၏ ၃.၄ % သာလျှင် သဘာဝ ထိန်းသိမ်းရေး နယ်မြေများတွင် ကျရောက် နေကြောင်း ထောက်ပြထားပါသည်။ ဂေဟစနစ်များ ပြန်လည်ကောင်းမွန်ရန်နှင့် ပျက်သုဉ်းခြင်းအန္တရာယ် လျော့နည်းသွားရန် ထိန်းသိမ်းရေး ကြိုးပမ်းချက်များ ပိုမိုလိုအပ်မည် ဖြစ်ပါသည်။ ထို့ကြောင့် မြန်မာ့သဘာဝ ဂေဟစနစ်များ ပျက်သုဉ်းပျောက်ကွယ်ခြင်း အန္တရာယ်ကို လျှော့ချနိုင်ရန်အတွက် ကောင်းမွန်မှန်ကန်သည့် ထိန်းသိမ်းရေးစီမံချက်များ ရေးဆွဲအကောင်အထည်ဖော်ရာတွင် ယခုဖော်ပြပါ မြန်မာ့ဂေဟစနစ် အကဲဖြတ်မှု စစ်တမ်းကို ထည့်သွင်းစဉ်းစား အသုံးပြုရန် အရေးကြီးမည် ဖြစ်ပါသည်။

Summary

The *Myanmar National Ecosystem Assessment* contributes to the GEF funded *Strengthening Sustainability of Protected Area Management* in Myanmar project. To support the Myanmar National Ecosystem Assessment, Myanmar's terrestrial ecosystems were assessed under the *International Union for the Conservation of Nature (IUCN) Red List of Ecosystems Categories and Criteria*. This report summarises the methods and findings of the assessment, including detailed ecological descriptions of the 64 ecosystem types assessed.

A total of 64 ecosystem types were identified and evaluated under the IUCN Red List of Ecosystems categories and criteria. Twenty-nine (45.3%) ecosystems were assigned a threatened status, consisting of 8 (12.5%) Critically Endangered ecosystem types, 9 (14.1%) Endangered and 12 (18.8%) Vulnerable ecosystem types. One ecosystem type, Central Ayeyarwady Palm Savanna ecosystem types was confirmed as Collapsed. A further two ecosystem types, Ayeyarwady kanazo swamp forest and Southern Rakhine hills evergreen rainforest, were assessed with an upper plausible status outcome of Collapsed, although their final assessment was Critically Endangered.

Twenty-eight ecosystem types were assessed as Near Threatened or Least Concern. However, a post-assessment expert review by experts suggested that 11 of the 25 Least Concern ecosystems could qualify for a different assessment outcome if more data was available. These 11 ecosystems were reclassified to Data Deficient.

Thus, 17 of Myanmar's ecosystem types were classified as Data Deficient. Data deficient ecosystem types were primarily ecosystems for which there were historical records, but with insufficient published information to assess the criteria (e.g. Rocky Tanintharyi karst). Alternatively, there were insufficient distribution records to incorporate into our mapping workflow to allow assessments of Criterion A and B (e.g. Grassy saltmarsh). Data deficient ecosystems also tended to occur in regions that were inaccessible to field researchers due to travel restrictions (e.g. Shan limestone grasslands). Urgent further work to confirm the distribution and assess the status of these data deficient ecosystems is recommended.

This IUCN Red List of Ecosystems assessment has shown a dire situation for Myanmar's ecosystems. Of the area assessed, nearly two-thirds (64%, 426,628 km^2) is mapped as a natural ecosystem type, but of this over half (57.8%, 24,750 km^2) of remaining area contains a threatened ecosystem type (CR, EN or VU). This means over one third of Myanmar's land area contains threatened ecosystems. There needs to be an increase in conservation efforts to reverse this situation and slow the trajectory towards collapse for ecosystems that are not currently threatened. Conservation planning will be key to identify what are the best conservation actions and where to apply them to reduce the risk of collapse for Myanmar's natural ecosystems.

1. Introduction

1.1 Background

The *Myanmar National Ecosystem Assessment* contributes to the GEF funded *Strengthening Sustainability of Protected Area Management* in Myanmar project. To support the Myanmar National Ecosystem Assessment, Myanmar's terrestrial ecosystems were assessed under the *International Union for the Conservation of Nature (IUCN) Red List of Ecosystems Categories and Criteria*.

This report describes the development of the *IUCN Red List of Ecosystems for Myanmar*, which included:

- A detailed literature review of all published and unpublished material relevant to the status of ecosystems in Myanmar;
- The development of an ecosystem typology for Myanmar suitable for conducting a national scale IUCN Red List of Ecosystems assessment;
- Production of a guide to the terrestrial ecosystems of Myanmar to describe the units assessed under the red listing criteria (see *ecosystem descriptions*);
- More than 4000 km of reconnaissance transects traversed across Myanmar to collect georeferenced field data relevant to the mapping and assessment of Myanmar's ecosystems;
- A country-wide satellite remote sensing analysis to develop high resolution maps of Myanmar's terrestrial ecosystems from earth observation data;
- The analysis of spatial, biotic and abiotic changes to ecosystems to identify those ecosystems at the greatest risk of ecosystem collapse;
- Application of the IUCN Red List of Ecosystems categories and criteria to each ecosystem in the national typology to develop a list of threatened terrestrial ecosystems of Myanmar; and
- An expert review process for the ecosystem typology, descriptions and assessments.

To promote ecosystem conservation in Myanmar and support national-scale conservation planning and environmental reporting, all data and analysis code have been made open access (see data availability, see Appendices).

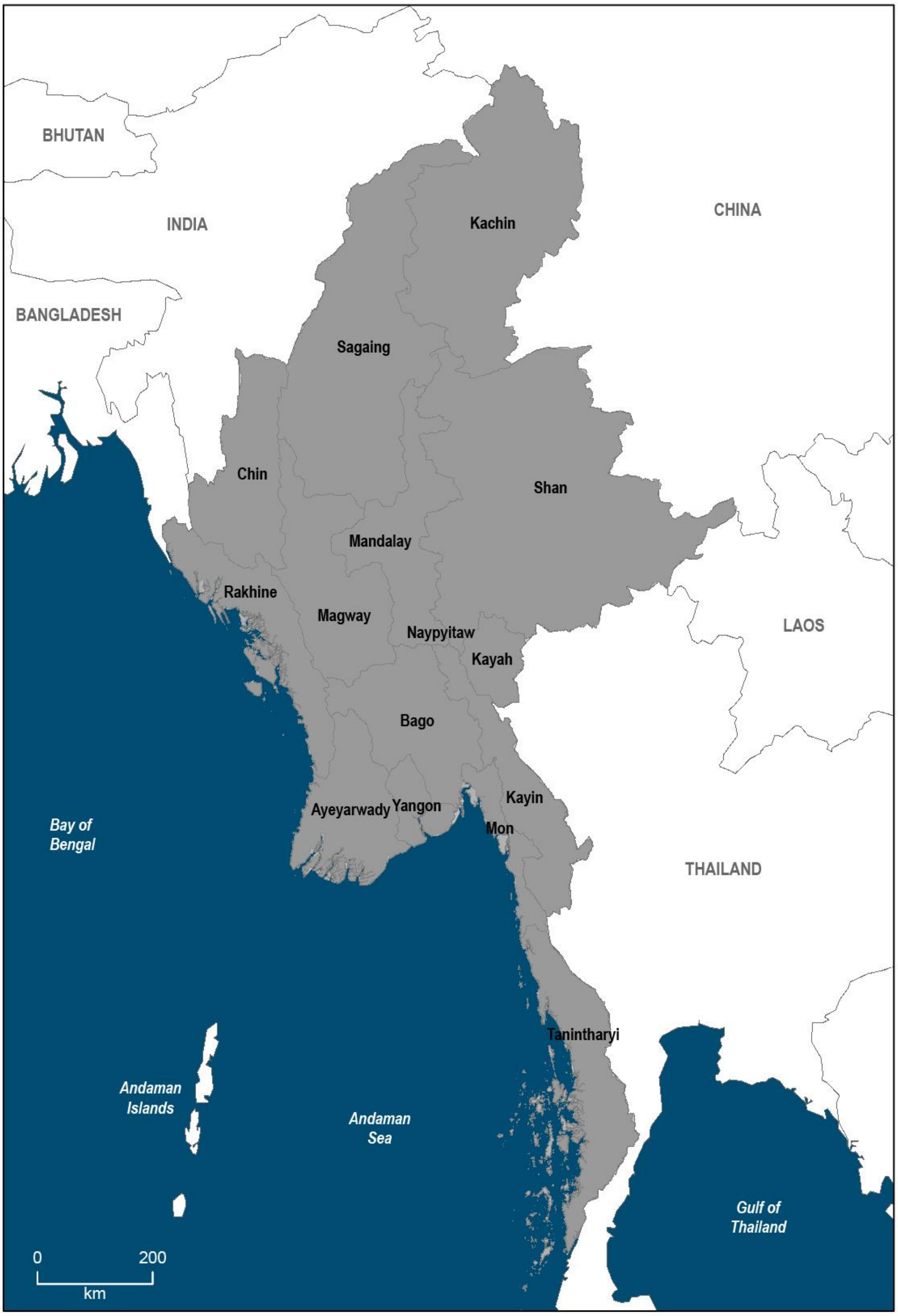


Figure 1.1 A map of Myanmar showing the area of assessment in grey.

1.2 The ecosystems of Myanmar: an overview

Myanmar (Figure 1.1) has a monsoonal climate throughout its full latitudinal range (9 - 28° N). The rain-bearing winds come from the south-west across the Bay of Bengal, with the wettest parts of the country being the Tanintharyi coast in the south and the Rakhine Bengal coast in the north receiving in excess of 5,000 mm of rainfall annually (Figure 1.2). The peak rainy season lasts from June to September, with rainfall persisting into October and November. December, January and February constitute the dry 'cool' season. Precipitation averages close to zero for the months December-March and, although temperatures are marginally cooler than in the rainy season, much of the country experiences significant rates of evapotranspiration and water deficits, especially in warmer months April and May at the end of the dry season prior to arrival of the monsoon.

The strong seasonal drought, alternating with reliable and abundant rain underpins ideal conditions for development of tropical dry forests, which dominate the majority of the country throughout most of the lowlands, foothills and plateaus. The dry forests are dominated by dipterocarps and teak, and usually have a mixed evergreen-deciduous phenology, with a variable proportion of tree canopies devoid of living leaves in the latter part of the dry season when water deficit is at its maximum. A patchy distribution of dense bamboo breaks through these forests is associated with human disturbance, but may also reflect legacies of natural disturbances such as tropical storms or rare fires.

The effect of the monsoon on water balance within ecosystems is profoundly modified by topography. Coastal lowlands receiving exceptionally high rainfall or areas where evapotranspiration is reduced by topographic shelter or elevation, avoid high water deficits, and may support tropical or subtropical evergreen rainforests. An important example of these forests is found in the Tanintharyi lowlands, where the rainforests are diverse and include Sundaic elements shared with equatorial forests of Malaysia and Indonesia. Other evergreen rainforests are found in the sheltered lowland valleys of the Chindwin and upper Ayeyarwady and on the western rim of the Shan plateau.

A few of the highest tropical mountains and escarpments receiving substantial orographic condensation may support tropical montane forests, including mist forests with low, even tree canopies and abundant arboreal bryophytes, lichens, orchids and other epiphytes. These ecosystems are poorly documented in Myanmar, but similar forests have been recorded in other tropical parts of southeast Asia (Ashton and Seidler, 2014).

In other parts of the country, topography reduces moisture inputs and exacerbates loss. The monsoon winds are intercepted by the Arakan Yoma which runs parallel to the west coast and separates the central region of Myanmar from the sea. This creates a marked rain shadow in the centre of Myanmar - the "Dry Zone" were rainfall is as low as 550 mm per annum and exposed flat topography results in major evapotranspirative moisture loss in the dry season. Here, the dominant ecosystems are grassy savannas dominated by acacias and thorny shrubs amongst a continuous ground layer of C4 tussock grasses. The grass layer cures in the dry season, allowing these ecosystems to become fire-prone when ignited by lightning (associated with dry monsoonal storms late in the dry season) or by humans. These savannas extend into the adjacent foothills surrounding the central Ayeyarwady valley, where they are dominated by dry-season deciduous broad-leaf trees. Rainfall generally increases with elevation, and landscapes tend to be characterised by savannas with increasingly taller and denser tree canopies on drier (south-facing) slopes, with tropical dry forests, essentially devoid of flammable grasses on more sheltered slopes. Finertextured soils that retain higher levels of moisture and nutrients also tend to favour tropical dry forests over savannas.

An interesting expression of savanna ecosystems occurs on elevated hills 1000-2000 m above sea level, where reduced evapotranspiration moderates the severity of dry season droughts. These are tall forests dominated by relatively high densities of pine trees, which nonetheless have open canopies promoting seasonal growth and curing of flammable C4 grasses. The trees have high survival rates after surface fires due to their thick insulating bark, but may be killed on rare occasions when intense fires consume their leaf canopies. Pine savannas are scattered through the Kachin, Shan and Chin hills and extend to adjacent countries. Functionally similar pine savannas occur in the Caribbean and southeastern North America. Although the pine savannas contrast markedly with the low, open acacia savannas of the dry lowlands, they are united by their flammable grassy ground layer.

With increasing elevation, temperatures decline, mild frosts may occur, precipitation increases and evapotranspirative losses decline. Under these conditions, tropical forests are replaced by temperate forests with simpler structure and lower diversity. These forests are dominated by tree families with strong northern temperate affinities including oaks, chestnuts, laurels and cherries, including a number with winter-deciduous phenology, which become dominant at higher elevations. At higher elevations still, where winter snow persists for weeks or months, these temperate broad-leaf deciduous forests are replaced by temperate montane conifer forests, which become lower in stature and more open with increasing exposure to cold winds. Both types of temperate forests are largely confined to the eastern Himalayan foothills in Kachin state, but limited occurrences extend south to the highest parts of the Chin Hills.

At higher elevations, with increasingly cold temperatures, shorter growing seasons and prolonged snow cover, trees give way to alpine shrublands and herbfields, and ultimately to permanent snowfields, glaciers and icy cliffs and screes at more than 5,000 m above sea level (Figure 1.3).

Freshwater ecosystems are partly beyond the scope of this study, but notable examples include glacial lakes restricted to the southern ridges of the Himalayas, seasonal lakes on the Ayeyarwady floodplain and rare geothermal wetlands on the Rakhine coast.

Palustrine wetlands on the interface between terrestrial and freshwater realms are extensive on the Ayeyarwady floodplain and riparian corridors that extend along the major rivers. These wetlands are densely vegetated with grasses, sedges and other non-woody hydrophytes, and have strongly seasonal filling and drying regimes synchronised with the monsoon. Most dry completely during January – April, but some retain permanent water. The river banks and levees support forested wetlands with tree recruitment triggered by seasonal flood recession. The lowest part of the floodplain behind the Ayeyarwady deltas includes peat forests (characterised by kanazo), which are uncommon outside equatorial regions worldwide.

The interface between the terrestrial and marine realms are occupied by several coastal ecosystems, including several different compositional and structural expressions of mangrove forests, grassy saltmarshes, tidal mudflats and coastal dune vegetation.

Finally, subterranean ecosystems are largely beyond the scope of this assessment, but we recognise important karst systems that include extensive dry caves and subterranean waters likely to harbour a diverse and endemic biota, and should be a focus of future assessments.

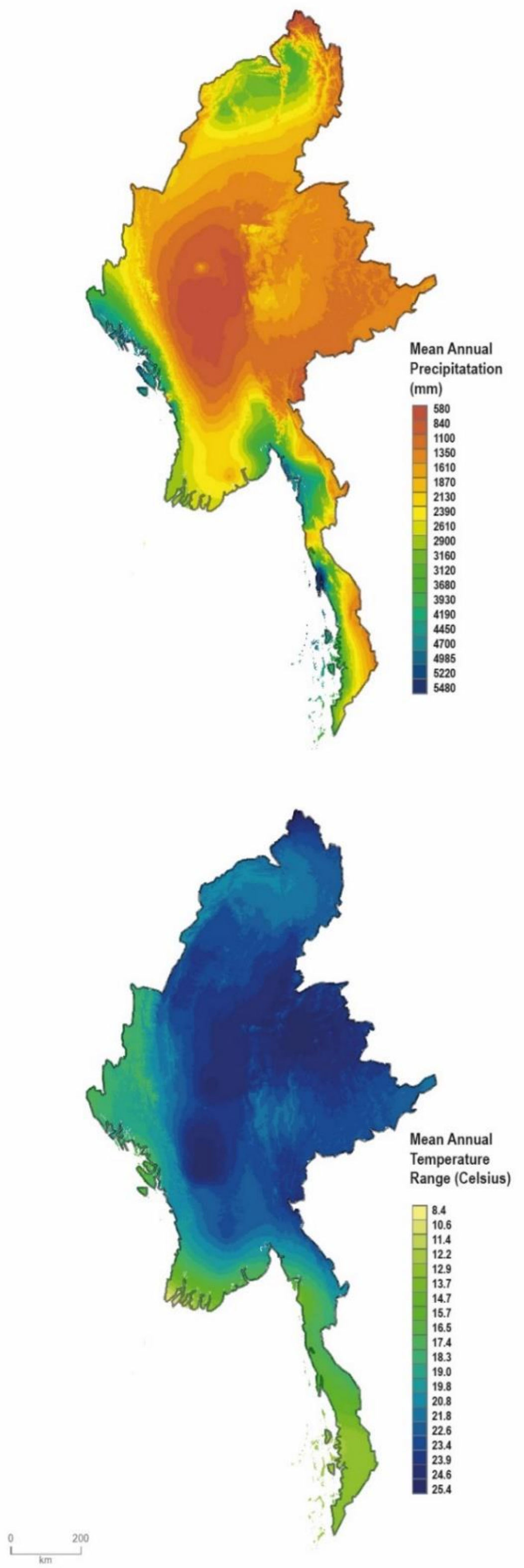


Figure 1.2 Major climatic gradients across Myanmar.

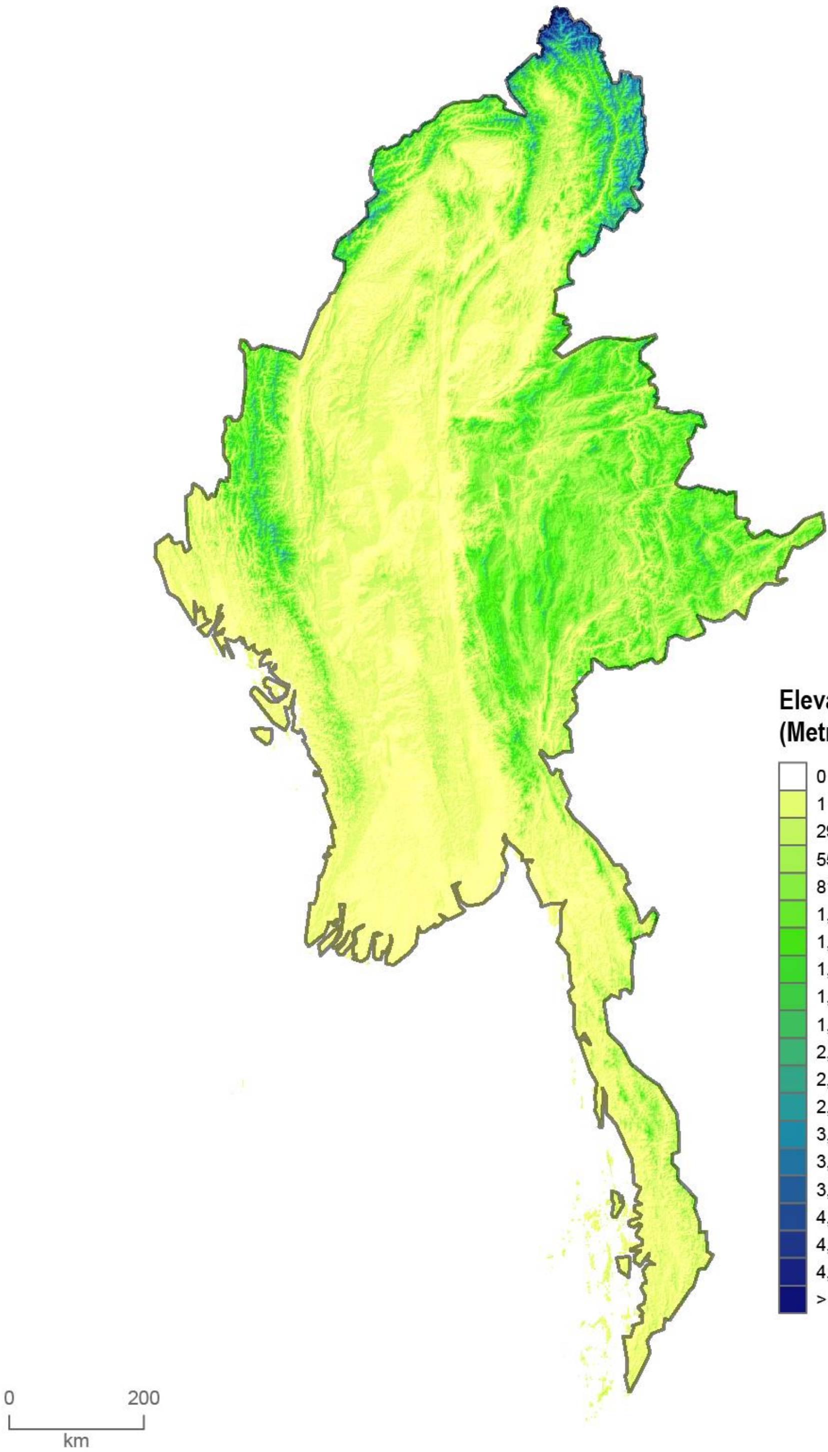


Figure 1.3 Elevation map of Myanmar.

1.3 Introduction to the IUCN Red List of Ecosystems

The IUCN Red List of Ecosystems (RLE) aims to support conservation in resource use and management decisions by identifying ecosystems most at risk of loss or collapse (Keith et al., 2013; Keith et al., 2015). Similar to the IUCN Red List of Threatened Species, the outcome of an RLE assessment is a list of ecosystems and their status for a region (Figure 1.4; Rodríguez et al., 2015). Because the RLE was developed to promote a consistent framework suitable for assessing and monitoring the status of ecosystems, it enables comparisons of collapse risk between countries, locations and ecosystem types (Keith et al., 2013).

For further information on the development of the RLE protocol, the theory and scientific foundations upon which they were developed, and detailed information on the purpose of each of the five criteria refer to the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria (Bland et al., 2017a). More information on the IUCN Red List of Ecosystems, is available in multiple languages on the IUCN Red List of Ecosystems website (www.iucnrle.org).

Assessments of ecosystem types (commonly termed 'assessment units' within Red List of Ecosystems assessments) are conducted by applying five criteria and their associated thresholds, enabling each ecosystem type to be classified according to their risk of collapse (termed 'status'). To ensure the assessment process is transparent and repeatable, each ecosystem type is clearly described according to the IUCN Red List of Ecosystems guidelines (Bland et al., 2017a). This standard approach of applying the IUCN Red List of Ecosystems Categories and Criteria to clearly described ecosystems is critical to allow for accurate, comparable and repeatable assessments of ecosystems status and to contribute to the global IUCN Red List of Ecosystems programme.

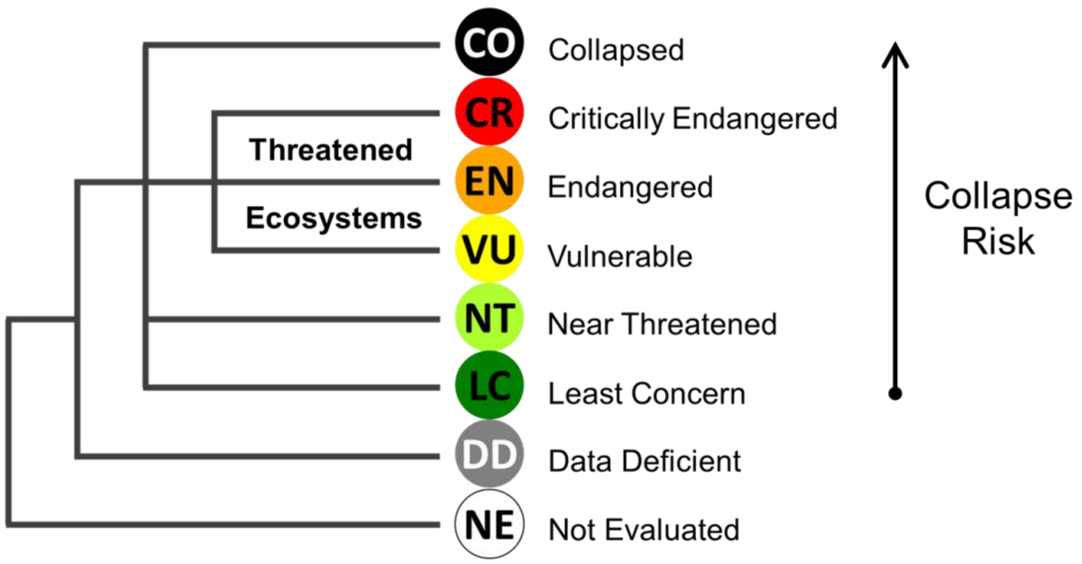


Figure 1.4 The IUCN Red List of Ecosystems categories, indicating the status of ecosystems. Threatened ecosystems are those assessed as Vulnerable, Endangered, or Critically Endangered. Source: (Bland et al., 2017a)

1.3.1 Definitions

There are several key concepts that must be clearly defined to allow for repeatable ecosystem risk assessments:

Risk

Risk is defined as the probability of an adverse outcome over a specified time-frame. Here, the adverse outcome is the endpoint of ecosystem decline, which the RLE terms ecosystem collapse.

Ecosystem collapse

Understanding the concept of ecosystem collapse is critical for interpreting IUCN RLE assessments. For the purposes of the RLE, "an ecosystem is Collapsed when it is virtually certain that its defining biotic or abiotic features are lost from all occurrences, and the characteristic native biota are no longer sustained. Collapse may occur when most of the diagnostic components of the characteristic native biota are lost from the system, or when functional components (biota that perform key roles in ecosystem organisation) are greatly reduced in abundance and lose the ability to recruit." According to the IUCN guidelines (Bland et al., 2017a), risks to ecosystems can be caused by a variety of threatening processes that are expressed through different symptoms of ecosystem collapse.

The RLE risk model groups these symptoms into four major types, which ultimately form the RLE criteria (Figure 1.5).

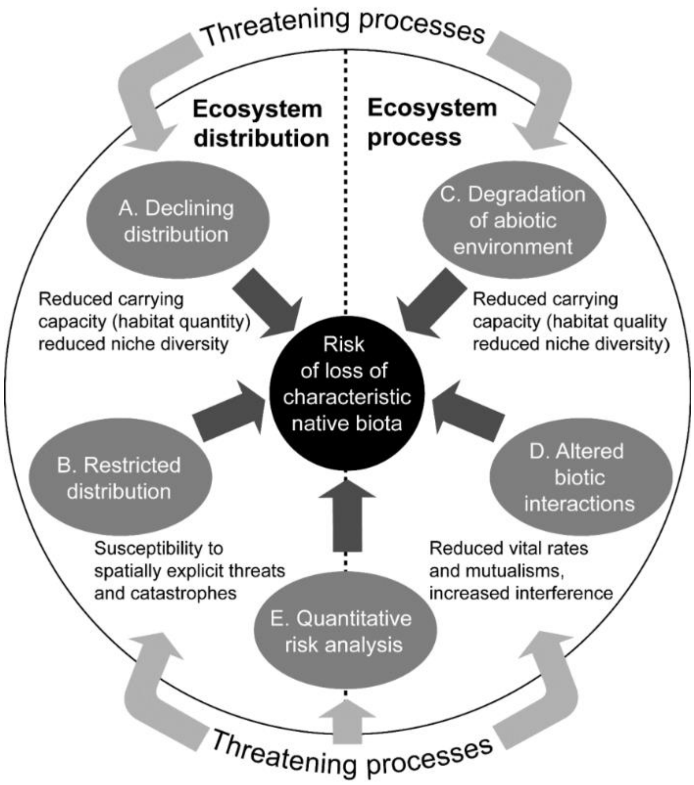


Figure 1.5 The IUCN Red List of Ecosystems risk assessment model. Source: (Bland et al., 2017a).

For more information on the concept of collapse and how to identify when an ecosystem is collapsed, we recommend referring to the IUCN Red List of Ecosystems guidelines, which describes this in detail (Bland et al., 2017a; Bland et al., 2018). In this report and as recommended by the guidelines, we explicitly define collapse for each ecosystem type in Myanmar in their ecosystem descriptions (See section 3).

Time frames

Because risks must be assessed over specified time frames, a standard set of time frames are carefully defined in the IUCN Red List of Ecosystems Categories and Criteria. There are four specified time frames used in the RLE:

- The historical past. We notionally use the year 1750, which marks the onset of industrial-scale exploitation of ecosystems in South-East Asia;
- The recent past. This is the past 50 years (1969-2019), which is considered long enough to distinguish directional change from natural variability;
- Any 50-year period including the recent past, present and future. Predictions and inferences based on past declines, simulation models and any other model considered suitable for assessing risks into the future may be used.
- The future. Again, predictions are required to assess risks over this time frame and are usually based on models that use information about the response of ecosystems to threatening processes.

1.3.2 IUCN Red List of Ecosystems Categories and Criteria

IUCN Red List of Ecosystems Criteria

To assess the risk of ecosystem collapse, each ecosystem is assessed under five rule-based criteria that form the IUCN Red List of Ecosystems Criteria. These criteria were developed following nearly a decade of scientific work focused on understanding pathways of ecosystem decline, degradation, loss and collapse (Nicholson et al., 2009; Rodríguez et al., 2011; Keith et al., 2013; Keith et al., 2015; Rodríguez et al., 2015; Bland et al., 2017b; Murray et al., 2017; Keith et al., 2018; Murray et al., 2018). Importantly, they relate the symptoms of ecosystem decline with the risk that an ecosystem will lose its defining features.

The five criteria were designed to target different symptoms of ecosystem collapse (Figure 1.5). These symptoms are both distributional and functional:

- Criterion A: declines in distribution, which reduce carrying capacity for dependent biota;
- Criterion B: restricted distribution, which predisposes the system to spatially explicit threats;
- Criterion C: degradation of the abiotic environment, reducing habitat quality or abiotic niche diversity for component biota; and
- Criterion D: disruption of biotic processes and interactions

- Criterion E: allows for the integration of the above four symptoms into a simulation model of ecosystem dynamics to allow quantitative estimates of the risk of ecosystem collapse.

For further information on the criteria refer to the *Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria* (Bland et al., 2017a).

Categories

Applying thresholds (decision rules) for each of the IUCN RLE criteria enables each ecosystem to be assigned to a category of risk ('status'). An ecosystem assessed under the RLE criteria can be placed into eight categories: Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE; Fig 1.4). The first six categories (CO, CR, EN, VU, NT and LC) are ordered in decreasing risk of collapse. The categories Data Deficient and Not Evaluated do not indicate a level of risk.

For further details of the categories refer to the *Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria* (Bland et al., 2017a). We applied version 2.2 of the IUCN Red List of Ecosystems Criteria (Table 1.1).

Table 1.1 The IUCN Red List of Ecosystems Criteria, Version 2.2. Source: (Bland et al., 2017).

A. Reduction in geographic distribution over **ANY** of the following time periods:				
		CR	**EN**	**VU**
A1	Past (over the past 50 years)	≥ 80%	≥ 50%	≥ 30%
A2a	Future (over the next 50 years)	≥ 80%	≥ 50%	≥ 30%
A2b	Any 50 year period (including the past, present and future)	≥ 80%	≥ 50%	≥ 30%
A3	Historical (since approximately 1750)	≥ 90%	≥ 70%	≥ 50%

B. Restricted geographic distribution indicated by **ANY OF** B1, B2 or B3:				
		CR	**EN**	**VU**
B1	Extent of a minimum convex polygon (km^2) enclosing all occurrences (extent of occurrence, EOO) is no larger than: **AND** at least one of the following (a-c): (a) An observed or inferred continuing decline in **ANY** of: i. a measure of spatial extent appropriate to the ecosystem; **OR** ii. a measure of environmental quality appropriate to characteristic biota of the ecosystem; **OR** iii. a measure of disruption to biotic interactions appropriate to the characteristic biota of the ecosystem (b) Observed or inferred threatening processes that are likely to cause continuing declines in geographic distribution, environmental quality or biotic interactions within the next 20 years.	≤ 2,000 km^2	≤ 20,000 km^2	≤ 50,000 km^2
	(c) Ecosystem exists at:	1 threat-defined location	≤ 5 threat-defined locations	≤ 10 threat-defined locations
B2	The number of 10 × 10 km grid cells occupied (area of occupancy, AOO) is no more than: **AND** at least one of a-c above (same as for B1).	≤ 2	≤ 20	≤ 50
B3	The number of threat-defined locations is very small (generally fewer than 5) **AND** prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus capable of Collapse or becoming Critically Endangered (CR) within a very short time period (B3 can only lead to a listing as **VU**).			**VU**

C. **Environmental degradation** over **ANY** of the following time periods:		Relative severity (%)			
C1	The past 50 years, based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	Extent (%)	≥ 80	≥ 50	≥ 30
		≥ 80	**CR**	**EN**	**VU**
		≥ 50	**EN**	**VU**	
		≥ 30	**VU**		
C2	**C2a.** The next 50 years, based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table; **OR** **C2b.** Any 50-year period including the past, present and future, based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	Extent (%)	≥ 80	≥ 50	≥ 30
		≥ 80	**CR**	**EN**	**VU**
		≥ 50	**EN**	**VU**	
		≥ 30	**VU**		
C3	Since 1750 based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	Extent (%)	≥ 90	≥ 70	≥ 50
		≥ 90	**CR**	**EN**	**VU**
		≥ 70	**EN**	**VU**	
		≥ 50	**VU**		

D. Disruption of biotic processes or interactions over **ANY** of the following time periods:		Relative severity (%)			
D1	The past 50 years based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	Extent (%)	≥ 80	≥ 50	≥ 30
		≥ 80	**CR**	**EN**	**VU**
		≥ 50	**EN**	**VU**	
		≥ 30	**VU**		
D2	**D2a**. The next 50 years, based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table; **OR** **D2b.** Any 50-year period including the past, present and future, based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	Extent (%)	≥ 80	≥ 50	≥ 30
		≥ 80	**CR**	**EN**	**VU**
		≥ 50	**EN**	**VU**	
		≥ 30	**VU**		

		Extent (%)	≥ 90	≥ 70	≥ 50
D3	Since 1750, based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	**CR**	**EN**	**VU**
		≥ 70	**EN**	**VU**	
		≥ 50	**VU**		

E. Quantitative analysis that estimates the probability of ecosystem collapse to be:	
CR	≥ 50% within 50 years
EN	≥ 20% within 50 years
VU	≥ 10% within 100 years

1.3.3 Assessment process

Application of the IUCN Red List of Ecosystems Categories and Criteria follows a generic sequential process that includes:

- Adapting the newly developed global ecosystem typology (Keith et al., 2019; Keith et al., In review) to the area of assessment (Myanmar's terrestrial environment, Figure 1.1). This process is guided by experts and the result is a list of ecosystem types for the area of assessment that will be assessed under the RLE protocol;

- Describing each of the ecosystem types in ecosystem typology following the standard approach detailed in the Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria (Bland et al., 2017a);

- If no map data is available to support the assessment, an ecosystem mapping project is required to support the ecosystem descriptions and assessment of several of the RLE criteria;

- Applying the assessment criteria to each ecosystem type, which requires extensive data searches and analyses. The outcome of each ecosystem assessment consists of a status of the ecosystem under 5 criteria and 18 subcriteria of the IUCN Red List of Ecosystems categories and criteria;

- Compiling the results into a comprehensive IUCN Red List of Ecosystems for the area of assessment (this report), which describes each ecosystem and identifies ecosystems according to their risk of collapse.

This report details each of these steps in the following sections.

1.4 Methods

1.4.1 Overview

The Myanmar National Ecosystem Assessment required the development of an ecosystem typology that lists the individual assessment units (ecosystems) to be assessed under the IUCN Red List of Ecosystems categories and criteria (Rodríguez et al., 2015; Bland et al., 2017a).

Developing the ecosystem typology for Myanmar included:

- A structured and unstructured literature review of all available information on ecosystems, forest types and other classification systems in Myanmar and across South and South-east Asia;
- Workshops held with local experts to assist in ensuring the diversity of ecosystems in Myanmar was adequately captured in the ecosystem typology;
- More than 200 hours of field work to identify ecosystem types and their characteristic native biota across >4,000 km of transects in May 2018 and May 2019;
- Cross-walking the list of ecosystems identified in Myanmar with the newly developed global hierarchical ecosystem typology (Keith et al., in submission);
- Developing a database suitable to host the ecosystem descriptions and manage the red listing process;
- Describing each ecosystem using the standard IUCN approach for the Red List of Ecosystems; and
- A public peer-review process to allow for input from a wide variety of experts and interested parties.

Following the development of the ecosystem typology, a red list assessment of each ecosystem was conducted.

1.4.2 Ecosystem Typology

Literature Review

We conducted a broad review of academic, natural history and grey literature relevant to the Myanmar ecosystem assessment. The literature review included targeted searches for ecosystems that are likely to occur or have been reported to occur in Myanmar and surrounding countries and a structured approach to identify the relative number of studies conducted on ecosystems likely to occur in Myanmar. We also searched for national scale ecosystem assessments and mapping projects in surrounding countries, with the aim to ensure the typology developed in this project can cross-walk effectively with neighbouring countries.

Workshops

We conducted three workshops in Naypyidaw over 2017-2019 to develop the ecosystem typology, gather any available information on each ecosystem type and gather data on known occurrences of each ecosystem type to support the ecosystem mapping component of the assessment.

Field work

A two-week field trip across west and central Myanmar was conducted in late May 2018. The field trip covered more than 2,600 km across nine states of Myanmar (Figure 1.6). The field trip was designed to maximise coverage across a broad range of ecosystem types and enabled information on the distribution of ecosystem types, their characteristic flora and fauna and formulation of the draft ecosystem typology. For more information, refer to the report entitled *Myanmar National Ecosystem Assessment: Trip report and project progress update May 2018* (WCS and UNSW, 2018).

1.4.3 Ecosystem Mapping

To develop a map of the ecosystems of Myanmar, we used a supervised learning approach to classify earth observation data and other geospatial datasets into broad mappable units, which was then split into ecosystem types. The result of the mapping process is a hierarchical set of classified draft maps, including maps at the Biome (11 classes), Functional Ecotype (21 classes) and Ecosystem Type (66 classes) level of the typology. The approach to the map development is detailed below.

Training data

To support the supervised classification method, WCS Myanmar developed a set of training observations, stratified on a nation-wide grid (to ensure representative geographic coverage of the whole country; Figure 1.6). For each mappable unit (Table 1.2), a GIS analyst reviewed existing maps, field data, street view imagery, and high resolution imagery available from Google Earth to allocate point locations to the unit. This was supplemented by points collected during field trips, and provided by experts (e.g. S. Platt, *pers. comm.*). Our training set was developed in Remap (Murray et al., 2018), ArcGIS, and QGIS, and consisted of 63,124 point observations (Figure 1.9).

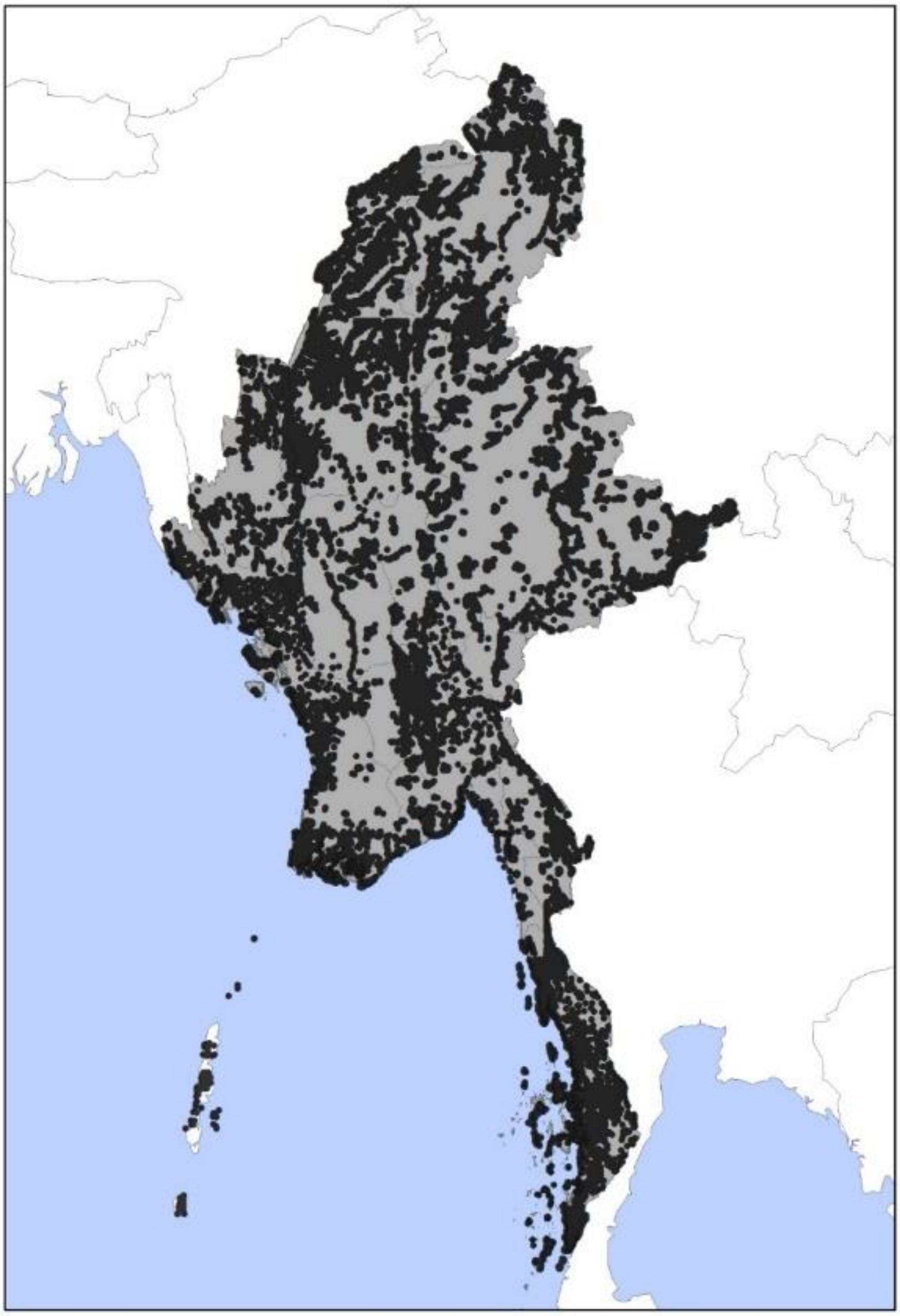


Figure 1.6 The training set developed by WCS Myanmar used in a supervised classification of ecosystem types in the Myanmar National Ecosystem Assessment.

Table 1.2 Mappable units incorporated into the remote sensing workflow. These units are then split to the ecosystem typology using a fusion of administrative boundaries, ecoregion data, and expert knowledge.

Unit	Map class description	Example ecosystem type
1	Evergreen rainforests	Tanintharyi island rainforests
2	Semi-evergreen forest (mixed forests)	Tanintharyi semi-evergreen forest
3	Dry forests and scrubs	Indaing forest
4	Cloud forests	Tanintharyi cloud forest
5	Bamboo breaks	Rhakine hills bamboo break
6	Montane forests and woodlands / mountain hardwood forest	Shan warm temperate rainforest
7	Montane conifer forests	Kachin mountain conifer forest
8	Dry scrub forests	Central Ayeyarwady Than-Dahat grassy forest
9	Sha-bamboo thickets	Shwe Settaw Sha-Bamboo thicket
10	Mountain pine savannas	Shan hills pine savanna
11	Polar/alpine rocky outcrops	Alpine cliffs and screes
12	High mountain scrubs	High mountain scrub
13	Alpine herbfields	Alpine herbfield
14	Snowfields	Kachin snowfields
15	Spiny scrubs	Dry zone foothills spiny scrub
16	Thorn scrubs	Sha thorny scrub
17	Sandy shores	Sandy shoreline
18	Mangroves	Tanintharyi mangrove forest
95	Urban areas	Not applicable
96	Croplands, sown pastures	Not applicable
97	Ricefields	Not applicable
98	Plantations	Not applicable
99	Permanent water	Not applicable

Remote sensing classification

We modelled the distribution of the mappable units using a random forest classifier and 89 covariate layers for the year 2018 (Table 1.3). Our mapping framework closely followed Murray et al. (2018), whereby ecologically relevant covariate layers are composited to remove clouds, mosaicked, and used in a random forest classification. We ran binary random forest models to enable the production of data layers where a pixel represents the probability of membership to the focal map class (0-100), which better allowed us to flexibly incorporate expert feedback into the mapping process (Figure 1.7). Each random forest classification was formulated as a single map class against a random subset of training points for all other map classes, using a random sample of 5,000 training points from our training set.

We compiled a single map from these probability maps using a decision ruleset that utilised information from each probability layer and expert opinion about the most likely class in a region. In addition, we applied simple biogeographical rules (such as elevation thresholds) to further split the map into ecosystem types. We masked all non-natural map classes (e.g. plantations, croplands, urban areas). The result was wall-to-wall ecosystem map for Myanmar depicting the distribution 52 terrestrial ecosystem types at 90-m spatial resolution. All remote sensing analyses were conducted in Google Earth Engine (Gorelick et al., 2017).

Table 1.3 Predictors used in the remote sensing model for ecosystem distribution mapping.

Source data	Description	Number of covariate layers developed from source	Covariate description	Reference
Landsat 8 Collection 1 Surface Reflectance	Long-term earth observatory data; 30 m spatial resolution, 185 km swath width and 16 day repeat cycle.	56	Composite metrics1 and phenology layers produced from greenest pixel annual composites	USGS (2016)
ALOS World 3D: 30m	Global digital surface elevation model dataset at 30 m resolution.	2	Elevation, slope	Takuku et al. (2014)
JRC Global Surface Water Mapping Layers, v1.0	Global temporal surface water occurrence, 1984-2015	3	Water occurrence, water seasonality, water recurrence	Pekel et al. (2016)
WorldClim V1 Bioclim	Global derived precipitation and temperature values, from raw data 1960-1991	6	Precipitation: Mean annual, driest month, seasonality; Temperature: Mean annual, driest quarter, annual temperature range.	Hijmans et al. (2005)
Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log scaling	Calibrated and ortho-corrected Ground Range Detected (GRD) scenes: Interferometric Wide Swath mode; 5x20 m spatial resolution and 250 km swath width; varying temporal resolution	22	Composite metrics1 and phenology layers produced from median value composites	Copernicus Sentinel data (2019)

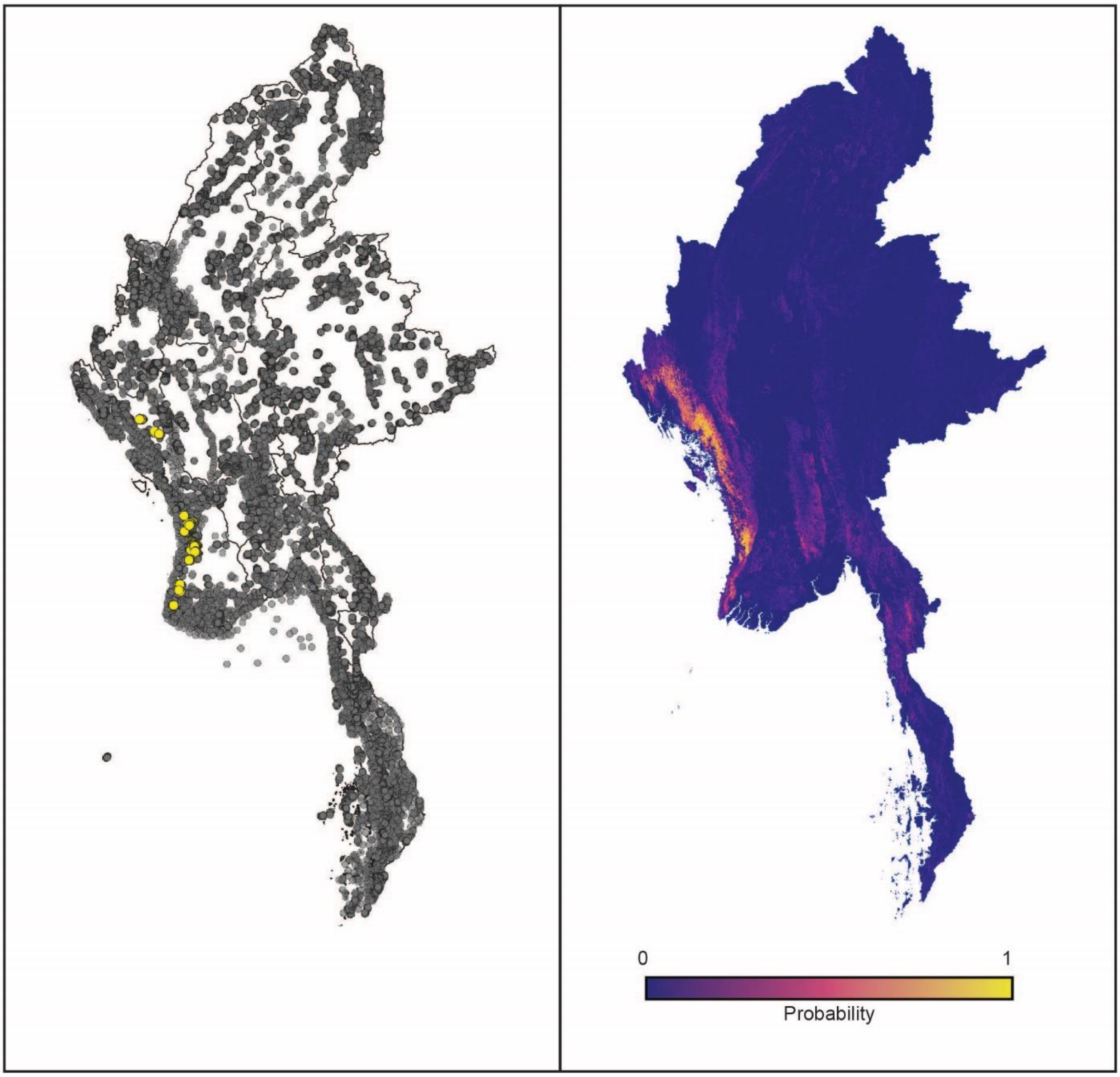


Figure 1.7 Distribution of the spatially stratified training dataset (a) showing training data for a single map class, Rakhine hills bamboo brake (yellow), and (b) a probability map for Rakhine hills bamboo brake. The map depicts the probability that a 90-m pixel is classified correctly during the classification procedure. These probability layers were compiled into a single wall-to-wall ecosystem map.

Map unit processing to ecosystem types

After developing the maps representing the mappable units, we developed a set of spatial splitting rules to reduce those units into biogeographical representations of ecosystem functional groups (our ecosystem typology; Keith et al., in review). We used ecoregion data, river basins, observations from field work and information gathered in expert workshops to determine the major boundaries between different ecosystem functional groups, splitting the 18 class remote-sensing derived map into 52 classes suitable for the ecosystem assessment.

For ecosystems that could not be incorporated into our remote sensing workflow (n = 12, Table 1.4), we used alternative data sources where possible to represent their current distribution in our final map. Two floodplain ecosystems identified in our ecosystem typology were mapped using JRC water cover data to identify (Pekel et al., 2016). Subterranean ecosystem types (n = 1, Aerobic karst caves) were represented using a dataset depicting the distribution of bat caves across Myanmar. Coastal mudflats required specialised remote sensing methods, so we used a recently developed global distribution map of tidal flats (Murray et al., 2019). Occurrence data from experts was used for the distribution of the single dwarf mangrove ecosystem type that occurs in Myanmar.

Several ecosystem types, such as Shan plateau grasslands, were considered not mappable due to a lack of training observations or extreme uncertainty in their distribution, which was primarily a result of long-term access issues to the regions in which they occur (Table 1.4).

Expert review

At the end of the mapping procedure, the preliminary ecosystem map of Myanmar was reviewed in a workshop attended by forestry department officials, vegetation and ecosystem experts from Myanmar and elsewhere, and members of the NGO community with direct experience of Myanmar's natural ecosystems. We also conducted further field work to resolve any outstanding issues in the mapping process and confirm our interpretation of ecosystem distributions and revised the map when necessary by incorporating additional training data or post-processing.

Table 1.4 Ecosystem units that could not be mapped

Code	Ecosystem type	Notes	Solution
MMR-T1.2.2	Rocky Tanintháyri karst	No occurrence records available for training set due to uncertainty in distribution or inaccessibility	Not mapped
MMR-T2.4.5	Mountain bamboo brake	No occurrence records available for training set due to uncertainty in distribution or inaccessibility	Not mapped
MMR-T4.2.3	Central Ayeyarwady Palm savanna	No occurrences found, entirely converted to agriculture	Not mapped.
MMR-T4.5.1	Shan plateau grasslands	No occurrence records available for training set due to uncertainty in distribution or inaccessibility	Not mapped
MMR-S1.1.1	Aerobic Karst caves	Not suitable for satellite remote sensing	Bat cave data used
MMR-TF1.1.1	Ayeyarwady kanazo swamp forest	No occurrences found, probably converted to agriculture	Not mapped
MMR-TF1.1.2	Central dry evergreen riparian forest	No occurrences found, occurs as thin band and not suitable for inclusion in remote sensing analysis, probably mostly converted to village forest, gardens	Not mapped
MMR-TF1.1.3	Mixed delta scrub	No occurrence data found	Not mapped
MMR-MT2.1.1	Tanintharyi coastal dune forest	Thin band occurring along coastline, not possible to incorporate into mapping workflow	Not mapped
MMR-MT2.1.2	Rakhine coastal dune forest	Thin band occurring along coastline, not possible to incorporate into mapping workflow	Not mapped
MMR-MFT1.3.1	Grassy saltmarsh	No occurrence data found	Not mapped
MMR-MFT1.2.3	Dwarf mangrove (shrubland) on shingle	Only two point occurrences known	Point data from experts used
MMR-MT1.2.1	Coastal mudflats	Requires specialised remote sensing methods	Used global intertidal change data (Murray et al., 2019)

1.4.4 IUCN Red List of Ecosystems Assessment

For each terrestrial ecosystem in Myanmar, we assessed all of the Red List of Ecosystems criteria. In this section we outline the broad methods used to assess each ecosystem under each criterion. Further details of the specific methods used to assess each ecosystem are provided in *Section 3 - Ecosystem description and assessment*.

Criterion A

Assessments of criterion A require the extent of ecosystem loss to be quantified over each of the Red List of Ecosystems timeframes. We assessed this criterion in several ways, depending on the data available and previous research conducted:

- *Existing information.* Information on the extent of ecosystem lost obtained from published studies identified in the literature search was used where possible (e.g. Ayeyarwady delta mangrove forest; Webb et al., 2014). If the timeframes reported in the studies did not match those required by the criteria, we extrapolated estimates to 50 year time frames using standard functions provided in the R package *redlistr* to assess the criteria (Lee et al., 2019).

- *Time series analysis.* Where spatial data was freely available (e.g. Coastal mudflats; Murray et al., 2019), we analysed changes in area using linear models and made extrapolations to the required time frames using the R package *redlistr* (Lee et al., 2019).

- *Spatial inferences.* In many cases, sufficient spatial data was not available to assess Criterion A. Where possible, we assessed historical change (Criterion A3) using ancillary information that could be reliably used to infer the extent of ecosystem loss since 1750 (e.g. using the extent of rice paddies as an estimate of the former extent of Ayeyarwady floodplain wetlands).

Ecosystems where none of these approaches could yield reliable information on the extent of ecosystem loss were assessed as Data Deficient.

Criterion B

We developed a Google Earth Engine module (*GEE-redlist*; Murray et al. 2020) to assess Criterion B within Earth Engine (Gorelick et al., 2017). We used the maps that were derived from remote sensing (Section 1.4.3) to compute the number of 10 x 10 km grid cells occupied by each ecosystem (AOO) and the area of a minimum convex polygon that encompassed the entire distribution of each ecosystem within Myanmar (EOO). To account for commission error in the mapping process we invoked the 1% rule for the majority of ecosystems assessed (see each ecosystem assessment, Section 3).

We assessed the ongoing decline sub-criteria by reviewing literature and asking experts, and detailed the results in Section 3.

Criterion C

Assessments of Criterion C require data on degradation of the abiotic environment for each ecosystem. For each ecosystem, we first reviewed published studies to assess whether any information or analyses on abiotic degradation was available and suitable to support the assessment. For example, for intertidal forests and shrublands we were able to utilise a published model of the expected extent of inundation as a result of sea level rise. For these ecosystems, we provide details of this process in *Section 3 – Ecosystem description and assessment*.

For selected ecosystems amenable to bioclimatic modelling (n = 33 from 11 ecosystem functional groups), we used environmental suitability modeling to assess projected changes in bioclimatic suitability (Ferrer-Paris et al., 2019). These ecosystems were selected using the following criteria:

a) The ecosystem is likely to be directly influenced by climate, rather than soil, topography or other ecological drivers;
b) There was sufficient training data from the remote sensing training library to implement the model (section 1.4.3 – Ecosystem Mapping)

We used occurrence data from the remote sensing component of this project (n = 57,955). To understand the relationship between climate and current ecosystem distributions, we focused in natural ecosystem functional groups that are likely to be directly influenced by climate rather than soil, topography or other ecological drivers. We removed spatial and environmental replicates, points from transformed ecosystems and poorly represented classes. Then we partitioned the remaining data representing 16 natural ecosystem functional groups into training (n=9,101, 75%) and testing (n=3,042, 25%) subsets using a geographic checkerboard pattern to reduce effects of spatial auto-correlation.

A random forest classification model was fitted to discriminate suitable conditions for each class using the training data and 'current' climate data, as represented by 19 standard bioclimatic variables (WorldClim v1.4; 1960-1990; 30 sec spatial resolution). We used stratified sampling of training data to allow balanced representation of all classes, number of variables per tree was set to six, and number of trees was set to 2,000 for optimal fitting. The model was used only for ecosystem functional groups for which nominal classification error was lower than 20% in both training and the testing samples (a combination of model performance error and natural overlap between related classes), and the area under the sensitivity and specificity curve (AUC) for the focal class was higher than 85% (specific predictive performance). The predicted suitability for each focal class was calculated as the proportion of "votes", or proportion of classification trees assigning this class to a raster cell using either current bioclimatic conditions (representing conditions in 2000) or expected future bioclimatic conditions according to four alternative global circulation models and four representative emission scenarios for the year 2050.

For each ecosystem where these models were used, the relative severity across its current distribution was calculated using these predictions as initial and final values, the threshold of equal sensitivity and specificity of the corresponding ecosystem functional group was used as the collapse threshold. The relative severity of the impact of climate change over a 50 year period (2000-2050), was calculated for each of the 16 combination of models and emission scenarios and assessed against the red list category thresholds. The overall ecosystem status under Criterion C was assigned the mode of the assessment outcomes with plausible bounds >90% of the assessment outcomes.

Criterion D

Assessments of the severity and extent of biotic degradation were conducted by first reviewing published studies to identify datasets that could be used to support the assessment. Details of this literature review are provided in each ecosystem assessment (see *Section 3 – Ecosystem description and assessment*).

For mangrove ecosystems, we used a recently developed remote-sensing method to identify areas of mangrove forests that have undergone apparent ecosystem degradation (Worthington and Spalding, 2018). The approach utilises several vegetation indices (NDVI, SAVI, EVI and NDMI) that represent vegetation greenness and vegetation moisture condition. The indices are derived from Landsat time-series data and identify pixels that have undergone decreases in the index values of >40% relative to the reference period (pre 2000) and had not recovered to within <20% of the reference value.

For many forest ecosystems, we used a dataset that represents the distribution and change of primary forest in south-east Asia (Potapov et al., 2019). For each forest ecosystem where preliminary analyses showed that it reliably depicted primary forest distributions, we computed the proportion of the ecosystem that was mapped as primary forest and used it to assess Criterion D3. Additionally, we used time-series primary forest data to develop projections from a linear model to estimate the potential change in primary forest cover per ecosystem, allowing an estimate of Criterion D2b. Uncertainty in these projections were estimated using confidence intervals from the linear model (see *Section 3 – Ecosystem description and assessment*).

For forest ecosystems where primary forest data was not available, and for which composite indicator datasets were considered useful, we analysed the extent and severity of biotic change using the recently developed Forest Landscape Integrity Index (Grantham et al., 2020). The index integrates maps of changes in forest connectivity with data on human pressures known to result in ecosystem degradation to compute a continuous value of contemporary forest degradation at high resolution. We assumed that the index is relative to a natural (historical) state, and therefore used it to assess criterion D3.

The index is a single score of 0-10 for each 300-m pixel, with near 0 indicating an ecosystem has been subject to a wide range of severe threatening processes and is considered heavily degraded. The index is not linear and the authors found through investigation of widely distributed case studies that a score of above 9.6 suggests that the ecosystem has not been subject to any threatening processes and is considered intact. In contrast, forest ecosystems with scores below 6 are considered to be approaching a degraded state. We set thresholds for >=90, >=70 and >=50 relative severity by reviewing maps of the index in Myanmar with reference to areas visited during field trips. We clipped the index data to the distribution of this ecosystem, and quantified the proportion of the ecosystem mapped with index scores in each of the following ranges:

- 0-1: > 90% relative severity
- 1-3: >=70 < 90% relative severity
- 3-6: >= 50 < 70% relative severity
- >6: <50% relative severity

To investigate the sensitivity of the choice of these Forest Landscape Integrity Index thresholds, we conducted sensitivity analyses by modifying the thresholds (+0.25 and -0.25) and reassessing the outcome.

Criterion E

No stochastic ecosystem models were used in this assessment. For each ecosystem type, a search for suitable models was conducted, which revealed a general lack of ecosystem models that could be quickly adapted for the assessment. These ecosystems were assessed as Data Deficient for

Criterion E. If a model was found and appeared suitable, but could not be incorporated into this assessment due to time limitations, the ecosystem was assessed as Not Evaluated for Criterion E.

1.4.5 Expert review

Ecosystem descriptions and assessment

Ecosystem descriptions were distributed to experts familiar with a specific ecosystem type or a region of Myanmar throughout the project to help identify useful further information and data not yet identified, and to provide the opportunity to contribute to the national ecosystem assessment. In many cases, experts co-authored the descriptions and assessments (see Section 3).

Post-assessment review of Least Concern ecosystems

A final step in the assessment process aimed to identify ecosystems that assessed as Least Concern using available data but may not receive a Least Concern status if more data about ecosystem status was available. This process sought to incorporate unpublished information about risks to ecosystems to avoid at-risk ecosystems incorrectly being assigned to the Least Concern category. Experts were asked to review the list of Least Concern ecosystems and provide a judgement on whether further data would change the assessment outcome.

Example processes include impacts to an ecosystem that are not yet quantified, threatening processes that were not detected in the assessment due to not yet being a subject of scientific study, or being at imminent risk from a threat that has not yet had an impact but is certain to within the red list assessment time frames. Applying the precautionary principle, these ecosystems were assigned the status of Data Deficient and all are recommended for urgent further work to complete the assessment. Evidence to support the decision is provided within each ecosystem assessment and in Appendix 8.

2. Terrestrial ecosystems of Myanmar

The Myanmar ecosystem typology includes of 64 ecosystem types across 10 biomes (Table 2.1). The ecosystem typology is consistent with the IUCN global ecosystem typology (Keith et al., 2019) to support crosswalks and comparisons with Red Lists of ecosystems in other countries and regions. The Myanmar ecosystem typology has a hierarchical structure, where each ecosystem type is assigned to a realm, biome and functional group (ecotype).

Realm refers to one of the four component media in the biosphere (Figure 2.1), biome is the segment of the biosphere united by major functional traits and macro-environmental features (Figure 2.2), and functional group is a group of related ecosystems within a biome (Figure 2.3). The distribution of Myanmar's ecosystem types is shown in Figure 2.4, and map data is made publicly available (Murray et al., 2020).

Table 2.1 List of the terrestrial ecosystems of Myanmar developed in this project.

Biome / Functional Group / Ecosystem Type	ID
REALM: TERRESTRIAL	
Tropical and subtropical forests (T1)	
Tropical/subtropical lowland rainforests (T1.1)	
Tanintharyi island rainforests	MMR-T1.1.1
Tanintharyi Sundaic lowland evergreen rainforest	MMR-T1.1.2
Tanintharyi limestone tropical evergreen forest	MMR-T1.1.3
Tanintharyi upland evergreen rainforest	MMR-T1.1.4
Kayin evergreen tropical rainforest	MMR-T1.1.5
Southern Rakhine hills evergreen rainforest	MMR-T1.1.6
Western Shan Plateau subtropical evergreen rainforest	MMR-T1.1.7
Kachin-Sagaing low elevation subtropical rainforest	MMR-T1.1.8
Kachin-Sagaing mid elevation subtropical rainforest	MMR-T1.1.9
Kachin Hills subtropical rainforest	MMR-T1.1.10
Tropical/subtropical dry forests and scrubs (T1.2)	
Tanintharyi semi-evergreen forest	MMR-T1.2.1
Rocky Taninthayri karst	MMR-T1.2.2
Mixed cane break	MMR-T1.2.3
Bago semi-evergreen forest	MMR-T1.2.4
Dry zone foothills spiny scrub	MMR-T1.2.5
Rakhine hills bamboo brake	MMR-T1.2.6
Rakhine hills semi-evergreen dry forest	MMR-T1.2.7
Magway dry cycad forest	MMR-T1.2.8
Magway semi-evergreen dry gully forest	MMR-T1.2.9
East Myanmar dry valley forest	MMR-T1.2.10

Eastern Shan semi-evergreen forest	MMR-T1.2.11
Western Shan semi-evergreen forest	MMR-T1.2.12
Indaing forest	MMR-T1.2.13
Northern semi-evergreen forest	MMR-T1.2.14
Tropical/subtropical moist montane rainforests (T1.3)	
Tanintharyi cloud forest	MMR-T1.3.1
Temperate-boreal forests and woodlands (T2)	
Boreal and temperate montane forests and woodlands (T2.1)	
Kachin mountain conifer forest	MMR-T2.1.1
Warm temperate rainforests (T2.4)	
Shan Warm Temperate Rainforest	MMR-T2.4.1
Chin Hills Warm Temperate rainforest	MMR-T2.4.2
Sagaing Warm Temperate Rainforest	MMR-T2.4.3
Kachin Warm Temperate Rainforest	MMR-T2.4.4
Mountain bamboo brake	MMR-T2.4.5
Kachin Montane Temperate Broadleaf Forest	MMR-T2.4.6
Savannas and grasslands (T4)	
Pyric tussock savannas (T4.2)	
Rakhine coastal savanna	MMR-T4.2.1
Central Ayeyarwady Than-Dahat grassy forest	MMR-T4.2.2
Central Ayeyarwady Palm Savanna	MMR-T4.2.3
Shwe Settaw Sha-Bamboo thicket	MMR-T4.2.4
Magway Than-Dahat dry grassy forest	MMR-T4.2.5
Sha Thorny Scrub	MMR-T4.2.6
Shan foothills Than-Dahat grassy forest	MMR-T4.2.7
Shan hills pine savanna	MMR-T4.2.8
Chin hills pine savanna	MMR-T4.2.9
Sagaing hills pine savanna	MMR-T4.2.10
Kachin pine savanna	MMR-T4.2.11
Temperate grasslands (T4.5)	
Shan limestone grassland	MMR-T4.5.1
Polar/alpine (T6)	
Ice sheets, glaciers and perennial snowfields (T6.1)	
Kachin snowfields	MMR-T6.1.1
Polar/alpine rocky outcrops (T6.2)	
Alpine cliffs and screes	MMR-T6.2.1
Temperate alpine meadows and shrublands (T6.4)	
High mountain scrub	MMR-T6.4.1
Alpine herbfield	MMR-T6.4.2
REALM: SUBTERRANEAN	

Dry subterranean (S1)	
Subterranean lithic systems (S1.1)	
Aerobic karst caves	MMR-S1.1.1
REALM: FRESHWATER/TERRESTRIAL	
Palustrine wetlands (TF1)	
Tropical flooded forests and peat forests (TF1.1)	
Ayeyarwady kanazo swamp forest	MMR-TF1.1.1
Central dry evergreen riparian forest	MMR-TF1.1.2
Mixed delta scrub	MMR-TF1.1.3
Seasonal floodplain marshes (TF1.4)	
Ayeyarwady floodplain wetlands	MMR-TF1.4.1
Central Ayeyarwady floodplain grasslands	MMR-TF1.4.2
REALM: FRESHWATER	
Lakes (F2)	
Freeze-thaw freshwater lakes (F2.4)	
Glacial Lakes	MMR-F2.4.1
REALM: MARINE/TERRESTRIAL	
Shoreline systems (MT1)	
Muddy shores (MT1.2)	
Coastal mudflats	MMR-MT1.2.1
Sandy shores (MT1.3)	
Sandy shoreline	MMR-MT1.3.1
Supralittoral coastal systems (MT2)	
Coastal shrublands and grasslands (MT2.1)	
Tanintharyi coastal dune forest	MMR-MT2.1.1
Rakhine coastal dune forest	MMR-MT2.1.2
REALM: MARINE/FRESHWATER/TERRESTRIAL	
Brackish tidal systems (MFT1)	
Intertidal forests and shrublands (MFT 1.2)	
Tanintharyi mangrove forest	MMR-MFT1.2.1
Ayeyarwady delta mangrove forest	MMR-MFT1.2.2
Dwarf mangrove (shrubland) on shingle	MMR-MFT1.2.3
Rakhine mangrove forest on mud	MMR-MFT1.2.4
Coastal saltmarshes (MFT 1.3)	
Grassy saltmarsh	MMR-MFT1.3.1

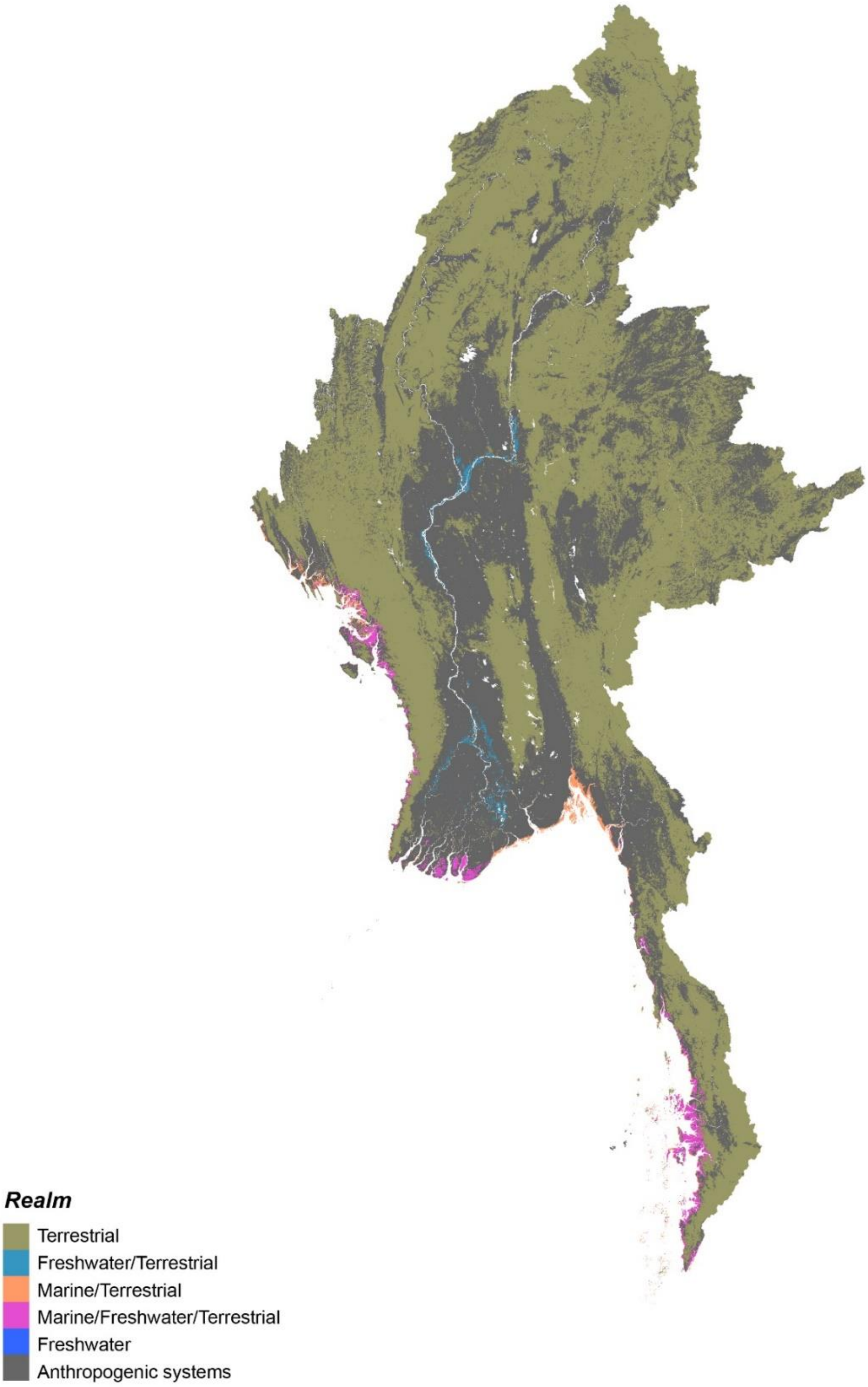


Figure 2.1 The distribution of the realms of Myanmar.

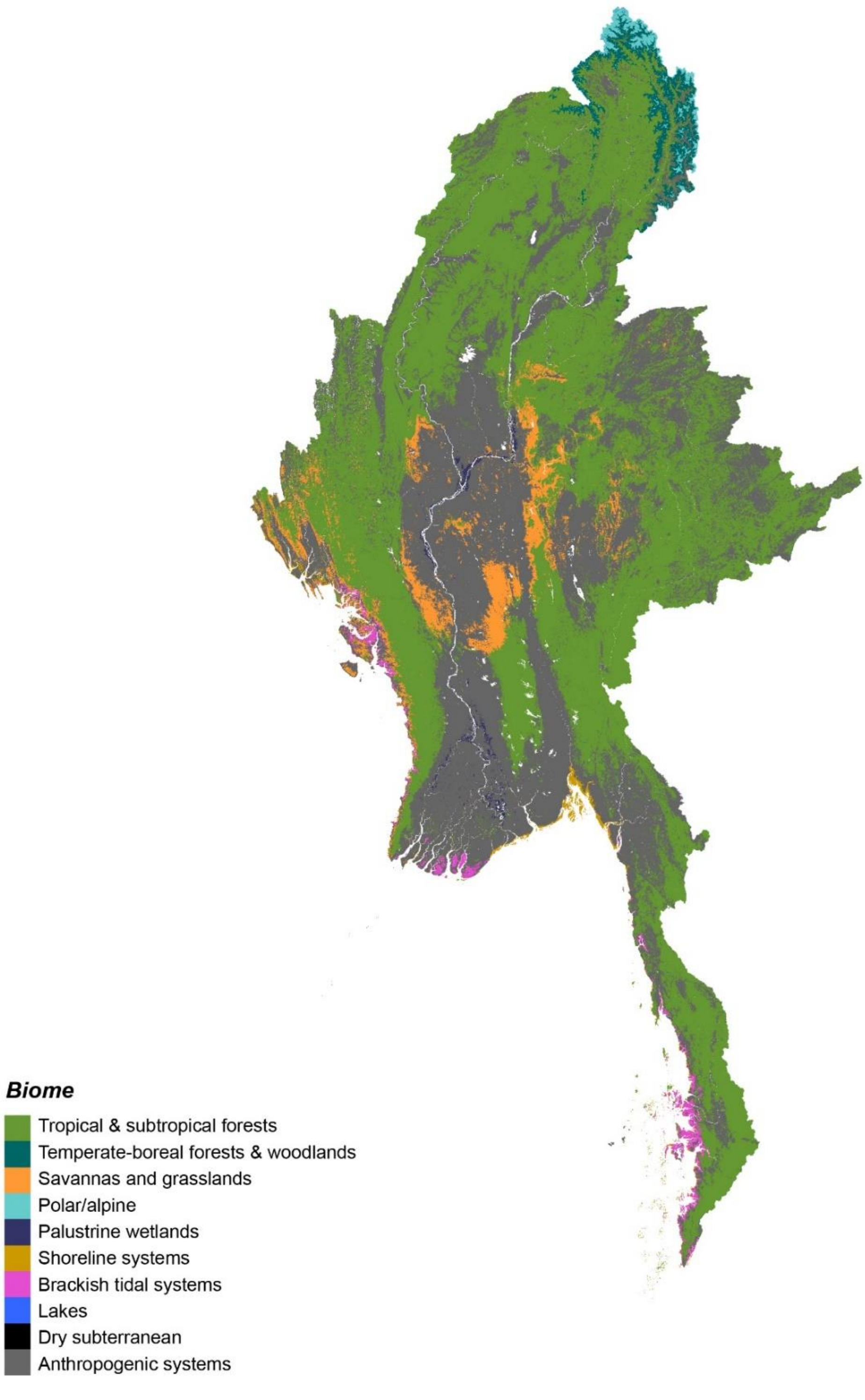


Figure 2.2 The distribution of the biomes of Myanmar. Note: Areas depicted in white were not included in the assessment (primarily freshwater and marine systems, see Methods).

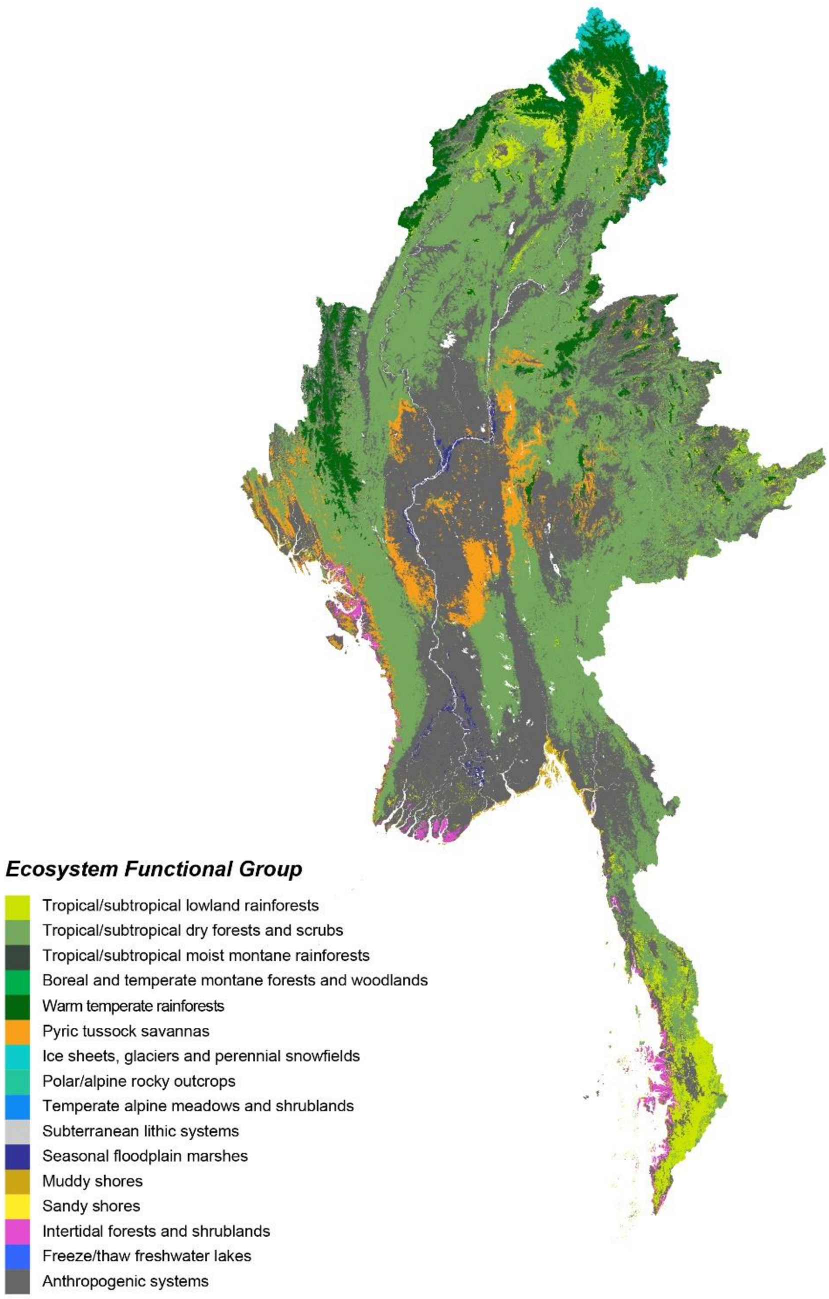


Figure 2.3 The distribution of ecosystem functional groups of Myanmar. Note: Areas depicted in white were not included in the assessment (primarily freshwater and marine systems, see Methods).

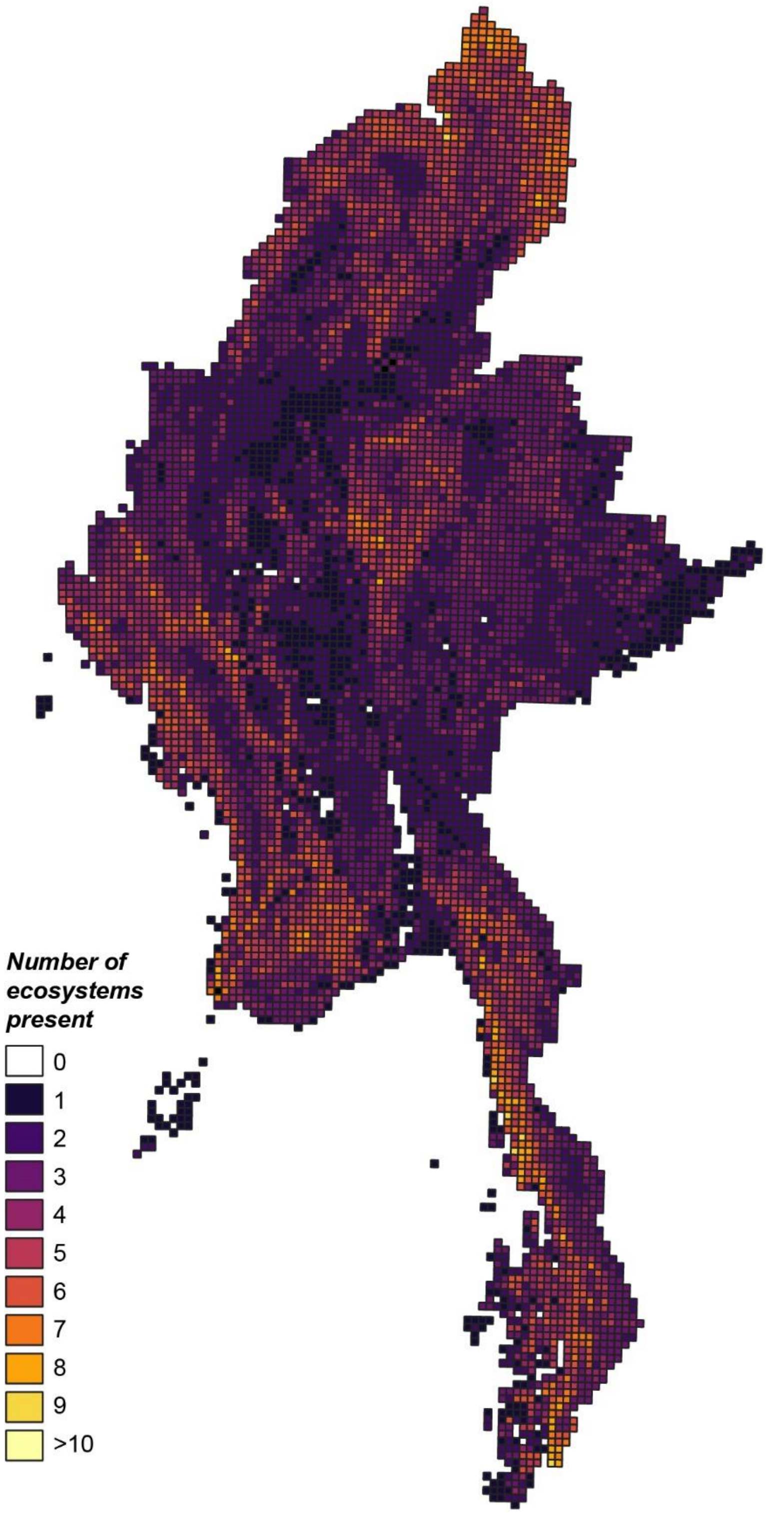


Figure 2.4 Heat map of the distribution of the natural ecosystem types of Myanmar, mapped as the number of ecosystems intersecting a 10 x 10 km grid.

3. Ecosystem description and assessment

Ecosystem accounts provided in this section consist of two components, an ecosystem description and a detailed summary of the application of the IUCN Red List of Ecosystem criteria.

The ecosystem description follows the standard format suggested by the IUCN. Ecosystem descriptions are an essential component of IUCN Red List of Ecosystems assessments and serve the purpose of clearly defining each assessment unit. This allows repeated application of the categories and criteria to a single defined unit and supports red listing and cross-walking at the global scale.

The associated assessment section provides the details the Red List assessments, including the data sources, methods of analysis, evidence statements and key references.

Table 3.1 Components of ecosystem description.

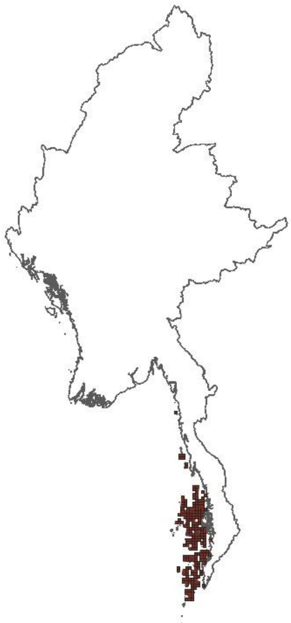
Component	Description
Authors	Authors of the description and the assessment.
Myanmar ecosystem names	Alternative names of the ecosystem.
Biome	Biome membership according to the global ecosystem typology.
Functional group	Functional group membership according to the global ecosystem typology.
Global classification	Classification code according to the global ecosystem typology.
Description	General overview of the principal components and dynamics of the ecosystem. Includes a photograph of the ecosystem.
Distribution	Short written description and range map of the spatial distribution of the ecosystem.
Characteristic native biota	Identifies the defining biotic features of the ecosystem, including diagnostic native taxa, functional components of the characteristic biota.
Abiotic environment	Identifies the defining abiotic features of the ecosystem, including descriptions of the characteristic states or summary of values of the key abiotic variables.
Key processes and interactions	Describes the key ecosystem drivers and interactions among biota and the abiotic environment.
Major threats	Short summary of the major threats and impacts to the ecosystem.
Ecosystem collapse definition	Short description of the collapsed state of the ecosystem and any associated thresholds.
Assessment summary	Short summary of the red list of ecosystems assessment.
Assessment outcome	Short format assessed status of the ecosystem.
IUCN Red List of Ecosystems Categories and Criteria	Version of the IUCN Red List of Ecosystems criteria used in the assessment.
Year published	Publication year.
Date assessed	The date the ecosystem assessment was completed.
Assessment credits	Names the authors, reviewers and contributors to the assessment.
Assessment summary	Short summary of the red list of ecosystems assessment.
Criterion A	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion B	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion C	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion D	Description of data, analysis and methods used to assess the criterion and the status outcome.
Criterion E	Description of data, analysis and methods used to assess the criterion and the status outcome.

Tanintharyi island rainforest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Tropical rainforest (Kress et al., 2003), Lowland evergreen rainforest (Connette et al., 2016)
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical lowland forest (T1.1)
Global classification T1.1.1
IUCN Status **Vulnerable (Least Concern – Vulnerable)**

Description

Tanintharyi island rainforest occurs on offshore islands across Tanintharyi, including the Myeik archipelago. It is a lowland, primarily evergreen, forest ecosystem that has some maritime influence. It shows a tolerance of salty ocean seaspray and historically received much of its nutrient input from nesting seabird populations that have subsequently collapsed. It occurs across a wide range of island types including limestone, rubble and sand islands. The canopy is primarily evergreen Dipterocarpaceae (Tagane et al., 2019). Stamp (1924b) reported forests of "tall varied trees who dense canopy, cutting off nearly all light from the ground, is made more intense by the wealth of woody climbers which have struggled upwards to reach the light".



Distribution

Occurs on offshore islands in Tanintharyi state.

Characteristic native biota

Largely unknown but probably moderately diverse. A recent survey of the Myiek archipelago reported a total of 305 species belonging to 241 genera and 91 families (Tagane et al. 2019). Surveys of Lampi Island marine park indicated 20 species of Dipterocarpaceae. The islands support several localized species along the coastal edges including Great-billed Heron *Ardea sumatrana,* Beach Thick-knee *Esacus magnirostris* (NT) and Black-naped Tern *Sterna sumatrana,* and Collared Kingfisher *Todiramphus chloris.* The islands also support a range of nomadic frugivores including Nicobar Pigeon *Caloenas nicobarica* (NT), Large Green-pigeon *Treron capellei* (VU), Pied Imperial-pigeon *Ducula bicolor,* and Plain-pouched Hornbill *Rhyticeros subruficollis* (VU).

The islands also support a population of tool using Long-tailed Macaque *Macaca fascicularis.*

Abiotic environment

This ecosystem occurs on offshore islands exposed to the influence of maritime salt. Largely monsoonal, with a minimum temperature of 21 degrees in December to a maximum of 28.8 in August. Precipitation is highly seasonal, with a dry season occurring from November to March followed by a strong wet season from May to October (Oo et al., 2019).

Key processes and interactions

This ecosystem received much of its nutrients from nesting seabird populations that are mostly no longer present. Dispersal is similarly mediated by mobile fauna, and endemism due to isolation is likely to be high.

Major threats

Unregulated tourism development is the principal threat to this ecosystem (UNESCO, 2014).

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

This ecosystem is broadly distributed across many isolated islands in southern Myanmar, but there is an expected reduction in climate suitability over the next three decades. Threats from humans and biotic degradation are expected to be low, as confirmed by an analysis of the Forest Landscape Integrity Index. The ecosystem qualified for listing as **Vulnerable** under Criterion C, with a plausible range of Least Concern – Vulnerable. **Vulnerable (Least Concern – Vulnerable).**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**VU(LC-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable (Least Concern – Vulnerable)

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

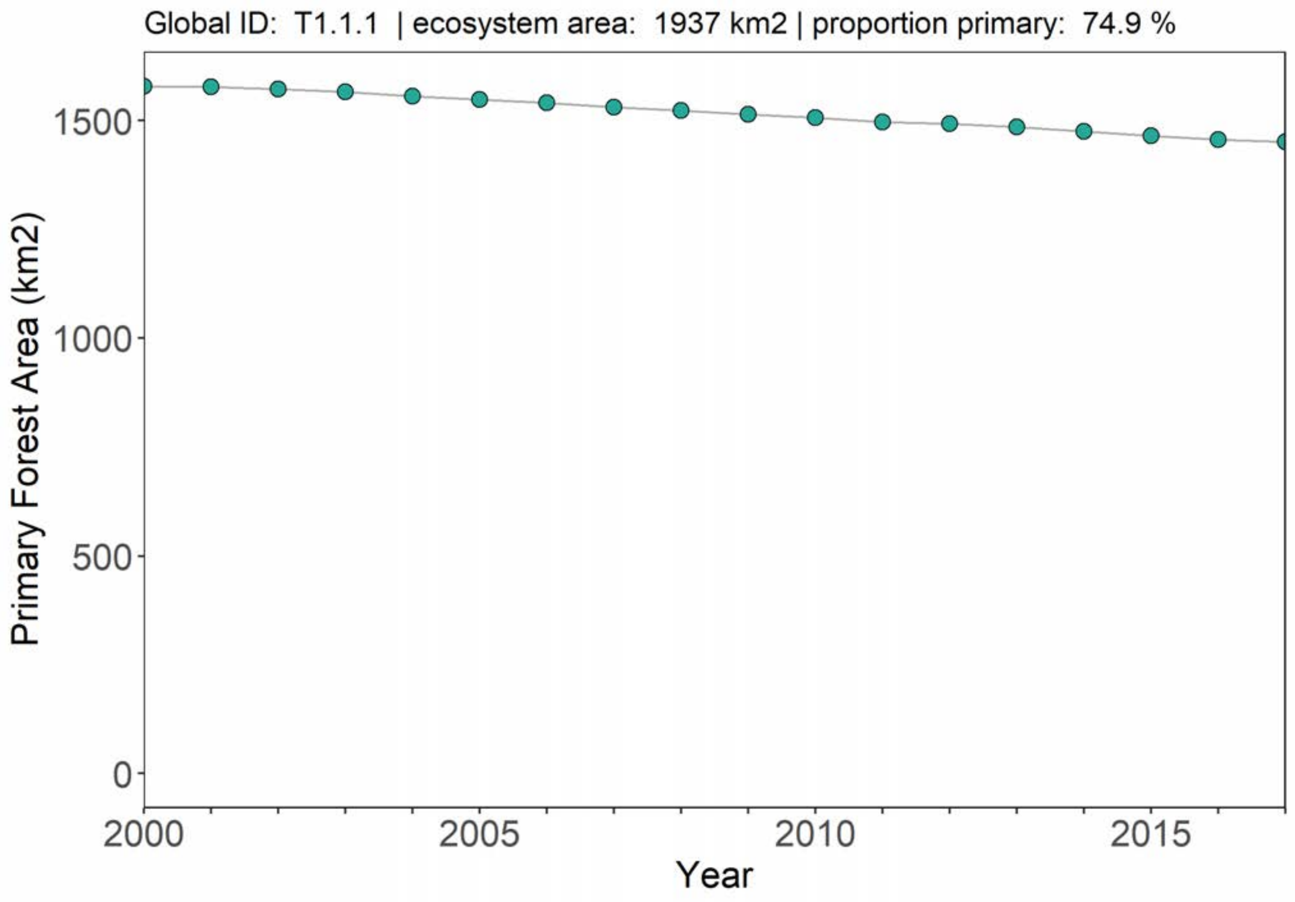
AOO and EOO were measured as 206 10 x 10 km grid cells and 50,337 km^2, respectively. There is no evidence that suggests this ecosystem should meet the criteria to be listed as Near Threatened. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

An environmental suitability model (Ferrer-Paris et al. 2019; see methods) suggests that reductions in climate suitability will occur with an extent and severity to meet the category thresholds for Vulnerable under Criterion C2a. Variation in the outcomes of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Least Concern to Vulnerable, and therefore the ecosystem is assessed as Vulnerable (the most commonly returned result from all scenarios), with plausible bounds of Least Concern – Vulnerable. **Vulnerable (Least Concern – Vulnerable).**

Criterion D

Analyses of a dataset that depicts the distribution of primary forests in South-East Asia (Potapov et al. 2019) suggest that 74.9% of the remaining extent of this ecosystem is primary forest. If 100% of the ecosystem is assumed to be primary forest in 1750, we estimate a 25.1% loss in primary forest extent since 1750. Here we assume that loss of primary forest extent has a relative severity of >90%, and the ecosystem is assessed as Least Concern under Criterion D3. Analyses of the full time-series of primary forest data (n = 18) suggests an 8.1% reduction of primary forest in this ecosystem over the period 2000-2017. A linear model fit to this dataset suggests that primary forest cover in this ecosystem will not decline sufficiently to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Tanintharyi Sundaic lowland evergreen forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Tropical rainforest (Kress et al., 2003), Lowland evergreen rainforest (Connette et al., 2016)
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical lowland forest (T1.1)
Global classification TMMR-T1.1.2
IUCN Status **Vulnerable**

Description This ecosystem occurs at low elevations (mostly <200 m, Connette et al., 2016 to <160 m, Eames et al., 2005) across Tanintharyi state, south of around 14.5 degrees latitude. It may extend to up to around 640 m in some areas (Kress et al., 2003). Highly diverse, with a very tall, dense and closed canopy of many co-existing dipterocarp species. Canopy height may extent 25-70 m. Epiphytes are abundant, buttressed roots common, lianas and ferns are present. Diversity in flora species is extremely high, and a diverse fauna is also present and including a large number of mammal and bird species. Distribution is largely defined by mean monthly rainfall in excess of mean evapotranspiration, generally around 100 mm per month. Considered one of the largest remaining lowland forests in the Indochinese and Sundaic regions of Southeast Asia (De Alban et al., 2018).

Distribution

Occurs in wet lowland areas of Tanintharyi state primarily below 160-200 m, although may extend to up to 650 m.

Characteristic native biota

Stamp (1924b) lists the tree species occurring in this ecosystem as including *Dipterocarpus alatus*, *D. grandiflorus*, and *D. turbinatus*, *Shorea* spp, Anisoptera sp., *Hopea odorata*, and *Parashorea stellata*. This ecosystem supports the remaining populations of sundaic avifauna in Myanmar. This includes Great Argus *Argusianus argus* (NT), Storm's Stork *Ciconia stormi* (EN), White-crowned Hornbill *Berenicornis comatus* (EN), Helmeted Hornbill *Rhinoplax vigil* (CR), Red-throated Barbet *Psilopogon mystacophanos* (NT), Blue-rumped

Parrot *Psittinus cyanurus* (NT), Banded Broadbill *Eurylaimus harterti,* Black-and-yellow Broadbill *Eurylaimus ochromalus* (NT), Green Broadbill *Calyptomena viridis* (NT), Crested Jay *Platylophus galericulatus* (NT), as well as a range of Bulbuls (Pycnonotidae) and Ground Babblers (Pellorneidae). This ecosystem also holds the last remaining population of Gurney's Pitta *Hydrornis gurneyi* (CR). The mammalian fauna is equally impressive with significant populations of Banded Langur *Presbytis femoralis robinsoni* (NT), Dusky Langur *Trachypithecus obscurus* (NT), Lar Gibon *Hylobates lar* (EN), Banded Civet *Hemigalus derbyanus* (NT), Tiger *Panthera tigris* (EN), Mainland Clouded Leopard *Neofelis nebulosa* (VU), Asian Elephant *Elephas maximus* (EN) and Malayan Tapir *Tapirus indicus* (EN; Eames et al., 2005).

Abiotic environment

Reliable year-round rainfall of >100 mm per month and warm temperature that rarely falls below 10°C. Mean annual rainfall is around 3,100 mm and mean annual temperature 26.3°C.

Key processes and interactions

Distribution is largely defined by mean monthly rainfall in excess of mean evapotranspiration, equating to around 100 mm per month. Dense canopy supports humid microclimates and abundant shade. In some areas droughts may occur, which has been shown to influence seedling performance and mortality (Ashton, 2014).

Major threats

Clearing for Oil Palm plantations is considered a primary threat to this ecosystem type (Connette et al., 2016). Forest clearing for logging, rice agriculture, shifting cultivation and betal nut plantations. Unregulated tourism development may also impact this ecosystem, particularly in coastal areas.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

This ecosystem is threatened by forest clearing for a range of commodities. Although no data is available to assess loss in the extent of this ecosystem since 2000, we use primary forest data to assess declines of primary forest extent within the distribution of the ecosystem. Our analyses suggest that a reduction of primary forest in this ecosystem of >50% has occurred since 1750, meeting the category threshold for **Vulnerable (D3)**. Additionally, recent trends in primary forest extent suggest considerable ongoing degradation of this ecosystem, and when projected to a 50 year time frame it is estimated that a decline of 39.6% of primary forest is likely to occur (D2b). **Vulnerable.**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**VU**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable

Year Published

2020

Date Assessed

19th February 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

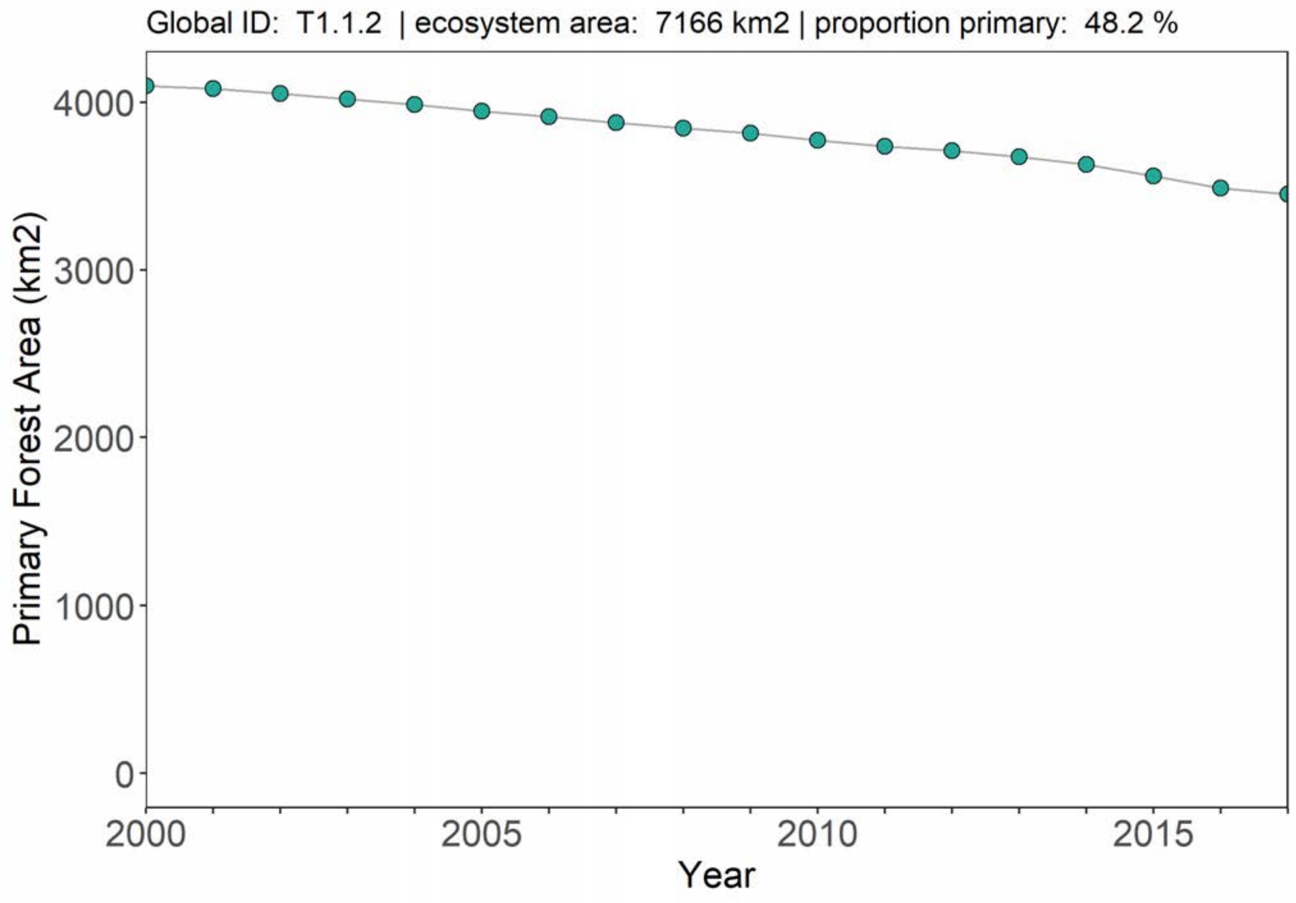
AOO and EOO were measured as 381 10 x 10 km grid cells and 56,209 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Connette et al. (2016) suggested that 52.5% of Tanintharyi sundaic lowland evergreen rainforest met criteria to be considered intact. In broad agreement, analyses of a dataset that depicts the distribution of primary forests in South-East Asia (Potapov et al., 2019) suggest that 48.2% of the remaining extent of this ecosystem is primary forest. If 100% of the ecosystem is assumed to be primary forest in 1750, we estimate a 51.8% loss in primary forest extent since 1750. Here we assume that loss of primary forest extent has a relative severity of >90%, and the ecosystem meets category threshold for Vulnerable under Criterion D3. Analyses of the full time-series of primary forest data (n = 18) suggests a 51.8% reduction of primary forest in this ecosystem over the period 2000-2017. A linear model fit to this dataset suggests that primary forest cover in this ecosystem is expected to decline sufficiently over a 50 year period (1984-2034) to meet the category threshold for Vulnerable under Criterion D2b. **Vulnerable**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Tanintharyi limestone tropical evergreen forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Tropical rainforest (Kress et al., 2003), Lowland evergreen rainforest (Connette et al., 2016), Forest on Limestone (Whitten et al., 1997)
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.3
IUCN Status **Endangered**

Description

Tanintharyi has extensive patches of limestone karst scattered across the region. In these karst landscapes Tanintharyi limestone tropical evergreen forest occurs. Primary tree species are Dipterocarps that form a closed canopy, although they occur at lower density and lower tree height than surrounding lowland and upland evergreen forest ecosystems. Soils are characteristically extremely shallow and acidic, and may be humus-rich. These forests can be found across the Tanintharyi lowlands on limestone hills and slopes, and in some cases may occur on very steep slopes and cliffs. As a result of the discontinuous distribution of limestone in Myanmar, which can frequently become very dry, endemism is very high. For example, 12 new karst-adapted species of gecko were recently discovered in karst environments, some of which are restricted to isolated caves and limestone towers (Grismer et al. 2018). Reliable year round rainfall, averaging in excess of 100 mm per month and between around 1,900 mm and 3,000 mm per year.

Distribution

Occurs in karst landscapes in southern Tanintharyi. We used a global karst layer to refine our maps of this ecosystem type, and further work to map karst landscapes in southern Myanmar is recommended.

Characteristic native biota

Characteristic species of this ecosystem remain relatively unknown. Stamp (1924b) lists the tree species occurring in this ecosystem as including *Dipterocarpus alatus*, *D. grandiflorus*, and *D. turbinatus*, *Shorea* spp, Anisoptera sp., *Hopea odorata*, and *Parashorea stellata*.

This ecosystem occurs in isolated fragments and has high physical complexity, a suite of microhabitats, and relatively stable climate, this ecosystem provides habitat for a large number of endemic species, including gekkos and molluscs (Whitten et al., 1997; Grismer et al., 2018

This ecosystem supports some of the remaining populations of sundaic avifauna in Myanmar. This includes Great Argus *Argusianus argus* (NT), Storm's Stork *Ciconia stormi* (EN), White-crowned Hornbill *Berenicornis comatus* (EN), Helmeted Hornbill *Rhinoplax vigil* (CR), Red-throated Barbet *Psilopogon mystacophanos* (NT), Blue-rumped Parrot *Psittinus cyanurus* (NT), Banded Broadbill *Eurylaimus harterti,* Black-and-yellow Broadbill *Eurylaimus ochromalus* (NT), Green Broadbill *Calyptomena viridis* (NT), Crested Jay *Platylophus galericulatus* (NT), as well as a range of Bulbuls (Pycnonotidae) and Ground Babblers

(Pellorneidae). The mammalian fauna is equally impressive with populations of Banded Langur *Presbytis femoralis robinsoni* (NT), Dusky Langur *Trachypithecus obscurus* (NT), Lar Gibbon *Hylobates lar* (EN), Banded Civet *Hemigalus derbyanus* (NT), Tiger *Panthera tigris* (EN), Mainland Clouded Leopard *Neofelis nebulosa* (VU), Asian Elephant *Elephas maximus* (EN) and Malayan Tapir *Tapirus indicus* (EN; Eames et al., 2005).

Abiotic environment

Shallow soils that can be fairly acidic, topographically complex and reliable year-round rainfall of >100 mm per month and warm temperature that rarely fall below 10° C.

Key processes and interactions

Distribution is largely defined by the occurrence of Karst landscapes coinciding with a mean monthly rainfall of around 100 mm per month. This ecosystem may periodically become very dry, but a dense evergreen canopy can support humid microclimates throughout these periods (Whitten et al., 1997).

Major threats

Unregulated quarrying is considered a primary threat to this ecosystem (Grismer et al., 2018). In addition, deforestation is widespread in this region, primarily for the development of oil palm plantations, rubber plantations and other agroforestry, with deforestation rates reaching 7.85% in some areas of Tanintharyi, the highest rate of forest loss so far recorded in Myanmar (Connette et al., 2017).

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

This ecosystem is highly restricted to limestone substrates and ongoing threats, particularly from quarrying, suggest that this ecosystem is undergoing a continuing decline. **Endangered.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**EN**
	B2	**LC**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Endangered

Year Published

2020

Date Assessed

24th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Lee Grismer

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

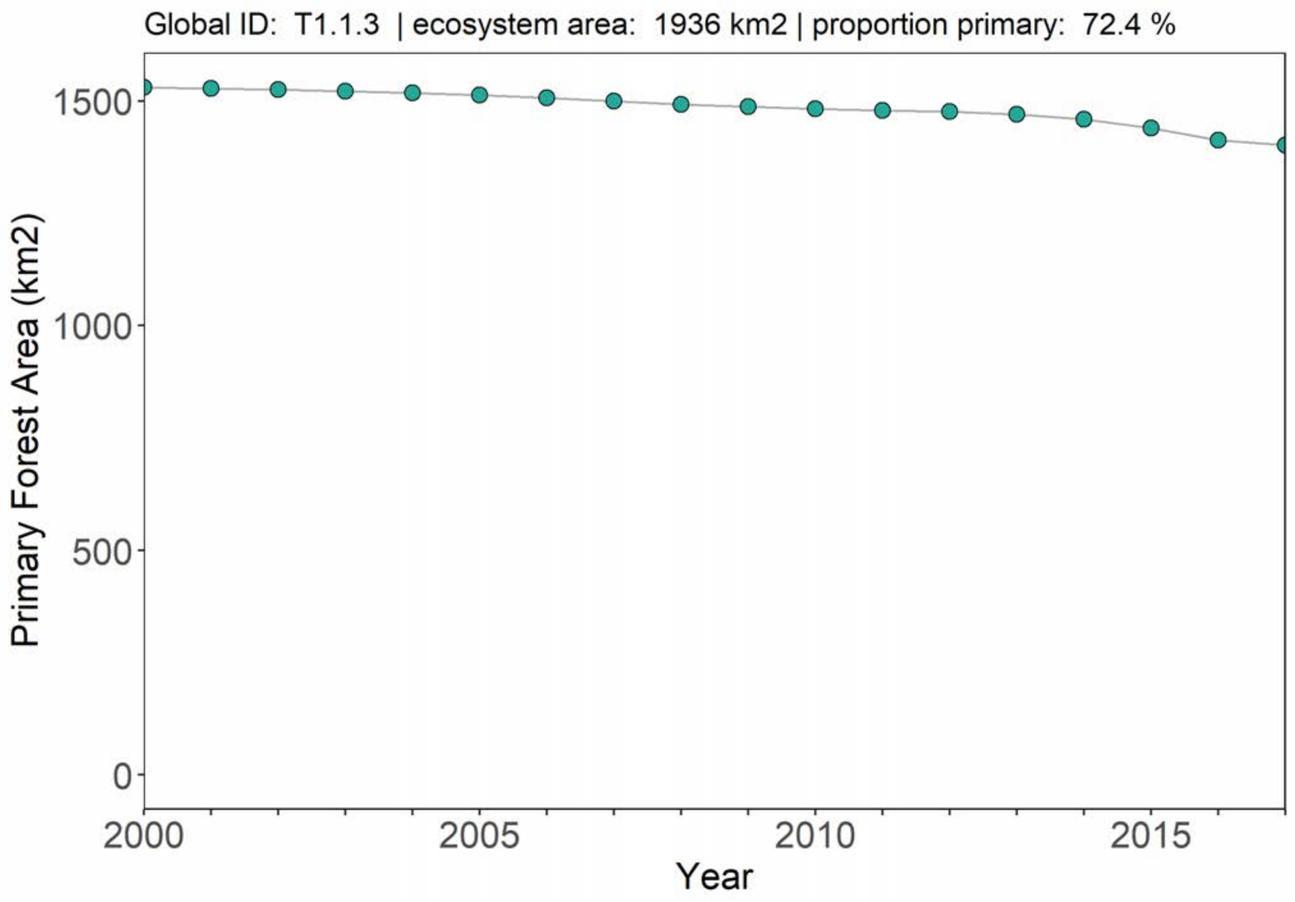
This ecosystem is highly restricted in limestone landscapes and has an AOO of 56 10 x 10 km grid cells and an EOO of 3,796 km^2 There is evidence that limestone quarrying and other threats are leading to continuing decline, meeting subcriteria a(i) and a(iii). The ecosystem is assessed as **Endangered**.

Criterion C

Climate simulation models suggest that environmental conditions within the limestone landscapes of southern Myanmar are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. It should be noted that the occurrence of Karst landscapes is a key distributional driver of this ecosystem, and the scale at which the suitability models were run may not adequately depict the fine-scale changes expected over the next three decades. We recommend further work to refine maps of Karst landscape to better limit the distribution of our model. **Least Concern.**

Criterion D

Remote sensing analyses suggest that 72.4% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 27.6% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing Criterion D. With an 27.6% loss of primary forest extent, the ecosystem is assessed as Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 8.4% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Tanintharyi upland evergreen forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Tropical rainforest (Kress et al., 2003), Upland evergreen rainforest (Connette et al., 2016), Evergreen dipterocarp forest (Kress et al., 2003).
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.4
IUCN Status **Data Deficient ***

Description

This ecosystem occurs at higher elevation (mostly >200 m, Connette et al., 2016) across Tanintharyi state. Differs to lowland sundaic evergreen forest by having a lower mean canopy height, increased presence of conifers (Kress et al., 2003) and reduced leaf area index as a result of smaller mean leaf size. These higher altitude areas have lower mean annual precipitation and lower mean temperature than lowland sundaic evergreen forest. This ecosystem is very diverse, with a closed canopy consisting primarily of Dipterocarpaceae. Buttressed trees common, epiphytes, ferns and lianas are present, and mosses and lichens are likely to be more abundant than in adjacent lowland forests. Very diverse fauna community with birds, bats and insects being important pollinators in the canopy. Distribution is largely defined by mean monthly rainfall in excess of mean evapotranspiration, generally around 100 mm per month.

Distribution

Occurs in wet upland areas of Tanintharyi state mostly above about 200-600 metres to around 2,000 metres along the Thailand border.

Characteristic native biota

Stamp (1924b) lists the tree species occurring in tropical evergreen forests in Tanintharyi as including *Dipterocarpus alatus*, *D. grandiflorus*, and *D. turbinatus*, *Shorea* spp., Anisoptera sp., *Hopea odorata*, and *Parashorea stellata*. Kress et al. (2003) notes there is a greater component of conifers above around 650 m. This ecosystem provides habitat for a poorly understood endemic fauna including Tickell's Brown Hornbill *Anorrhinus tickelli* (NT), Tenasserim Langur

Trachypithecus barbei (DD) and Fea's Muntjac *Muntiacus feae* (DD). Most of the other species are more widespread north and south of this ecosystem.

Abiotic environment

Reliable year-round rainfall of >100 mm per month and warm temperature that rarely fall below 10° C. Mean annual rainfall is about 2,300 mm and mean annual temperature 24.9° C.

Key processes and interactions

Distribution is largely defined by mean monthly rainfall in excess of mean evapotranspiration, of around 100 mm per month. Dense canopy supports humid microclimates and abundant shade.

Major threats

Clearing for Oil Palm plantations is considered a primary threat to this ecosystem type (Connette et al., 2016). Forest clearing for logging, rice agriculture, shifting cultivation and betal nut plantations. Unregulated tourism development may also impact this ecosystem, particularly in coastal areas. As an upland ecosystem that will presumably undergo altitudinal migration as a result of climate change, this ecosystem is threatened by climate warming.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

Our assessment of range size, future climatic suitability and trends in primary forest cover indicate that the ecosystem does not meet any category thresholds for the Red List of Ecosystems and was therefore initially assessed as Least Concern. However, as a result of a post-assessment review by experts that highlighted a range of severe threats that have not yet been quantified, including illegal forest clearing, the assessment outcome was modified to Not Evaluated. This change reflects that the standards of evidence were not sufficient to warrant a Least Concern listing, and that further data could yield an assessment outcome other than Least Concern. We recommend urgent further work to address this knowledge gap and enable a complete assessment of this ecosystem type. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2020

Date Assessed

19th February 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

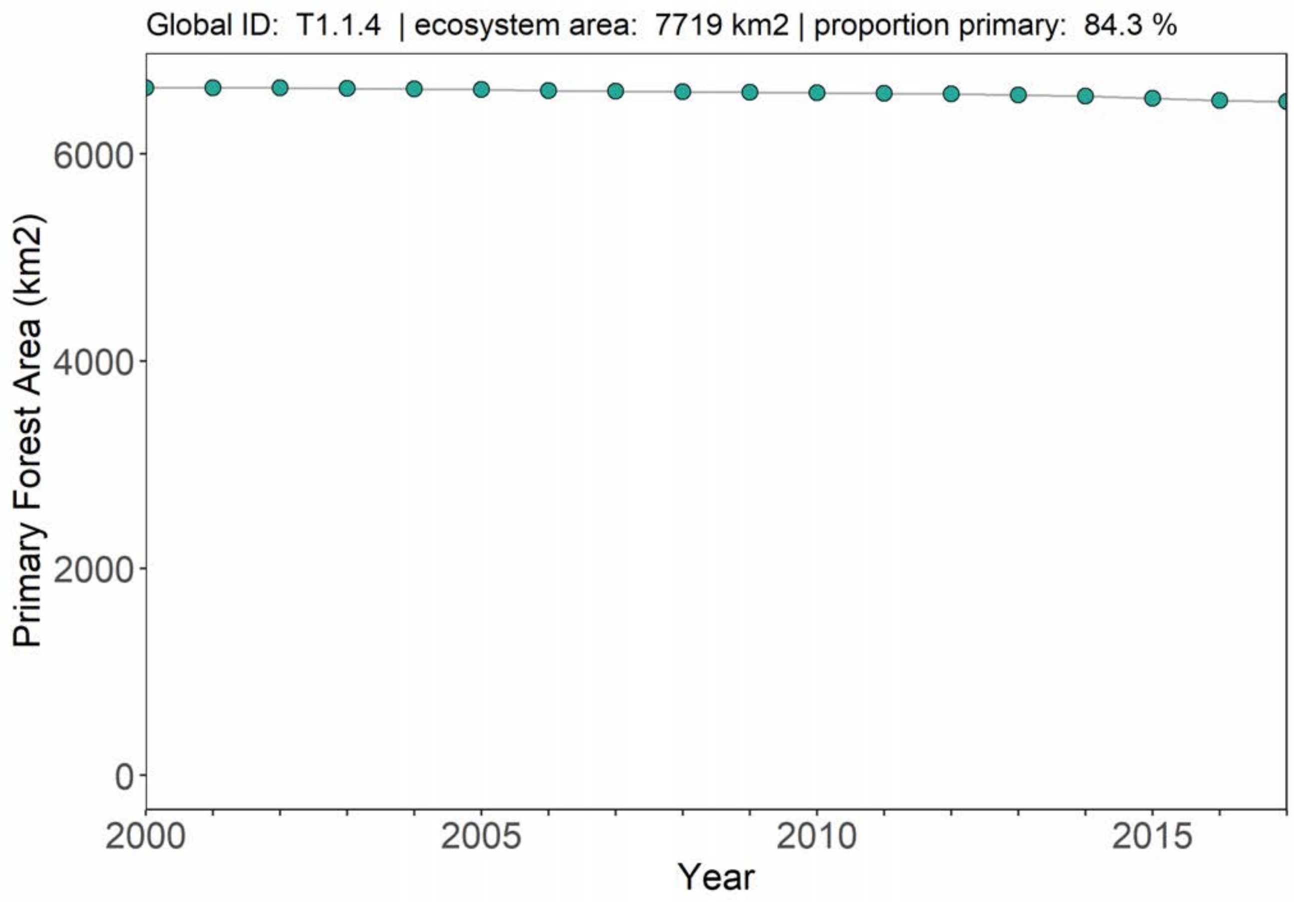
AOO and EOO were measured as 361 10 x 10 km grid cells and 58,256 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Remote sensing analyses suggest that 84.3% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, we estimate that there has been a 15.7% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing Criterion D. With <50% of primary forest loss since 1750, the ecosystem is assessed Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 2.1% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent necessary to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, an expert review indicated that it is subject to a range of rapidly expanding and intensifying threats, including oil pipeline development, roads development and plantation development (Connette et al., 2016). The impacts of these threats have not yet been quantified, but it is likely that further work would lead to an assessment outcome other than Least Concern. It is therefore considered to not have met minimum evidence standards and assigned as Data Deficient. We recommend urgent further work to complete the assessment of this ecosystem type. **Data Deficient.**

Kayin evergreen tropical rainforest

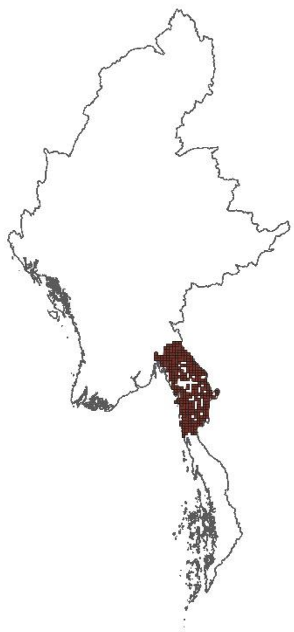
Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Tropical rainforest (Kress et al., 2003), Upland evergreen rainforest (Connette et al., 2016), Evergreen dipterocarp forest (Kress et al., 2003).
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.5
IUCN Status **Endangered**

Description

This very diverse, closed-canopy, non-sundaic rainforest comprises a diverse suite of trees including prominent Dipterocarpaceae, but few emergents. Buttressed trees are common, epiphytes, ferns and lianas are abundant. Canes, palms and bamboos are present in the understorey, and become abundant in areas of high disturbance. This ecosystem has a more seasonal climate, and a less diverse biota than upland and lowland rainforests further south in Tanintharyi. Nevertheless, it supports a diverse fauna community with birds, bats and insects being important pollinators in the canopy.

Distribution

Occurs in areas of Kayin state that have reliable year-round rainfall of at least 100 mm per month.



Characteristic native biota

The biota of these forests is largely unreported, but is expected to be transitional between the elevated subtropical rainforests of the western Shan plateau and the Sundaic tropical rainforests of Tanintharyi (Davis, 1960). Stamp (1924b) lists the tree species occurring in tropical evergreen forests in Tanintharyi as including *Dipterocarpus alatus*, *D. grandiflorus*, and *D. turbinatus*, *Shorea* spp, *Anisoptera scaphula*, *Hopea odorata*, and *Parashorea stellata*, all from the Dipterocarpaceae. Ground cover includes canes, palms and bamboos.

The fauna includes the Indochinese Grey Langur *Trachypithecus crepusculus* (EN) a recent split from the Phayre's Langur group. This ecosystem also supports some of the best populations of large mammals remaining in Southern Myanmar including Lar Gibbon *Hylobates lar* (EN), Dhole *Cuon alpinus* (EN), Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), Tiger *Panthera tigris* (EN), Leopard *Panthera pardus* (VU), Mainland Clouded Leopard *Neofelis nebulosi* (VU), Asian Elephant *Elephas maximus* (EN), Malayan Tapir *Tapirus indicus* (EN), Sambar *Cervus unicolor* (VU), and Gaur *Bos gaurus* (VU).

Abiotic environment

Reliable year-round rainfall of >100 mm per month, but maximum rainfall in June-November and warm temperature that rarely fall below 10° C. Mean annual rainfall is about 2,960 mm and mean annual temperature 25.2° C. Soils are relatively fertile loams and clay loams.

Key processes and interactions

Distribution is largely defined by mean monthly rainfall of at least 100 mm per month and in excess of mean evapotranspiration. Reliably warm and moist conditions support continuous growth and recruitment of trees and a complex trophic web. Dense canopy generates humid microclimates and abundant shade and is likely to promote gap-phase dynamics.

Major threats

Development of rubber plantations is probably the primary threat, with forest clearing and fragmentation for timber extraction, rice agriculture, shifting cultivation and betal nut plantations also key threats (Bhagwat et al., 2016).

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when all patches of primary forest are smaller than 1-10 km^2.

Assessment summary

This ecosystem is restricted to southeast Myanmar, and there is evidence of ongoing declines due to rubber plantation development, logging, and cutting timber for shifting cultivation. A climate simulation model does not suggest major reductions in environmental suitability and the Forest Landscape Integrity Index suggests remaining patches are relatively intact. Primary forest data suggest that more than 77% of this ecosystem has been degraded since 1750, meeting category thresholds for **Endangered under Criterion D3**. **Endangered.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**EN**
Criterion E	E	**NE**

Assessment Outcome

Endangered

Year Published

2020

Date Assessed

24th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

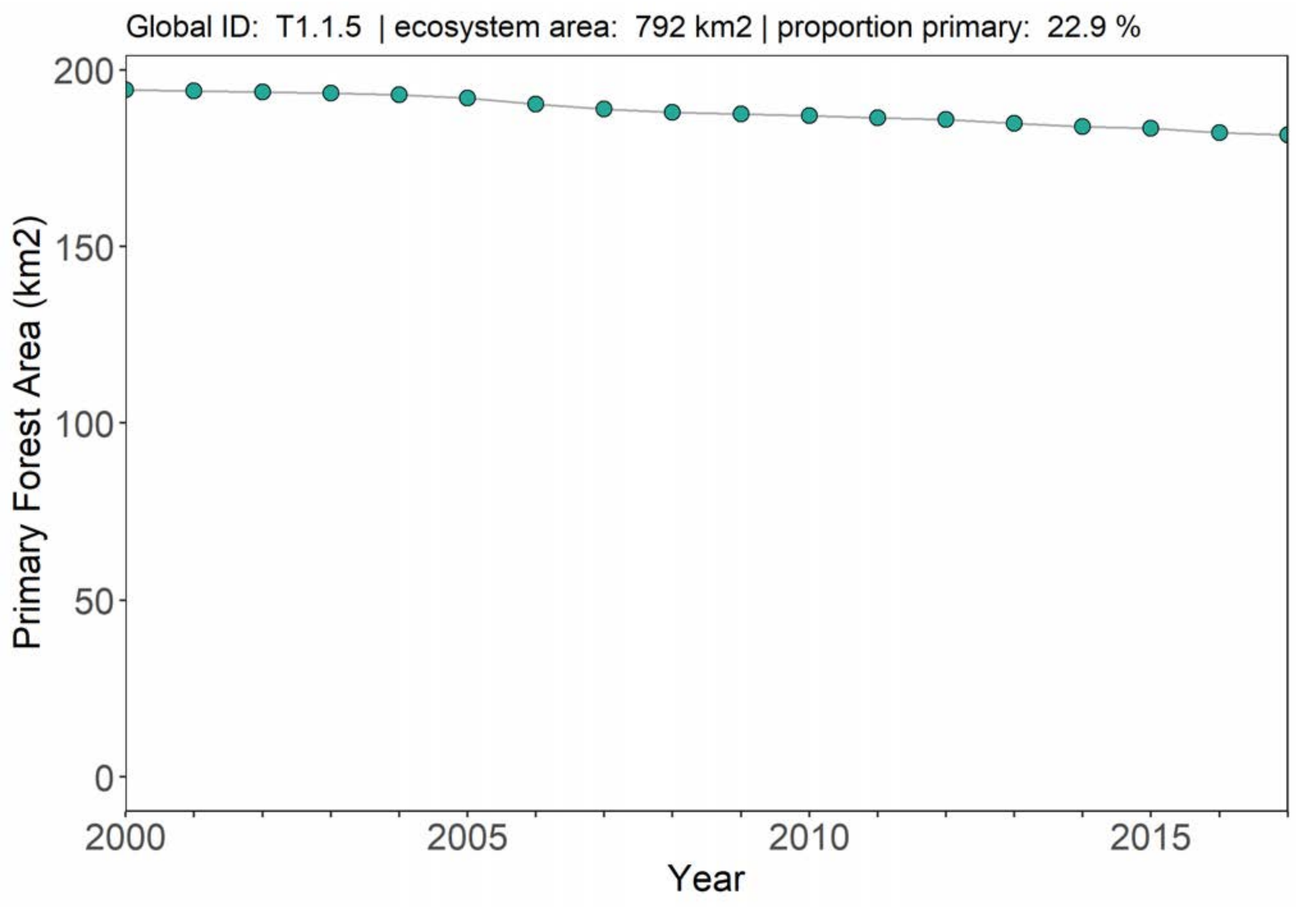
AOO and EOO were measured as 289 10 x 10 km grid cells and 39,269 km^2, respectively. With threats including clearing due to the ongoing development of rubber in this region, this ecosystem meets the category thresholds for B1a(i) and B1a(iii). The ecosystem is therefore assessed as Vulnerable under Criterion B1. **Vulnerable**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Remote sensing analyses suggest that only 22.9% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to have been primary forest in 1750, we estimate that there has been a 77.1% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing Criterion D. With between 70 and 90% of primary forest loss since 1750, the ecosystem is assessed Endangered under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) suggest losses of primary forest have slowed, as indicated by a 6.6% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent necessary to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Endangered**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Southern Rakhine evergreen rainforest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Rainforest
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.6
IUCN Status **Critically Endangered (Critically Endangered – Collapsed)**

Description

No confirmed occurrences of this ecosystem remain. However, Davis (1960) mapped all of Rakhine as Tropical rain forest and noted that evergreen tropical rainforest occurs where annual rainfall is >2,250 mm. This suggests that small areas of southern Rakhine were once evergreen forest, occurring where weather is warm throughout the year and wet enough to compensate a short dry season. tropical rainforests in climatically comparable areas to the east of the Ayeyarwady delta in Kayin state have complex structure and closed tree canopies up to 40 m tall, with numerous epiphytes and few deciduous species present, unlike forests further north on the Rakhine Range. Owing to extensive agricultural expansion and forest cutting for hardwood, this ecosystem is likely to be collapsed. If any small patches remain, they are likely to be under severe human pressure.

Distribution

The original distribution of this ecosystem was likely to be restricted to a relatively small portion of the southern Rakhine Range, to the west and northwest of the Ayeyarwady delta. It would have been isolated from other tropical rainforests by a matrix of semi-evergreen forests and savannas exposed to more severe dry-season water deficits. Small patches may remain in southern Rakhine, but these have not been confirmed.

Characteristic native biota

No information on the characteristic species of this ecosystem was found, however, descriptions of tropical ranforests by Stamp (1924b) and Davis (1960) are likely to be indicative. When intact, the ecosystem is likely to have supported a diverse megafauna, including Asian Elephant *Elephas maximus* (EN).

Abiotic environment

Southern Rakhine has warm minimum temperatures (mean temperature of coldest month is 20.7° C) and our data suggests mean annual rainfall is in excess of 3,000 mm.

Key processes and interactions

Reliable water availability from regular rainfall, warm temperatures, rich soils are likely key to sustaining this ecosystem and its complex trophic web through small-scale gap-phase dynamics. Occasional destructive monsoonal storms are likely to have driven larger successional changes.

Major threats

Forest disturbance through timber harvest, repeated burning, cultivation of crops and plantation establishment are likely to have caused this ecosystem to collapse.

Ecosystem collapse definition

This ecosystem is considered as collapsed when its distribution has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment Summary

Very small patches of evergreen tropical rainforest have been mapped on the southern Rakhine Range within the high rainfall zone. These are potentially small relics of the ecosystem, but remain to be confirmed on the ground. If these patches prove not to be tropical rainforest, then the ecosystem has collapsed. If any patches are confirmed, then the status of the ecosystem is Critically Endangered under criteria B1. The status of the ecosystem is therefore **Critically Endangered** (plausible range Critically Endangered – Collapsed).

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**CR**
	B2	**EN**
	subcriteria	**B1a(i), B1a(iii), B2a(i), B2a(iii)**
	B3	**NE**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered (Critically Endangered – Collapsed)

Year Published

2019

Date Assessed

20th June 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

This ecosystem was reported to occur historically in the high rainfall areas of southern Rakhine. No formal estimate of its former distribution has been made. The mapping conducted in this project suggested some very small patches may remain, but have not been confirmed. **Data deficient**.

Criterion B

Our mapping suggested a very small amount of this ecosystem may still exist in southern Rakhine. However, the remaining patches are very small fragments that are likely to be under severe pressure from threats in this region that meet subcritera B1a(i), B1a(iii), B2a(i), and B2a(iii). With an AOO of 18 (5 with the one per cent rule invoked) and EOO of 1,619 km^2, the ecosystem qualifies for listing as Critically Endangered under Criterion B1. **Critically Endangered.**

Criterion C

Owing to extreme uncertainty in the distribution of this ecosystem we opted to not run a climate simulation model to assess Criterion C. **Data Deficient.**

Criterion D

Owing to extreme uncertainty in the distribution of this ecosystem we could conduct analyses suitable for assessing Criterion C. **Data Deficient.**

Criterion E

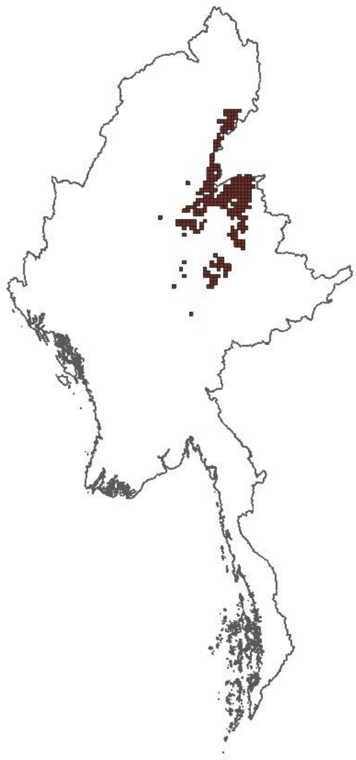
No models were used to assess Criterion E. **Not Evaluated.**

Western Shan Plateau subtropical evergreen rainforest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Rainforest
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.7
IUCN Status **Vulnerable**

Description

This is a complex evergreen rainforest that occurs on rich limestone and shale soils on the western Shan plateau. The closed tree canopy is up to 25-40 m tall, with a diversity of notophyll to microphyll leaf sizes. The trees represent a diverse array of plant families, and some have buttress roots and cauliflory. Epiphytic orchids and ferns, and lianas are abundant in the tree canopy. The understorey includes ferns and forbs. Subtropical rainforest on the western Shan plateau typically forms distinct mosaics with Shan Hills pine savanna with fine-scale distributions probably mediated by water availability and occurrence of fire. However, the rainforest matrix has been severely fragmented by intensive agricultural land use. A particularly good remnant example of this ecosystem can be found at Ye Aye reservoir, Kalaw.



Distribution

Distributed in small fragments between about 900 m and 1,400 m elevation along the western Shan plateau.

Characteristic native biota

The biota is likely to share some affinities with distant subtropical rainforests of upper Myanmar and Yunnan plateau in China including Scimitar-babblers and their allies (Timaliidae) as well as the recently described Skywalker Hoolock Gibbon *Hoolock tianxing* (EN).

Abiotic environment

Western Shan Plateau subtropical evergreen rainforest occurs in areas with reliable year-round rainfall of between about 1,400 and 2,000 mm, with the majority falling during June-November. Forms on rich limestone and shale soils at elevations of 900-1,400 m.

Most fragments remain on slopes and hills, although some small remnant patches occur on flatter areas of the Shan plateau.

Key processes and interactions

Reliable water availability from regular rainfall, warm temperatures and the occurrence of rich soils support a highly diverse ecosystem. These conditions support continuous growth and gap-phase recruitment of trees and a complex trophic web. Dense-canopies and abundant rainfall maintain a humid micro-climate, with thick leaf litter that is not fire-prone unless fragmented by human activity.

Major threats

The ecosystem has been widely cleared and fragmented for agriculture, primarily rice and crops. Cutting for hardwood. Anthropogenic fires after clearing limit regeneration.

Ecosystem collapse definition

Western Shan Plateau subtropical evergreen rainforest is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when all patches of primary forest are smaller than 1-10 km^2.

Assessment Summary

This ecosystem has been highly fragmented and now only remains in very small patches across wetter areas of western Shan state. Our map data, developed by mapping evergreen forest cover in the regions with greater than 1,500 mm per year rainfall and between 900-1,400 m in altitude, suggested that very small patches of this ecosystem still occur across Shan state. Primary forest maps suggest than >50% of this ecosystem is not considered primary forest, meeting category thresholds for Vulnerable under D3. Further work to better identify the remaining patches of this ecosystem is required to refine this first assessment. **Vulnerable.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

15th September 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. Field work suggests that this ecosystem was once extensive across the Shan Plateau and has now largely been converted to agriculture, with only very small patches remaining on hilltops and wet gullies. We recommend a targeted mapping project that aims to develop a time-series of the extent of this ecosystem. Until that has been produced, the ecosystem is listed as **Data Deficient.**

Criterion B

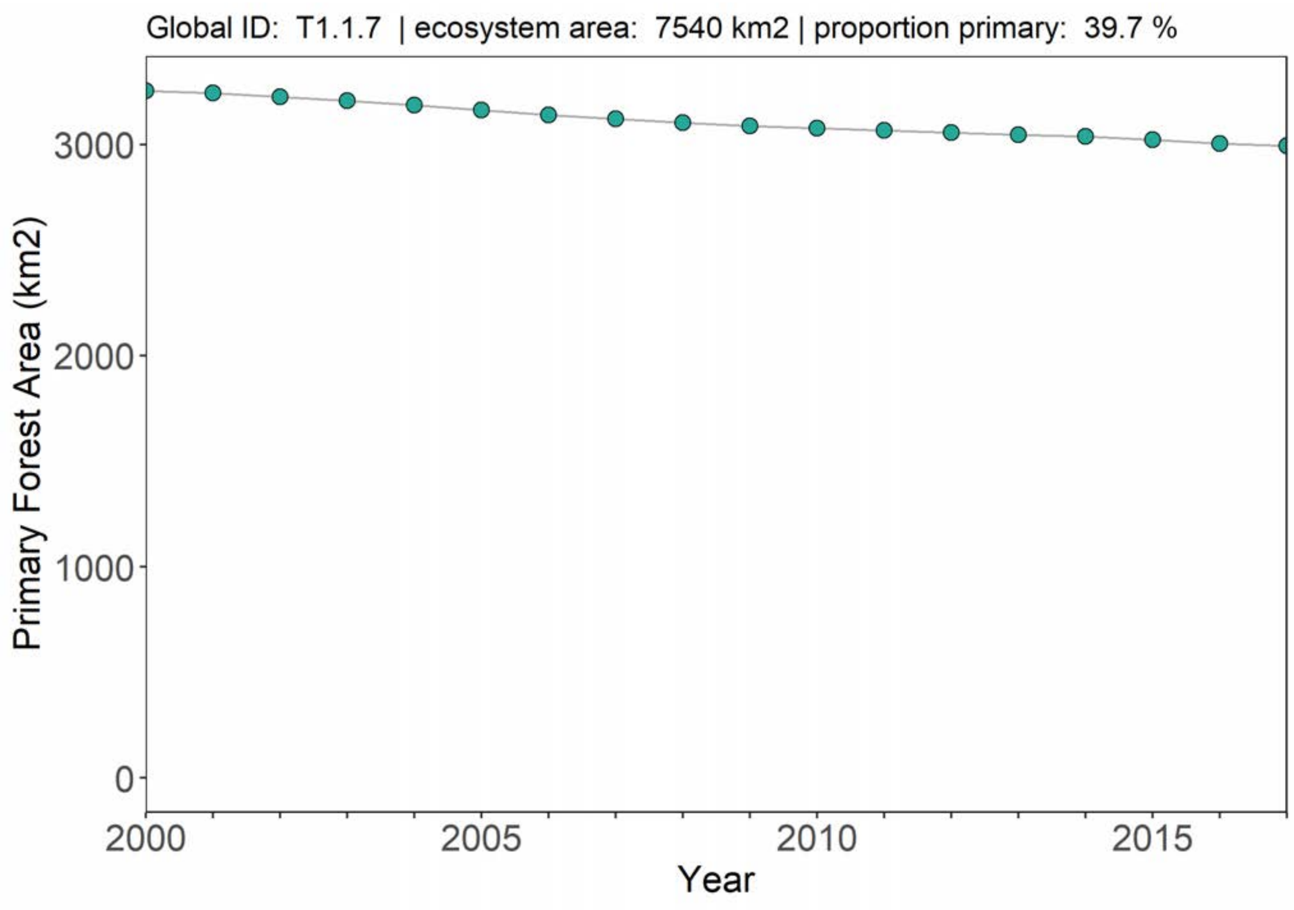
This ecosystem remains in only very small patches throughout western Shan (likely <1-2 ha). Our maps of evergreen rainforest in this region suggest it has an AOO of 1,644 10 x 10 km grid cells (invoking the one % rule) and an EOO of 288,485 km^2. We note that our maps of evergreen rainforest in this area performed poorly due to few observed occurrences of this ecosystem to use as training points, as well as the very small patches that this ecosystem appears to remain in. Ongoing declines in remaining patches due to edge effects and further forest cutting were observed, and we expect these threats could have a significant impact on this ecosystem in the next 20 years. The ecosystem therefore meets category thresholds for **Least Concern**.

Criterion C

Without map data, it was not possible to assess Criterion C. **Data Deficient.**

Criterion D

The few remaining patches that we observed during field work, primarily in wet gullies and hilltops, suggest that this ecosystem is highly threatened by edge effects, including the incursion of invasive species. Remote sensing analyses suggest that 39.7% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 60.3% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation Criterion D. Thus, degradation of this ecosystem is assessed as greater than 50% but less than 70%, therefore meeting the D3 category threshold for Vulnerable. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 8.0% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034), and is therefore assessed as Least Concern under D2b. The ecosystem is assessed as Least Concern under Criterion D2b. **Vulnerable**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Kachin-Sagaing low elevation evergreen subtropical rainforest

Authors Armstrong, K., Tizard, R., Grantham, H.G.

Myanmar ecosystem names Tropical evergreen rainforest (UNESCO, 2014), subtropical lowland forest/hardwood rainforest (Davis, 1960), Wet evergreen forest (northern type; Stamp, 1924b)
Biome Tropical and subtropical forests (T1)
Functional Group Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.8
IUCN Status **Data Deficient ***

Description

This evergreen closed forest ecosystem is found in the lowlands of northern Myanmar from around 100-300 m where there is abundant rainfall (2,000 mm+) and generally moist conditions. The forest has floristic affinities with northern Thailand and Assam, India, but unlike the tropical evergreen forests to the south, there are fewer species of dipterocarps. It is biologically complex, with some emergent trees, palms, numerous lianas, and strangler figs. This forest type transitions seamlessly into Kachin-Sagaing mid-elevation subtropical forest above 300 m, to which it is similar, but with a different assemblage of species.

Distribution

This ecosystem is found in northern Sagaing Region along the Chindwin river (e.g. in Htamanthi Wildlife Sanctuary), and low elevation areas of Kachin State. Kingdon-Ward (1944) notes that dense forests north of Myitkyina fill the main valleys including much of the plain south of Putao.

Characteristic native biota

Characteristic tree species include many species of *Ficus,* as well as *Artocarpus lakoocha* (Moraceae), *Dipterocarpus turbinatus*, *Vatica* spp., *Shorea siamensis* (Dipterocarpaceae), *Gluta elegans*, *Spondias pinnata* (Anacardiaceae), *Alstonia scholaris*, *Holarrhena pubescens*, *Wrightia arborea* (Apocynaceae), *Saraca indica*, *Acrocarpus fraxinifolius*, *Archidendron kerrii* (Fabaceae), *Diospyros coetanea*, *Diospyros undulata* (Ebenaceae), *Oroxylum indicum*, *Stereospermum* sp, *Markhamia* sp. (Bignoniaceae), *Litsea* spp., *Cinnamomum bejolghota*, *Phoebe lanceolata*, (Lauraceae), *Crypteronia paniculata* (Crypteroniaceae), *Mesua ferrea*, *Mesua assamaica* (Callophyllaceae), *Turpinia pomifera* (Staphyleaceae), *Balakata baccata* (Euphorbiaceae), *Hibiscus macrophyllus*, *Heritiera burmensis*, *Pterospermum acerifolium* (Malvaceae), *Ailanthus triphysa* (Simaroubaceae), *Tetrameles nudiflora* (Datiscaceae), *Hydnocarpus castaneus, H. macrocarpa* (Achariaceae), *Daphniphyllum laurinum* (Daphniphyllaceae), *Toona ciliata*, *Aglaia lawii* (Meliaceae), *Anthocephalus chinensis* (Rubiaceae), *Knema globularia*, *Knema linifolia*, (Myristicaceae), *Xanthophyllum flavescens* (Polygalaceae), *Viburnum punctatum* (Adoxaceae), *Baccaurea ramiflora* (Phyllanthaceae), *Atalantia* sp. (Rutaceae), *Apodytes dimidiata* (Icacinaceae), *Carallia brachiata* (Rhizophoraceae), *Gironniera subaequalis* (Cannabaceae), *Holoptelea integrifolia* (Ulmaceae), *Dillenia indica*

(Dilleniaceae), *Castanopsis* spp. (Fagaceae), and *Strychnos nux-blanda* (Loganiaceae). Along waterways the following tree species are common: *Sloanea sterculiacea* (Elaeocarpaceae*), Aesculus assamica* (Sapindaceae), *Crateva magna* (Capparaceae), *Cynometra* sp. (Fabaceae), *Paranephelium xestophyllum* (Sapindaceae), *Duabanga grandiflora* (Sonneratiaceae) and very tall stands of *Pterygota alata* (Malvaceae). Small tree and shrub layer include abundant Rubiaceae of various genera such as *Ixora*, *Psychotria*, Lasianthus *Chassalia curviflora* and *Saprosma ternatum*. *Gomphandra quadrifida* (Stemonuraceae), *Dracaena angustifolia* (Asparagaceae), *Tabernaemontana divaricata*, *Kopsia arborea* (Apocynaceae), *Leea* (Leeaceae), *Piper* (Piperaceae), *Trevesia* (Araliaceae), *Goniothalamus sesquipedalis*, *Trivalvaria pumila* (Annonaceae), the screwpine *Pandanus urophyllus* (Pandanceae), and tree fern *Cyathea gigantea* (Cyatheaceae), as well as the palms *Wallichia siamensis*, *Pinanga acuminata*, *Areca triandra*, *Arenga nana* and *Salacca griffithii* (Arecaceae). Common climbers/vines include *Gnetum gnemonoides* (Gnetaceae), *Myxopyrum smilacifolium* (Oleaceae), *Stixis scandens* (Capparaceae), *Plagiopteron suaveolens* (Celastraceae), *Combretum, Getonia floribunda* (Combretaceae), various *Bauhinia* spp. (Fabaceae), *Strychnos* (Loganiaceae), *Dichapetalum longipetalum* (Dichapetalaceae), *Congea tomentosa, Sphenodesme* (Lamiaceae), *Artabotrys* sp. (Annonaceae), *Erycibe, Merremia* (Convolvulaceae), *Pothos chinensis* (Araceae), *Colubrina asiatica*, *Ventilago maderaspatana* (Rhamnaceae), *Hiptage*, *Aspidopterys* (Malpighiaceae), *Illigera* (Hernandiaceae), *Connarus paniculatus* (Connaraceae), and various rattans, Calamus spp. (Arecaceae). The forest Herb layer includes many Acanthaceae, including *Acanthus leucostachys*, *Staurogyne argentea,* and *Staurogyne gracilis* as well as *Ophiorrhiza*, *Hedyotis* (Rubiaceae), *Rhynchotechum obovatum* (Gesneriaceae)*, Aglaonema hookerianum* (Araceae) *Moliniera capitulata* (Hypoxidaceae), and numerous gingers *Amomum, Alpinia, Curcuma, Etlingera, Globba, larsenianthus*, and *Zingiber* (Zingiberaceae).

This ecosystem supports a significant population of White-winged Duck *Asarcornis scutulata* (EN) that breed in cavities of large trees along waterways and along the undisturbed rivers in most remote corners White-bellied Heron *Ardea insignis* (CR) still occurs. Similar cavities throughout the ecosystems are also used by several species of hornbill including Great Hornbill *Buceros bicornis* (VU), and Austen's Brown Hornbill *Anorrhinus austeni* (NT). Other species found through the forest include Blue-throated Barbet *Psilopogon asiaticus,* Bay Woodpecker *Blythipicus pyrrhotis,* Long-tailed Broadbill *Psarisomus dalhousiae,* Grey Treepie *Dendrocitta formosae*, and Sultan Tit *Melanochlora sultanea.* This ecosystem is found on both banks of the Chindwin River. The Chindwin is major biogeographic barrier for primates supporting Capped Langur *Trachypithecus pileatus pileatus* (EN) and Shortridge's Langur *Trachypithecus shortridgei* (EN) as well as Western Hoolock Gibbon *Hoolock hoolock* (EN) and Eastern Hoolock Gibbon *Hoolock leuconedys* (VU). This ecosystem also supports significant populations of large mammals including Dhole *Cuon alpinus* (EN)*,* Sun Bear *Helarctos malayanus* (VU)*,* Himalayan Black Bear *Ursus thibetanus* (VU), Tiger *Panthera tigris* (EN)*,* Leopard *Panthera pardus* (VU)*,* Mainland Clouded Leopard *Neofelis nebulosa* (VU)*,* Asian Elephant *Elephas maximus* (EN)*,* Sambar *Cervus unicolor* (VU), Gaur *Bos gaurus* (VU), Indochinese Serow *Capricornis milneedwardsii* (NT)*,* and Red Serow *Capricornis rubidus* (NT).

Abiotic environment

Kachin-Sagaing low-elevation subtropical rainforest is found at c. 100 – 300 m, with a tropical to sub-tropical climate and high rainfall.

Key processes and interactions

A complex forest structure with several layers and emergent trees is important to maintain the health of this ecosystem. Rainfall and high atmospheric moisture are also key processes.

Major threats

Deforestation, degradation (e.g. through logging and hunting), and fragmentation are major threats to this ecosystem. There has also been significant forest clearing in the past. Gold mining and some amber mining along the Chindwin and Uru rivers is also a major threat to the ecosystem.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0 km^2.

Assessment summary

While deforestation and fragmentation are known to occur in this ecosystem, our analysis of primary forest data did not indicate that this ecosystem meets thresholds for Criterion D. The ecosystem is sufficiently broadly distributed to not meet category thresholds for Criterion B. Data deficient outcomes for Criterion A and C suggest further work is needed, and we recommend a reassessment of this ecosystem as soon as sufficient time-series data becomes available. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2019

Date Assessed

19th February 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Hedley Grantham, Kate Armstrong

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 559 10 x 10km grid cells and 68469 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

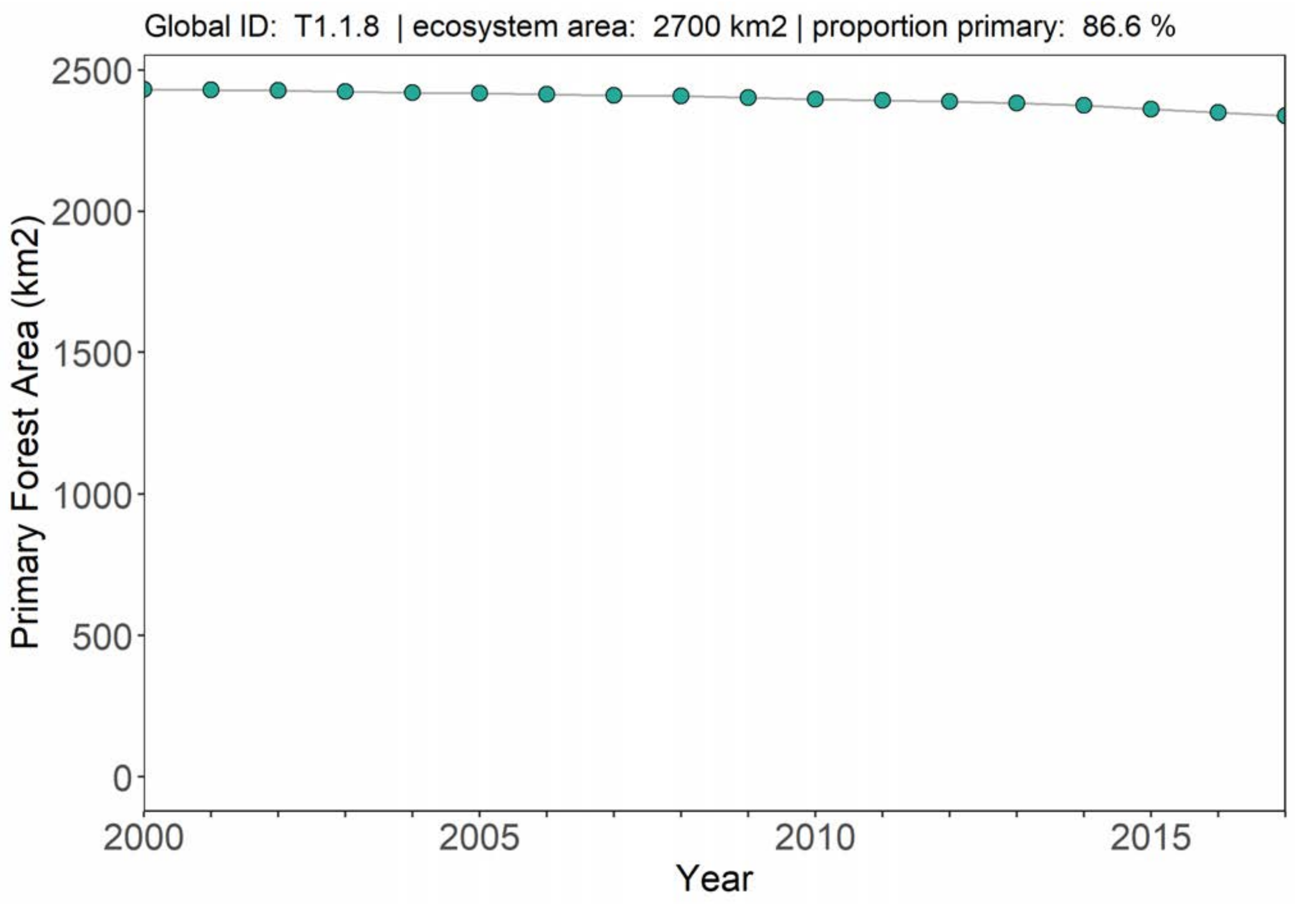
Criterion C

Owing to uncertainty in the distribution of this ecosystem while we conducted the climate scenario modelling, no climate simulation models were run for Kachin-Sagaing lowland evergreen subtropical rainforest. No other information on environmental degradation was found during the assessment. The ecosystem is assessed as **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 86.6% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest

in 1750, there has been an 13.4% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss since 1750 (13.4%) as a biotic variable for assessing Criterion D. With <50% of primary forest loss since 1750, the ecosystem is assessed Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 3.8 % reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, an expert review identified a range of threats to this ecosystem that coule lead to a status outcome other than Least Concern. Threats identified in the review include: land clearing for gold mining along the Chindwin and Uru rivers, leading to heavy metal contamination and silting (Bhagwat 2017, Lim et al 2017, Piman et al 2017, Lee et al 2020), extensive logging and mining in Tanai/Hukaung Valley (Bhagwat 2017) new gold mining concessions in the foothills around Putao, extensive clearing and secondary forest around Myitkyina and towards the Chinese border due to logging and agricultural expansion/plantation development (Bhagwat 2017, Wang & Myint 2016, Global Witness 2009), exacerbated by military conflict (Lim et al 2017), risk from potential Myitsone dam project (Fawthrop 2019, International Rivers 2013), risk from future roads linking to Chinese belt and road initiative, which would open access to further forest cutting (Lo 2019). These drivers of environmental degradation are likely to appreciably increase the risk of collapse of this ecosystem within the assessment time frame. The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to assess the impacts of these threats and enable a robust assessment.

Kachin-Sagaing mid elevation subtropical rainforest

Authors Armstrong, K., Tizard, R., Grantham, H.
Myanmar ecosystem names Tropical evergreen rainforest (UNESCO, 2014), subtropical lowland forest/hardwood rainforest (Davis, 1960), Wet evergreen forest (northern type; Stamp 1924b)
Biome Tropical and subtropical forests (T1)
Functional Group Tropical/subtropical lowland forest (T1.1)
Global classification MMRT1.1.9
IUCN Status **Data Deficient ***

Description

This evergreen closed forest ecosystem is found in the low to mid elevations of northern Myanmar from c. 300-700 m, where there is abundant rainfall (2000 mm+) and generally moist conditions associated with elevation. The ecosystem covers a climate condition that transitions from almost tropical to subtropical and is found in unusually high latitudes here above the Tropic of Cancer due to this atypical climate (Kingdon-Ward, 1944). In higher altitude areas, around 700 m, in the north, Kachin-Sagaing mid-elevation subtropical rainforest transitions into the Kachin Hills subtropical forest ecosystem.

Distribution

This ecosystem occurs in low elevation areas of northern Kachin State and northern Sagaing Region, namely the upper Chindwin and upper Ayeyarwady valleys, including Putao and low elevation areas of Hponkanrazi Wildlife Sanctuary, Hkakaborazi National Park, Hukaung Valley Wildlife Sanctuary, and the foothills of the Naga Hills. Kingdon Ward (1948) noted that north of Myitkyina, dense forest fills the main valleys including much of the plain south of Putao.

Characteristic native biota

Key tree species include, many species of *Ficus* including *F. roxburghii, F. semicordata, F. auriculata,* (Moraceae), *Terminalia myriocarpa* (Combretaceae), *Hopea, Shorea* (Dipterocarpaceae), *Rhus chinensis* (Anacardiaceae), *Kydia calycina*, *Sterculia* hamiltonii, *S. lanceolata* (Malvaceae), *Mallotus*, *Cleidion javanicum, Ostodes paniculata* (Euphorbiaceae), *Antidesma montanum, A. fordii*, *Bridelia balanse, B. affinis*, *Glochidion* (Phyllanthaceae) *Helicopsis henryi* (Proteaceae), *Altingia excelsa* (Hamamelidaceae), *Alangium* (Cornaceae) *Meliosma pinnata* (Sabiaceae), *Picrasma chinensis* (Simaroubaceae), *Styrax* (Styracaceae), *Symplocos sumuntia, S. cochinchinensis* (Symplocaceae), *Saurauia cerea*, *S. roxburghii*, and *S. yunnanensis* (Actinidiaceae), *Drimycarpus* (Anacardiaceae) *Elaeocarpus* spp. (Elaeocarpaceae), *Eurya groffii, Adinandra griffithii* (Pentaphyllacaceae), *Shima wallichii* (Theaceae), *Beilschmeidia fasciata*, *Cinnamomum*, *Litsea*, *Phoebe* (Lauraceae), *Castanopsis tribuloides* (Fagaceae), *Clausena excavata, Micromelum integerrimum* (Rutaceae), *Chisocheton*, *Dysoxylum* (Meliaceae), Syzygium (Myrtaceae), *Eriobotrya platyphylla* (Rosaceae), *Apananthe cuspidata* (Cannabaceae), the fishtail palm *Caryota urens* (Arecaceae), and the tree ferns *Cyathea contaminans*, and *C. glabra* (Cyatheaceae).

Small tree and shrub layer includes *Psychotria* spp., *Mycetia longifolia*, *Saprosma ternatum* (Rubiaceae), *Polygala globulifera* var. *longiracemosa* (Polygalaceae), *Lepionurus sylvestris* (Opiliaceae), *Chloranthus, Sarcandra glabra* (Chloranthaceae), *Oxyspora paniculata* (Melastomataceae), *Piper* spp. (Piperaceae), *Ardisia* spp. (Primulaceae), *Xylosma longifolia* (Salicaceae), *Viburnum lutescens* (Adoxaceae), *Capparis assamica* (Capparaceae), *Silvianthus bracteatus* (Carlemanniaceae), *Dichroa febrifuga* (Hydrangeaceae), *Oreocnide integrifolia*, *Debregeasia longifolia* (Urticaceae), palms *Pinanga acuminata*, and *Wallichia caryotoides* (Arecaceae), as well as at least 3 banana species, *Musa aurantiaca*, *M. chunii,* and *M. nagensium* (Musaceae). Climbers in this ecosystem include *Mussaenda, Uncaria macrophylla, Paederia cruddassiana* (Rubiaceae), *Embelia floribunda*, *E. arunachalensis*, *Maesa* spp. (Primulaceae), *Sabia paniculata*, *S. lanceolata* (Sabiaceae), *Tetrastigma* (Vitaceae), *Rubus* spp. (Rosaceae), *Thunbergia coccinea* (Acanthaceae), *Pegia sarmentosa* (Anacardiaceae), *Pottsia laxiflora, Dischidia bengalensis, Hoya pandurata* (Apocynaceae), *Schefflera* (Araliaceae), *Celastrus monospermus* (Celastraceae), *Byttneria* (Malvaceae), *Medinilla himalayana* (Melastomataceae), *Fibraurea recisa* (Menispermaceae), *Erythropalum scandens* (Olacaceae), *Clematis zeylanica*, (Ranunculaceae), *Poilikospermum naucleiflorum* (Urticaceae), *Aeschynanthus lineatus, A. fulgens,, A. superbus, Lysionotus levipes, L. serratus* (Gesneriaceae) and the rattan *Calamus kingianus* (Areceaceae). The herb layer includes *Hydrocotyle javanica* (Araliaceae), *Impatiens* spp. (Balsaminaceae), numerous *Begonia* species including *B. flaviflora* (Begoniaceae), *Phlogacanthus curviflorus, Asystasia neesiana* (Acanthaceae), *Floscopa scandens* (Commelinaceae), *Torenia* (Linderniaceae), *Spiradiclis cylindrica* (Rubiaceae), *Henckelia pumila*, *Loxostigma griffithii*, *Rhynchotechum obovatum, R. vestitum* (Gesneriaceae), *Peliosanthes* (Asparagaceae) and the parasites *Balanophora laxiflora* (Balanophoraceae) and *Burmannia wallichii* (Burmanniaceae).

This ecosystem supports nesting and feeding for several species of hornbill including Great Hornbill *Buceros bicornis* (VU), and Austen's Brown Hornbill *Anorrhinus austeni* (NT). Along the undisturbed rivers in the most remote corners of the ecosystem White-bellied Heron *Ardea insignis* (CR) still occurs. Other species found through the forest include Blue-throated Barbet *Psilopogon asiaticus,* Bay Woodpecker *Blythipicus pyrrhotis,* Long-tailed Broadbill *Psarisomus dalhousiae,* Collared Treepie *Dendrocitta frontalis*, and Sultan Tit *Melanochlora sultanea.* This ecosystem is found on both banks of the Chindwin River. The Chindwin is major biogeographic barrier for primates supporting Capped Langur *Trachypithecus pileatus pileatus* (EN) and Shortridge's Langur *Trachypithecus shortridgei* (EN) as well as Western Hoolock Gibbon *Hoolock hoolock* (EN) and Eastern Hoolock Gibbon *Hoolock leuconedys* (VU). This ecosystem also supports large mammals including Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), Mainland Clouded Leopard *Neofelis nebulosa* (VU), Asian Elephant *Elephas maximus* (EN), Gaur *Bos gaurus* (VU), Indochinese Serow *Capricornis milneedwardsii* (NT), and Red Serow *Capricornis rubidus* (NT) as well as the recently described and poorly known Leaf Muntjac *Muntiacus putaoensis* (DD).

Abiotic environment

Kachin-Sagaing mid-elevation subtropical forest is found between 300 – 700 m, in areas with a tropical to sub-tropical climate and high rainfall.

Key processes and interactions

A complex forest structure with several layers and emergent trees is important to maintain the health of this ecosystem. Rainfall and high atmospheric moisture are also key processes.

Major threats

Deforestation, degradation (e.g. through logging and hunting), and fragmentation are major threats to this ecosystem. There has also been significant forest clearing in the past. Gold mining and some amber mining along the Chindwin and Uru rivers is also a major threat to the ecosystem.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0 km^2.

Assessment summary

ECOSYSTEM DESCRIPTION

Deforestation and fragmentation are known to occur in this ecosystem, but our assessment of primary forest data did not indicate that this ecosystem meets thresholds for Criterion D. There was no information available to assess Criterion A, and we suggest further urgent work to fill this knowledge gap. Thus, although quantitative data suggested this ecosystem is Least Concern, our expert review indicated that this ecosystem is under sufficient threat to potentially meet category thresholds not assessed during this project. Therefore, we recommend urgent further work to address this knowledge gap and enable a complete assessment of this ecosystem type **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2019

Date Assessed

19th June 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Hedley Grantham, Kate Armstrong

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

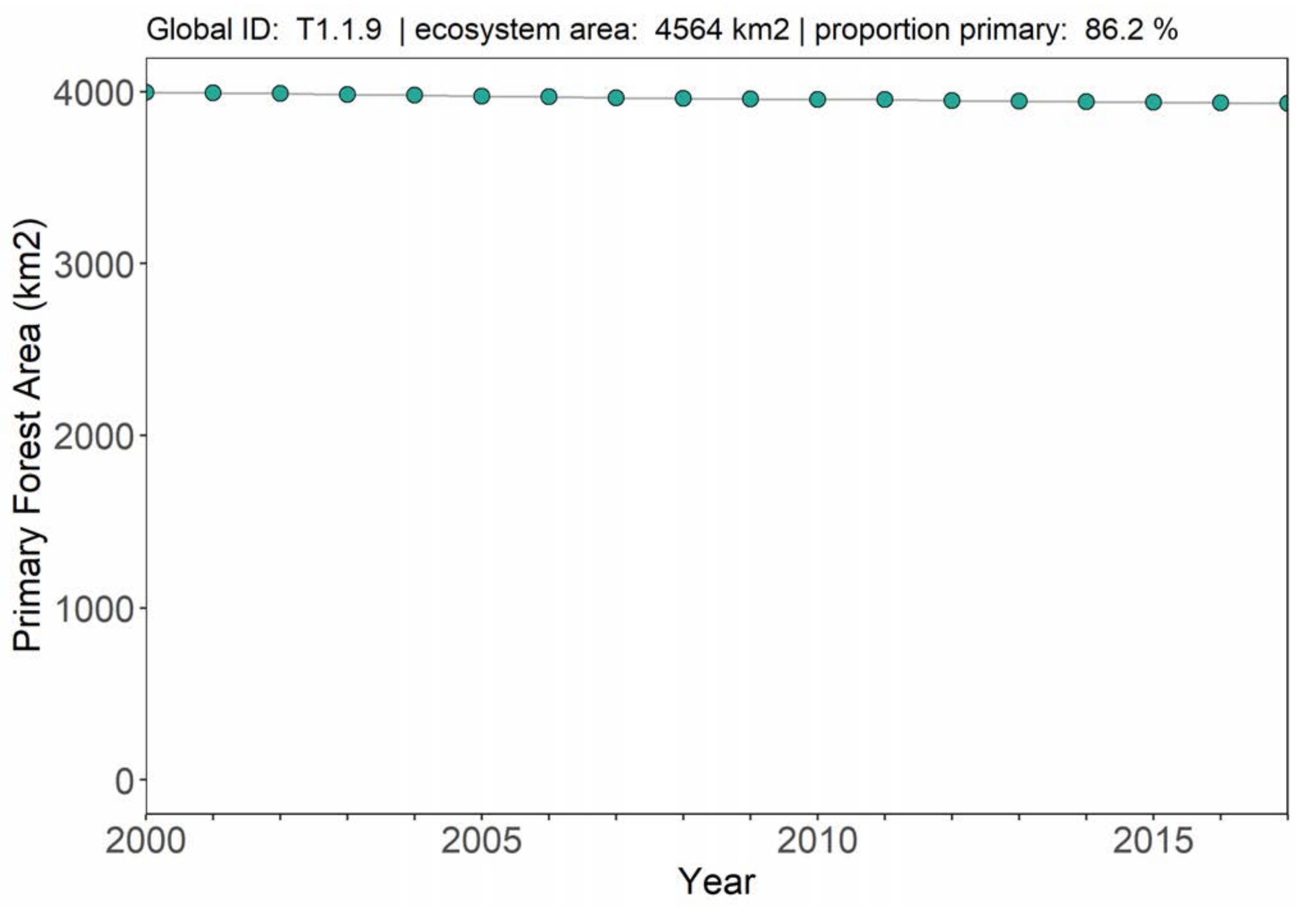
AOO and EOO were measured as 638 10 x 10 km grid cells and 58,922 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Owing to uncertainty in the distribution of this ecosystem while we conducted the climate scenario modelling, no climate simulation models were run for Kachin-Sagaing lowland evergreen subtropical rainforest. No other information on environmental degradation was found during the assessment. The ecosystem is assessed as **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 86.2% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 13.8% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss since 1750 (13.8%) as a biotic variable for assessing Criterion D. With <50% of primary forest loss since 1750, the ecosystem is assessed Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 1.6 % reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

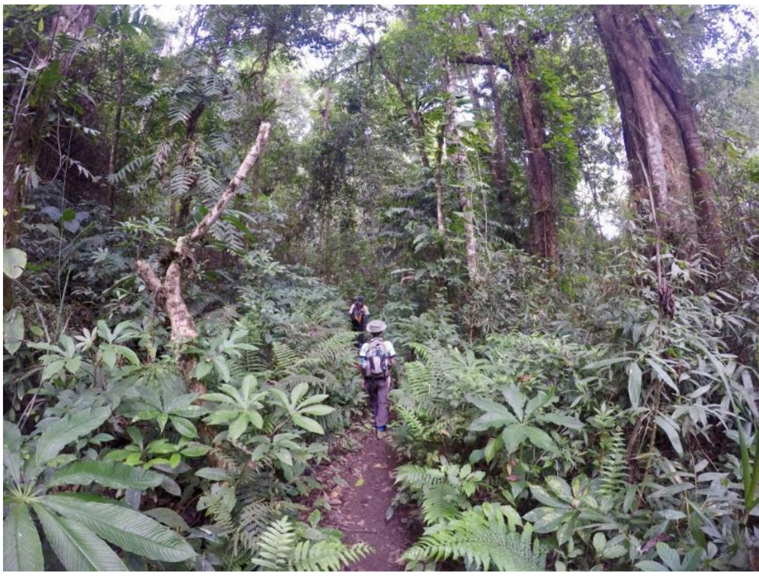
Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, there is extensive secondary forest in the Naga Hills due to slash and burn agricultural practices over many generations, mining for jade, gold and amber in many areas within the extent of this ecosystem, extensive clearing and secondary forest around Myitkyina and towards the Chinese border due to logging and agricultural expansion/plantation development (Bhagwat 2017, Wang & Myint 2016, Global Witness 2009), exacerbated by military conflict (Lim et al 2017), risk from future roads linking to Chinese belt and road initiative, which would open access to further forest cutting (Lo 2019). These observed drivers of environmental degradation suggest that, with sufficient data, this ecosystem may qualify for threatened status. Therefore, the ecosystem is assessed as Data Deficient and urgent work to gather data on the impacts of these threats is recommended to allow an assessment of the status of this ecosystem. **Data Deficient.**

Kachin Hills subtropical rainforest

Authors Armstrong, K.E., Tizard, R., Grantham, H.
Myanmar ecosystem names subtropical hill jungle (UNESCO, 2014), hardwood rainforest/moist hardwood (Davis, 1960), Subtropical hill jungle (Kingdon-Ward, 1944)
Biome Tropical and subtropical forests (T1)
Functional Group Tropical/subtropical lowland forest (T1.1)
Global classification MMR-T1.1.10
IUCN Status **Data Deficient ***

Description



The Kachin hills subtropical rain forest is a biologically complex, closed canopy lower montane forest. It is mainly found between 700 – 1,500 m where there are high moisture levels. Kingdon-Ward (1944) defined the lower limit of this zone as roughly the winter mist line, which is the altitude above which winter mists do not normally lie. The upper limit of this ecosystem corresponds roughly with the upper distribution of palm species such as *Pinanga sylvestris* and *Wallichia caryotoides* (Arecaceae). Within this zone there is a transition of taxa from those with tropical to subtropical-temperate affinities. Rhododendron (Ericaceae) first appears within the ecosystem at around 1,000 m in altitude. Epiphytes, including many ferns and Ericaceous shrubs (e.g. *Vaccinium* and *Agapetes*) become more common at the higher elevations in this zone. Due to the exceptionally high moisture levels, woody taxa which are typically terrestrial become epiphytes here, completely covering the trees. This evergreen subtropical forest is found at higher elevations and often higher slope than Kachin lowland evergreen subtropical forest.

Distribution

Kachin hills subtropical rainforest is found from c. 700 m to 1,500 m in Kachin State and across into Sagaing Region.

Characteristic native biota

Trees include Trees include *Engelhardtia spicata* (Juglandaceae), *Calophyllum polyanthum* (Callophyllaceae), *Toxicodendron succedaneum, T. griffithii*, *Haplospondias brandisiana, Choreospondias axillaris* (Anacardiaceae), *Elaeocarpus rugosus*, *E. varununa*

(Elaeocarpaceae), *Daphniphyllum himalense* (Daphniphyllaceae), *Alnus nepalensis*, *Betula cylindrostachya* (Betulaceae), numerous *Castanopsis* species including *C. fleuryi*, *Quercus*, (Fagaceae), *Mastixia euonymoides* (Cornaceae), numerous species of *Saurauia* including *S. napaulensis*, *S. polyneura*, *S. punduana*, *S. armata* (Actinidiaceae), *Chionanthus ramiflorus* (Oleaceae), *Adinandra latifolia*, *Eurya groffi E. quinquelocularis* (Pentaphylacaceae), *Ilex macrocarpa* (Aquifoliaceae), *Symplocos sulcata* (Symplocaceae), *Syzygium tetragonum* (Myrtaceae), *Albizia sherriffii, Archidendron clypearia* (Fabaceae), *Prunus*, *Pygeum macrocarpum*, *Eriobotrya salwinensis* (Rosaceae), *Knema erratica* (Myristicaceae), *Wendlandia speciosa, Tarennoidea wallichii* (Rubiaceae) *Cleidiocarpon laurinum*, *Macaranga indica* (Euphorbiaceae), *Sarcosperma arboreum* (Sapotaceae), *Tetradium fraxinifolium* (Rutaceae), *Sarcochlamys pulcherrima* (Urticaceae) *Podocarpus* (Podocarpaceae) and *Taxus wallichiana* (Taxaceae). Small tree and shrub species include *Lasianthus*, *Mycetia, Duperrea pavettifolia, Luculia pinceana*, *Ixora kingdon-wardii* (Rubiaceae), *Brassaiopsis*, *Dendropanax* and *Metapanax* (Araliaceae), *Reinwardtia indica* (Linaceae), *Euonymus*, *Microtropis discolor* (Celastraceae), *Callicarpa maingayi, C. rubella* (Lamiaceae), *Capparis multiflora* (Capparaceae), *Oxyspora paniculata* (Melastomataceae), *Maesa chisa, M. argentea* (Primulaceae), *Neillia thyrsiflora* (Rosaceae), *Camellia caudata* (Theaceae), *Edgeworthia gardneri* (Thymelaeaceae), *Fagraea ceilanica* (Loganiaceae), *Miliusa roxburghiana* (Annonaceae) and *Rhododendron simsii* (Ericaceae), the lowest elevation species of *Rhododendron*, which grows along the Taron river. The tree ferns *Cyathea costularis* and *C. spinulosa* (Cyatheaceae) also occurs in this zone.

Climbers/vines include *Deeringia amaranthoides*, *Cyathula tomentosa* (Amaranthaceae), *Hoya yingjiangensis* (Apocynaceae), *Dinetus racemosus* (Convolvulaceae), *Aspidopterys floribunda* (Malpighiaceae), *Dactylicapnos paucinervia* (Papaveraceae), *Cissampelopsis corifolia*, *Notoseris scandens, Vernonia blanda* (Asteraceae), *Iodes* (Icacinaceae), *Celastrus monospermus* (Celastraceae), *Embelia arunachalensis, E. floribunda, E. parviflora* (Primulaceae), *Smilax lanceifolia* (Simlacaceae), and *Gnetum oblongum* (Gnetaceae). *Raphidophora decursiva* and *R. glauca* (Araceae) completely cover the tree trunks in some areas. The herb layer contains the regional endemic *Carlemannia tetragona* (Carlemanniaceae), as well as numerous species of *Arisaema* including *A. decipiens, A. consanguineum, A. galeatum, A. muratae, A. petiolatum* (Araceae), *Chirita, Rhynchoglossum obliquum, Henckelia spp., Rhynchotechum obovatum*, *R. vestitum* and *R. burmanicum* (Gesneriaceae),numerous species of *Ophiorrhiza* including *O. gracilis*, *O. lignosa*, *O. umbricola* (Rubiaceae), *Persicaria* (Polygonaceae), *Begonia longifolia*, *B. palmata*, *B. pedatifida* (Begoniaceae), *Impatiens arguta*, *I. bracteolata*, *I. casseabriae, I. rheophytica, I. kamtilongensis, I. duclouxii*, *I. gongshanensis*, *I. xanthina* (Balsaminaceae), *Cyclocodon parviflorus, Lobelia nummularia*, *L. nicotianifolia*, *L. doniana* (Campanulaceae), *Strobilanthes* (Acanthaceae). *Paphiopedalum villosum* and *Paphiopedalum wardii* (Orchidaceae) both endemic to northern Myanmar are also native to this elevation range.

In montane forest, frugivores such as Rufous-necked Hornbill *Aceros nipalensis* (VU), Great Barbet *Psilopogon virens* and Gold-whiskered Barbet *Psilopogon chrysopogon* are relatively widespread when not being hunted. This is the beginning of the Eastern Himalaya avifauna with a growing diversity of Bush-warblers (Scotocercidae), Old World Warblers and Parrotbills (Sylviidae), Scimitar-babblers and allies (Timaliidae), and Laughingthrushes and allies (Leiotrichidae). This ecosystem is the upper altitudinal barrier for primates supporting Capped Langur *Trachypithecus pileatus pileatus* (EN) and Shortridge's Langur *Trachypithecus shortridgei* (EN) as well as Western Hoolock Gibbon *Hoolock hoolock* (EN) and Eastern Hoolock Gibbon *Hoolock leuconedys* (VU). Large mammals are not as well represented as at lower elevations, although Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), and Mainland Clouded Leopard *Neofelis nebulosi* (VU) still occur as well as the poorly understood Leaf Muntjac *Muntiacus putaoensis* (DD) and Gongshan Muntjac *Muntiacus gongshanensis* (DD) as well as Indochinese Serow *Capricornis milneedwardsii* (NT) and Red Serow *Capricornis rubidus* (NT).

ECOSYSTEM DESCRIPTION

Abiotic environment

High rainfall occurs in this ecosystem, and some areas have very steep slopes.

Key processes and interactions

A complex forest structure with several layers and emergent trees is important to maintain the health of this ecosystem. Rainfall and high atmospheric moisture are also key processes.

Major threats

Forest clearing and degradation, including hunting and logging, are major threats to this ecosystem.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0 km^2.

Assessment summary

This ecosystem is threatened by widespread logging, shifting cultivation and mining. However, our assessment did not identify losses of primary forest over the past two decades of a magnitude sufficient to reach category thresholds. With no time-series map data of its changing distribution, this ecosystem remains data deficient for Criterion A. A post-assessment review indicated that further data may result in an assessment outcome other than Least Concern. Therefore, we recommend urgent further work to address this knowledge gap and enable a complete assessment of this ecosystem type. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2019

Date Assessed

20th June 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Hedley Grantham, Kate Armstrong, Adam Duncan

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

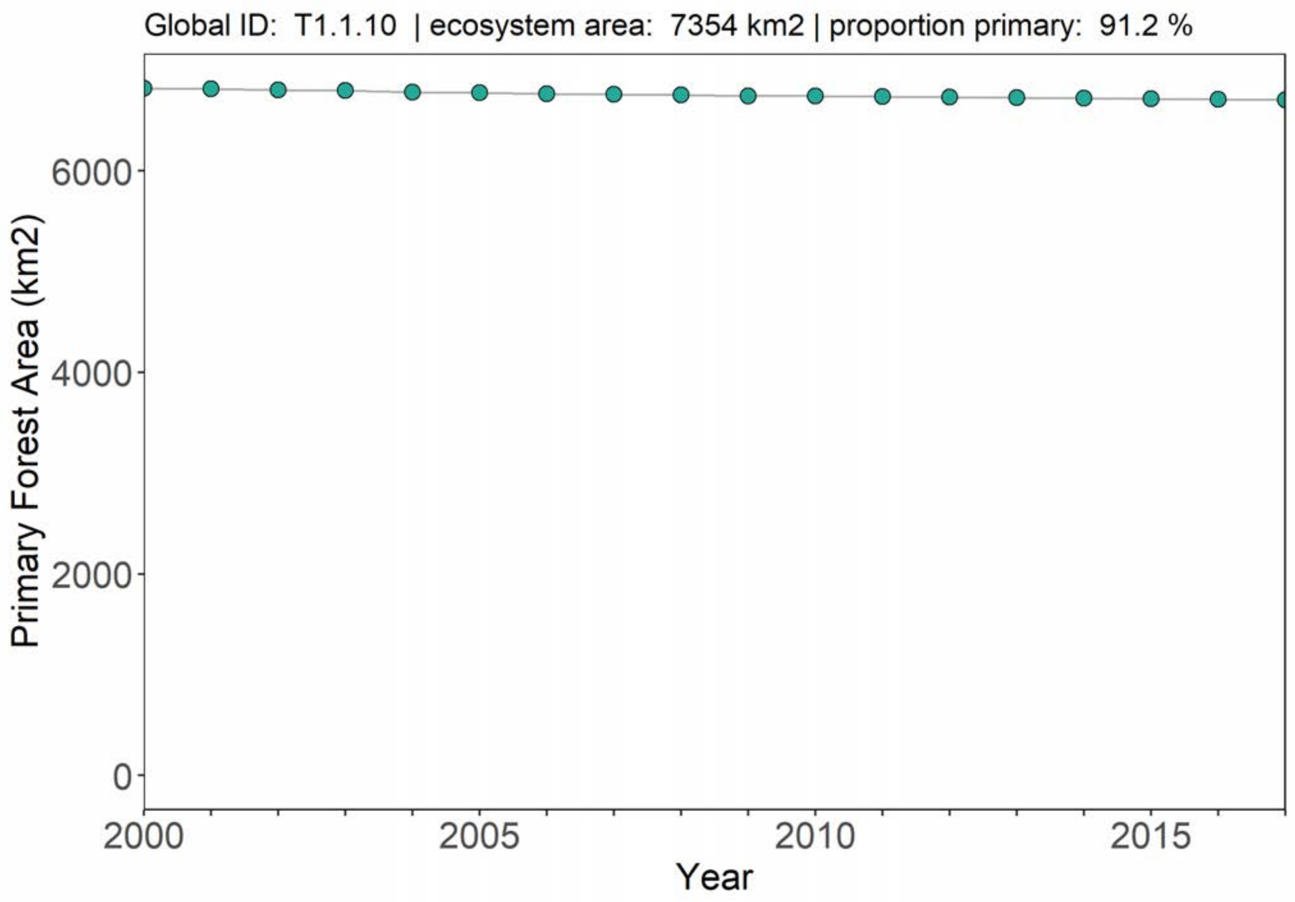
This ecosystem is very broadly distributed in northern Myanmar. AOO and EOO were measured as 684 10 x 10 km grid cells and 132,457 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Owing to uncertainty in the distribution of this ecosystem while we conducted the climate scenario modelling, no climate simulation models were run for Kachin Hills subtropical rainforest. No quantitative information on environmental degradation was found during the assessment. The ecosystem is assessed as **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 91.2% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed primary forest in 1750, there has been an 8.8% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss since 1750 (8.8%) as a biotic variable for assessing Criterion D. With <50% of primary forest loss since 1750, the ecosystem is assessed Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 1.7 % reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, extensive illegal logging over a period of around 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009, Papworth et al 2017), concessions and land grabbing for agriculture, clearing and secondary forest around Myitkyina and towards the Chinese border, exacerbated by military conflict (Lim et al 2017), risk from future roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting. Work to assess the rate of loss of this ecosystem and enable an assessment of Criterion A may result in this ecosystem being assigned a status other than Least Concern. We recommend urgent work to gather data on the impacts of these threats to enable a robust assessment of the status of this ecosystem. It is therefore considered to have a Data Deficient status. **Data Deficient.**

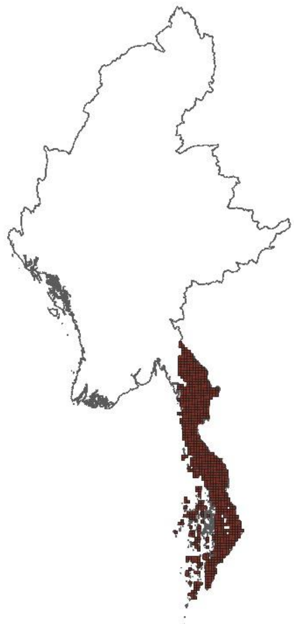
Tanintharyi semi-evergreen forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Semi-evergreen forest (Kress et al., 2003), Mixed deciduous forest (Connette et al., 2016)
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.1
IUCN Status **Data Deficient ***

Description

This semi-evergreen forest is scattered across eastern Tanintharyi, Kayin and Mon states. The tree canopy is primarily deciduous, although some evergreen species may occur (Davis, 1960; Connette et al., 2016). Connette et al (2016) defined this ecosystem as having a closed canopy (>80% canopy cover) comprising a mixture of trees with and without leaves during the dry season, and estimated that it accounts for about 10.8% of Tanintharyi state. Occurs in areas with highly seasonal rainfall, averaging 1,500 to 2,500 mm per annum. The ecosystem is mostly contiguous intact forest, however, road development is opening large areas of Tanintharyi up for deforestation and plantation (Connette et al., 2016).

Distribution



Occurs across north and north-eastern Tanintharyi Region, Mon and Kayin states (Davis, 1960; Connette et al., 2016; De Alban et al., 2018).

Characteristic native biota

The biota of these forests is poorly known. No studies of Myanmar's forests were found that listed the characteristic species in this ecosystem type. The forests may have a largely evergreen mature stage with emergent deciduous diperocarps, and a deciduous pioneer phase (Ashton, 2014). *Lagerstroemia calyculata* (Lythraceae), *Afzelia xylocarpa* (Fabaceae), *Xylia xylocarpa* (Fabaceae), *Pterocarpus marsupium* (Fabaceae) and *Syzygium* (Myrtaceae) species may be in the canopy, but composition varies depending on soil texture.

Dipterocarpus turbinatus (Dipterocarpaceae) and *Tectona grandis* (Lamiaceae) are present in the northern part of the distribution (Mon State), but unlike other semi-evergreen forest ecosystems in Myanmar, they are largely absent from most of the forests in this ecosystem.

Several species of large crown vines are conspicuous components of the system, with Zingerberaceae (gingers) in the ground layer (Ashton, 2014).

The avifauna is similar to East Myanmar dry valley forest with species such as Chestnut-headed Bee-eater *Merops leschenaulti,* Lineated Barbet *Psilopogon lineatus,* Red-breasted Parakeet *Psittacula alexandri,* Alexandrine Parakeet *Psittacula eupatria* and Purple Sunbird *Cinnyris asiaticus*. This ecosystem can support lower populations of large mammals that include Leopard *Panthera pardus* (VU) and Sambar *Cervus unicolor* (VU).

Abiotic environment

This ecosystem occurs in areas with moderately high rainfall with high seasonality. Mean annual temperature is 24.8°C and mean rainfall is 2500 mm, with most rainfall occurring in a distinct wet season, punctuated by a 4-5 month dry season.

Key processes and interactions

Rainfall seasonality and seasonal water stress is a key factor that influences the distribution and species composition of seasonally dry ecosystems such as Tanintharyi semi-evergreen forest (Banda et al., 2016). Rainfall patterns drives seasonal patterns of growth productivity and leaf phenology in deciduous trees, as well as flowering and fruit production, which flows through complex trophic networks including herbivorous canopy arthropods, nectivorous insects, frugivorous mammals and birds, predators and invertebrate detritivores. Dry season fires may occur occasionally on the forest floor. The biota may have some tolerance to fire but flammability is likely to be low, except in areas where there are large tracts of bamboo.

Major threats

Considerable areas of this ecosystem have been degraded as a result of shifting cultivation and development of rubber plantations (Connette et al., 2016). New road development has opened large areas of this forest and is expected to continue to pressure this ecosystem (Connette et al., 2016).

Ecosystem collapse definition

Tanintharyi semi-evergreen forest is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when patches of remnant primary forest are less than 1-10 km^2 in area.

Assessment summary

This ecosystem is increasingly threatened by land use change for plantations, and some studies have suggested nearly half of its extent can be considered degraded. However, our analysis suggests that it does not yet meet any category thresholds and was therefore initially assessed as Least Concern. However, the post-assessment review indicated degradation has been observed and ongoing threats are likely to increase in the future. The ecosystem was therefore assessed as Data Deficient, and we recommend urgent further studies and ongoing monitoring to enable a complete assessment of this ecosystem. **Data Deficient**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. Projections of future land use change (criterion A2), including plantation development, could be important to assessing the status of this ecosystem and we recommend close monitoring over the next 2-5 years to determine rates of change. **Data Deficient.**

Criterion B

AOO and EOO were measured as 729 10 x 10 km grid cells and 139,401 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

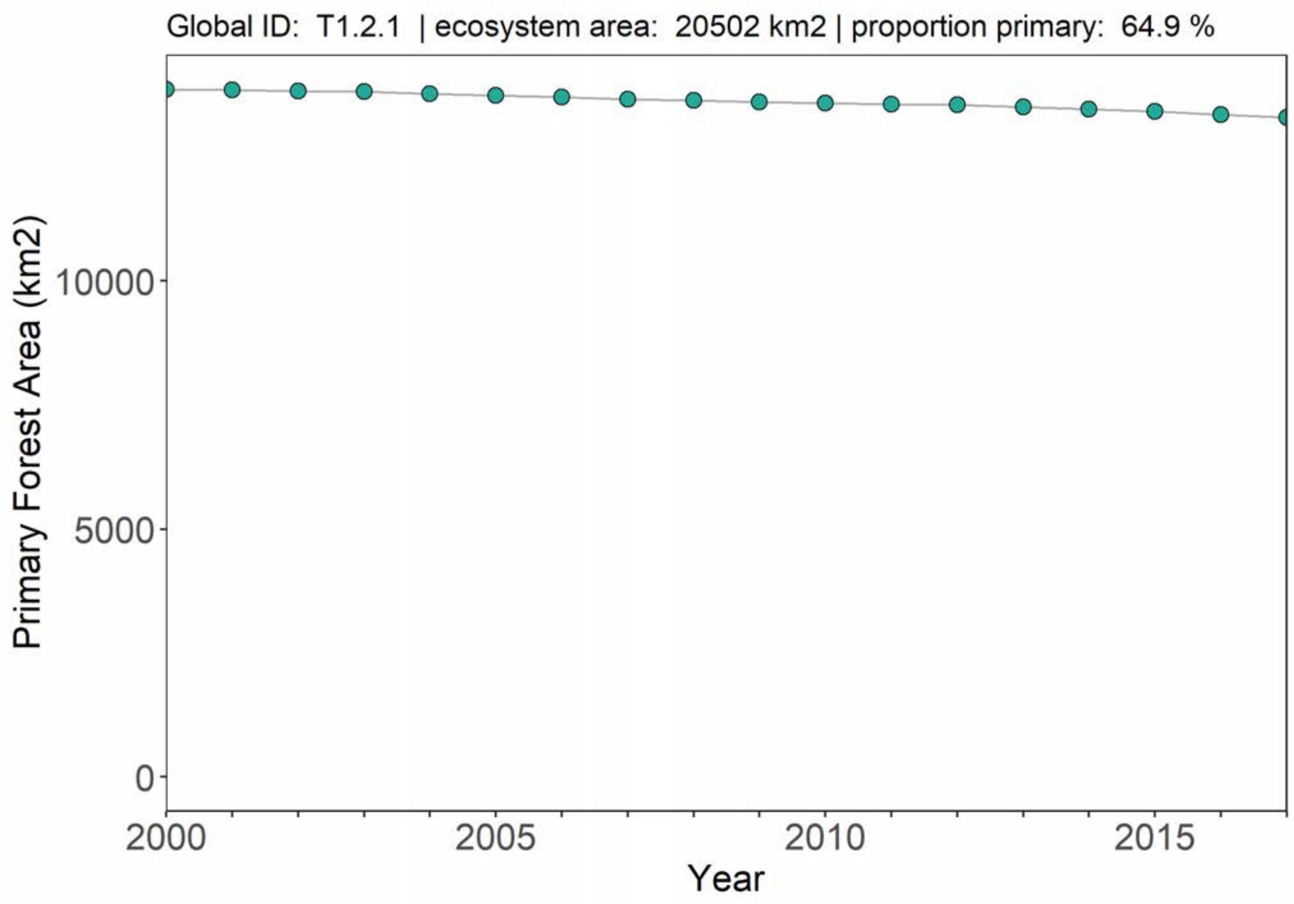
Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Remote sensing analyses suggest that 64.9% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest

in 1750, we estimate that there has been a 35.1% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing Criterion D. With <50% of primary forest loss since 1750, the ecosystem is assessed Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 4.2% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent necessary to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as **Least Concern** under Criterion D2b.



Connette et al (2016) mapped this forest type and showed that only 47.1% of the ecosystem qualified as intact, which was defined as a canopy cover of >= 80%. The remainder of the ecosystem was shown to have a canopy cover <80%, which was considered degraded. However, without raw data and evaluation of a suitable collapse threshold using canopy cover, we were unable to use these estimates in the Red List of Ecosystems assessment process. Our assessment therefore rests on the analysis of primary forest. **Least Concern**.

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, this ecosystem is subject to a range of rapidly expanding threats, including clearing for oil pipeline development, new roads and for rapid rubber and oil palm plantation development (Connette et al 2016, Bhagwat et al 2017). These threats have yet to be quantified sufficiently over a time-frame long enough to support a quantitative assessment but are very likely to result in extensive degradation of this ecosystem that could meet the category thresholds. Further work to quantify these threats and incorporate into the assessment are required, and therefore it is assigned Data Deficient status. **Data Deficient.**

Rocky Tanintharyi Karst

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Karst forest
Biome Tropical and subtropical forests (T1)
Functional Group Tropical/subtropical dry forests and scrubs (T1.2)
Global classification MMR-T1.2.2
IUCN Status **Data Deficient**

Description

Rocky Tanintharyi Karst is a forest type that occurs in karst landscapes. Karst landscapes are commonly defined as areas where highly soluble and porous rocks such as limestone support distinctive hydrology and landforms (Ford and Williams, 2007). These landscapes often have a complex topography, widespread presence of caves and underground water systems. Where a soil layer can form, such as gullies, a vegetation community consisting of herbaceous species and bryophytes can form (Clements et al., 2006).

Karst environments show high degrees of endemism and high diversity among isolated patches. Such endemism results from extreme niche diversity afforded by their complex terrain and high isolation among fragments. In Myanmar, all three Karst ecosystems (MMR-S1.1.1, MMR-T1.1.3 and MMR-T1.2.2) are expected to have high biodiversity and endemism. However, increasing quarrying and other impacts are a key concern.

Distribution

This ecosystem occurs primarily in the karst landscapes of Tanintharyi, although patches may also occur in Karen State, Mon State and Shan State (Day and Urich, 2000). No map data is available for this ecosystem.

Characteristic native biota

Although very little is known about this karst ecosystem, it likely includes a large number of endemic calcicolous species that may be restricted to very small areas (Grismer et al, 2018). There is a single near-endemic bird, Greyish Limestone-babbler *Turdinus crispifrons* restricted to this ecosystem in Myanmar and neighboring Thailand.

Recent studies have shown that the rate of discovery of new species of karst-associated amphibians and reptiles is high, and recent studies have discovered nearly 30 new species in just three years. It is expected that targeted field work will fill this knowledge gap in this ecosystem.

Abiotic environment

The occurrence of limestone substrate. Karst systems are rugged, rugose and steep elevation change is common, which influences the vegetation species that occur (Qi et al., 2019).

Key processes and interactions

Water coming into limestone caves and aquifers is acidified by carbon dioxide from plant root respiration and by organic acids released by vegetation. The acidified water dissolves limestone and calcium carbonate is deposited in underground caves. Shallow soils associated with Karst landscapes influence the structure and species composition of karst vegetation communities.

Major threats

Limestone quarrying for cement production is considered a key threat to karst environments in Myanmar (Forest Department, 2015, BirdLife/FFI/IUCN/WWF, 2015). The key stages of limestone extraction include clearing extraction sites, often using a bulldozer, and stripping of topsoil, trees and vegetation using excavators. The subsequent stages include drilling and blasting to expose and excavate the desired rock, before loading excavated rock onto front-end loaders. The limestone is then crushed and separated in stockpiles, which are ultimately loaded onto trucks for transport to Yangon or other markets or storage places. In nearby China, karst landscapes that have been subject to farming over-exploitation have resulted in karst rocky desertification, the process of which soil is partially or completely eroded (Qi et al., 2019).

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2.

Assessment summary

Despite targeted searches of the literature and liaison with experts in South-east Asian Karst environments, no information was found that could be used to assess this ecosystem. Further work to develop ecosystem maps, species inventories and assessments of ecosystem decline is recommended. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient

Year Published

2019

Date Assessed

23rd January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Lee Grismer

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

Owing to no publicly available maps of Karst regions in Tanintharyi and a lack of access during field work for this project, no maps of this ecosystem suitable for assessing Criterion B are available. **Data Deficient.**

Criterion C

Despite literature searches and liaison with Karst experts familiar with south-east Asian Karst ecosystems, we found no information or data suitable for assessing Criterion C. **Data Deficient.**

Criterion D

No information that could be reliably used to assess biotic disruption in this ecosystem was found during this assessment. **Data deficient.**

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found.
Data Deficient.

Mixed canebrake

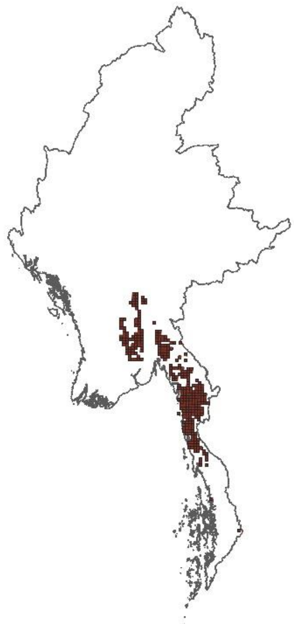
Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Cane scrub, Cane jungle
Biome Tropical and subtropical forests (T1)
Functional Group Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.3
IUCN Status **Least Concern**

Description

Mixed cane brake occurs in valleys and gulleys in the wetter regions of Myanmar, where rainfall is over about 2,500 mm per year, particularly in Tanintharyi and Kayin. It occurs as a dense thicket of canes, palms and bamboos (Platt et al., 2001; Stamp, 1924b;. Kress et al., 2003).

Distribution

Mixed cane brake is distributed in moist valleys throughout southeast Myanmar, where it primarily occurs in association with evergreen rainforest.



Characteristic native biota

Stamp (1925) states that the typical species occurring in this ecosystem are palms such as *Calamus arborescens, Licuala peltata* and *Zalacca wallichiana,* together with canes (*Calamus spp.*) (Arecaceae) and creeping bamboos (Poaceae).

Abiotic environment

Little is known about the abiotic features that influence the distribution and functioning of this ecosystem. It is thought to occur in particularly wet areas, particularly along riverbanks where there is ample access to freshwater, a moist microclimate and a short dry season (Stamp, 1924b).

Key processes and interactions

Similar to bamboo brake ecosystems, mixed cane brake is often formed when cane, creeping bamboo and palms that occur naturally as undergrowth respond rapidly to forest disturbance. Following disturbance, often caused by deforestation, tree falls, storms or fire, high levels of light stimulate dense growth of palms and bamboo that develop into impenetrable thickets (Kress et al, 2003).

Major threats

The key threat to this ecosystem is clearing associated with deforestation of surrounding evergreen forests. Cane brakes may also be threatened by shifting agriculture.

Ecosystem collapse definition

This ecosystem is considered collapsed when the distribution of cane brake declines to 0 km^2 or when broadleaf rainforest trees account for more than 40% of total tree cover.

Assessment summary

Cane brake ecosystems in Myanmar were first recorded nearly a century ago, but remain almost entirely unstudied. Reviews of the literature and our remote sensing analyses suggest they are fairly restricted, but they do not meet any category thresholds for range size and are listed as Least Concern under Criterion B. An assessment of a composite variable, the Forest Landscape Integrity Index, which synthesises a wide range of drivers known to cause biotic disruption, suggests the ecosystem is Least Concern. **Least Concern.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2020

Date Assessed

20th July 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Steven G. Platt

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 311 10 x 10 km grid cells and 105,271 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

No data or analyses that were suitable for assessing criterion C were found during the assessment process. **Data Deficient.**

Criterion D

Primary forest data was identified as unsuitable for this ecosystem. However, our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	21.63	29.12	21.94	27.31	85.9
Status (D3)	LC	LC	LC	-	-

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Bago semi-evergreen forest

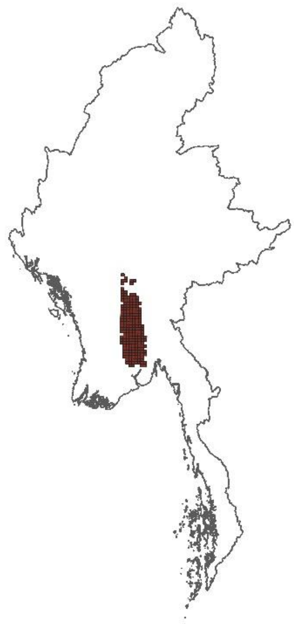
Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Moist teak forest, dry teak forest, Pyinkado, Semi-evergreen forest (Kress et al., 2003), Mixed deciduous forest (Campos-Arceiz et al., 2008)
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.4
IUCN Status **Critically Endangered (Endangered-Critically Endangered)**

Description

A semi-evergreen forest that formally occurred across much of the Bago Yoma. *Xylia xylocarpa* and Teak (*Tectona grandis*) are the primary species with dominance changing from south to north along a precipitation gradient (Stamp, 1924b). It is primarily deciduous, but some evergreen elements may occur. Much of the Bago Yoma range is now highly degraded with plantation teak and bamboo regrowth.

Distribution

Occurs across the majority of the Bago Yoma with approximately 18,000 km^2 identified in our remote sensing analysis.



Characteristic native biota

The dominant tree species in Bago semi-evergreen forest are *Xylia xylocarpa* (or *X. dolabriformis*) (Fabaceae) and *Tectona grandis* (Lamiaceae), with *Lagerstoemia* spp. (Lythraceae), *Dipterocarpus alatus* and *D. turbinatus* (Dipterocarpaceae) also present (Suzuki et al 2004). Bamboos are present throughout, particularly in degraded or formerly cleared areas, and include the species *Bambusa polymorpha* and *Cephalostachyum pergracile* (Poaceae). *Terminalia tomentosa* (Lamiaceae) may be present in the drier northern region of the Bago Yoma. The avifauna is similar to Ecosystems further south and east including Tanintharyi semi-evergreen forest and East Myanmar dry valley forest with species such as Chestnut-headed Bee-eater *Merops leschenaulti,* Lineated Barbet *Psilopogon lineatus,* Red-breasted Parakeet *Psittacula alexandri,* Alexandrine Parakeet *Psittacula eupatria* and Purple Sunbird *Cinnyris asiaticus*. There is at least one endemic bird found in this ecosystem Grey-crowned Bulbul *Alophoixus* *griseiceps* which has recently been elevated to full species but has yet to be studied. This ecosystem can still support small populations of large mammals that include Leopard *Panthera pardus* (VU), Sambar *Cervus unicolor* (VU), Gaur *Bos gaurus* (VU) and Banteng *Bos javanicus* (EN). Asian Elephant *Elephas maximus* (EN) is known to continue to occur in small numbers in this ecosystem (Campos-Arceiz, 2008).

Abiotic environment

This ecosystem occurs in areas with moderately high rainfall with high seasonality, with most rainfall occurring between May and October. Mean annual rainfall varies from 1,500 mm in the north to 2,500 mm in the south, but to the driest foothills in rain shadows may receive as little as 950 mm (Kress et al., 2003). Mean temperature 26.1° C. Soils are generally light-textured and erodible, with increasing clay content with depth (Suzuki et al., 2004).

Key processes and interactions

Rainfall seasonality and seasonal water stress is a key factor that influences the distribution and species composition of seasonally dry ecosystems such as Bago semi-evergreen forest (Banda et al., 2016). The dominant tree species are drought-deciduous, enabling them to persist through prolonged water deficits in the dry season, and support rapid growth when monsoon rains fuel primary productivity. Flammability is likely to be low, except where extensive disturbance has promoted increased fire activity, particularly in areas with large tracts of bamboo regrowth.

Major threats

The ecosystem has been extensively logged, fragmented by shifting cultivation and the development of plantations (Shimuzu et al., 2017). Only tiny patches of primary forest remain, with the vast majority of this ecosystem now occurring as highly degraded forest regrowth dominated by bamboo. Post-disturbance bamboo thicket may be a persistent steady state, with dense stands limiting dispersal and establishment of tree species typical of primary forest. They may also maintain a fire regime that limits establishment of primary forest species. The impact of shifting cultivation has been reported to be decreasing in the last decade, while logging, plantation development, urban development and water conversion (new dams) have expanded (Shimuzu et al., 2017). Poaching of wild fauna, including elephants, appears regular (Sampson et al., 2018).

Ecosystem collapse definition

Bago semi-evergreen forest is regarded as collapsed when its mapped distribution has declined to zero, or when primary forest accounts for 0% of total forest cover, or when patches of remnant primary forest are less than 1-10 km^2 in area.

Assessment summary

This ecosystem now occurs across a relatively small distribution, and about 33.9% of the ecosystem is considered degraded since a primary state at year 1750. Ongoing degradation is clearly occurring, with 6.8% of remaining primary areas lost between 2000-2017. Projections from this dataset suggest that ongoing degradation will not occur sufficiently to meet category thresholds for D2b. However, a climate suitability simulation model suggests that environmental suitability for this ecosystem will severely reduce by 2050, with an extent and severity sufficient to meet the thresholds for **Critically Endangered**, with model uncertainty suggesting a plausible bound of listing between Endangered and Critically Endangered.

Assessment Summary

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**EN**
	B2	**LC**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**CR (EN-CR)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered (Endangered - Critically Endangered)

Year Published

2019

Date Assessed

20th June 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

This ecosystem has an AOO of 193 10 x 10 km grid cells and an EOO of 19,562 km^2. Ongoing threats relate primarily to logging, plantation development and shifting cultivation and have been confirmed through analyses of satellite imagery and field work (Shimuzu et al., 2017). The ecosystem therefore meets the category threshold for Endangered (B1) and sub-criteria (B1a(i) and B1a(iii)). **Endangered**

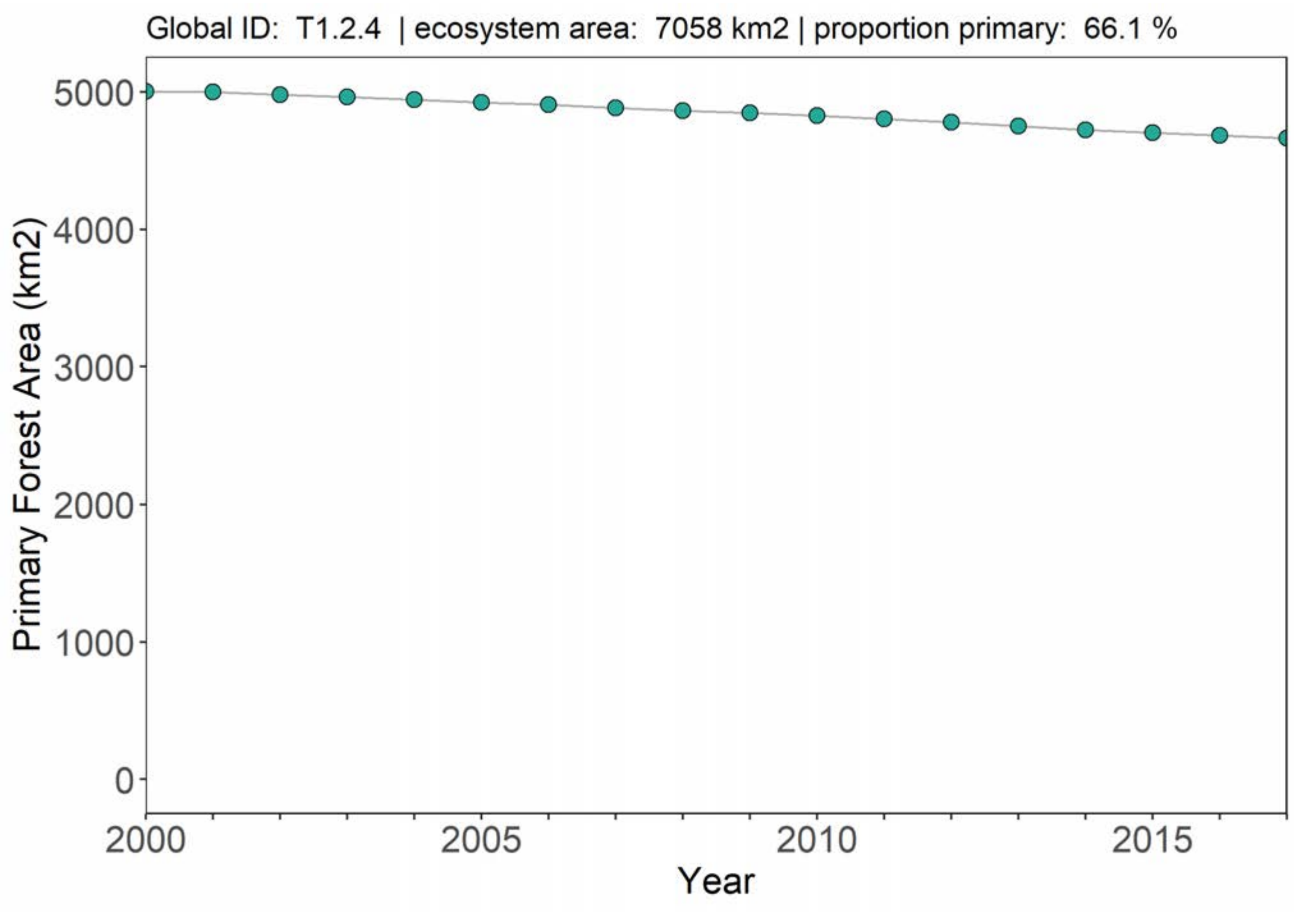
Criterion C

A climate simulation model suggests this ecosystem is severely threatened by climate change over the next few decades. Indeed, the majority of model outcomes suggested this ecosystem would meet category thresholds for Critically Endangered, with an uncertainty bound of Endangered to Critically Endangered. **Critically Endangered (Endangered – Critically Endangered).**

Criterion D

Shimizu et al., (2017) analysed forest disturbance in the Bago Yoma using time-series Landsat data, which indicated that 10% of the Bago Yoma experienced forest disturbance between 2000-2014 (Shimuzu et al., 2017). Disturbances were identified as logging (59.8%), plantation development (8.4%), shifting cultivation (10.4%), and urban expansion (6.8%). Inundation by water storage reservoirs was also identified as a disturbance to the Bago Yoma forest ecosystems, accounting for 14.6% of the disturbance area. Despite estimating these disturbances, spatial data from the Shimizu et al. (2017) analysis is not freely available, and therefore we were unable to assess category thresholds using this information.

Our analyses of primary forest data suggest that 66.1% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, we estimate that there has been a 33.9% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing Criterion D. With <50% of primary forest in this ecosystem lost since 1750, the ecosystem is assessed Least Concern under Criterion D3. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 6.8% reduction in primary forest cover over the period 2000-2017; a broadly similar estimate to Shimuzu et al. (2017). A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent necessary to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

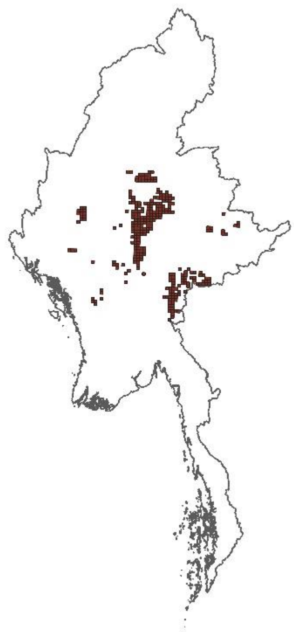
Dry zone foothills spiny scrub

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Thorn scrub, euphorbia semi-desert (Stamp 1924b)
Biome Tropical and subtropical forests (T1)
Ecotype Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.5
IUCN Status **Data Deficient ***

Description

This ecosystem occurs on the rocky foothills of the eastern dry zone and is characterised by the presence of thorny species mixed with low bushy Dahat (*Tectona hamiltoniana*). Low canopy of less than 5 m and very sparse. Occurs on both limestone and siltstone. Includes succulent Euphorbia, some patchy Themeda and Aristida, but grass cover may be continuous enough to carry fire. Bamboo may be present.

Distribution



This ecosystem is restricted to the foothills surrounding the central dry zone. This ecosystem was particularly difficult to develop a remotely sensed map for due to a lack of training data and field access. We therefore expect this ecosystem may be even further restricted than depicted in this distribution map.

Characteristic native biota

Thorny *Euphorbia antiquorum* (Euphorbiaceae) are common, and bushes of *Diospyros burmanica* (Ebenaceae), *Tectona hamiltoniana* (Lamiaceae) from 1-3 m high. Other species may include *Acacia catechu* (Fabaceae), and the bamboo *Dendrocalamus strictus* (Poaceae). *Ziziphus oenoplia* and *Zizyphys jujuba* (Rhamnaceae) may also be abundant, along with introduced species such as *Jatropha gossypifolia* and *Ricinus communis* (Euphorbiaceae) (Stamp, 1925, Stamp and Lord, 1923). A range of vines are present in the shrub and ground layers, forbs are present in rocky sites and tussock grasses, including *Themeda triandra* and *Aristida* spp. (Poaceae) may be abundant in open patches. This ecosystem continues to support a range of dry zone species including Asian Green Bee-eater *Merops orientalis,* Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler

Chatarrhaea gularis. Mammals are limited although Golden Jackal *Canis aureus* and Burmese Hare *Lepus peguensis* are still widespread.

Abiotic environment

The mean annual precipitation is low, around 1,200 mm with a regular seasonal drought extends from October to late May, followed by monsoonal rains which deliver the majority of rainfall in period of a few months. Occurs mainly on dry foothills and toeslopes with westerly and southerly aspect, often in rocky sites with clay-loam soils.

Key processes and interactions

The distribution, amount and timing of rainfall is important in this ecosystem, producing a flush of productivity following the onset of monsoonal rain and a severe water deficit during the dry season. Grazing and burning interact with the fine-scale distribution of rocky substrates that may create refuges. Thus, fires may occur but do not appear to be common.

Major threats

Similar to surrounding ecosystems, this ecosystem has been impacted extensively by agricultural development (cattle grazing and some cropping; Ashton, 2014). Recurring fires may threaten the persistence of succulent elements such as *Euphorbia* spp. Disturbance from clearing and cattle grazing promotes the ingress of invasive plants that may exclude native species.

Ecosystem collapse definition

This ecosystem is collapsed when its area has declined to zero or when woody plants make up less than 20% projected crown cover due to overgrazing.

Assessment summary

Dry zone foothills thorny scrub is broadly distributed around Myanmar's central dry zone. This ecosystem is likely to have been extensively degraded historically, with much of the degradation process continuing. However, no information that could reliably be used to assess Criterion C or D was found. We recommend further work to better assess Criteria A, C and D. Despite an initial assessment from available data as Least Concern, a post-assessment expert review indicated that further data could lead to an assessment outcome other than Least Concern. The status of this ecosystem is therefore Data Deficient, and we recommend urgent further work to enable a full assessment of the status of this ecosystem. **Data Deficient**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 295 10 x 10 km grid cells and 200,014 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Our climate simulation model showed poor predictive performance and could therefore not be used to assess this ecosystem under Criterion C. No other information was found during literature reviews or workshops that was sufficient to assess this criterion. **Data Deficient.**

Criterion D

The major biotic threat to this ecosystem is livestock grazing, which degrades the structure of vegetation and drives declines of more palatable plant species. Trampling by livestock also results in soil degradation. Owing to the sparse vegetation and low canopy, primary forest data was not suitable for assessing degradation of this ecosystem. Despite targeted searches, no data were found that were sufficient to assess the impact of these degradation processes. **Data Deficient.**

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, owing to a limited amount of training data the maps developed during this project may potentially overestimate the extent of the ecosystem and underestimate the amount of fragmentation of what remains. Further work to improve maps of this ecosystem, as well as develop a map time-series, may lead to an assessment outcome other than Least Concern. The ecosystem is therefore assessed as Data Deficient, and we recommend urgent further work to improve confidence in the assessment outcome and to establish whether there are appreciable edge effects from adjoining land uses. **Data Deficient.**

Rakhine hills bamboo brake

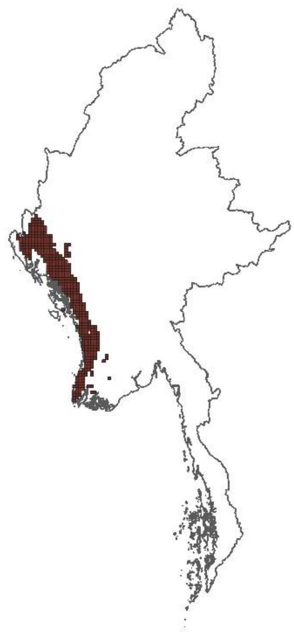
Authors: Murray, N.J., Platt, S.G., Keith, D.A.

Myanmar ecosystem names Bamboo scrub, Bamboo jungle (Platt et al., 2010a), Arakan Mountain Range bamboo brake (Fava and Colombo, 2017)
Biome Tropical and subtropical forests (T1)
Functional Group Tropical/subtropical dry forest (T1.2)
Global classification MMR-T1.2.6
IUCN Status **Least Concern**

Description

Rakhine hills bamboo brake is a dense, monotypic ecosystem dominated by a single bamboo species, *Melocanna baccifera* (Poaceae; Platt et al., 2010a), although many other species of bamboo occur throughout Myanmar (Bystriakova et al., 2003a, 2003b). It occurs along the Rakhine hills where its high density and vigoruos growing habits inhibit tree growth. In Rakhine, bamboo brake may occur in response to disturbance of other ecosystems, such as Rakhine hills semi-evergreen dry forest (Stamp, 1924b; Davis, 1960). Stamp (1924b) considered that 'most, if not all', bamboo break in Myanmar was established following disturbances including shifting cultivation, forest clearing, and frequent fires.

Distribution



Rakhine hills bamboo brake occurs along the Rakhine Hills in Western Myanmar, where it is thought to cover about 75% of the hilly regions (Platt et al., 2010a). Our remote sensing analysis suggests that this ecosystem has a total extent of around 7,500 km^2 along the Rakhine Hills.

Characteristic native biota

This ecosystem is dominated by monotypic stands of *Melocanna baccifera.* Diverse fauna assemblages occur in bamboo brake, including primates such as Phayre's langur *Trachypithecus phayrei* (EN) and Western Hoolock Gibbon *Hoolock hoolock* (EN), and carnivores including Dhole *Cuon alpinus* (EN), Sun Bear *Helarctos* malayanus (VU) and Asian Black Bear *Ursus thibetanus* (VU). Asian elephant *Elephas maximus* (EN) do occur and consume the culms, foliage and seeds of *M. baccifera* (Platt et al., 2010b).

Historic accounts suggest the presence of Sumatran Rhinoceros *Dicerorhinus sumatrensis* (CR), which is now extinct in Myanmar (Platt et al., 2010a). Tiger *Panthera tigris* (EN) is thought to be extirpated relatively recently, with reports up until about 2008 (Platt et al., 2010b). Very little is known about avifauna and herpetofauna of Rakhine hills bamboo brake, although some observations are provided by Platt et al. (2010a). This ecosystem hosts the endemic Arakan Forest Turtle *Heosemys depressa* (CR); Platt et al., 2010b, Platt et al., 2014).

Abiotic environment

Bamboo brakes occur throughout the Rakhine Hills up to elevations of 900 m to 1,200 m above sea level, where mean annual precipitation reaches around 3,150 mm which mostly occurs in a pronounced monsoonal wet season from May to October.

Key processes and interactions

The dominant bamboo is semelparous, having a life cycle with a single reproductive event. According to a remote sensing study, mass mortality events display wave-like spatiotemporal dynamics between synchronous bamboo flowering, fruiting and mortality, which correlates strongly with increased burned area (Fava and Colombo, 2017). Heavy, dry fuel loads following mass mortality events produce intense fires when they occur, typically in the dry season and following post-fruiting mass mortality events, which are reported in a repeating cycle approximately every 48 years (Fava and Colombo, 2017). The dense regenerative phase further inhibits the establishment of woody species and excludes the incursion of evergreen and semi-evergreen trees from adjacent ecosystem types (Platt et al., 2010a). Fires are therefore a primary process that maintains the Rakhine hills bamboo brake ecosystem (Platt et al., 2010a).

The bamboos are rhizomatous and able to spread vegetatively over local areas, with new shoots emerging in the wet season. They are resilient to physical disturbance by humans and large animals including elephants. Dense groves of bamboo may be important refuges from predators.

Major threats

This ecosystem type is threatened by deforestation for cultivation, changed fire regimes, and extensive utilisation by rural communities. Fire prior to reproduction of the bamboo may be expected to cause reductions in bamboo density, but many individuals may survive and resprout from rhizomes.

Ecosystem collapse definition

This ecosystem is considered collapsed when the distribution of *M. baccifera* declines to 0 km^2. Or when bamboos account for less than two-thirds of the tree canopy cover.

Assessment summary

This ecosystem is widely distributed along the Rakhine hills. With very little data available to assess the criteria, the majority of criteria are considered data deficient. However, map data indicating a range size that exceeds the category thresholds by nearly an order of magnitude, and few threatening processes operating across the entire range, the ecosystem is assessed as **Least Concern**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**LC**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Least Concern

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

11th July 2019

Assessment Credits

Assessed by: Nicholas J. Murray, Steven G. Platt.

Reviewed by: David Keith

Contributions by: Nil

Assessment Summary

This ecosystem is widely distributed along the Rakhine hills. With very little data available to assess the criteria, the majority of criteria are considered data deficient. However, map data indicating a range size that exceeds the category thresholds by nearly an order of magnitude, and few threatening processes operating across the entire range, the ecosystem is assessed as **Least Concern**.

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. However, increasing human population density and activity since British invasion suggest a likely increase in forest disturbance, particularly forest logging, which has likely facilitated an expansion of the distribution of bamboo brake within the Rakhine Range. The status of the ecosystem is therefore assessed as **Least Concern** under criterion A3**.**

Criterion B

AOO and EOO were measured as 390 10 x 10 km grid cells and 92,133 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Despite extensive literature searches, no data suitable for Criterion C were found. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	1.75	6.69	12.24	79.32	99.8
Status (D3)	LC	LC	LC	-	-

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Not Evaluated.**

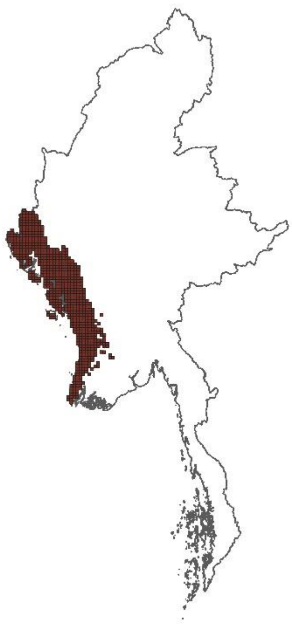
Rakhine hills semi-evergreen dry forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Dry forest.
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.7
IUCN Status **Vulnerable**

Description

A semi-evergreen forest that occurs at mid-elevation across the Rakhine hills. This area experiences an annual seasonally dry period, typically extending up to 7 months between November to May each year, followed by monsoonal rains. Rainfall is typically around 2,000 mm to 2,800 mm, and local elevation and moisture gradients are likely the primary factors that influence its distribution (Wolfhart et al., 2010). It co-occurs with Rakhine dry coastal deciduous and Rakhine hills Bamboo Brake, which occurs at lower elevation and in the coastal lowlands and is distinguished by a very strong browning during the dry season, reflecting most species completely losing their leaves.

Distribution



Occurs on hilltops and mid-elevations along the Rakhine Arakan hills (Davis, 1960).

Characteristic native biota

These forests include both evergreen and deciduous dipterocarps, including *Dipterocarpus turbinatus, D. alatus, D. obtusifolius, Shorea* spp., *Hopea odorata* and *Anisoptera costata* (Dipterocarpaceae) (Ashton 2014). A diversity of other trees include *Artocarpus lacucha* (Myauk-lok) (Moraceae), *Syzygium fastigiatum* (Thabye) (Myrtaceae), *Pentace griffithii* (Ye-hmyoke) (Malvaceae), *Garcinia microstigma* (Taung Thale-ani) (Clusiaceae), *Antidesma bunius* (Kinbilin) (Phyllanthaceae), *Stereospermum teragonum* (Thakut-pho) (Bignoniaceae), *Knema cinerea* var. *glauca* (Kwye-thwe) (Myristicaceae), *Microcos paniculata* L. (Mya-yar) (Malvaceae), and the palm *Wallichia disticha* (Min-baw) (Arecaceae). These forests have a poorly understood avifauna sill supporting Great Hornbill *Buceros bicornis* (VU) and also provide substantial habitat for

Western Hoolock Gibbon *Hoolock hoolock* (EN), Leopard *Panthera pardus* (VU), Asian Elephants *Elephas maximus* (EN) and Gaur *Bos gaurus* (VU).

Abiotic environment

This ecosystem occurs where mean annual rainfall is around 2,000 to 2,800 mm. The coastal range has an important orographic influence on monsoons from the Bay of Bengal, enhancing rainfall with elevation. These also bring storms that may disturb forest structure. A seasonally dry period of five to seven months from early November to late May is followed by several months of monsoonal rains (Platt et al., 2010). Typically occurs on a range of mostly sandy-textured soils sheltered slopes and in gullies in the foothills of the range, extending to ridges and hilltops in the upper parts of the Rakhine Range.

Key processes and interactions

Rainfall seasonality defines the distribution of this dry forest ecosystem along the east coast of Myanmar (Banda et al., 2016). Deciduous trees respond to the dry season, but rainfall is sufficient to support co-occurring evergreen species that time their growth to the wet season. Local moisture gradients, including elevation gradients to 600 m, are important influences on composition. Monsoonal storms periodically disturb forest structure and may promote initial regrowth dominated by bamboo. Fire is infrequent and confined to the forest understorey, but may be promoted by human disturbance and bamboo regrowth.

Major threats

The ecosystem has been widely cleared for shifting cultivation and logging for timber harvest, and extensive tracts are now severally degraded by bamboo regrowth. Opening of forest structure promotes high intensity canopy fires that can threaten the persistence of some woody and herbaceous species, as well as forest fauna.

Ecosystem collapse definition

Rakhine hills semi-evergreen dry forest is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when all patches of primary forest are smaller than 1-10 km^2.

Assessment summary

Analyses of the distribution of primary forest suggest that this ecosystem has been degraded over an extent sufficient to meet the D3 category thresholds for Vulnerable. Our climate suitability model suggests this ecosystem is threatened by climate change, although uncertainty is broad enough to span category thresholds for Least Concern to Vulnerable. No time-series spatial data was found to assess Criterion A. Thus, the ecosystem is assessed as Vulnerable under D3. **Vulnerable.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC (LC-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

20th June 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

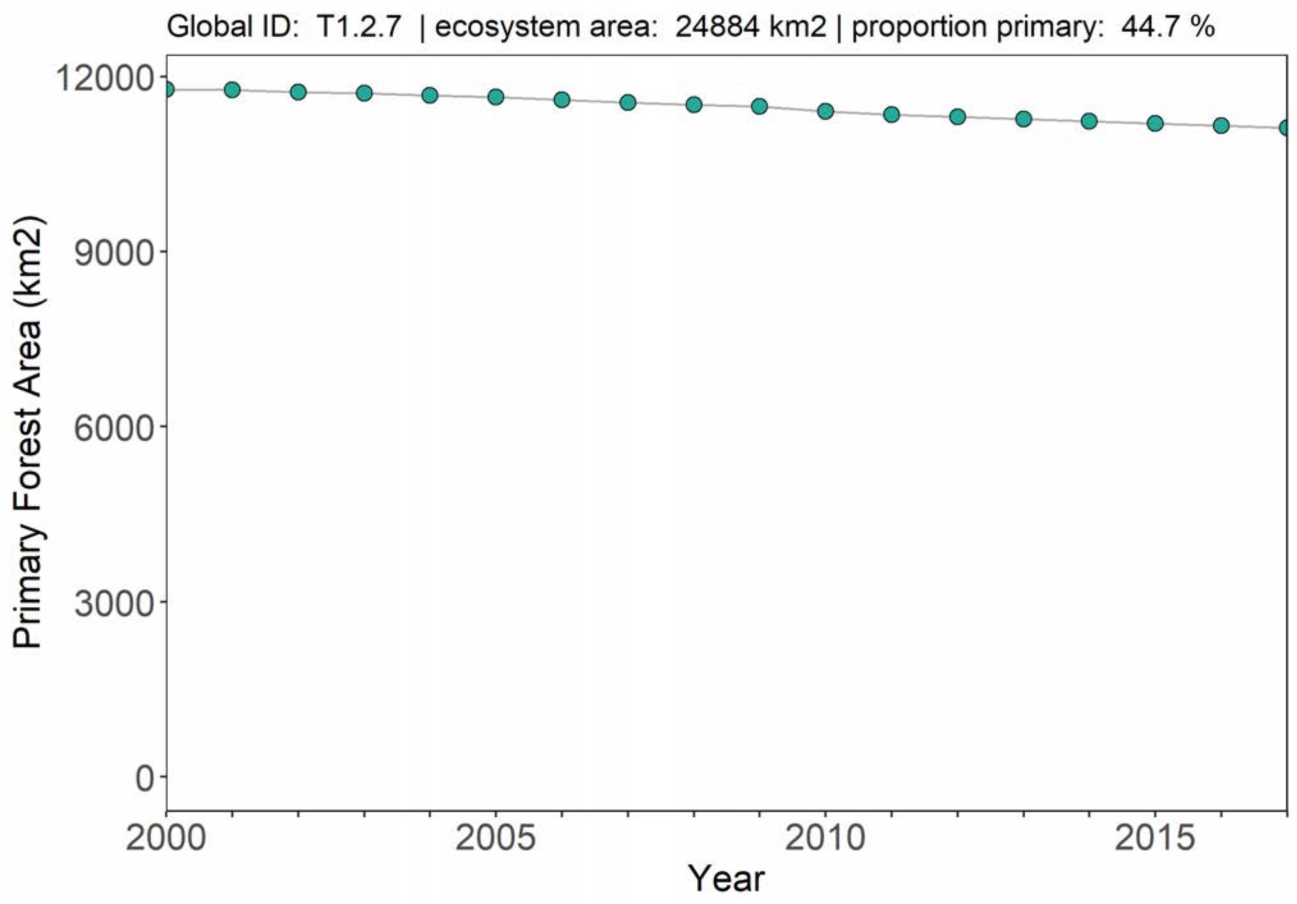
AOO and EOO were measured as 649 10 x 10 km grid cells and 11,2864 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Several scenarios in a climate simulation model led to assessments of Vulnerable for this ecosystem by 2050. However, the majority of simulations indicated Least Concern. **Least Concern (Least Concern – Vulnerable).**

Criterion D

Remote sensing analyses suggest that 44.7% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 55.3% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 50% but less than 70%, meeting the D3 category threshold for Vulnerable. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 5.6% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Vulnerable**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Magway dry cycad forest

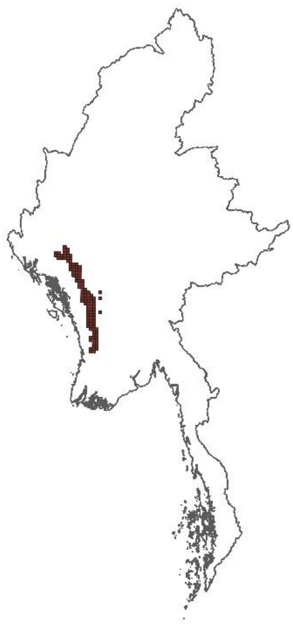
Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Dry deciduous forest (Songer et al., 2006), Deciduous dipterocarp forest (Ashton, 2017), Dry dipterocarp forest (Stamp, 1924b), Indaing, Low Indaing (Songer et al., 2006),
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical dry forests and scrubs (T1.2)
Global classification MMR-T1.2.8
IUCN Status **Endangered (Endangered – Critically Endangered)**

Description

Magway dry cycad forest is a very distinctive ecosystem that occurs under drier conditions than other semi-evergreen forests in this region, yet hosts a high proportion of evergreen tree species. It is a seasonally dry tropical forest with elements of dipterocarp (probably *Dipterocarpus tuberculatas*), *Shorea*, and *Terminalia* (Dipterocarpaceae). It characteristically includes Cycads (probably *Cycas cf. pectinata*). It occurs primarily red sandy soils at the eastern foothills of the Rakhine hills on the western edge of the central dry zone. In this region there is a seasonally dry period of greater than 6 months, where monthly rainfall rarely exceeds 100 mm. Canopy is predominantly low, between 5-10 m. A distinct lack of grass in the understorey, which is rather dominated by copious amounts of leaf litter.

Distribution

This ecosystem is found on the low foothills and toeslope of the eastern Rakhine hills.



Characteristic native biota

A very distinctive assemblage of plants including the dipterocarp *Dipterocarpus tuberculatas, Shorea siamensis* and other *Shorea* species (Dipterocarpaceae) are also common. Cycads are conspicuous in the understorey. The avifauna of the area is similar to other forested areas along the western edge of the dry zone Chestnut-headed Bee-eater *Merops leschenaultia,* Lineated Barbet *Psilopogon lineatus,* Red-breasted Parakeet *Psittacula alexandri* (NT)*,* Alexandrine Parakeet *Psittacula eupatria* (NT), Oriental Paradise-flycatcher *Terpsiphone affinis* and Purple Sunbird *Cinnyris asiaticus* all regularly occur. Large mammals are relatively limited and numbers suppressed due to local hunting but include

Rhesus Macaque *Macaca mulatta,* Golden Jackal *Canis aureus,* Leopard Cat *Prionailurus bengalensis,* Jungle Cat *Felis chaus,* Eld's Deer *Cervus eldii thamin* (EN), Red Muntjac *Muntiacus muntjac* and Burmese Hare *Lepus peguensis.*

Abiotic environment

This ecosystem occurs on red sandy soils where there is a seasonally dry period of 5-9 months (Stamp, 1924b; Ashton, 2017). The soils are likely to be low in nutrients.

Key processes and interactions

Ecosystem dynamics are driven by seasonal water stress (Ashton, 2014). However, low levels of soil nutrients are likely to limit the degree of deciduousness to cope with seasonal water deficit, as evergreen phenology offers a more efficient retention of limited nutrients. Owing to thick leaf litter, fires may occur periodically and may play a role in limiting the establishment of seedling semi-evergreen species from adjacent ecosystems

Major threats

Magway dry cycad forest is highly fragmented as a result of clearing for agriculture and subsistence farming (Reddy et al., 2019).

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, when the proportion of the ecosystem considered primary forest declines to 0, or when tree canopy cover declines below 20% in the growth season.

Assessment summary

This ecosystem is restricted to a small band on the western foothills of the central dry zone. Ongoing threats, primarily clearing for agriculture and farming, as well as grazing within the ecosystem, suggest an ongoing decline. Furthermore, climate suitability modelling suggests large reductions in suitable conditions over the next three decades, although we do note some variability depending on various climate change scenarios. Analyses of primary forest data also suggest historical degradation of this ecosystem to an extent sufficient to meet the D3 category threshold for Endangered. The ecosystem is therefore assessed as **Endangered** with a plausible range of **Vulnerable – Critically Endangered**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**EN (VU-CR)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**EN**
Criterion E	E	**NE**

Assessment Outcome

Endangered (Vulnerable– Critically Endangered)

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Jose Rafael Ferrer-Paris, Adam Duncan

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

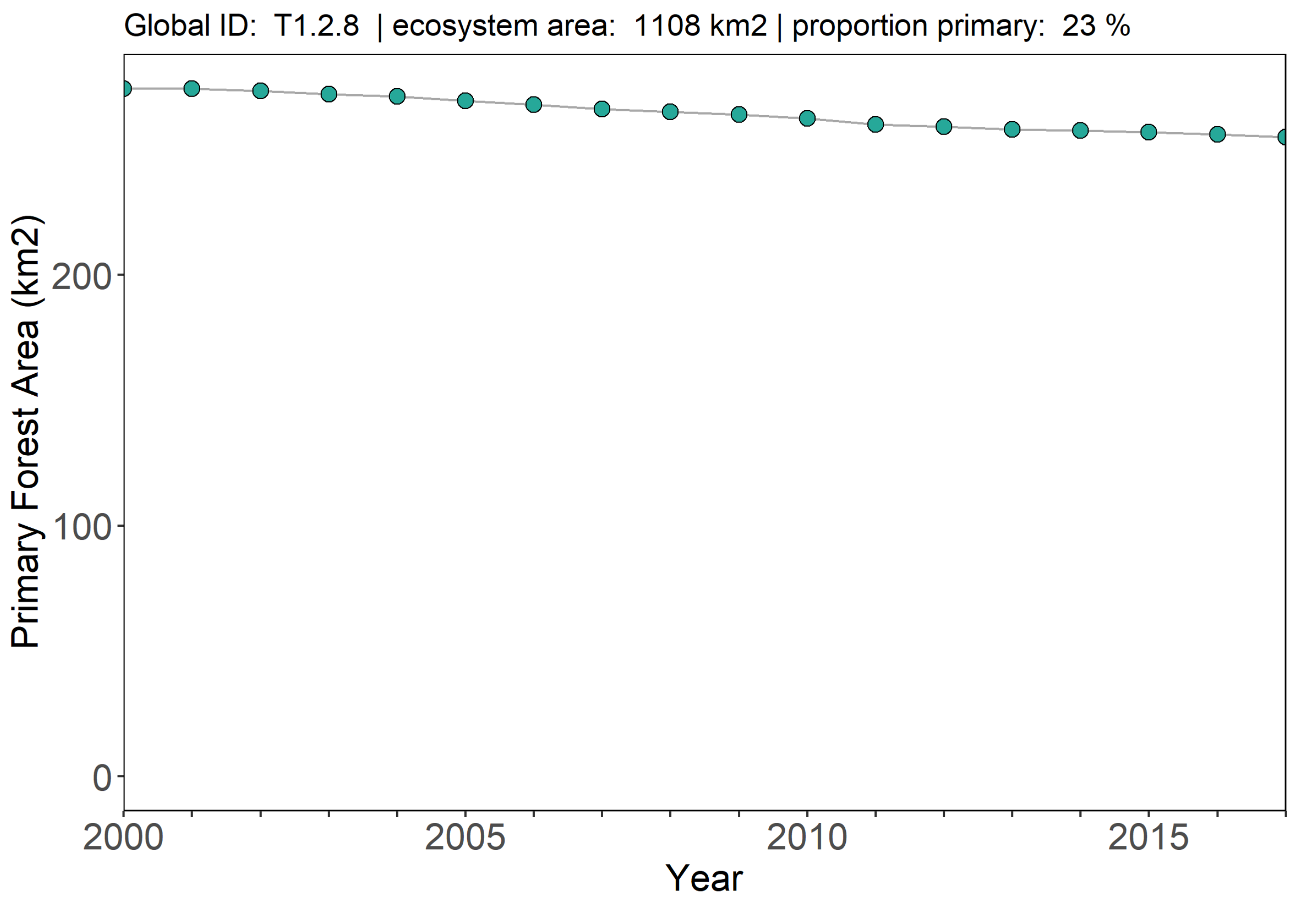
AOO and EOO were measured as 118 10 x 10 km grid cells and 24,7661 km^2, respectively. An analysis of threats and evidence from field work suggests this ecosystem is undergoing ongoing declines in the extent of the ecosystem and experiencing disruption of biotic interactions (see threatening processes). The ecosystem therefore meets the category threshold for Endangered (B1) and sub-criteria (B1a(i) and B1a(iii)). **Vulnerable.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will occur with an extent and severity to meet the category thresholds for Endangered under Criterion C2a. Furthermore, variation in the outcomes of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Vulnerable to Critically Endangered, and therefore the ecosystem is assessed as Endangered (the most commonly returned result), with plausible bounds of Vulnerable – Critically Endangered. **Endangered (Vulnerable – Critically Endangered).**

Criterion D

Remote sensing analyses suggest that only 23% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 77% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 70% but less than 90%, meeting the D3 category threshold for Endangered. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 7.1% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Endangered**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Magway semi-evergreen dry gully forest

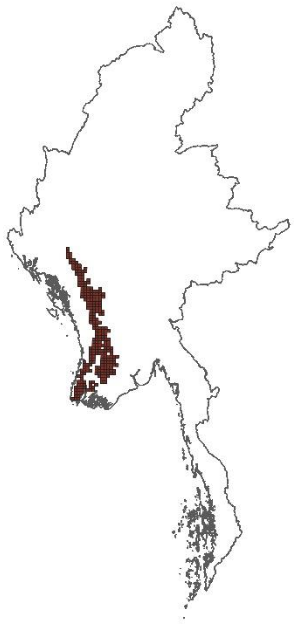
Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Dry forest (Oo and Koike, 2015)
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical dry forests and scrubs (T1.2)
Global classification T1.2.9
IUCN Status **Vulnerable (Near Threatened – Vulnerable)**

Description

Magway semi-evergreen dry gully forest is a dry forest ecosystem that occurs along the eastern foothills of the Rakhine range. It forms mosaic with Magway Than-Dahat dry grassy forest, occurring in moist gullies where it can avoid burning. In contrast to the Magway Than-Dahat grassy forest, the understory of this ecosystem is lacking grass but has copious leaf litter. The canopy is around 20 m.

Distribution

Occurs along the foothills of the Rakhine and Magway hills, where it forms mosaics with ecosystems such as Magway Than Dahat dry grassy forest and Shwe Settaw Sha-Bamboo thicket.



Characteristic native biota

The main woody species include *Tectona hamiltoniana* (Dahat) (Lamiaceae), *Grewia tiliifolia,* (Tayaw) (Malvaceae), *Harrisonia perforata*(Tabu/Sugyin) (Rutaceae), *Acacia catechu* (Sha) (Fabaceae), Diospyros sp. (Te) (Ebenaceae), *Lannea coromandelica* (Nabe) (Anacardiaceae), *Millettia pendula* (Thinwin) (Fabaceae), *Bombax insigne* (Didu) (Malvaceae), *Shorea siamensis* (Ingyin) (Dipterocarpaceae), *Xylia xylocarpa* (Pyinkado) (Fabaceae) and *Dalbergia oliveri* (Tamalan) (Fabaceae) and *Bauhinia* sp. (Swedaw) (Fabaceae). The avifauna is quite widespread including Chestnut-headed Bee-eater *Merops leschenaultia,* Lineated Barbet *Psilopogon lineatus,* Streak-throated Woodpecker *Picus xanthopygaeus,* Yellow-crowned Woodpecker *Leiopicus mahrattensis,* White-rumped Pygmy-falcon *Polihierax insignis,* Red-breasted Parakeet *Psittacula alexandri,* Alexandrine Parakeet *Psittacula eupatria,* Oriental Paradise-flycatcher *Terpsiphone affinis,* Burmese Shrike *Lanius collurioides* and Purple Sunbird).

Cinnyris asiaticus. This ecosystem type also supports populations of Eld's Deer *Rucervus eldii* (EN), Golden Jackal *Canis aureus* (Thu et al., 2019), and Burmese Star Tortoise *Geochelone platynota* (CR

Abiotic environment

Mean annual rainfall is up to 1,900 mm. A seasonally dry period occurs from October to late May when monsoonal rains arrive, and temperatures are hot, with little seasonal variation. However, the severity of the water deficit is ameliorated by topographic shelter, as these forests are found mainly in gullies.

Key processes and interactions

Rainfall gradients, landform and soil type are probably key drivers of the distribution of this ecosystem. Moist and sheltered gullies are likely to ameliorate dry season water deficits and limit the incursion of fire into this ecosystem, resulting in a restricted distribution surrounded by more flammable savanna ecosystem types.

Major threats

Changed fire regimes, which in some areas are burnt annually, can destroy natural woody vegetation cover (Thu et al., 2019), and promote ingress of C4 grasses, in turn, increasing flammability of the ecosystem. Deforestation for cultivation and firewood also occurs.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, when the proportion of the ecosystem considered primary forest declines to 0, or when tree canopy cover is below 20% in the growing season.

Assessment summary

Magway semi-evergreen forest is threatened by changed fire regimes, conversion to agriculture and firewood cutting. Its range size is close to the category thresholds for Criterion B, and climate simulation modelling suggests a decline in suitable areas over the next three decades. The ecosystem qualifies for listing as **Vulnerable** under Criterion C2a, with plausible bounds of **Near Threatened – Vulnerable.**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**NT**
	B2	**LC**
	subcriteria	**B1(b)**
	B3	**LC**
Criterion C	C1	**LC**
	C2a	**VU (NT-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable (Near Threatened – Vulnerable)

Year Published

2020

Date Assessed

21st January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 264 10 x 10 km grid cells and 54,179 km^2, respectively. With EOO approaching category thresholds for Vulnerable and evidence that threatening processes are likely to cause continuing declines in distribution and biotic interactions, this ecosystem qualifies for listing as Near Threatened under B1(b). **Near Threatened.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will occur with an extent and severity to meet the category thresholds for Vulnerable under Criterion C2a. Furthermore, variation in the outcomes of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Near Threatened to Vulnerable, and therefore the ecosystem is assessed as Vulnerable (the most commonly returned result), with plausible bounds of Near Threatened - Vulnerable. **Vulnerable (Near Threatened – Vulnerable).**

Criterion D

Primary forest data was not suitable for assessing degradation of this ecosystem, because tree canopy cover for this ecosystem is not likely to meet the >25% threshold for inclusion in the Potapov et al. (2019) analysis. However, our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	1.02	1.14	9.7	88.14	60.66
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

East Myanmar dry valley forest

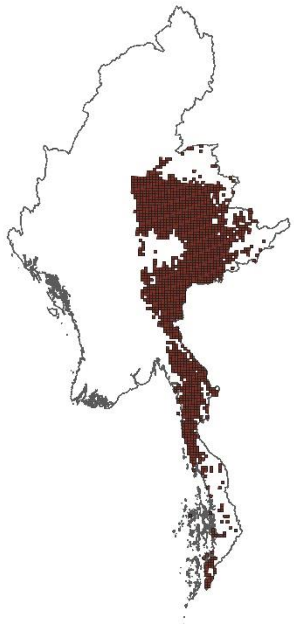
Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Dry forest.
Biome Tropical and subtropical forests
Functional ecotype Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.10
IUCN Status **Vulnerable**

Description

East Myanmar dry valley forest is a closed-canopy deciduous forest that occurs throughout southern Shan State. In this region there is an annual seasonally dry period, typically around 6 months long between November and May each year, followed by monsoonal rains (Platt et al 2010). Mean annual rainfall is typically around 1400 mm, and local elevation, moisture gradient and soil type are the key factors that influence the distribution of this ecosystem (Wolfhart et al 2010).

Distribution

Distributed in dry valleys across southern Shan state and south through Kayin to northern Tanintharyi. It occurs across the plateau in rainshadow areas with a regular seasonal water deficit. Owing to access issues, we have been unable to confirm the distribution of this ecosystem. Our distribution map may overpredict the extent of this ecosystem, which we expect to be primarily limited to rain shadow valleys and may not occur as extensively in the south.



Characteristic native biota

Very little information is available for this ecosystem. We recommend targeted field work to fill this knowledge gap and to develop a detailed ecosystem description. The avifauna is similar to other dry forest ecosystems in the region with species such as Chestnut-headed Bee-eater *Merops leschenaulti,* Lineated Barbet *Psilopogon lineatus,* Red-breasted Parakeet *Psittacula alexandri,* Alexandrine Parakeet *Psittacula eupatria* and Purple Sunbird *Cinnyris asiaticus*. This ecosystem can also support lower populations of large mammals that include Leopard *Panthera pardus* (VU) and Sambar *Cervus unicolor* (VU).

Abiotic environment

Occurs where mean annual rainfall is around 1,250 mm to 1,500 mm, and there is a distinct annual seasonally dry period for about 6 months per year. In the dry period monthly rainfall is normally 0-100 mm, followed by several months of monsoonal rains (Platt et al., 2010).

Mean annual temperature is 23° C with little variability throughout the year. Mostly occurs on rocky slopes and hills exposed to drying, and may have undergone some clearing in flatter areas.

Key processes and interactions

Water availability is the key driver of the dynamics of this dry forest ecosystem (Ashton and Seidler, 2014; Banda et al., 2016). The availability of water is probably climatic but may also include an edaphic component, (Ashton and Seidler, 2014). The amount and timing of monsoonal rains determine annual flushes of productivity in vegetation. Fires may reduce the establishment of evergreen tree species and maintain the predominantly deciduous phenology of the ecosystem (Ashton and Seidler, 2014).

Major threats

The ecosystem is thought to have been widely cleared for agriculture, primarily cropland. Increasing numbers and regularity of bushfires promoted by local clearing and burning activity promotes ingress of grasses, making the ecosystem more flammable and may reduce the persistence of key herbaceous and woody species (Ratnam et al., 2011).

Ecosystem collapse definition

East Myanmar dry valley forest is regarded as collapsed when its area has declined to zero, or when the proportion of the ecosystem considered primary forest declines to 0 km^2.

Assessment Summary

A remote sensing model suggests this ecosystem is very broadly distributed in eastern Myanmar. Widespread degradation and deforestation has likely occurred. Analyses of the declining extent of primary forest within this ecosystem suggest that nearly 70% of this ecosystem has been converted from primary forest to secondary forest since 1750, and projections to a 50 year time frame suggest a potential loss sufficient to meet category thresholds for Vulnerable under D2b and D3. **Vulnerable.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**VU**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

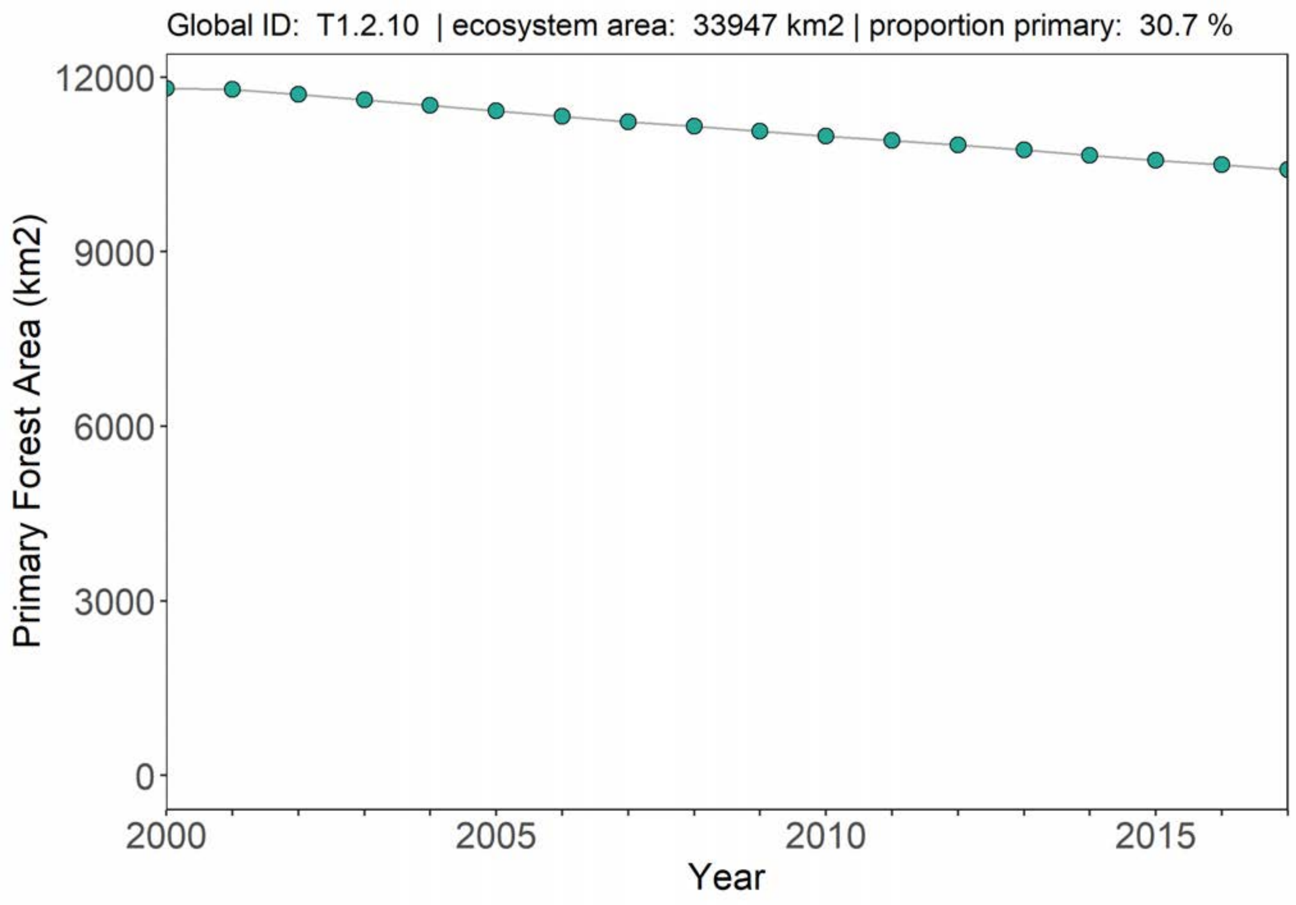
AOO and EOO were measured as 1,552 10 x 10 km grid cells and 426,132 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. We do note that our ecosystem distribution model could not be validated in eastern Shan, so it is possible that the extent of this ecosystem is overestimated in the east and south-east. However, field work in accessible regions indicated this ecosystem is very broadly distributed, so a listing of Least Concern is justified. **Least Concern.**

Criterion C

A climate simulation model suggests that areas of suitable environmental conditions for this ecosystem are unlikely to reduce sufficiently to result in this ecosystem being listed as threatened by 2050. **Least Concern.**

Criterion D

Analyses of a dataset that depicts the distribution of primary forests in South-East Asia (Potapov et al., 2019) suggest that 30.7% of the remaining extent of this ecosystem is primary forest. If 100% of the ecosystem is assumed to be primary forest in 1750, we estimate a 69.3% loss in primary forest extent since 1750. Here we assume that loss of primary forest extent has a relative severity of >90%. The ecosystem therefore meets the category threshold for Vulnerable under Criterion D3, and further losses of primary forest will quickly result in uplisting to Endangered. Analyses of the full time-series of primary forest data (n = 18) suggests an 11.9% reduction of primary forest in this ecosystem over the period 2000-2017. A linear model fit to this dataset suggests that primary forest cover in this ecosystem is expected to decline sufficiently over a 50 year period (1984-2034) to meet the category threshold for Vulnerable under Criterion D2b. **Vulnerable**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Eastern Shan semi-evergreen forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Mixed deciduous forest
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.11
IUCN Status **Vulnerable**

Description

This ecosystem is likely to be similar to Western Shan semi-evergreen forest. It occurs at higher elevations on the eastern and southern regions of the Shan plateau, with lower mean annual temperatures and lower precipitation. It is a semi-evergreen forest with both evergreen and deciduous canopy species and a closed canopy around 20-25 m tall, possibly up to 40 m.

Distribution

Occurs along the east and south of Shan state. Owing to access issues to this region, there is considerable uncertainty about the distribution of this ecosystem and we suggest further work to refine estimates of its distribution.

Characteristic native biota

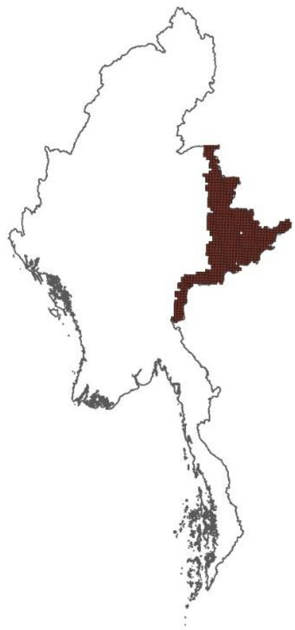
No access to this ecosystem was possible during our field investigations, so developing detailed information on characteristic native biota has not been possible. Expected to be similar to Western Shan Escarpment wet semi-evergreen dipterocarp forest. The fauna is poorly studied in Myanmar but is similar to species in similar ecosystems across Thailand, Laos and Yunnan, China.

Abiotic environment

Mean annual rainfall around 1,300 mm. Dry periods of less than 4-5 months, though not as pronounced as in other parts of Myanmar. Primarily occurs across the Shan plateau in the rain shadow of the western escarpment. Mean temperature of around 22° C.

Key processes and interactions

In dry months, the average evapotranspiration exceeds rainfall. Fire does not typically penetrate into primary stands of this ecosystem. A short dry season drives seasonal productivity.



Major threats

Deforestation for the development of rubber plantation (Liu et al., 2013), opium poppy (Tian et al., 2011), timber or fuelwood, and shifting agriculture are considered the primary threats to this ecosystem.

Ecosystem collapse definition

This ecosystem is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when all patches of primary forest are smaller than 1-10 km^2.

Assessment Summary

Although we were able to develop a distribution map from remote sensing data trained from field data acquired in western Shan, it was not possible to confirm the distribution or change of this ecosystem type. Nevertheless, our map data suggests this ecosystem is widespread throughout eastern Shan. Primary forest cover data suggest that >50% of the ecosystem is degraded with a relative severity of >90%, and the ecosystem meets category thresholds for Vulnerable under Criterion D3. **Vulnerable**.

Assessment summary

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**VU**
Criterion E	E	**DD**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

21st January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

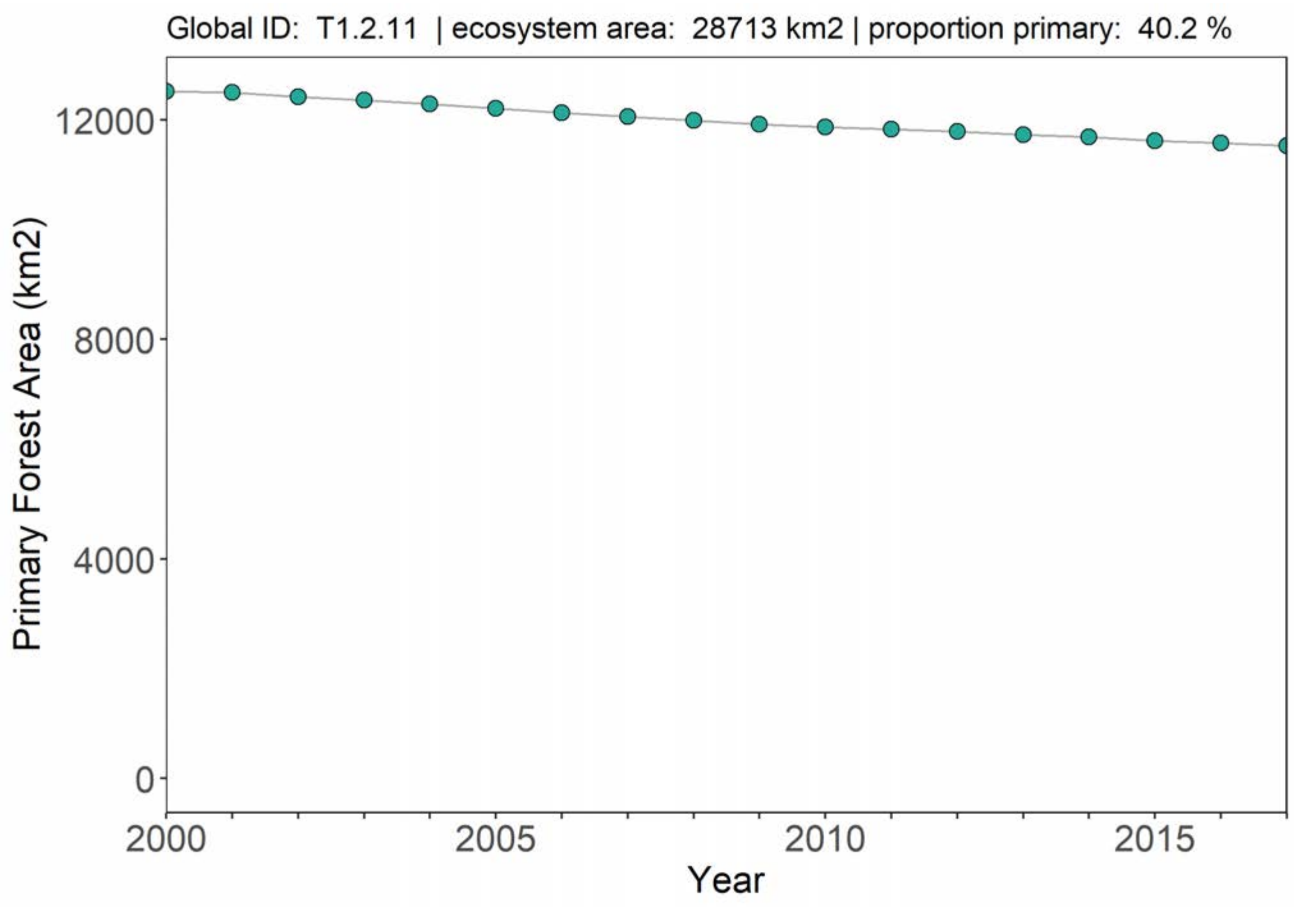
AOO and EOO were measured as 630 10 x 10 km grid cells and 124,498 km^2, respectively. However, this region was inaccessible during this project and no confirmation of our map predictions could be made, so this assessment should be revised as soon as improved information on this ecosystem can be obtained. **Data Deficient.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. However, these predictions are estimated from training data for an adjacent ecosystem, so we consider uncertainty in the predictions to be too high to reliably assess this criterion. **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 40.2% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 59.8% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 50% but less than 70%, meeting the D3 category threshold for Vulnerable. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 7.9% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034), and is therefore assessed as Least Concern under D2b. **Vulnerable.**



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Western Shan semi-evergreen forest

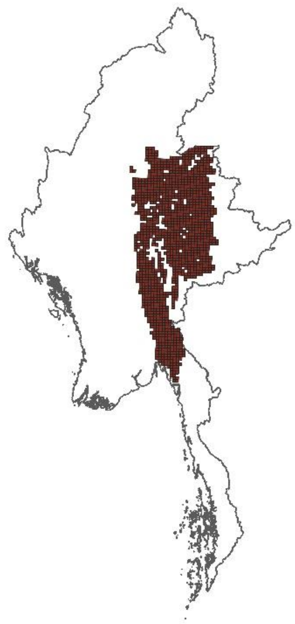
Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Mixed forest, semi-evergreen forest.
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical dry forest and scrubs (T1.2)

Global classification MMR-T1.2.12
IUCN Status **Vulnerable**

Description

Western Shan semi-evergreen forest has a closed canopy reaching about 20-25 m in height, with both evergreen and deciduous tree species, though the former are dominant, including dipterocarps and Myrtaceae. It occurs on loamy soils, and may extend well down the escarpment in sheltered gullies. Now heavily degraded with large bamboo thickets and regrowth throughout as a response to extensive cultivation, few intact patches remain. This ecosystem is distinguished from Western Shan Plateau evergreen forest by the present of deciduous canopy species. At lower elevations where dry periods of the year become extended up to 7 or 8 months, this ecosystem transitions into Shan foothills Than-Dahat grassy forest.

Distribution



Distributed along the western Shan hills up to about 1,300 m elevation, and south to Mon State.

Characteristic native biota

These forests are dominated by a closed canopy of evergreen trees 20-25m tall, with a subdominant component of deciduous species, many of which are pioneer species. Stamp (1924) suggests that *Xylia xylocarpa* (Fabaceae) is the main tree species in this ecosystem, and teak is almost totally absent. *Lagerstroemia* (Lythraceae) and *Dalbergia* (Fabaceae) species occur throughout, as do several leguminous tree species, and the main dipterocarps are *Dipterocarpus alatus* and *D. turbinatus* (Dipterocarpaceae).

Primary bamboos are *Bambusa polymorpha* and *Cephalostachyum pergracile* (Poaceae; Stamp 1924b). The ground cover includes vines, forbs and fernsbut grasses are comparatively sparse.

The avifauna includes Red-headed Trogon *Harpactes erythrocephalus,* a range of breeding and wintering Leaf-warblers (Phylloscopidae) Bush-warblers (Scotocercidae), Scimitar-babblers and allies (Timaliidae) and Black-breasted Thrush *Turdus dissimilis.* This ecosystem also supports the near-endemic Burmese Yuhina *Yuhina humilis.* Mammal populations are depleted but still include populations of Phayre's Langur *Trachypithecus phayrei shanicus* (EN)*,* Sun Bear *Helarctos malayanus* (VU)*,* Himalayan Black Bear *Ursus thibetanus* (VU) and the widespread Red Muntjac *Muntiacus muntjac.*

Abiotic environment

Mean annual rainfall ranges from 2000 to 2500 mm, with around 6 months of dry season where rainfall is less than 100 mm per month (Stamp 1924b). Primarily occurs at low- to mid-elevations (up to 1000 m) on the escarpment, in loamy soils of moderate fertility, mostly derived from sedimentary substrates.

Key processes and interactions

In dry months, the average evapotranspiration exceeds rainfall. Fire does not get into primary stands because the relatively short dry season of up to about 4-5 months, combined with the largely evergreen tree canopy, which maintains a moist microclimate and low grass cover (Ashton, 2014).

Major threats

The ecosystem has been widely logged for hardwood and cleared for shifting agriculture except in the steepest terrain and is now heavily degraded with extensive bamboo regrowth. Construction of major infrastructure including mines, dams and roads pose further threats, including severe erosion on steep slopes during wet season downpours.

Ecosystem collapse definition

Western Shan Plateau subtropical evergreen rainforest is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when all patches of primary forest are smaller than 1-10 km^2.

Assessment Summary

This ecosystem has been widely logged for hardwood and is heavily degraded throughout its range. However, we found no historical map data suitable for assessing Criterion A. Primary forest time-series data suggest this ecosystem has been sufficiently degraded since 1750 to meet the category thresholds for Vulnerable (D3). Further work to refine distribution maps and better understand recent extent changes (Criterion A) are suggested to fill crucial knowledge gaps for this ecosystem. **Vulnerable.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

20th June 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

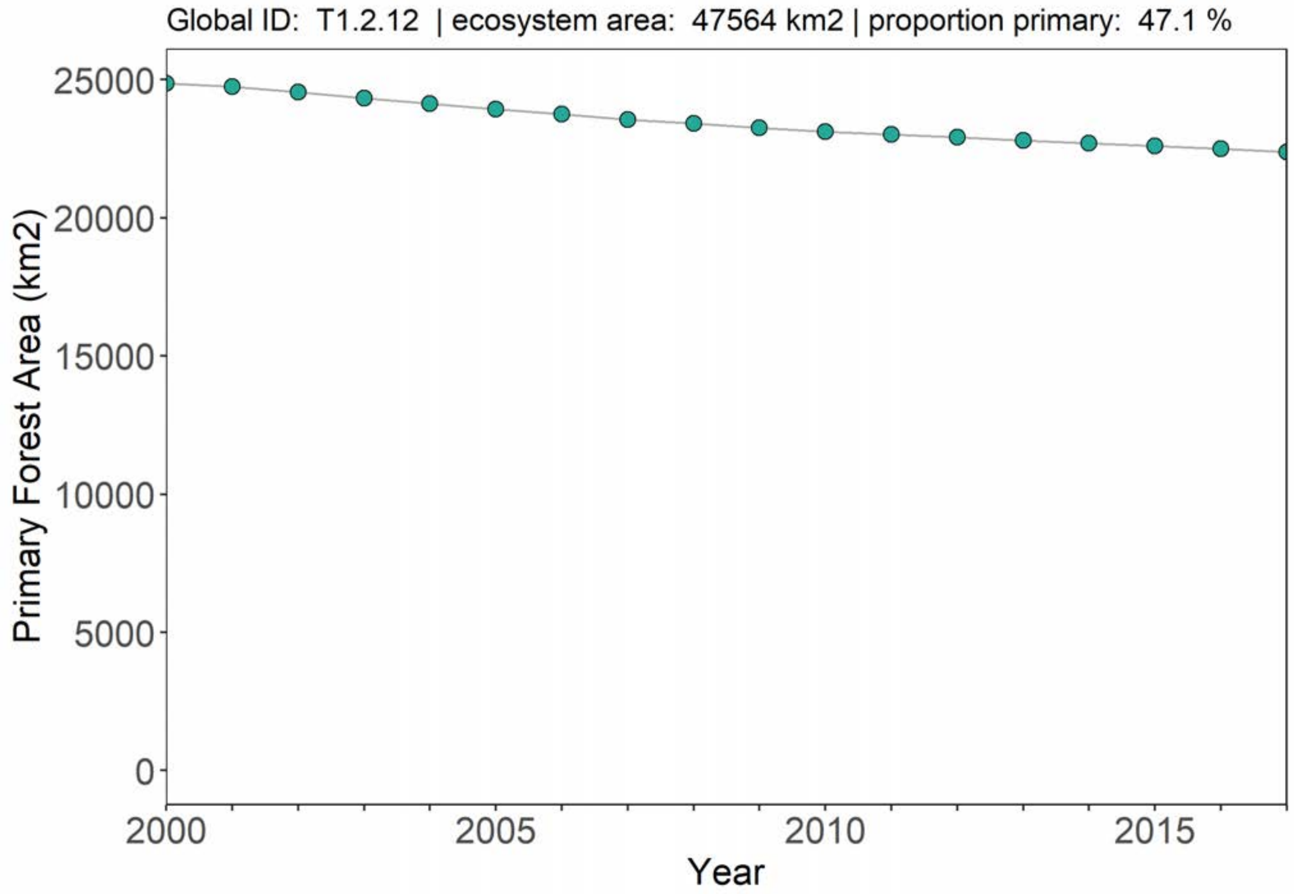
AOO and EOO were measured as 1,444 10 x 10 km grid cells and 177,030 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Remote sensing analyses suggest that 47.1% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 52.9% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 50% but less than 70%, meeting the D3 category threshold for Vulnerable. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 10.0% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034), and is therefore assessed as Least Concern under D2b. The ecosystem is assessed as Least Concern under Criterion D2b. **Vulnerable**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

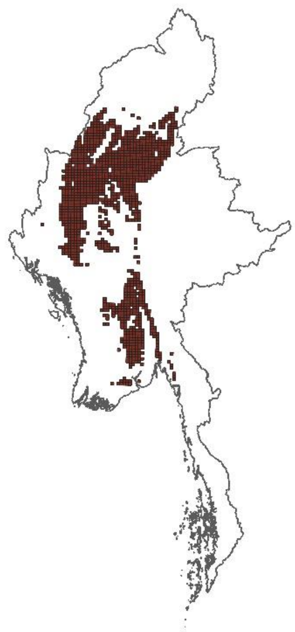
Indaing forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Dry deciduous forest (Songer et al., 2006), Deciduous dipterocarp forest (Ashton, 2014), Dry dipterocarp forest (Stamp., 1924b)
Biome Tropical and subtropical forests (T1)
Functional ecotype Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.13
IUCN Status **Endangered**

Description

Indaing forest is a diverse seasonally dry tropical forest dominated by the canopy dipterocarp *Dipterocarpus tuberculatas,* a slow growing, large-leaved deciduous hardwood species (Aung et al., 2004). A diverse range of tree genera cohabit the forest. Across its distribution, this ecosystem ranges from almost entirely deciduous (Songer et al., 2006) to seldom completely leafless (Ashton, 2014).

Indaing was formerly very extensive in Myanmar but deforestation due to widespread agricultural expansion has resulted in fragmentation and extensive deforestation. It is now restricted to the margins of the dry zone, with only a few intact remnants remaining, including in Chattin Wildlife Sanctuary (Songer et al., 2006).



Distribution

This ecosystem is found in a horseshoe shaped area wedged between the countries northern hill regions and the central dry zone (Songer et al., 2006).

Characteristic native biota

Indaing is dominated by the dipterocarp *Dipterocarpus tuberculatas* (In) with *Shorea siamensis* (Ingyin), *Shorea obtusa* (Thitya) (Dipterocarpaceae), *Tectona grandiflora* (teak) (Lamiaceae), *Vitex pubescens* (Kyun-gaung-nwe) (Lamiaceae), *Anthocephalus cadamba* (Ma-U) (Rubiaceae), *Syzygium fastigiatum* (Thabye) (Myrtaceae), *Firmiana colorata* (Wet-shaw) (Malvaceae), *Erythrina suberosa* (Kathit) (Fabaceae), *Ficus* cunia (Ka-dut), *Ficus benghalensis* (Pyi-nyaung) (Moraceae), *Dalbergia* spp.(Fabaceae), *Lannea coromandelica* (Nabe) (Anacardiaceae), *Pentacme suavis*

(Malvaceae), *Terminalia* (Combretaceae) and *Melanorrhea* (Anacardiaceae) (Songer et al., 2009, Ashton 2016).

Patches of bamboo, *Gigantochloa auriculata* (Thaike-wa) (Poaceae) are scattered through the forest. Vines, including ratans, *Calamus* spp (kyein) (Arecaceae) occur occasionally, as do epiphytes such as the fern *Platycerium* (Polypodiaceae) but these are less common than in evergreen forests. The forest floor includes forbs, ferns such as *Microsorium* (Polypodiaceae) and subshrubs such as *Zingiber* spp.(Zingiberaceae),

The tree canopy is between 10 and 30 m, sometimes to 40 m in the northwest (Ashton, 2014), and some authors recognise two community types (high and low Indaing) depending on canopy height and structure. However, both are dominated by deciduous dipterocarps including *Dipterocarpus tuberculatus, Shorea obtusa, Shorea siamensis* (Dipterocarpaceae) and are considered a single ecosystem type here. Grassland and evergreen patches are found throughout this ecosystem (Songer et al., 2009).

The avifauna is similar to much of the dry forests across Myanmar with populations of Chestnut-headed Bee-eater *Merops leschenaultia,* Lineated Barbet *Psilopogon lineatus,* Streak-throated Woodpecker *Picus xanthopygaeus,* Yellow-crowned Woodpecker *Leiopicus mahrattensis,* White-rumped Pygmy-falcon *Polihierax insignis* (NT), Red-breasted Parakeet *Psittacula alexandri* (NT), Alexandrine Parakeet *Psittacula eupatria* (NT), Oriental Paradise-flycatcher *Terpsiphone affinis,* Burmese Shrike *Lanius collurioides* and Purple Sunbird *Cinnyris asiaticus.*

This ecosystem supports the bulk of the world population of Eld's Deer *Cervus eldii thamin* (EN), the subspecies endemic to Myanmar. It also supports populations of Golden Jackal *Canis aureus,* Leopard Cat *Prionailurus bengalensis,* Jungle Cat *Felis chaus,* Red Muntjac *Muntiacus muntjac* and Burmese Hare *Lepus peguensis.*

Abiotic environment

Indaing occurs in hilly terrain around the dry zone of Myanmar where rainfall averages 1,200-1,500 mm per annum and there is a seasonally dry period of 5-9 months (Ashton, 2014). Stamp (1924b) noted that Indaing forest typically occurs in sandy soils.

Key processes and interactions

Ecosystem dynamics are driven by seasonal edaphic water stress mediated by local topography and substrate rather than seasonality (Ashton 2014). This ecosystem type occasionally experiences ground fires, which burn through thick leaf litter but rarely scorch the tree canopy. Fires may limit the establishment of seedling semi-evergreen species in areas where semi-evergreen may otherwise establish. Nevertheless, species from adjacent ecosystems tend to invade Indaing where conditions are moist enough (Ashton 2017).

Major threats

The ecosystem has been widely cleared for agriculture and for subsistence driven deforestation. Shifting cultivation is similarly a key driver of deforestation and is considered a first step towards agricultural conversion (Songer et al 2006). It has also been extensively logged since British invasion as a valuable source of construction timber. This has resulted in transformation of primary forest structure to regrowth, which reduces habitat suitability for mammals and birds that are dependent on mature forest structure.

Ecosystem collapse definition

Indaing forest is regarded as collapsed when its area has declined to zero, when tree cover declines below 20%, when primary forests accounts for 0% of the distribution, or when primary forest patches are smaller than 1-10 km^2.

Assessment summary

Time-series analysis conducted within Chatthin Wildlife Sanctuary revealed widespread clearing and loss of this ecosystem. Assessments of Criterion A using data from Songer et al (2009) suggests the ecosystem meets the category threshold for **Endangered** (A2b). The ecosystem has undergone extensive degradation, as suggested by only 35.3% of the distribution of this ecosystem being identified as primary forest. These primary forest data suggest ecosystem degradation over a sufficient extent of this ecosystem to be assessed as Vulnerable (D3). **Endangered.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**EN**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**VU (NT-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC (LC-VU)**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Endangered

Year Published

2020

Date Assessed

15th December 2019

Assessment Credits

Assessed by: Nicholas Murray, David Keith

Reviewed by: Hedley Grantham

Contributions by: Nil

Criterion A

A time series analysis of change in forest cover was undertaken for Indaing forests in the Chatthin Wildlife Sanctuary and surrounding area by Songer et al. (2006). The sanctuary was initially established in 1919 as a fuel reserve, then converted to a wildlife sanctuary in 1941, and the surrounding study area (within 10 km of the sanctuary) includes 34 villages with >25,000 people (Songer et al., 2009). This area is within the core distribution of Indaing forests in Myanmar, but also represents one of the more accessible areas within the distribution. We therefore assumed that rates of change observed in Chatthin, averaged within and outside the sanctuary, represent a plausible upper bound of the trends across the range in recent decades. We also assumed an exponential temporal pattern of decline, given that rates of forest conversion are higher outside protected areas and that the decline is expected to slow proportionately as it contracts to protected areas and topographically inaccessible sites.

Songer et al. (2009) mapped forest extent in five years spanning 1973-2005, a 32-year period. We fitted an exponential model to the estimates of total area of Indaing forest and extrapolated the estimated decline to a 50 year period. The exponential model *Forest extent (km^2)* = $1.8 \times 10^{31} \times e^{-0.03241 \times (year)}$ produced an estimate of 79.6% over the period 1973 – 2022. The decline of Indaing forest extent across its full distribution over a 50-year period including the present is likely to be 50-80%, and its status is therefore **Endangered** under criterion A2b.

Criterion B

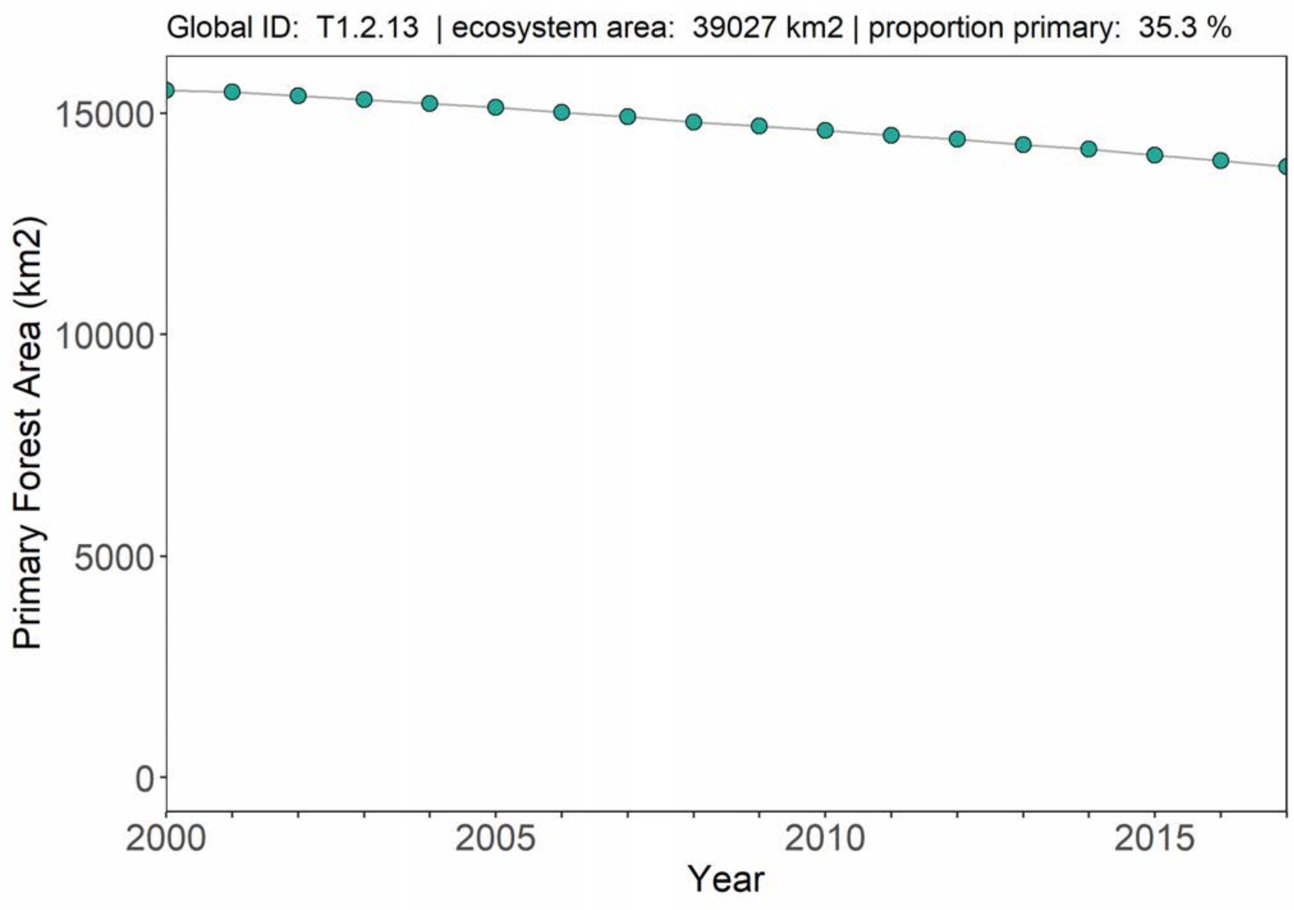
AOO and EOO were measured as 1,836 10 x 10 km grid cells and 380,133 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will occur with an extent and severity to meet the category thresholds for Vulnerable under Criterion C2a. Furthermore, variation in the outcomes of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Near Threatened to Vulnerable, and therefore the ecosystem is assessed as Vulnerable (the most commonly returned result), with plausible bounds of Near Threatened - Vulnerable. One extreme prediction (Endangered) was discarded from the analysis. **Vulnerable (Near Threatened – Vulnerable).**

Criterion D

Remote sensing analyses suggest that 35.3% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 64.7% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 50% but less than 70%, meeting the D3 category threshold for Vulnerable. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 11.2% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). However, confidence intervals on the linear model suggest a slight chance that the ecosystem reaches decline thresholds for Vulnerable, and is therefore assessed as Least Concern with range Least Concern – Vulnerable under D2b. **Vulnerable**.



Criterion E

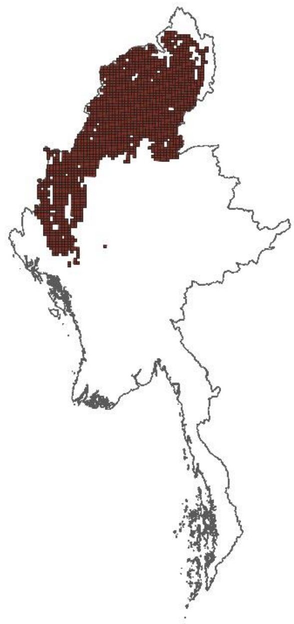
No models were used to assess Criterion E. **Not Evaluated.**

Northern semi-evergreen forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Mixed deciduous forest (Khaing et al., 2019), Monsoon forest (Rundel, 2009), Dry Mixed Deciduous Forest (Zaw Htun, 2011), Mixed dipterocarp forest (Ashton, 2017), Tropical semi-evergreen forest (Ashton 2014), semi-evergreen dipterocarp and other tropical semi-evergreen forests (Ashton, 2014)
Biome Tropical and subtropical forests (T1)
Functional group Tropical/subtropical dry forest and scrubs (T1.2)
Global classification MMR-T1.2.14
IUCN Status **Data Deficient ***

Description

Northern semi-evergreen forest is known by a wide range of names, including mixed deciduous forest, monsoon forest, and semi-evergreen dipterocarp forest. With an extent of around 75,000 km^2, it is among the most extensive ecosystem types in Myanmar. It is primarily composed of canopy evergreen dipterocarp species and deciduous pioneer species. Unlike nearby evergreen forest ecosystems epiphytes are relatively uncommon (Rundel, 2009; Ashton, 2014). In contrast to seasonally dry forest ecosystems in northern Myanmar such as Indaing, this ecosystem retains appreciable vegetative cover during the dry season (Songer, 2006). Northern semi-evergreen forest occurs in areas where the dry season is longer than around 4.5 months and primarily on fertile fine-textured soils, although it also occurs on sandy, karst, or clay loam soils (Ashton, 2014).



Ground fires may occur at moderate frequencies (c. 4-20 year return intervals) in this ecosystem and influences tree recruitment, ground layer composition and structure (Ashton, 2014; Khaing et al., 2019). The extent of deciduousness in this ecosystem is thought to be related to both length of dry season, and increasing nutrient and clay content in the soil (Ashton, 2014). Canopy cover varies from 70 to 85% height extends to around 30 m (Khaing et al., 2019).

Distribution

Northern semi-evergreen forest forms a broad band across the foothills and hills of north-central and northwestern Myanmar to around 900 m elevation (Khaing et al., 2019).

Characteristic native biota

Northern semi-evergreen forest includes dipterocarp species such as *Shorea siamensis, Shorea obtusa* and *Dipterocarpus tuberculatus* (Dipterocarpaceae). Numerous other tree families are represented in the canopy. At Chatthin Wildlife Sanctuary, for example, Northern semi-evergreen forest commonly includes *Lannea coromandelica* (Anacardiaceae)*, Celtis timorensis* (Cannabaceae)*, Lophopetalum wallichii* (Celastraceae)*, Terminalia tomentosa* (Combretaceae)*, Chukrasia tabularis* (Meliaceae) and *Haldina cordifolia* (Rubiaceae). (Khaing et al 2019). More broadly, *Lagerstroemia* (Lythraceae)*, Xylia* (Fabaceae), *Dalbergia* (Fabaceae)*, Pterocarpus* (Fabaceae)*, Terminalia* (Combretaceae) may also be important canopy genera (Ashton, 2014). *Xylia xylocarpa* (Fabaceae) is particularly common and the ecosystem sometimes includes teak (*Tectona grandis,* Lamiaceae), which tends to occur on more fertile soils with high calcium content (Ashton, 2014). Bamboos such as *Dendrocalamus strictus* (Poaceae), are scattered beneath the tree canopy. The forest floor includes subshrubs, forbs, ferns, vines and graminoids. Commonly encountered species include *Hibiscus fragrans* (Malvaceae)*, Cheilocostus speciosus* (Costaceae)*, Curcuma petiolata* (Zingiberaceae)*, Kaempferia candida* (Zingiberaceae), the vines *Disoscorea persimilis* (Dioscoreaceae) and *Smilax macrophylla* (Smilacaceae), and C4 grasses such as *Andropogon fastigiatus* and *Saccharum ravennae* (Poaceae). Plant species richness is generally greater in Northern Semi-evergreen forests than co-occurring Indaing forests, for both trees and ground vegetation (Khaing et al., 2019).

This large ecosystem supports a range of globally important species which have been well surveyed in several large protected areas in Sagaing Region and Kachin State. This ecosystem includes the country's best population of White-winged Duck *Asarcornis scutulata* (EN), and substantial populations of Great Hornbill *Buceros bicornis* (VU), Austen's Brown Hornbill *Anorrhinus austeni* (NT), and Wreathed Hornbill *Rhyticeros undulates.*

The ecosystem occurs on both sides of the Chindwin River, which is an important biogeographic barrier for primates including Capped Langur *Trachypithecus pileatus* (VU), Shortridge's Langur *Trachypithecus shortridgei* (EN), Western Hoolock Gibbon *Hoolock hoolock* (EN) and Eastern Hoolock Gibbon *Hoolock leuconedys* (VU). This area also supports a full suite of large carnivores including Dhole *Cuon alpinus* (EN), Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), Tiger *Panthera tigris* (EN), Leopard *Panthera pardus* (VU), Mainland Clouded Leopard *Neofelis nebulosi* (VU) and all the smaller cats. Asian Elephant *Elephas maximus* (EN) are still found throughout this ecosystem as well as large prey species such as Sambar *Cervus unicolor* (VU), Gaur *Bos gaurus* (VU)*,* Indochinese Serow *Capricornis milneedwardsii* (NT) and Red Serow *Capricornis rubidus* (NT)*.*

Abiotic environment

This ecosystem occurs in hilly areas with more fertile soils than Indaing forests, particularly in relation to soil Potassium and to a lesser degree, Phosphorus and Nitrogen. It is confined to the lowland hills to around 900 m (Khaing et al 2019). These areas in northern Myanmar typically have pronounced dry season lasting up to 6 months (commonly 4.5-6.5 months) and rainfall of around 890-2100 mm per year (Khaing et al 2019).

Key processes and interactions

An interaction between length of dry season, nutrient availability and disturbance mediates the persistence of semi-evergreen forest ecosystems such as this one (Ashton 2014). These ecosystems have some propensity to burn, as leaf litter and moderate abundance of C4 grasses provide fine fuels, (Khaing et al 2019), But where soils are fertile, however, trees will grow sufficiently fast to overcome fires, maintaining the semi-evergreen character of the forest, rather than transitioning to a savanna or Indaing ecosystem types. Kahing et al. (2019) noted higher soil nutrient levels, particularly Potassium, in Northern semi-evergreen forests compared to Indaing forests, but no detectable difference in fire frequency.

Major threats

Deforestation, logging and shifting agriculture are the main threats to this ecosystem. Mining for gold and amber is also a key threat in some areas (Baghwat et al., 2017). Annual burning of leaf litter for grass for cattle is ubiquitous and may suppress the establishment of evergreen seedlings and saplings (Ashton, 2014).

Ecosystem collapse definition

Northern semi-evergreen forest is considered collapsed when its area has declined to 0 km^2, when the proportion of the ecosystem considered primary forest declines to 0, when C4 grasses dominate the ground layer with more than 60% cover, or when deciduous trees account for more than 70% or less than 20% of the total tree canopy cover.

Assessment summary

Northern semi-evergreen forest is the most widely distributed ecosystem identified in Myanmar. However, a wide range of threats are operating on this ecosystem throughout its range. This suggests this ecosystem has probably been widely deforested and degraded, but without data on historical extent an assessment of Criterion A was not possible. The assessment outcome therefore relies on a climate simulation model, which suggests that environmental conditions will remain suitable for the ecosystem for the next decade, although some scenarios suggested that its climate envelope will reduce sufficiently to meet thresholds for Vulnerable (Criterion C2a). A post-assessment review indicated that further data for this ecosystem may result in an assessment outcome other than Least Concern (Least Concern-Vulnerable). We therefore recommend a targeted study of historical extents of this ecosystem and further investigations of ecosystem degradation to allow an assessment to be completed. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	Subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC (LC-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2020

Date Assessed

15th August 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

Despite several studies of deforestation in northern Myanmar, no studies have explicitly mapped the changing distribution of this ecosystem. No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

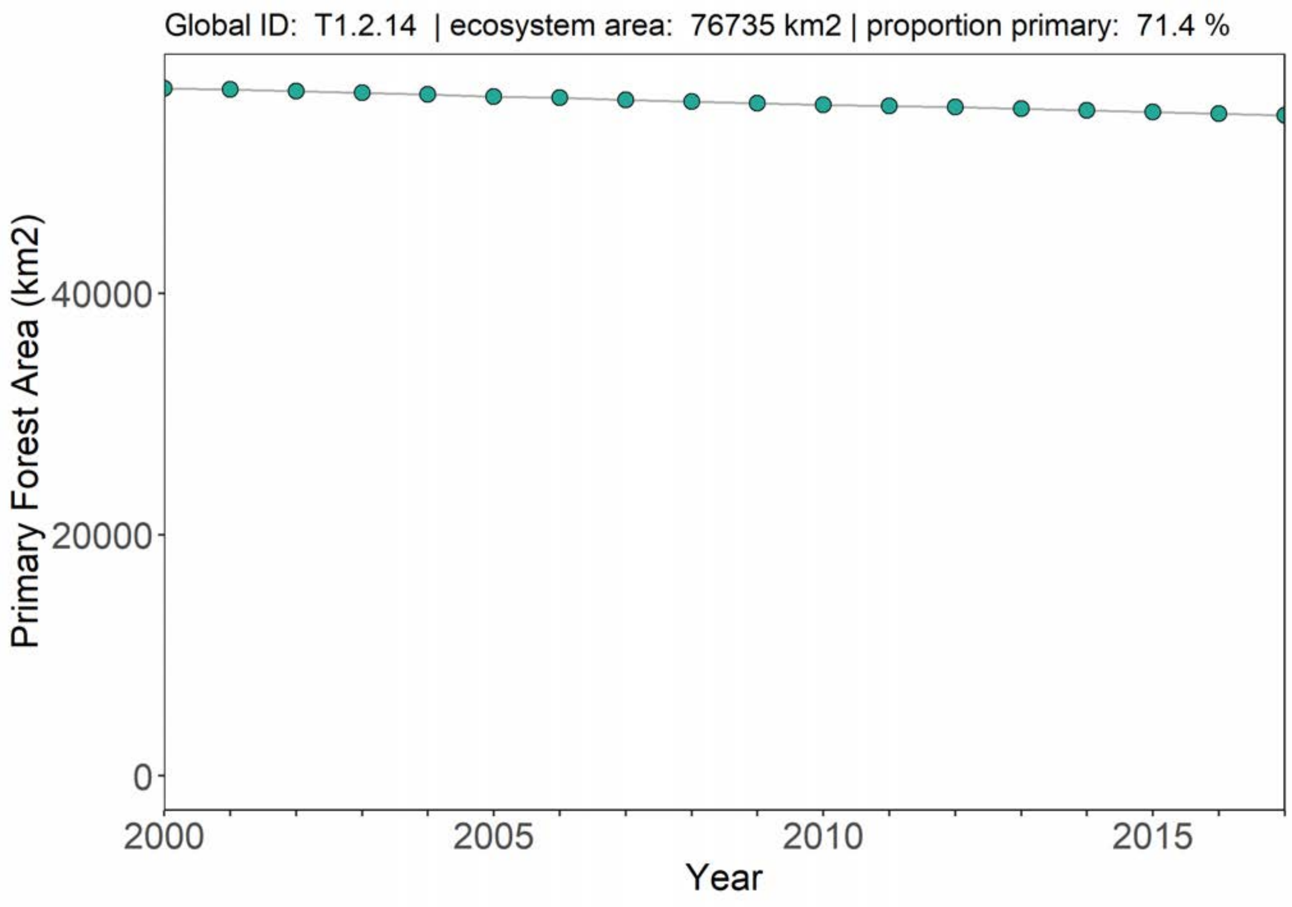
This ecosystem is very broadly distributed in northern Myanmar. AOO and EOO were measured as 1,828 10 x 10 km grid cells and 276,614 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will not occur with an extent and severity to meet the category thresholds for threatened under Criterion C2a. However, some scenarios suggested a possible listing as Vulnerable, so the ecosystem is assigned the most commonly returned outcome (Least Concern) with plausible bounds of Near Threatened – Vulnerable. **Least Concern (Least Concern – Vulnerable)**

Criterion D

Remote sensing analyses suggest that 71.4% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an 28.6% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as less than 30%, not meeting any D3 category threshold and therefore assessed as Least Concern (D3). Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been 4.0% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034), and is therefore assessed as Least Concern under D2b. **Least Concern**.



Criterion E

Not Evaluated.

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, the extent of this ecosystem is likely to have reduced considerably over the past 50 years with expanding agriculture, mining and road development (Khaing et al 2019, Ashton & Sedler 2014). The ecosystem is also likely to be subject to ongoing illegal logging, fragmentation, and road development. The extent and intensity of these threats is considered to be sufficient that, should detailed data become available, the ecosystem would receive a status other than Least Concern. Therefore, the ecosystem is assessed as Data Deficient and we recommend urgent further work to assess historical change in extent and assess extent and severity of degradation of this ecosystem. **Data Deficient.**

Tanintharyi cloud forest

Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Cloud forest, elfinwood forest, upper montane forest, montane mossy forest, mid-mountain wet evergreen forest (Ashton, 2014)
Biome Tropical and subtropical forests (T1)
Functional group Tropical-subtropical montane rainforests (T1.3)
Global classification MMR-T1.3.1
IUCN Status **Critically Endangered**

Description

Only one confirmed occurrence of a cloud forest is known from Myanmar, occurring in the torrid zone at 2,074 m in Kayin state. However, we have mapped all areas >1,950 m in southern Myanmar as potential areas where cloud forest may occur. Cloud forests are closed canopy evergreen forests that have low or stunted canopies (mostly about 5-20 m), small leaf sizes and pervasive mossy cover (Ashton, 2014). Also abundant bryophytes, often covering the majority of the ground, lichens, liverworts, ferns and orchids, all of which utilise atmospheric moisture by cloud stripping. Largely aseasonal due to persistent annual cloud cover. There may be high endemism in flora and fauna.

Distribution

May occur on a few hill tops at altitudes greater than 1,950 m in Tanintharyi Region, Kayin, Mon and Kayah states.

Characteristic native biota

There have been no recent studies in this ecosystem. The last ornithological studies were during the colonial period, before World War II. This includes Dark-backed Sibia *Heterophasia melanoleuca castanoptera* and Green-tailed Sunbird *Aethopyga nipalensis karenensis.* These were both described form high elevation areas in Kayin State and Southern Shan State. Mammals in these areas are virtually unknown for Myanmar.

Abiotic environment

Altitudinal gradients are critical in forming the abiotic conditions necessary to support cloud forest formation. Cloud formation occurs when saturation deficit declines to zero while temperature declines with altitude (Ashton, 2014). This can occur at around 800 m along coastlines, but in inland areas typically occurs at around 1,000 to 2,000 m (Ashton, 2014).

According to a global analysis, annual cloud cover in altitudes less than 1,950 m is uncommon (Wilson and Jetz, 2014) and no occurrences of cloud forest in Myanmar are known at lower altitudes. We therefore expect suitable abiotic conditions for cloud forest at altitudes over 1,950 m. The mountains identified in our analysis have a mean annual temperature of 16.8° C and precipitation of around 1,300 mm**.**

Key processes and interactions

Component species of Tanintharyi cloud forest obtain moisture by both direct rainfall and cloud stripping. Persistent cloud cover also leads to reduced temperature and fog penetration into the forest canopy maintains humidity, which is particularly important for epiphytes. Cloud cover also reduces local temperatures, reduces desiccation of individuals, and maintains a microclimate that can support the diverse community of epiphytes (Auld et al., 2015). Storms may also influence dynamics by increasing light penetration through disturbed canopies and allowing weed invasion.

Major threats

Climate change is considered to be a major threat to cloud forests globally (Ponce-Reyes et al., 2011; Auld et al., 2015). With climate warming, it is expected that environmentally suitable areas for cloud forest will decline. The lack of mountains >1,950 m in southern Myanmar suggests that no other areas may become suitable. Similarly, increased storm activity may result in ecosystem collapse through increased light penetration and weed invasion. The construction of roads and temples on high mountain tops may also threaten this ecosystem in some parts of its range.

Ecosystem collapse definition

Cloud forest is considered to have collapsed when its distribution declines to 0 km^2.

Assessment summary

This ecosystem occurs in only a few very small patches in south-eastern Myanmar. Knoweldge of these patches is alarmingly low, but it is expected that ongoing declines due to climate warming are occurring. Urgent work to visit and document these sites and fill these knowledge gaps is recommended. **Critically Endangered.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**CR**
	B2	**CR**
	Subcriteria	**B1**
	B3	**CR**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Rob Tizard

Criterion A

Owing to their location on high mountain tops, some cloud forest may have been cleared where temples were constructed. However, no time-series map data was found that was deemed suitable for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

Cloud forest in Myanmar is thought to be highly restricted to only a few peaks in Southern Myanmar. AOO calculated as all mountain tops >1,950 m ASL indicates this ecosystem is very restricted, consisting of only two 10x10 km grid cells (meeting category threshold for Endangered). EOO is 108 km^2 (Critically Endangered). A variety of studies (Jarvis and Mulligan, 2011, Ponce-Reyes et al., 2011, Auld et al., 2015, Wilson et al., 2016) have suggested ongoing declines of cloud forest are likely occurring due to climate warming. This ecosystem is therefore considered to have met subcriterion B1b and B2b. **Critically Endangered**.

Criterion C

We could not apply a climate simulation model for this ecosystem due to its occurrence in such a tiny patch. Cloud forests are expected to be at risk from climate warming, and further work to assess ongoing climate suitability (such as Ponce-Reyes et al., 2013) is crucial to help fill this knowledge gap. **Data Deficient.**

Criterion D

This ecosystem occurs in only one small patch, which is adjacent to a temple. Although some human impacts, particularly incursion of invasive species, are likely due to direct road access, biotic disruption at a scale sufficient to meet category thresholds appears not to have occurred over the last 50 years given the protection afforded by the religious site. A site visit is suggested to confirm this analysis. **Least Concern**.

Criterion E

No model was used to estimate probability of collapse in this ecosystem. **Not Evaluated.**

Kachin mountain conifer forest

Authors Armstrong, K., Grantham, H., Tizard, R., Keith, D.A.
Myanmar ecosystem names Silver fir forest (UNESCO, 2014), Pine forest (Stamp, 1924a), High mountain conifer forest (Davis, 1960), Silver fir forest (Kingdon-Ward, 1944)
Biome Temperate-boreal forests and woodlands (T2)
Functional Group Boreal and temperate montane forests and woodlands (T2.1)
Global classification MMR-T2.1.1
IUCN Status **Data Deficient ***

Description

Kachin mountain conifer forest is comprised of open to dense woodlands of conifers with an understory of hardwoods. Epiphytic shrubs and bryophytes are abundant on the dominant tree species, *Abies delavayi*. At this altitude deep snow lies for at least a month during the year (Kingdon-Ward, 1944). The tree line occurs around 3,300 to 3,600 m. However, this is variable and depends on the relief. Very steep slopes (50-90°) are exposed to snow and land slides and cannot develop large forests. From this point upwards in altitude the vegetation mainly consists of shrubs, particularly *Rhododendron* and dwarf bamboo, transitioning into high mountain scrub. At its lowest elevation, this ecosystem overlaps with Kachin deciduous cool temperate forest.

Distribution

This ecosystem is found in far northern Kachin State in Hkakaborazi National Park, Hponganrazi Wildlife Sanctuary and along Myanmar's northeast border with China at around 2,700 – 3,600 m.

Characteristic native biota

From 3,000 m the conifers *Abies delavayi* and *Larix griffithiana* (Pinaceae), along with *Rhododendron arizelum* (Ericaceae), form the dominant vegetation. Tall trees are covered in bryophytes and epiphytic shrubs (*Vaccinium*, *Rhododendron*, *Agapetes*). Trees of lesser stature, including hemlock (*Tsuga dumosa*, Pinaceae), maple (*Acer*, Sapindaceae) birch (*Betula*), hazel (*Corylus*, Betulaceae), cherry (*Prunus*, Rosaceae), and mountain ash (*Sorbus wardii*, *S. filipes*, *S. reheriana*, Rosaceae) make up the understory at lower elevations in this zone. Shrubs include numerous species of *Rhododendron* (*R. sino-grande*, *R. siderum*, *R. arizelum*, *R. niphargum R. beesianum,* and *Vaccinium* (Ericaceae), as well as

Skimmia (Rutaceae), *Rosa, Rubus* (Rosaceae), *Deutzia* (Hydrangeaceae), *Daphne* (Thymelaeaceae), *Lonicera myrtillus*, *L. cyanocarpa*, (Caprifoliaceae), *Ilex intricata*, *I. georgei*, (Aquifoliaceae) and the woody climbers *Schisandra* (Schizandraceae) and *Hydrangea anomala* (Hydrangeaceae). Sino-Himalayan herbs such as *Paris* (Melianthaceae), *Podophyllum* (Berberidaceae) and *Panax pseudoginseng* (Araliaceae), *Toefieldia thibetica* (Toefieldiaceae), *Berneuxia thibetica* (Diapensiaceae), *Hypericum* (Hypericaceae), *Disporum* (Liliaceae), *Ainsliaea* (Asteraceae), *Fritillaria* (Liliaceae) and *Crawfurdia* (Gentianaceae) also make up the flora at this elevation. These herbs include important medicinal plants, which local villagers collect to sell to China.

The avifauna is predominantely palearctic with species such as Southern Nutcracker *Nucifraga hemispila* and Coal Tit *Periparus ater*, Rufous-vented Tit *Periparus rubidiventris,* and Grey-crested Tit *Lophophanes dichrous* occurring year-round. This area also supports the only populations of palearctic mammals such as Red Fox *Vulpes vulpes* and Stone Martin *Martes foina.*

Abiotic environment

Kachin mountain conifer forest can be found on cold ridges and slopes typically ranging from 2,700 to 3,600 m elevation, receiving frequent winter snow, with a deep snow cover persisting for at least one month.

Key processes and interactions

Near the upper limits of their growth, *Abies* become lower in stature, and many are of wind-blown form. Frosts limit establishment of trees. The treeline is cold-limited, and occurs at around 3,300-3,600 m, with forest transitioning into a subalpine *Rhododendron*-dominated high mountain scrub ecosystem. Seasonally freezing temperatures and snow cover define a short growing season and limit cold-sensitive species. Soils are relatively shallow and acidic. High relief terrain, often with steep slopes, triggers periodic mass movement, initiating forest succession processes. Vertebrates are either summer migrants from lower elevations or else hibernate during winter.

Major threats

Climate change, and the collection of medicinal herbs and firewood collection are the primary threats to this ecosystem.

Ecosystem collapse definition

This ecosystem is considered collapsed when its area has declined to 0 or when tree cover declines to 0 km^2.

Assessment summary

No spatial time series data was available to assess Criterion A and a lack of occurrence data limited our ability to fit climate models to assess Criterion C. However, mapping suggests that this Kachin mountain conifer forest exceeds spatial thresholds for threatened status under criterion B. Futhermore, an assessment of forest intactness suggested that this ecosystem is largely intact and free from human disturbance and fails to qualify for threatened status under D3. However, a post-assessment review by experts suggested that this ecosystem is subject to a range of threats that, if data were available, could lead to an outcome other than Least Concern. The ecosystem is therefore assessed as Data Deficient and we recommend urgent further work to enable a complete assessment. **Data Deficient**.

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2019

Date Assessed

26th November 2019

Assessment Credits

Assessed by: Kate Armstrong, Nicholas Murray, Hedley Grantham

Reviewed by: David Keith

Contributions by: Jose-Rafael Ferrer-Paris, Adam Duncan

Criterion A

No time-series map data was available to assess this ecosystem under Criterion A. **Data Deficient.**

Criterion B

Our map data suggest that this ecosystem has an AOO of 155 10 x 10 km grid cells and an EOO of 85,269 km^2. Relative to the primary threats to this ecosystem, this ecosystem is considered to occur at more than five threat defined locations. The ecosystem does not meet any of the category thresholds for Criterion B, and is therefore assessed as **Least Concern.**

Criterion C

We sought to fit a climate projection model for this ecosystem type. However, occurrence data to train the model was lacking and no projections could be reliably made. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0	0.01	0.54	99.44	75.78
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, experts identified a range of threats that, if quantified, could lead to an assessment outcome other than Least Concern. These include: Illegal logging along the border with Yunnan over a period of 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009). Risk from roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting and over-extraction of resources such as medicinal plants and animal parts (e.g. adjacent to Hpimaw, Kanbaiti, Chipwi/Pianma, Khaunglanphu/ Fugong and Gongshan). The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem. **Data Deficient.**

Shan warm temperate rainforest

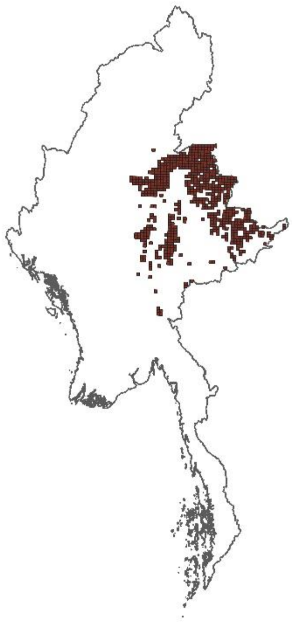
Authors Murray, N.J., Grantham, H., Keith, D.A.
Myanmar ecosystem names Warm temperate rainforest (UNESCO, 2014), Moist hardwood forest (Davis, 1960), Temperate mountain forest (Davis, 1960), warm temperate rainforest (Kingdon-Ward, 1944)
Biome Temperate boreal forests and woodlands (T2)
Ecotype Warm temperate rainforest (T2.4)
Global classification MMR-T2.4.1
IUCN Status **Endangered**

Description

Scattered on the mountain tops and sheltered gulleys of east and north Shan State. Occurs in areas with temperate climate where temperature ranges between about 11° C and 20° C. Mean annual precipitation is around 1,700 mm and sufficient to support an evergreen forest ecosystem. Closed-canopy, structurally simple forests with a generally uniform tree height that is conspicuous in lacking emergents. Tree canopies consist of notophyll-microphyll foliage. Lichens are present, although in contrast to nearby semi-evergreen rainforests there are relatively few epiphytes and the majority of trees lack large buttressed roots.

Distribution

Occurs on the highest mountains of Shan where warm temperate climates prevail.



Characteristic native biota

This ecosystem occurs in inaccessible areas of eastern and northern Shan, and therefore the characteristic native biota ecosystem is largely unknown. However, related forests mapped across the border in China are dominated variously by *Castanopsis indica, Castanopsis hystrix Castanopsis delavayi, Castanopsis fleuryi*, *Quercus delavayi, Quercus schottkyana, Lithocarpus truncatus* (Fagaceae) and *Schima wallichi* (Theaceae). (ECVC-CAS 2007).

Abiotic environment

Shan warm temperate rainforest occurs at higher elevations, extending over about 1,200 m. Mean annual temperature is 16.9 °C, with warmest and coldest quarters 20.5 °C and 11.8 °C. Mean annual precipitation is 1,700 mm. Occurs on mountain tops and sheltered slopes.

Key processes and interactions

Largely monsoonal climate, but severity of the dry season is ameliorated by altitude, with an overall water surplus, supporting a moist microclimate that sustains vegetation through periods of dry weather. Fauna such as birds, bats and invertebrates are important for pollination and seed dispersal in the canopy, and detritovores on the forest floor are important for nutrient cycling.

Major threats

Conversion of this ecosystem to tea plantations, and deforestation due to logging are the primary threats to this ecosystem. Like all warm temperate rainforests, this ecosystem is not considered flammable due to an overall moist microclimate. However, catastrophic fires resulting from intensive human activity (shifting cultivation), particularly following periods of drought or extended warm weather, may threaten this ecosystem.

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2, or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

Remote sensing analyses suggest this ecosystem is very broadly distributed across wet, high altitude areas of Shan State. Owing to inaccessibility, we have not been able to confirm the accuracy of our distribution map and therefore recommend further work to confirm this assessment outcome. A climate simulation based on the map data suggests the ecosystem may be at risk from declining climatic suitability over the next three decades, but the majority of model runs returned a result of Least Concern. Primary forest data suggests extensive degradation of this ecosystem since 1750, with an extent sufficient to meet the D3 category threshold for Endangered.
Endangered.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC (LC-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**EN**
Criterion E	E	**NE**

Assessment Outcome

Endangered

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray, Hedley Grantham

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

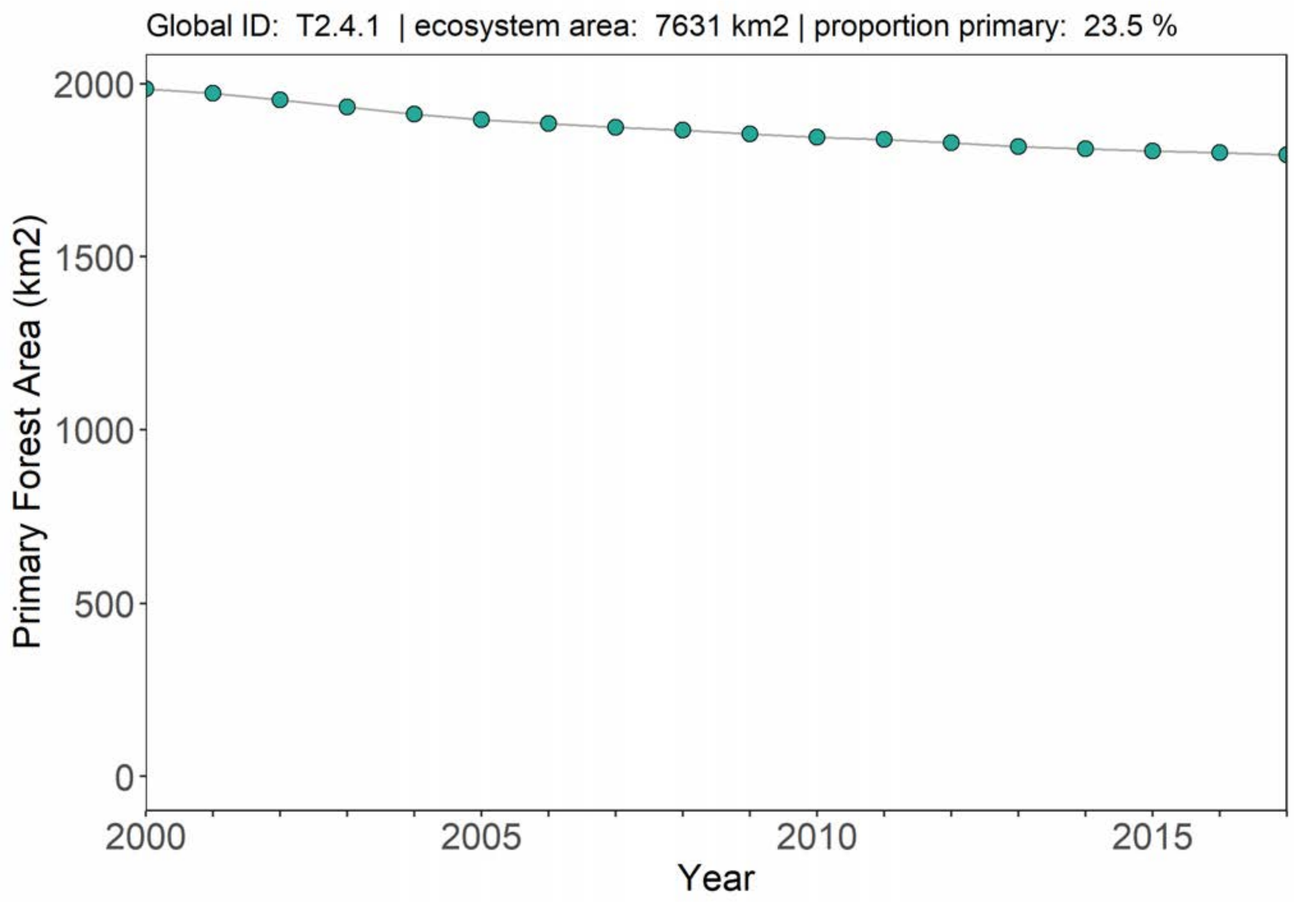
This ecosystem is broadly distributed throughout high altitude areas of eastern Shan. AOO and EOO were measured as 603 10 x 10 km grid cells and 190,658 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. However, further work to refine the distribution estimates of this ecosystem are recommended. **Least Concern.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will not occur with an extent and severity to meet the category thresholds for threatened under Criterion C2a. However, some scenarios suggested a possible listing as Vulnerable, so the ecosystem is assigned the most commonly returned outcome (Least Concern) with plausible bounds of Near Threatened – Vulnerable. **Least Concern (Least Concern – Vulnerable)**

Criterion D

Remote sensing analyses suggest that 23.5% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 76.5% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 70% but less than 90%, meeting the D3 category threshold for Endangered. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 9.7% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Endangered**.



Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Chin hills warm temperate rainforest

Authors Murray, N.J., Grantham, H., Tizard, R., Keith, D.A.

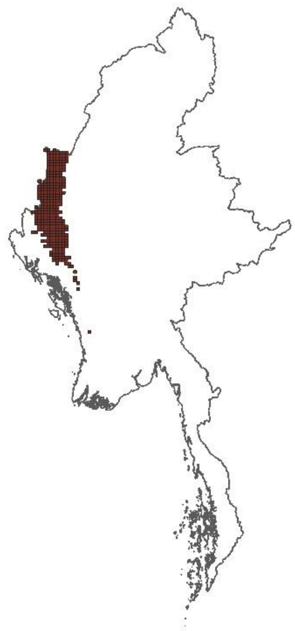
Myanmar ecosystem names Warm temperate rainforest (UNESCO, 2014), Moist hardwood forest (Davis, 1960), Temperate mountain forest (Davis, 1960), warm temperate rainforest (Kingdon-Ward, 1944)
Biome Temperate boreal forests and woodlands (T2)
Ecotype Warm temperate rainforest (T2.4)
Global classification MMR-T2.4.2
IUCN Status **Vulnerable**

Description

An overwhelmingly evergreen closed-canopy forest type occuring in the humid warm temperate areas of north-western Myanmar. This ecosystem is structurally simple, with a relatively uniform canopy consisting of notophyll-microphyll leaf sizes, buttreses are uncommon. Common at elevations over about 1500 m. Oaks (*Quercus*) and chestnuts (*Castanopsis*) are common in this ecosystem, and Dipterocarps are generally rare. A particularly good example of this ecosystem is Natma Taung National Park, the highest point in Chin State.

Distribution

Chin hills warm temperate rainforest is widespread across the higher altitude areas of Chin State.



Characteristic native biota

Fagaceae including Oaks (*Quercus*) and chestnuts (*Castanopsis*) are abundant in this ecosystem (Davis, 1960). Other genera include *Acer, Betula, Celtis, Capinus, Fraxinus* and *Magnolia* (Davis, 1960). Tree species listed by Davis (1960) for the region include *Dipterocarpus alatus* (Dipterocarpaceae), *Engelhardtia spicata* (Juglandaceae), *Figus benjamina* (Moraceae), and *Sterculia coccinea* (Malvaceae) (Davis, 1960). However, the forests of the Chin Hills have more subtropical elements than those of the Naga Hills. Rao (1974) lists the following tree genera: *Albizia* (Fabaceae), *Acer* (Sapindaceae), *Juglans* (Juglandaceae), *Quercus* (Fagaceae), and *Magnolia* (Magnoliaceae) with *Rhododendron* (Ericaceae), *Rubus* spp. (Rosaceae) and scattered *Arundinaria* bamboo (Poaceae) in the understorey. On somewhat higher slopes are *Alnus nepalensis* (Betulaceae), *Cornus controversa* (Cornaceae) and *Ilex* spp. (Aquifoliaceae) (Rao 1974).

This ecosystem supports the entire population of White-browed Nuthatch *Sitta victoriae* (EN) as well as a significant wintering population of Grey-sided Thrush *Turdus feae* (VU). There are numerous near-endemic species and subspecies shared with neighboring India including Blyth's Tragopan *Tragopan blythii blythii* (VU), Black-headed Shrike-babbler *Pteruthius rufiventer,* Leaf-warblers (Phylloscopidae), Bush-warblers (Scotocercidae), Burmese Tit *Aegithalos sharpei,* Scimitar-babblers and allies (Timaliidae), Laughingthrushes and allies (Leiotrichidae), Mount Victoria Babax *Garrulax woodi,* Brown-capped Laughingthrush *Trochalopteron austeni,* Striped Laughingthrush *Trochalopteron virgatum,* Slaty-blue Flycatcher *Ficedula tricolor cerviniventris* and Yellow-breasted Greenfinch *Chloris spinoides heinrichi.* The Mammalian fauna includes Western Hoolock Gibbon *Hoolock hoolock* (EN), Dhole *Cuon alpinus* (EN), Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), Leopard *Panthera pardus* (VU), Mainland Clouded Leopard *Neofelis nebulosa* (VU), Indochinese Serow *Capricornis milneedwardsii* (NT) and Red Serow *Capricornis rubidus* (NT).

Abiotic environment

This ecosystem occurs at moderate elevations (1,300 – 2,500 m) corresponding to areas where high altitudes moderate seasonal drought, with mild mean annual temperature of about 17° C and mean annual precipitation of 2,200 mm.

Key processes and interactions

The monsoonal wet-dry annual cycle is ameliorated by lower evapotranspiration at altitude, and there is an overall water surplus, supporting a moist microclimate that sustains vegetation through periods of dry weather.

Major threats

Conversion of this ecosystem to tea plantations, and deforestation due to logging are the primary threats to this ecosystem. This ecosystem is not flammable due to an overall moist microclimate but catastrophic fires resulting from human activity (shifting cultivation), particularly following periods of drought or extended warm weather, are also key threat.

Ecosystem collapse definition

This ecosystem is considered collapsed when its distribution declines to 0 km^2 or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

Chin hills warm temperate rainforest is broadly distributed and there is little evidence to suggest widespread losses of this ecosystem type or likely future declines under climate change. However, primary forest data suggest that historical degradation of this ecosystem has occurred, sufficient to meet the category thresholds for Vulnerable under Criterion D3. **Vulnerable.**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**VU**
Criterion E	E	**NE**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray, Hedley Grantham

Reviewed by:

Contributions by:

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

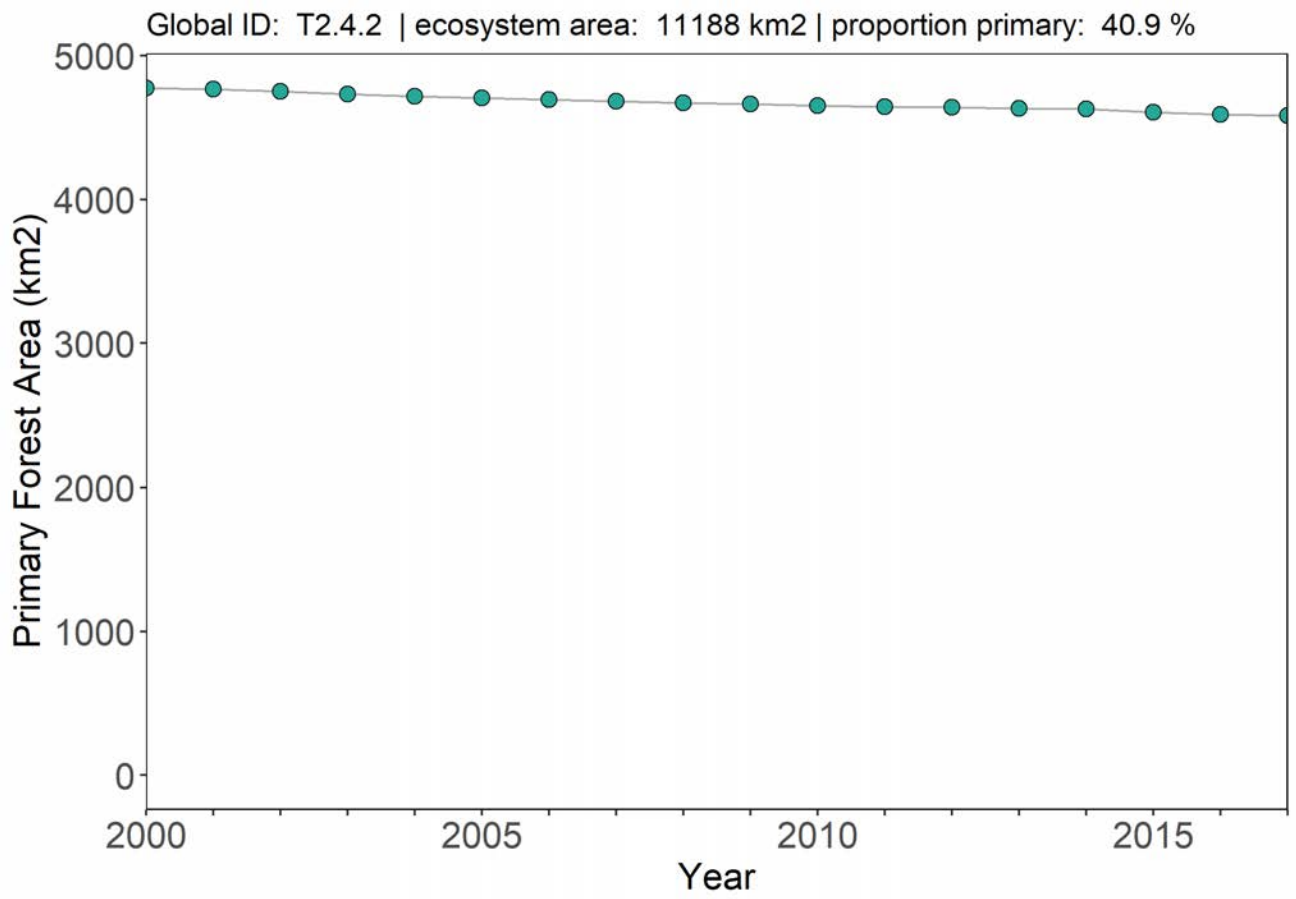
AOO and EOO were measured as 303 10 x 10 km grid cells and 57,427 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Remote sensing analyses suggest that 40.9% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 59.1% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is assessed as greater than 50% but less than 70%, meeting the D3 category threshold for Vulnerable. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 4.1% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Vulnerable**.



Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was used in this assessment. **Not Evaluated.**

Sagaing warm temperate rainforest

Authors Murray, N.J., Grantham, H., Tizard, R., Keith, D.A., Armstrong, K.E.
Myanmar ecosystem names Warm temperate rainforest (UNESCO, 2014), Moist hardwood forest (Davis, 1960), Temperate mountain forest (Davis, 1960), warm temperate rainforest (Kingdon-Ward, 1944)
Biome Temperate boreal forests and woodlands (T2)
Ecotype Warm temperate rainforest (T2.4)
Global classification MMR-T2.4.3
IUCN Status **Near Threatened**

Description

A closed-canopy, mostly evergreen forest occuring at intermediate elevation along the north-western border of Myanmar. Occurs at elevations where conditions are humid and there is sufficient rainfall to support an evergreen forest community. Warm temperate rainforests are structurally simple with a uniform canopy consisting of species with notophyll-microphyll leaf sizes. Oaks (*Quercus*) and chestnuts (*Castanopsis*) are common in this ecosystem, and Dipterocarps are generally rare.

Distribution

Primarily occurs along the Naga hills adjacent to India, but also scattered through the higher elevation hill regions of Sagaing.

Characteristic native biota

Quercus and *Castanopsis* species (Fagaceae) are abundant in this ecosystem (Davis, 1960). Other genera include *Acer, Betula, Celtis, Capinus, Fraxinus* and *Magnolia* (Davis, 1960). Tree species listed by Davis (1960) include *Dipterocarpus alatus* (Dipterocarpaceae), *Engelhardtia spicata* (Junglandaceae), *Figus benjamina* (Moraceae), and *Sterculia coccinea* (Malvaceae) (Davis, 1960). Rao (1974) lists the following trees for temperate forests of the Naga Hills: *Quercus lamellosa, Lithocarpus pachyphyllus, Lithocarpus xylocarpus, Castanopsis tribuloides* (Fagaceae), *Magnolia cathcartii, Magnolia doltsopa* (Magnoliaceae), *Exbucklandia populnea* (Hamamelidaceae), *Ficus neriifolia* (Moraceae), *Tetradium fraxinifolium* (Rutaceae), *Acer campbelii* (Sapindaceae) and *Cinnamomum impressinervum* (Lauraceae).

This ecosystem has had relatively few recent faunal surveys and has high levels of hunting reducing populations of large birds and mammals.

The ecosystem does support Great Barbet *Psilopogon virens,* Gold-whiskered Barbet *Psilopogon chrysopogon,* Blue-throated Barbet *Psilopogon asiaticus,* Bay Woodpecker *Blythipicus pyrrhotis,* Long-tailed Broadbill *Psarisomus dalhousiae,* Bush-warblers (Scotocercidae), Old World Warblers and Parrotbills (Sylviidae), Scimitar-babblers and allies (Timaliidae) and Laughingthrushes and allies (Leiotrichidae). Mammalian fauna includes Capped Langur *Trachypithecus pileatus* (VU), Western Hoolock Gibbon *Hoolock hoolock* (EN), Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), Mainland Clouded Leopard *Neofelis nebulosi* (VU), Leaf Muntjac *Muntiacus putaoensis* (DD), Gaur *Bos gaurus* (VU), Indochinese Serow *Capricornis milneedwardsii* (NT) and Red Serow *Capricornis rubidus* (NT).

Abiotic environment

This ecosystem occurs at intermediate elevations (c. 1,300 – 2,000 m) corresponding to areas where altitude-moderated evapotranspiration mediates monsoonal seasonal droughts, with mild mean annual temperature of about 17° C and mean annual precipitation of 2,200 mm.

Key processes and interactions

A monsoonal rainfall pattern prevails but the dry season is less severe than at lower elevations, with an overall water surplus, supporting a moist microclimate that sustains vegetation through periods of dry weather.

Major threats

Conversion of this ecosystem to tea plantations, and deforestation due to logging and slash and burn are the primary threats to this ecosystem. Defaunation may be an additional threat to this ecosystem. This ecosystem is not flammable due to an overall moist microclimate but catastrophic fires resulting from human activity (shifting cultivation), particularly following periods of drought or extended warm weather, are also a key threat.

Ecosystem collapse definition

This ecosystem is considered collapsed when its distribution declines to 0 km^2 or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

This ecosystem is restricted to the hills bordering India in northern Myanmar. Its range does not meet threatened category thresholds for Criterion B, but ongoing threats and an EOO that is <1,000 km^2 larger than the Vulnerable thresholds for B1 warrant a listing of Near Threatened. A climate simulation suggested that for a few climate warming and emmissions scenarios, the ecosystem may warrant listing as Vulnerable, but the majority of results suggested Least Concern. An assessment of degradation using primary forest data suggests little degradation has occurred. **Near Threatened.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**NT**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC (LC-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Near Threatened

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray, Hedley Grantham

Reviewed by: David Keith

Contributions by: Robert Tizard

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

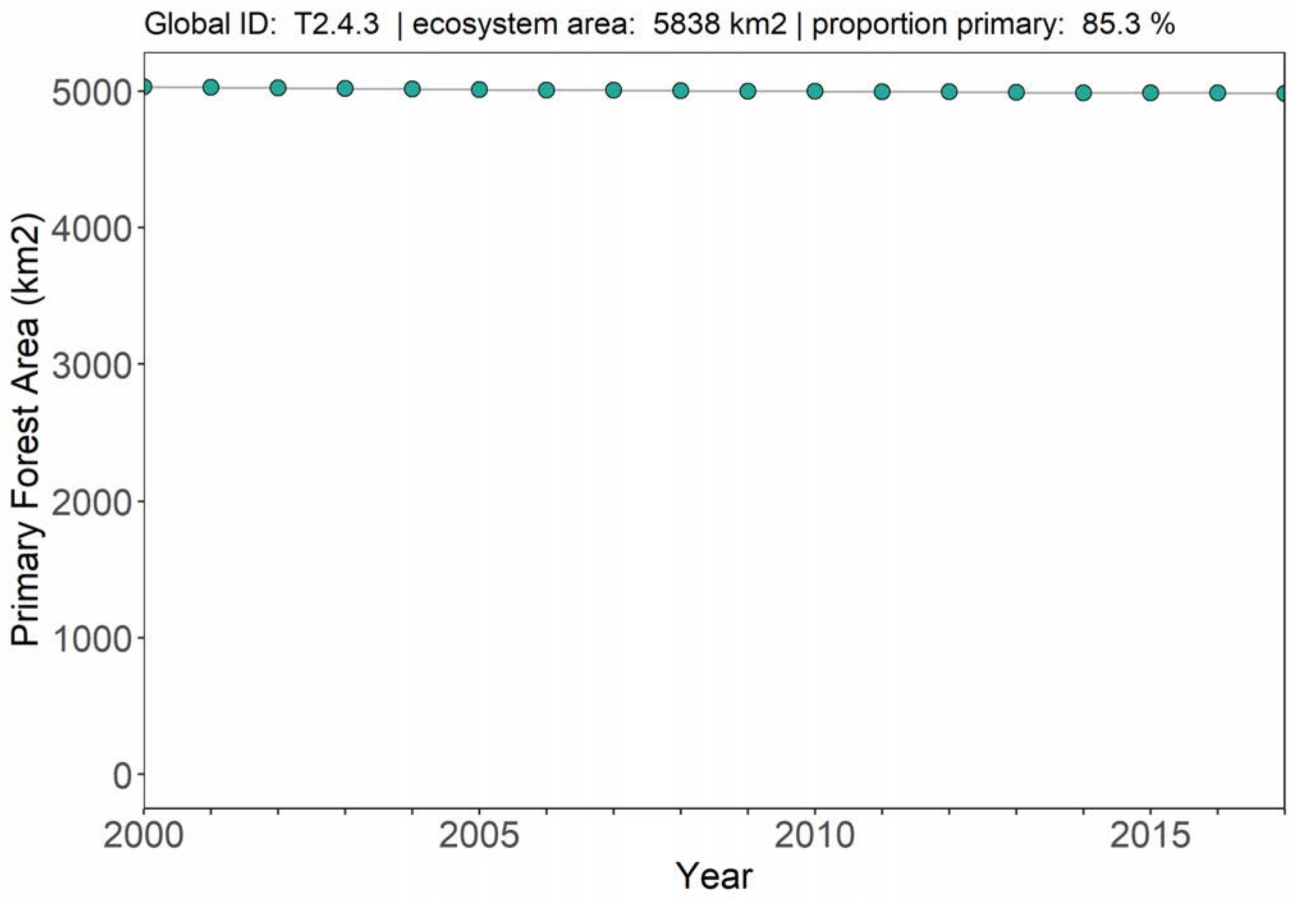
AOO and EOO was measured as 202 10 x 10 km grid cells and 50,913 km^2, respectively. Shifting cultivation and hunting are likely to be ongoing. The ecosystem is considered Near Threatened under Criterion B1. **Near Threatened.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will occur with an extent and severity to meet the category thresholds for Vulnerable under Criterion C2a. Variation in the outcomes of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Least Concern to Vulnerable, and therefore the ecosystem is assessed as Vulnerable (the most commonly returned result from all scenarios), with plausible bounds of Least Concern – Vulnerable. **Least Concern (Least Concern – Vulnerable).**

Criterion D

Remote sensing analyses suggest that 85.3% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 14.7% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is estimated as less than 50% since 1750, not meeting any D3 category thresholds and assessed as Least Concern. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 1.0% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Not Evaluated.**

Kachin warm temperate rainforest

Authors Armstrong, K.E., Grantham, H., Tizard, R., Keith, D.A.

Myanmar ecosystem names Warm Temperate Rain Forest (UNESCO, 2014), Moist Hardwood Forest (Davis, 1960), Warm Temperate Rainforest (Kingdon-Ward, 1944)
Biome Temperate boreal forests and woodlands (T2)
Ecotype Warm temperate rainforest (T2.4)
Global classification MMR-T2.4.4
IUCN Status **Data Deficient ***

Description

Kachin Warm Temperate Rain Forest occurs between c. 1,500 – 2,000 m in montane areas with distinct winter and spring seasons with little snow in winter. What makes this altitudinal zone special is the unique mix of taxa that are typically considered "tropical" with those that are considered "temperate" growing together. Kingdon-Ward (1945) noted that in this zone the temperate rain forest is probably richer in species than any other zone of equal depth in northern Myanmar. Many trees regarded as properly belonging to the "subtropical hill jungle" actually extend far into the temperate zone, and, it is impossible to draw a hard and fast line between the two. A subtler transition is also in effect, where different species in the same genus (e.g. *Rhododendron*, *Symplocos* or *Magnolia*) phase in and out as altitude increases. The upper canopy of this forest attains heights of 30 to 40 m and is heavily burdened with epiphytes. Many of them are shrubs and small trees (*Agapetes*, *Rhododendron*, *Sorbus medogensis*, *Aralia leschenaultii,* orchids and ferns). The burden of epiphytes and occasional gales cause tree limbs to break, opening the shade of the crown cover and giving way to new forest successions, often with bamboo.

This forest type is similar to the Kachin hills subtropical rain forest, however, there is not a distinct boundary between the two zones. According to Kingdon-Ward (1944), the lower and upper limits of *Exbucklandia populnea* mark this ecosystem.

Distribution

From about 1,500 m to over 2,000 m in north-east Myanmar.

Characteristic native biota

Trees in this ecosystem include *Exbucklandia populnea* (Hamamelidaceae), *Castanopsis*, *Quercus lamellosa*, *Cyclobalanopsis* (Fagaceae), *Schima* (Theaceae), *Litsea* (Lauraceae), *Prunus arborea* var. *montana* (Rosaceae), *Toxicodendron acuminatum*, (Anacardiaceae), *Symplocos glomerata*, *Symplocos viridissima* (Symplocaceae), *Saurauia macrotricha* (Actinidiaceae), *Eurya acuminata*, *Adinandra auriformis*, *Ternstroemia biangulipes* (Pentaphylacaceae), *Skimmia arborescens* (Rutaceae), *Wightia speciosissima* (Pawloniaceae), *Garcinia nujiangensis* (Clusiaceae), *Beilschmeidia fasciata, B. xizangensis* (Lauraceae), *Dendropanax* and *Brassaiopsis chengkangensis* (Araliaceae). *Ficus* species (Moraceae) taper off in this zone. In the **small tree and shrub layer**, Rubiaceae gradually become less common with elevation, although

Brachytome wallichii, *Mycetia longifolia* and *Lasianthus* continue to occur. Simultaneously, Araliaceae (e.g. *Dendropanax, Brassaiopsis chengkangensis, Aralia leschenaultii*) and Ericaceae (e.g. *Gaultheria*, *Agapetes, Rhododendron, Vaccinium*) begin to increase in occurrence. *Microtropis latifolia* (Celastraceae), *Hydrangea davidii*, *Hydrangea robusta* (Hydrangeaceae), *Myrsine semiserrata* (Primulaceae), *Camellia pachysandra* (Theaceae), *Debregeasia longifolia* (Urticaceae), and *Dobinea vulgaris* (Anacardiaceae) occur in this zone. **Climbers include** *Maesa, Embelia subcoriacea* (Primulaceae), *Streptolirion volubile* (Commelinaceae), *Notoseris yakoensis* (Asteraceae), *Clematis* (Ranunculaceae), and in the **herb layer** *Asystasia neesiana* (Acanthaceae), *Ophiorrhiza* (Rubiaceae) and *Hydrocotyle hookeri* (Araliaceae) can be found.

This ecosystem supports significant numbers of Rufous-necked Hornbill *Aceros nipalensis* (VU) as well as widespread frugivores such as Great Barbet *Psilopogon virens,* Gold-whiskered Barbet *Psilopogon chrysopogon* and Blue-throated Barbet *Psilopogon asiaticus.* There is also a growing diversity of Bush-warblers (Scotocercidae), Old World Warblers and Parrotbills (Sylviidae), Scimitar-babblers and allies (Timaliidae) and Laughingthrushes and allies (Leiotrichidae) which continue to higher elevations.

Mammals in this ecosystem include significant populations of Shortridge's Langur *Trachypithecus shortridgei* (EN), Stump-tailed Macaque *Macaca arctoides* (VU), Assamese Macaque *Macaca assamensis* (NT), Eastern Hoolock Gibbon *Hoolock leuconedys* (VU), Dhole *Cuon alpinus* (EN), Sun Bear *Helarctos malayanus* (VU), Himalayan Black Bear *Ursus thibetanus* (VU), Mainland Clouded Leopard *Neofelis nebulosa* (VU) and Leaf Muntjac *Muntiacus putaoensis* (DD).

Abiotic environment

Warm temperate rainforests are defined by an overall water surplus with no distinct dry season and rarely experience frosts. Moisture is mostly retained and, although there are distinct winter and growing seasons, the growing season persists for 6 to 8 months of the year.

Key processes and interactions

High rainfall promotes a moisture rich environment that is not fire prone. The closed-canopy forest assists in maintaining moisture into the dry season.

Major threats

This ecosystem is relatively isolated and is considered to be in better condition than the majority of ecosystem types that occur at lower altitudes.

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2 or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

This ecosystem is broadly distributed and relatively free from human impact throughout its range except for a few pockets. Some climate simulations suggested environmental conditions may reduce over the next three decades sufficiently to meet Vulnerable category thresholds, but the majority of model runs suggested that this will not occur on a scale or severity suitable to result in listing within a threatened category. However, a post-assessment expert review suggested this ecosystem could meet threatened category thresholds if further data were available on reductions in geographic distributions and ecosystem degradation. Therefore, the ecosystem is assessed as Data Deficient and we recommend urgent further work to address this knowledge gap to enable a complete assessment of this ecosystem type **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC (LC-VU)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2019

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

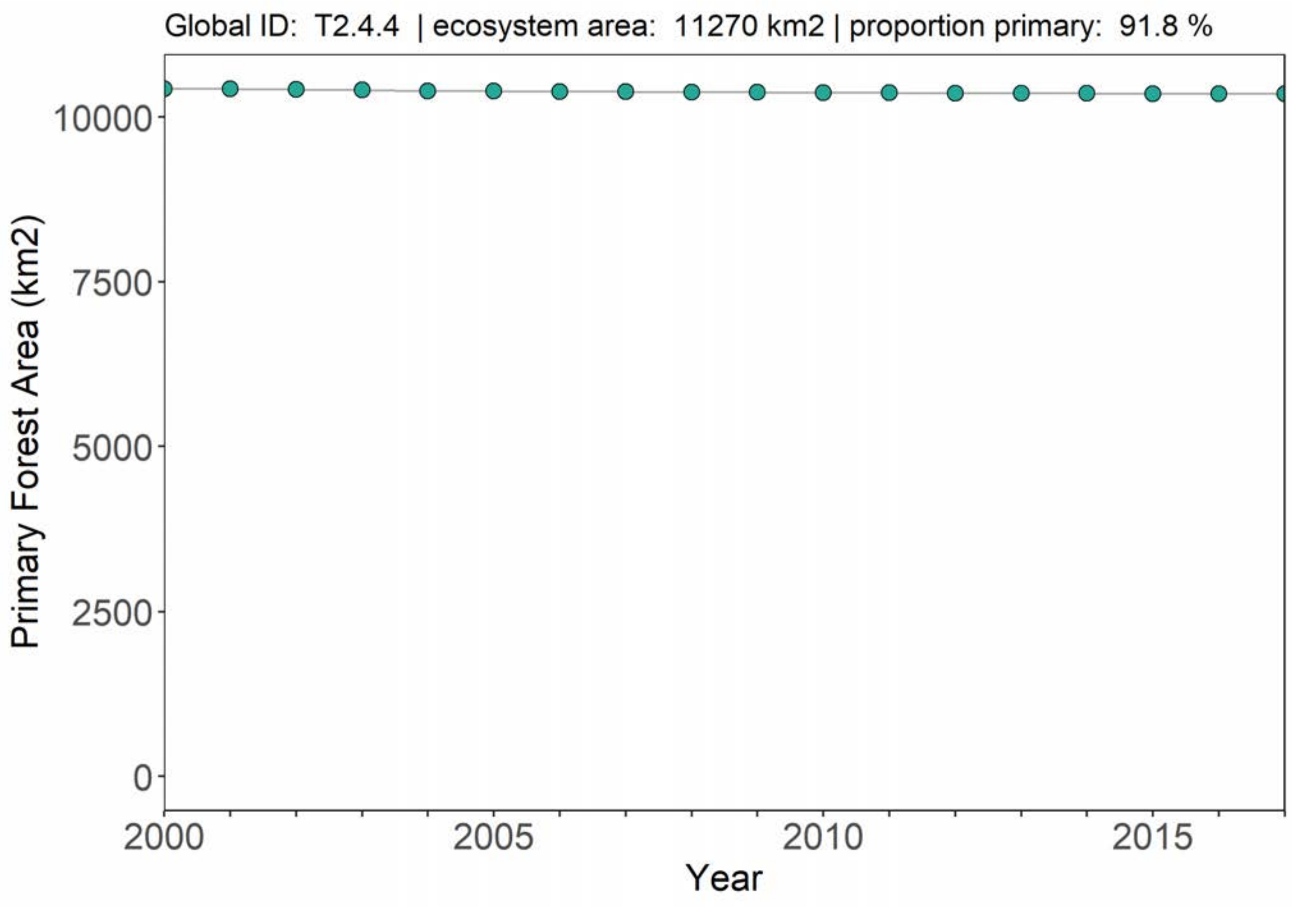
AOO and EOO were measured as 444 10 x 10 km grid cells and 79,334 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will not occur with an extent and severity to meet the category thresholds for threatened under Criterion C2a. However, some scenarios suggested a possible listing as Vulnerable, so the ecosystem is assigned the most commonly returned outcome (Least Concern) with plausible bounds of Near Threatened – Vulnerable. **Least Concern (Least Concern – Vulnerable)**

Criterion D

Remote sensing analyses suggest that 91.8% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 8.2% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is estimated as less than 50% since 1750, not meeting any D3 category thresholds and assessed as Least Concern. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 0.8% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, experts identified a range of threats that, if quantified, could lead to an assessment outcome other than Least Concern. These threats include illegal logging along the border with Yunnan over a period of 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009). Risk from roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting and over-extraction of resources such as medicinal plants and animal parts (Clements et al 2014.). The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem. **Data Deficient.**

Mountain bamboo brake

Authors: Murray, N.J., Grantham, H., Keith, D.A.
Myanmar ecosystem names Mountain bamboo scrub, Bamboo jungle (Platt et al., 2010)
Biome Temperate-boreal forests and woodlands (T2)
Functional Group Warm temperate rainforests (T2.4)
Global classification MMR-T2.4.5
IUCN Status **Data Deficient**

Description

Bamboo brakes are dense, thicket ecosystems dominated by bamboos and with few other trees. Mountain bamboo brake in Myanmar occurs in the north-east, where it occurs together with mountain hardwood forests at mid-high altitudes. Bamboo brake is often considered to occur in response to significant forest disturbances such as shifting cultivation, deforestation or changed fire regimes. However, in Myanmar the first descriptions of these ecosystems arose around 100 years ago (such as Stamp, 1924b), suggesting they may occur naturally in areas where they are able to supress the growth of broadleaf woody vegetation. Despite extensive literature searches, no further descriptions were found and there is therefore considerable uncertainty about the distribution, species diversity and change of this ecosytem.

Distribution

Mountain bamboo brake occurs in the north-east, primarily in association with wet mountain hardwood forest, particularly in very steep areas that cannot develop larger forests (World Heritage nomination). No map data is available for this ecosystem type in Myanmar, however, patches of *Dendrocalamus strictus* forest are mapped in China around 800 – 1,000 m altitude immediately north of Shan state (EVCMC-CAS, 2007)

Characteristic native biota

Very little is known about this ecosystem, and no recorded descriptions were found despite extensive literature reviews. Several species of bamboo are known to occur, including *Arundinaria* spp. and *Dendrocalamus strictus.* Red Panda (*Ailurus fulgens*) are closely associated with mountain bamboo brake, occurring above around 2,500 m.

Abiotic environment

Occurs primarily in wet, high mountain regions which receive considerable rainfall during the monsoon period (probably >6,000 mm).

Key processes and interactions

Mountain bamboo brake is thought to occur where high annual precipitation (>5,000-6,000 mm) complex topography, strong winds and seismic activity give rise to periodic mass movement (landslides) and disturbance of mountain hardwood forest. This opens up patches of forest and initiates successional processes, where mountain bamboo brake can quickly establish and may remain stable for many years.

Major threats

This ecosystem type may be threatened by deforestation. However, its location in remote high mountain regions where deforestation remains rare suggests this ecosystem is not subject to any major threats at this time.

Ecosystem collapse definition

This ecosystem is considered collapsed when its distribution declines to 0 km^2 or when bamboo no longer dominates the canopy.

Assessment summary

Owing to a lack of both occurrence data and descriptive data for this ecosystem, no assessment could be conducted. There remains considerable uncertainty on many components of this ecosytem (distribution, occurrence, drivers of change). Furthermore, the only descriptions we found were from a study conducted nearly 100 years ago (Stamp, 1924a) and we therefore recommend further work to confirm this ecosystem type. **Data Deficient.**

Mountain bamboo brake

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas J. Murray, Hedley Grantham

Reviewed by: David Keith.

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reductions in distribution for this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

No map data suitable for assessing the distribution of this ecosystem was found. **Data Deficient.**

Criterion C

Despite searches of the literature and liaison with ecosystem experts in Myanmar, no information suitable for assessing Criterion C was found. **Data Deficient.**

Criterion D

Despite searches of the literature and liaison with ecosystem experts in Myanmar, no information suitable for assessing Criterion D was found. **Data Deficient.**

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Kachin montane temperate broadleaf forest

Authors Armstrong, K.E., Grantham, H., Tizard, R., Murray, N.J., Keith, D.A.

Myanmar ecosystem names Temperate Forest (UNESCO, 2014), Oak Forest (Stamp, 1924a), Wet High Mountain Hardwood Forest (Davis, 1960), Cool Temperate Forest (Kingdon-Ward, 1944)
Biome Temperate-Boreal Forests and Woodlands (T2)
Functional Group Warm Temperate Rainforest (T2.4)
Global classification MMR-T2.4.6
IUCN Status **Data Deficient ***

Description

This ecosystem appears to be defined by the lowest altitude at which winter frost is prevalent and above which snow lies for an appreciable time (Kingdon-Ward, 1944). Of all the altitudinal zones, montane temperate broadleaf forest has the greatest diversity of epiphytic flowering plants, ferns and mosses, which is a reflection of the high atmospheric humidity. The flora is predominantly East Asian/Sino-Himalayan in affinity with numerous broad-leaved tree species, which shed their leaves in winter. Between c. 2,000-2,500 m the highest trees in the canopy attain 30 m, and from c. 2,500 – 3,000 m there is a gradual transition to a lower stature broadleaved forest overtopped by taller *Abies delavayi*. Ericaceous shrubs become more common, even dominant, along exposed ridges – including *Enkianthus*, *Gaultheria*, *Vaccinium*, *Pieris*, *Lyonia*, *Leucothoe griffithiana* and many more species of *Rhododendron* appear as shrubs, small trees and epiphytes.

Distribution

Montane temperate broadleaf forest can be found from 2,000 m to 3,000 m in northern Kachin State.

Characteristic native biota

Trees in this ecosystem include *Acer wardii* (Sapindaceae), *Cercidiphyllum japonicum* (Cercidiphyllaceae), *Cycloblanopsis*, *Lithocarpus* (Fagaceae), *Illicium* (Illiciaceae), *Magnolia campbellii, M. rostrata*, *M. cathcartii, M. doltsopa* (Magnoliaceae), *macrocarpum* (Styracaceae), *Daphniphyllum* (Daphniphyllaceae), and *Rehderodendron Cinnamomum*, *Litsea* (Lauraceae), *Dendropanax*, *Pentapanax* (Araliaceae)*, Photinia integrifolia* (Rosaceae),

Olea laxiflora (Oleaceae), *Schima khasiana* (Theaceae), *Symplocos* (Symplocaceae), *Toxicodendron acuminatum* (Anacardiaceae), and *Tsuga dumosa* (Pinaceae).
The small tree and shrub layer is comprised of *Viburnum tricostatum*, *V. setigerum* (Adoxaceae), *Leycesteria gracilis*, *Sambucus javanica* (Caprifoliaceae), *Gaultheria semi-infra*, *Enkianthus*, *Vaccinium*, *Lyonia* (Ericaceae), *Brassaiopsis hispida, B. shweliensis, Schefflera wardii, S. macrophylla* (Araliaceae), *Eurya perserrata* (Pentaphylacaceae), *Amblyanthopsis bhotanica* (Primulaceae), *Saurauia polyneura* (Actinidiaceae), *Euonymus* (Celastraceae), *Skimmia* (Rutaceae), *Daphne* (Thymelaeaceae), *Damnacanthus indicus* (Rubiaceae), and a very distinctive holly with flat pagoda branching, *Ilex nothofagifolia* (Aquifoliaceae). Epiphytic shrubs are also common at this altitude, including many taxa, which, in a drier locality, would be terrestrial, these include three species of *Sorbus*, such as the distinctive *S. medogensis* (Rosaceae) and *Neohymenopogon parasiticus* (Rubiaceae). There are fewer woody climbers at this altitude, but the herbaceous vine *Crawfurdia* (Gentianaceae) is common. Herbs include *Sarcopyramis nepalensis* (Melastomataceae), *Lobelia montana* (Campanulaceae), *Arisaema* (Araceae), *Ophiopogon* (Asparagaceae), *Persicaria* (Polygonaceae), and the small epiphyte *Polygonatum tesselatum* (Liliaceae), which grows on mossy tree trunks. The important medicinal plant *Coptis teeta* (Ranunculaceae) also occurs here. Endemics in this ecosystem include *Acer pectinatum* subsp. *taronense* (Sapindaceae), *Berberis hypokerina* (Berberidaceae), *Prunus kindonwardii* (Rosaceae), *Rhododendron butyricum* and *Rhododendron vesiculiferum* (Ericaceae), and *Juniperus coxii* (Cupressaceae).

This ecosystem supports important populations of Eastern Himalayan bird species including Blyth's Tragopan *Tragopan blythii* (VU), Temminck's Tragopan *Tragopan temminckii,* Blood Pheasant *Ithaginis cruentus,* Ward's Trogon *Harpactes wardi* (NT), Leaf-warblers (Phylloscopidae), Old World Warblers and Parrotbills (Sylviidae), Fire-tailed Myzornis *Myzornis pyrrhoura,* White-eyes and Yuhinas (Zosteropidae), Beautiful Nuthatch *Sitta formosa* (VU) and Scarlet Finch *Carpodacus sipahi.*

The eastern side of this ecosystem along the border with Yunnan, China supports the recently described Myanmar Snub-nosed Monkey *Rhinopithecus strykeri* (CR) and the only records of Tufted Deer *Elaphodus cephalophus* (NT). There are also significant populations of more widespread species including Red Panda *Ailurus fulgens* (EN), Gongshan Muntjac *Muntiacus gongshanensis* (DD) and Red Goral *Naemorhedus baileyi* (VU).

Abiotic environment

This ecosystem has a temperate climate with some snow fall during November-March. The mean annual temperature is around 12° C with a broad seasonal temperature range and long, cold winters.

Key processes and interactions

Tree recruitment and growth is limited by climatic conditions, particularly winter frosts and the persistence of snow into warmer seasons, as well as herbivory. The fauna assemblage is likely to be strongly seasonal in response to snowy winter conditions.

Major threats

Climate change is the primary threat likely to influence this ecosystem. It's location in isolated high mountain regions in the north-east suggests that timber cutting and other direct anthropogenic threats are unlikely to have an appreciable impact on this ecosystem in the near-term future.

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2.

Assessment summary

This ecosystem is broadly distributed across the high mountain regions of northern Myanmar. Threats are primarily related to climate change and subsequent changes in seasonal snow dynamics. No data was available to assess distribution changes of this ecosystem over any of the assessment time frames, but its broad distribution, low human impacts and low impacts expected from declining environmental suitability led to an initial assessment outcome of Least Concern.

However, a post-assessment review indicated that further data could yield an assessment outcome other than Least Concern, and we recommend urgent further work to address this knowledge gap to enable a complete assessment of this ecosystem type. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Kate Armstrong, Nicholas Murray

Reviewed by: David Keith

Contributions by: Hedley Grantham

Criterion A

No time-series map data was available for assessing reductions in distribution for this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 320 10 x 10 km grid cells and 60,480 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem exceeding category thresholds for threatened by 2050. **Least Concern.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0.01	0.11	2.43	97.45	97.21
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

This ecosystem type was initially assessed as Least Concern using published data. However, experts identified a range of threats that, if quantified, could lead to an assessment outcome other than Least Concern. These threats include Illegal logging along the border with Yunnan over a period of 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009). Risk from roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting and extraction of resources such as medicinal plants and animal parts (Clements et al 2014.). The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem. **Data Deficient.**

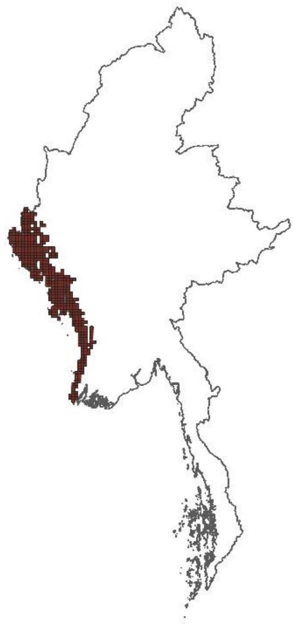
Rakhine coastal savanna

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Coastal dry forest
Biome Savannas and grasslands (T4)
Functional ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.1
IUCN Status **Data Deficient ***

Description

An open-canopy savanna with mostly deciduous phenology that occurs in lowland coastal areas along the eastern foothills of the Rakhine Hills. This area undergoes an annual seasonally dry period, typically extending up to 7 months between November to May each year, followed by monsoonal rains (Platt et al., 2010). Rainfall is typically around 850 to 1,250 mm, potentially up to 1,500 mm, and local elevation, fire frequency and moisture gradients are likely the principal factors that influence the distribution of this ecosystem (Wolfhart et al., 2014) It co-occurs with Rakhine hills semi-evergreen dry forest, which tends to occur at higher elevations (sometimes extending to the coastal plain) and is distinguished by the higher abundance of evergreen species, lack of a grassy ground layer and higher overall species diversity.

Distribution



Distributed throughout the eastern coastal lowlands and hills that fringe the Rakhine hills (Davis, 1960).

Characteristic native biota

Very little information was found on the characteristic biota of this ecosystem type. The largely deciduous tree canopy is 10 – 15 m tall and varies from less than 10% cover when defoliated in the dry season up to 80% in the wet season. Deciduous tree species are dominant. The main species include ironwood, Taku, Pin-ma, Didu bin and *Lannea coromandelica* (Anacardiaceae). Vines such as naughty monkey sprawl through the ground layer and into the tree canopies. The ground layer includes grasses, notably Myauk, Hlode (Kress et al., 2003).

The avifauna supports a range of widespread species including Chestnut-headed Bee-eater *Merops leschenaultia,* Lineated Barbet *Psilopogon lineatus,* Red-breasted Parakeet *Psittacula alexandri* (NT)*,* Alexandrine Parakeet *Psittacula eupatria* (NT) and Purple Sunbird *Cinnyris asiaticus.* Mammals in this ecosystem include Golden Jackal *Canis aureus* and Red Muntjac *Muntiacus muntjac.*

Abiotic environment

This ecosystem occurs on shallow stony soils on rises, ridges and dry slopes where mean annual rainfall is around 850 to 1,250 mm (Kress, 2003). It occurs in areas that experience a seasonally dry period (monthly rainfall 0-100 mm) of around seven months from early November to late May, followed by several months of monsoonal rains (Platt et al., 2010). Mean annual temperature is warm (25.8 °C) with little variability throughout the year. Fire is likely frequent and lit by humans farming adjacent lands.

Key processes and interactions

Seasonal water availability is the key driver of the dynamics of this dry forest ecosystem (Ashton and Seidler, 2014; Banda et al., 2016). A large seasonal water deficit from November to May drives deciduous phenology of trees and vines. The availability of water is mainly driven by the monsoonal climate, but may also include an edaphic component, with wide variation in soil type and topography likely influencing ecosystem dynamics (Ashton and Seidler, 2014). The amount and timing of monsoonal rains determine annual flushes of productivity in vegetation. Regular fires may be a key element that excludes semi-evergreen elements from establishing (Ashton and Seidler, 2014). In sheltered gullies, the water deficit is less severe, vegetation is less fire prone, and the savanna is replaced by semi-evergreen dry forest.

Major threats

The ecosystem has been widely cleared and fragmented across the coastal lowlands for the development of rice paddies and, to a lesser extent, shifting agriculture. It has also been a source of wood for construction and domestic fuel. Ingress of livestock occurs from adjacent farmland, with associated impacts of selective grazing, soil compaction and erosion. Changing fire regimes, particularly near villages or farms where fires may be suppressed, could also threaten this ecosystem by allowing the encroachment of upslope semi-evergreen forests.

Ecosystem collapse definition

Rakhine coastal savanna is collapsed when its mapped distribution has declined to zero, or when tree cover declines below 10% canopy cover, or when the tree canopy becomes dominated evergreen species (more than 50% of total cover).

Assessment

Rakhine coastal savanna remains broadly distributed along the coastal lowlands of Rakhine. Extensive losses of this ecosystem are likely to have occurred as a result of land-clearing for agriculture (primarily rice). Little information was found that could be used to assess changes in distribution, and no data suggested biotic or abiotic degradation sufficient to meet any category thresholds. However, a post-assessment review indicated that further data could yield an assessment outcome other than Least Concern, and we recommend urgent further work to address this knowledge gap to enable a complete assessment of this ecosystem type. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Data Deficient (as a result of post-assessment review of Least Concern ecosystems)

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. Further work to map the historical distribution of this ecosystem is required, which could include remote sensing studies (A1, A2) or an assessment of likely former range (A3). **Data Deficient.**

Criterion B

AOO and EOO were measured as 420 10 x 10km grid cells and 77,921 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

Climate simulation models suggest that environmental conditions are unlikely to reduce suitable areas sufficiently to result in this ecosystem becoming threatened by 2050. **Least Concern.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	3.48	10.9	34.21	51.41	90.09
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Post-assessment review of Least Concern ecosystems

Extreme fragmentation and loss of lowland areas of this ecosystem due to development of rice agriculture has likely occurred. However, an assessment of the amount of loss that has occurred over the past 50 years was not possible in this project. If data were available, experts suggest that the ecosystem would likely qualify for an assessment outcome other than Least Concern. The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem. **Data Deficient.**

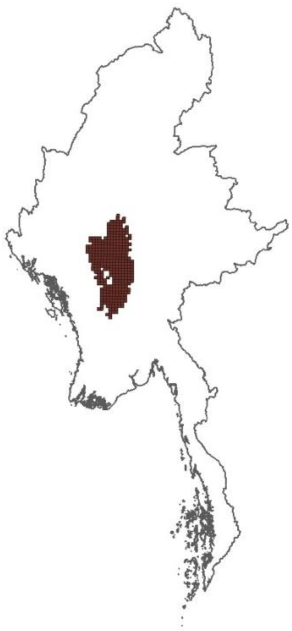
Central Ayeyarwady Than-Dahat grassy forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Than-Dahat, Dry Diosporos forest (Oo and Koike, 2015), Teak Savanna (Ratnam et al., 2016)
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.2
IUCN Status **Vulnerable**

Description

This ecosystem is a grassy open woodland dominated by *Tectona hamiltoniana* (dahat) and *Terminalia oliveri* (than) that occurs throughout the rolling hills of the dry zone, corresponding to community types 1-7 of Oo and Koike (2015). The presence of dry clay soils is thought to be the key driver of its distribution (Davis, 1960). Trees in Than-Dahat grassy forests are rarely greater than 10 metres tall, and have a fairly sparse, open, distribution, as is characteristic of a savanna. A thick ground cover of grasses is present, and bamboo may occur (Oo and Koike, 2015). Mostly deciduous with C4 grassy groundcover (Ratnam et al., 2016). Two other isolated Than-Dahat ecosystems fringe the central dry zone in Myanmar.

Distribution



Restricted to the central dry zone of Myanmar, primarily on low rolling hills where soil type and monsoonal patterns of rainfall patterns are sufficient to support a savanna ecosystem. Note that there remains uncertainty in the distribution of this ecosystem, and our map may overpredict Central Ayeyarwady Than-Dahat grassy forest in hillier terrain.

Characteristic native biota

Than-Dahat dry grassy forests have an open tree canopy dominated by two species, *Terminalia oliveri* (Combretaceae) and *Tectona hamiltoniana* (Lamiaceae). They may also include species found in drier areas, such as *Acacia catechu* (Fabaceae) and patches of bamboo (*Dendrocalamus strictus*, Poaceae). Other tree species include *Dalbergia paniculata*, *Bauhinia racemosa* (Fabaceae), *Diospyros burmanica*

(Ebenaceae), *Grewia tilifolia* (Malvaceae), *Limonia acidissima* (Rutaceae) and *Shorea siamensis* (Davis, 1960; Oo and Koike, 2015).

The vines *Hiptage benghalensis* (Malpighiaceae) and *Cissampelos pareira* (Menispermaceae) grow into the tree canopies and C4 grasses such as *Aristida depressa* (Poaceae) dominate the understorey with scattered shrubs of *Waltheria indica* (Malvaceae). This ecosystem is important habitat for endemic and near-endemic birds including Burmese Collared-dove *Streptopelia xanthocycla,* Jerdon's Minivet *Pericrocotus albifrons* (NT), Hooded Treepie *Crypsirina cucullate* (NT) Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler *Chatarrhaea gularis.* It also supports remnant populations of the Endangered Eld's Deer *Rucervus eldii* (EN); (Thu et al., 2019) and Burmese Star Tortoise *Geochelone platynota* (CR).

Abiotic environment

Mean annual rainfall of between about 800 mm and 1,000 mm (Stamp, 1924b; Khaine et al., 2017). A seasonally dry period occurs from October to late May. Temperatures are hot with little seasonal variation. Generally, occurs on clays (such as Peguan Clay) and dry soils, mostly on low rolling rises and foothills.

Key processes and interactions

The interaction of rainfall, soil type and the presence of fire are important in maintaining this ecosystem. The amount and very strong seasonality of monsoonal rains determine annual flushes of productivity in vegetation punctuated by prolonged water deficit over the dry season (Khaine et al., 2017). Most of the trees are equipped with thick bark enabling survival through recurring surface fires that consume the grassy groundcover when it cures in the dry season. The native vegetation is well adapted to fire, quickly resprouting while other woody species fail to establish.

Major threats

The ecosystem has been extensively fragmented by conversion to agriculture and the remnants are harvested for firewood and other human uses (Davis, 1960). Most fragments are highly degraded due to overgrazing and earthworks (e.g. quarrying or roads).

Ecosystem collapse definition

Central Ayeyarwady Than-Dahat Grassy Forest scrub is regarded as collapsed when its area has declined to zero or when cover of either grass or woody plant decline below 2% per hectare.

Assessment summary

This ecosystem has a restricted range, and ongoing threats suggest that it is undergoing a continuing decline. The ecosystem is assessed as **Vulnerable** under Criterion B1. Further work is recommended to fill key knowledge gaps in biotic and abiotic degradation, as well as refining the distribution map for this ecosystem type.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

5th December 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Jose Ferrer-Paris, Adam Duncan

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. We expect that this ecosystem is extensively depleted, and therefore recommend further work to estimate the historical distribution of Than-Dahat ecosystems in Myanmar. **Data Deficient.**

Criterion B

AOO and EOO were measured as 337 10 x 10 km grid cells and 37,937 km^2, respectively. Ongoing threats, particularly conversion to agriculture, shifting cultivation, livestock grazing and road development projects (Oo and Koike 2015) have been observed in the Central Ayereyarwady region. With an EOO of < 50,000 km^2 and meeting subcriteria for continuing decline in both extent (B due to conversion to agriculture 1a(i)) and biotic disruption due to grazing (B1a(iii)), the ecosystem is assessed as **Vulnerable** under Criterion B1.

Criterion C

Our climate suitability model (Ferrer-Paris et al., 2019, see methods) showed low predictive performance for this ecosystem and was considered too unreliable to assess Criterion C. Further studies of the impact of climate change on this ecosystem are recommended. No other information was found that was suitable for assessing Criterion C. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0.26	1.11	13.02	85.61	42.42
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Data Deficient.**

Central Ayeyarwady palm savanna

Authors Keith, D.A., Tizard, R., Murray, N.J.
Myanmar ecosystem names Palm savanna
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification T4.2.3
IUCN Status **Collapsed**

Description

An open woodland with conspicuous tall palms, *Borassus flabellifer*, ("Taung-on") up to 30 m tall, and distinctively white-trunked trees of *Acacia leucophloea* ("Htanaung") that grow up to 10-12 m tall occur in the driest climates of the central Myanmar plains. A ground layer comprises C4 grasses, sedges and forbs that become lush in response to monsoon rains. It co-occurs with Sha thorn scrub, which occurs on drier sites and is distinguished by the absence of palms and drier, more open ground layer vegetation. No remnant patches of this ecosystem were identified in the assessment, despite extensive field traverses, only relic trees and small plantations were observed.

Distribution

Although this ecosystem has never been mapped, fieldwork by the authors suggest that it was restricted to the central dry zone.

Characteristic native biota

There is very little information on the native plants and animals of this ecosystem. *Borassus flabellifer* (Arecaceae), *Acacia leucophloea* and *Acacia catechu* (Fabaceae) are the dominant trees, but some stands also have broad-leaved trees. The ground layer is highly disturbed by grazing and cultivation. It is dominated by introduced plants but likely to include native hydrophytic grasses, sedges and forbs, including *Paspalum*, *Isachne*, *Oryza* (Poaceae), *Carex*, *Cyperus* (Cyperaceae) and *Persicaria* (Polygonaceae). This ecosystem once supported endemic and near-endemic birds including Burmese Collared-dove *Streptopelia xanthocycla,* Jerdon's Minivet *Pericrocotus albifrons* (NT), Hooded Treepie *Crypsirina cucullate* (NT) Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler *Chatarrhaea gularis.* The

system probably supported an assemblage of large herbivores (e.g. cervids, rhinoceros, elephants) and their predators (tigers and smaller felines).

Abiotic environment

Mean annual rainfall is 700 - 1000 mm, with a regular seasonal drought from October to late May when monsoonal rains arrive. Palm savannas occur on flat terrain in low-lying areas that remain saturated in the monsoon season and may retain shallow surface water after deluges. Temperatures are hot, with little seasonal variation. The soils are depositional and fine-textured loams. They may be deep and have an appreciable organic content.

Key processes and interactions

Rainfall gradients define the distribution of this ecosystem in the rain shadow of Myanmar's central Ayeyarwady valley. The amount and timing of monsoonal rains determine annual flushes of productivity in ground layer vegetation. Grazing by native megafauna may have been important in the dynamics of groundlayer vegetation in historical times. Domestic cattle are now the principle herbivores. Surface movement and slow drainage of water seems critical to the ecology of the ground flora and fauna.

Major threats

This ecosystem has been transformed, almost in its entirety, to dry agriculture for beans and pulses, irrigated rice paddies and grazing pastures. Relictual palms and Acacias remain, but these species are also actively planted on roadsides and paddy boundaries, making the distribution difficult to interpret. The ground vegetation has been largely replaced by exotic crops and pastures, and is very poorly known. Alteration to surface water flows with small levees and application of fertilisers are likely to adversely affect remaining flora and fauna.

Ecosystem collapse definition

Central Ayeyarwady Palm Savanna is regarded as collapsed when its area has declined to 0 km^2.

Assessment Summary

The former range of this ecosystem is evident in agricultural landscapes by conspicuous palms up to 30m high (*Borassus flabellifer*). We found no occurrences of this ecosystem, rather only single trees scattered throughout agricultural landscapes. Overall, the palm savanna appears to have been transformed into anthropogenic ecosystems with scattered native trees and a large introduced biota, especially of exotic plants and domestic livestock. Therefore, it appears that the historical distribution of the ecosystem may have declined by 100% (Criterion A3). **Collapsed.**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**CO**
Criterion B	B1	**CO**
	B2	**CO**
	subcriteria	**-**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Collapsed

Year Published

2019

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Murray, N.J., Keith, D.A.

Reviewed by: Granthan, H.

Contributions by: Nil

Criterion A

We found no occurrences of this ecosystem, rather only single trees scattered throughout agricultural landscapes. Overall, the palm savanna appears to have been transformed into anthropogenic ecosystems with scattered native trees and a large introduced biota, especially of exotic plants and domestic livestock. Therefore, it appears that the historical distribution of the ecosystem may have declined by 100% (Criterion A3). **Collapsed.**

Criterion B

We found no occurrences of this ecosystem, rather only single trees scattered throughout agricultural landscapes. Therefore, Extent of Occurrence and Area of Occupancy appear to be close to zero, and the ecosystem may have collapsed. No information on the distribution of this ecosystem was found during this assessment. **Collapsed.**

Criterion C

Despite exhaustive reviews of the literature and discussion with ecosystem experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite exhaustive reviews of the literature and discussion with ecosystem experts from Myanmar, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

No model of Central Ayeyarwady palm savanna suitable for assessing Criterion E was identified. **Data Deficient.**

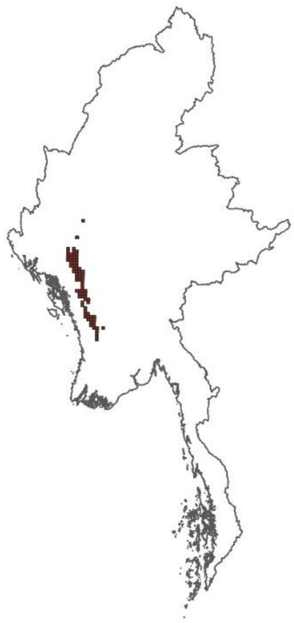
Shwe Settaw Sha-Bamboo thicket

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Bamboo scrub (Platt et al., 2011)
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification T4.2.4
IUCN Status **Near Threatened**

Description

Shwe Settaw Sha-Bamboo thicket occurs as a dense bamboo-dominated ecosystem distributed along the foothills of the Magway hills. It is dominated by thickets of narrow leaf bamboo (probably *Bambusa tulda* and *Dendrocalalmus strictus*) and *Acacia catechu* (Sha) (Platt et al., 2011). Some deciduous and evergreen species may be scattered through the thicket. Although ecosystem processes are largely unknown, fire is likely present and a key driver of the distribution of this ecosystem type.

Distribution



Occurs in narrow bands along the foothills of the Magway hills, and may have once had a broad distribution across the dry zone (Platt et al., 2011).

Characteristic native biota

This ecosystem consists primarily of dense thickets of bamboo (probably *Dendrocalamus strictus*, Poaceae) with Sha (*Acacia catechu,* Fabaceae). There is usually a heavy groundcover of leaf litter and interspersed with scattered grasses and forbs. These thickets are important sheltering habitat for populations of the

This ecosystem is important habitat for endemic and near-endemic birds including Burmese Collared-dove *Streptopelia xanthocycla,* Jerdon's Minivet *Pericrocotus albifrons* (NT), Hooded Treepie *Crypsirina cucullate* (NT) Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler *Chatarrhaea gularis.* It also supports remnant populations of the Endangered Eld's Deer *Rucervus eldii* (EN); (Thu et al., 2019) and Burmese Star Tortoise *Geochelone platynota* (CR).

Abiotic environment

Mean annual rainfall of between up to 1,400 mm delivered during the monsoon, with a strong seasonally dry period from October to late May. Temperatures remain hot throughout the year.

Key processes and interactions

It is possible that these thickets become established after major canopy fires or perhaps major storms that create large gaps in broad-leaf forests, allowing bamboos to establish in high densities. Secondary bamboo thickets may be established by human activities associated with shifting cultivation and burning, but these are dominated by opportunistic colonists and may lack the diversity exhibited by ‘natural’ thickets. Once established, high densities of bamboo and associated litter layers may limit the establishment of broad-leaved trees. Over decadal time scales, these may eventually become established and reach the canopy, however, recurring fires (ground or canopy) may reset this process. Many of the bamboo taxa undergo mast flowering, which may be important in fuelling interannual bursts of productivity Throughout the trophic web.

Major threats

The threats to Shwe Settaw Sha-Bamboo thicket are cutting bamboo, collecting fuelwood and grazing cattle (Platt et al., 2011). Bamboos are also often cut for roofing, house construction, fencing, agricultural implements (Thaung et al., 2006). However, these threats appear to be localised or of low severity. Regular fires in surrounding savanna ecosystems may also occasionally threaten this ecosystem, but the fire responses are not well understood and probably vary between bamboo species.

Ecosystem collapse definition

Shwe Settaw Sha-Bamboo thicket is regarded as collapsed when its area has declined to 0 km^2.

Assessment summary

This ecosystem is restricted along western Myanmar, but threats are expected to be relatively benign and therefore do not meet the subcriteria of Criterion B. However, if the intensity of threats to this ecosystem increases, it would likely become threatened. **Near Threatened.**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**NT**
	B2	**LC**
	subcriteria	**B1(i)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

5th December 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Jose Ferrer-Paris, Adam Duncan

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

This ecosystem is highly restricted to small bands along the foothills of the southern Arakan range. It tends to occur in small patches, with an AOO 81 10 x 10 km grid cells. EOO is 241,476 km^2. Ongoing threats include grazing, changing fire regime and cutting for use in housing, fencing and tools (Platt et al., 2011), but these appear to be localised or of low severity, even though they may be expected to continue into the future. Although these thickets have an EOO of < 50,000 km^2 they may not meet any subcriteria required for criterion B if threats are essentially benign. The ecosystem is therefore assessed as **Near Threatened** under Criterion B1(B1a(ii)).

Criterion C

We could not find any information to allow an assessment of Criterion C for this ecosystem. We recommend further field studies to fill this knowledge gap. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0.23	0.81	9.35	89.61	88.1
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Data Deficient.**

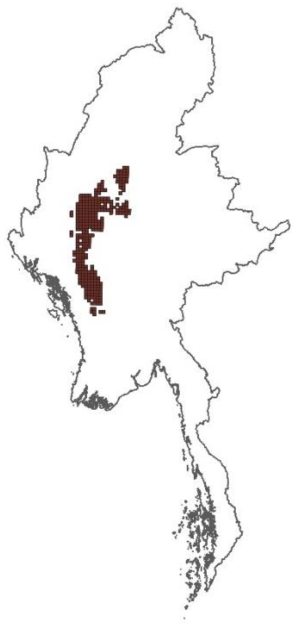
Magway Than-Dahat grassy forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Than-Dahat, Dry Diosporos forest (Oo and Koike, 2015), Teak Savanna (Ratnam et al., 2016)
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.5
IUCN Status **Least Concern**

Description

Magway Than-Dahat grassy forest is an open woodland dominated by *Tectona hamiltoniana* (dahat) and *Terminalia oliveri* (than; Stamp, 1924a; Davis, 1960). This ecosystem occurs along the western margin of the dry zone, primarily on clay soils along the foothills of Magway state. The sparse canopy of Than-Dahat is around 10 metres tall, and a ground cover of grasses is present. Bamboo thickets may occur, particularly in moister areas or fringing the surrounding Shwe Settaw Sha-Bamboo Thicket ecosystem. Mostly deciduous with a largely continuous ground layer of C4 grasses. Two other Than-Dahat ecosystems occur to the east in the central and eastern dry zone.

Distribution



Occurs along the foothills of the Rakhine and Magway hills, where it forms mosaics with drier non-grassy ecosystems such as Magway semi-evergreen dry gully forest and Shwe Settaw Sha-Bamboo thicket. Bounded to the East by Chindwin River.

Characteristic native biota

Main woody species are *Terminalia oliveri* (Dahat) (Combretaceae) and *Tectona hamiltoniana* (Than) (Lamiaceae). Other trees include *Phyllanthus emblica* (ziphyu) (Phyllanthaceae), *Lannea coromandelica* (nabe) (Anacardiaceae), *Bombax insigne* (didu) (Malvaceae), *Grewia tiliifolia* (tayaw) (Malvaceae), *Santalum album* (Santalaceae), *Markhamia stipulata* (Bignoniaceae), *Dalbergia paniculata, Delonix regia*, *Acacia catechu* (sha) (Fabaceae), and *Chukrasia tabularis* (Meliaceae),. Vines such as *Morinda tinctoria* (ny-pa-syr) (Rubiaceae) are occasionally found in the ground layer or may ascend into the tree canopies.

The continuous grassy ground layer includes several abundant C4 grass taxa; *Themeda triandra* (myat-swele), *Polytoca wallichiana* (na-yar-myat), *Cymbopogon virgatus* (myat-nam), *Cyrtococcum patens* (pa-taw-myet) and *Aristida* spp. (Poaceae). This ecosystem may also include bamboo thickets in moister gullies (*Dendrocalamus strictus*) (Poaceae) and some incursion of dry deciduous species from surrounding ecosystems (Oo and Koike, 2015). This ecosystem is important habitat for endemic and near-endemic birds including Burmese Collared-dove *Streptopelia xanthocycla,* Jerdon's Minivet *Pericrocotus albifrons* (NT), Hooded Treepie *Crypsirina cucullate* (NT) Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler *Chatarrhaea gularis.* It also supports remnant populations of the Endangered Eld's Deer *Rucervus eldii* (EN); (Thu et al., 2019) and Burmese Star Tortoise *Geochelone platynota* (CR). Termite mounds are relatively common

Abiotic environment

Mean annual rainfall of between about 800 mm and 1,000 mm (Stamp, 1924b). Occurs in fire-prone hills and slopes, but generally not in sheltered gullies. A seasonally dry period occurs from October to late May when monsoonal rains arrive, and temperatures are hot, with little seasonal variation. Generally, occurs on clays and dry soils, mostly on low rolling rises and foothills. Distribution is largely a result of the occurrence of dry soil types, and precipitation patterns.

Key processes and interactions

Rainfall gradients and soil type defines the distribution of this ecosystem. A strong seasonal water deficit drives the annual growth flush and curing of the C4 grass layer, as well as growth and defoliation of deciduous tree canopies that characterise this system. As a pyric savanna ecosystem, fire plays a key role in structuring the vegetation, maintaining tree/grass coexistence and supressing the establishment of trees from surrounding dry gully forests and bamboo thickets (Ratnam et al., 2011). Large herbivores would have once been quite abundant in the past prior to habitat loss and overexploitation. Termites continue to play significant roles in cycling of organic matter and nutrients.

Major threats

Changed fire regimes, which in some areas are burnt annually, can destroy natural vegetation cover (Thu et al., 2019). Deforestation for cultivation and firewood also occurs, exacerbating legacies of past fragmentation.

Ecosystem collapse definition

Magway Than-Dahat grassy forest is regarded as collapsed when its area has declined to 0 or when cover of either grass or woody plant decline below 2% per hectare.

Assessment

This ecosystem is broadly distributed and, despite a range of ongoing threats, did not meet any category thresholds of the Red List of Ecosystem criteria. Further work to assess the extent and severity of abiotic and biotic disruption are recommended, as well as refining the distribution maps developed in this project. **Least Concern.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

5th December 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Jose Ferrer-Paris, Adam Duncan

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. There has been extensive conversion to grazing pastures, especially in the southern part of the distribution and low relief terrain, but this has not yet been quantified. We recommend further work to estimate historical distributions of Than-Dahat ecosystems in Myanmar. **Data Deficient.**

Criterion B

AOO and EOO were measured as 332 10 x 10 km grid cells and 63,007 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

A climate suitability model for this ecosystem (Ferrer-Paris et al., 2019, see methods) showed low predictive performance and was considered too unreliable to assess Criterion C. Further studies of the impact of climate change on this ecosystem are recommended. No other information was found that was suitable for assessing Criterion C. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0.47	2.63	21.68	75.23	18.13
Status (D3)	LC	LC	LC	-	-

Criterion E

No models were used to assess Criterion E. **Data Deficient.**

Sha thorny scrub

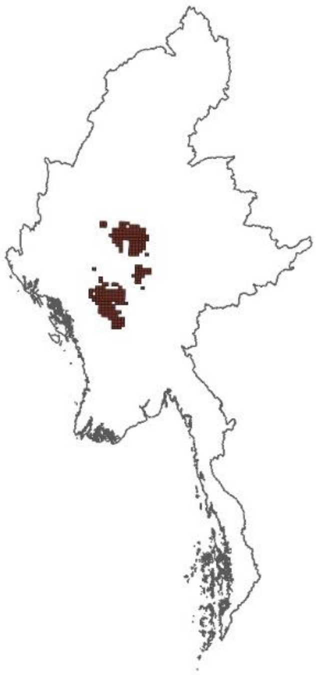
Authors Keith, D.A., Murray, N.J.
Myanmar ecosystem names Sha forests (Oo and Koike, 2015), Deciduous thorn forest (Ashton, 2014)
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.6
IUCN Status **Vulnerable**

Description

A sparse woodland of *Acacia catechu* ("sha"), that varies in form from low bushes (1 to 2 m tall) to small trees (<8 m tall) is distinctive of the driest climates in Myanmar in the centre of the country. A mixed ground layer comprises low thorny shrubs, occasional forbs and wiry C4 grasses, with frequent patches of bare ground. The height and density of trees and ground layer vegetation varies with rainfall, microtopography and soil texture and depth. It co-occurs with Central Ayeyarwady Palm Savanna, which occurs in lower lying areas and is distinguished by the presence of tall palms and more lush ground layer vegetation.

Distribution

Restricted to the central Ayeyarwady dry zone (Davis, 1960).



Characteristic native biota

Acacia catechu (Fabaceae) is the widespread dominant tree. *Zizyphus jujube* (Rhamnaceae), succulent *Euphorbia antiquorum* (Euphorbiaceae), and other thorny shrubs are scattered throughout. Other woody plants include *Tectona hamiltoniana* (Lamiaceae) (bushes often to 1 m high), *Miliusa velutina* (Annonaceae), *Limonia acidissima* (Rutaceae), *Carissa spinarum* (Apocynaceae), *Azima sarmentosa* (Salvadoraceae), *Capparis spinosum, C. zeylanica* (Capparaceae), *Phyllanthus reticulatus* (Phyllanthaceae), *Vitex negundo* (Lamiaceae), *Boerhavia* sp.(Nyctaginaceae), *Combretum latifolium* (Combretaceae) and *Vallaris solanacea* (Apocynaceae) and scattered trees of *Hypselandra variabilis* ("thamon") (Capparaceae). C4 grasses, notably *Dichanthium foveolatum, Tragus racemosus, Digitaria setigera*, *Aristida spp*. *Enteropogon spp.*, and *Themeda triandra*

(Poaceae) dominate the ground layer, but cover depends on grazing pressure and recent rainfall, and large patches of bare soil are common. Herbaceous plants with rosette growth forms (e.g., *Tridax procumbens*, Asteraceae) are scattered through the ground layer.

This 'dry savanna' system probably supported an assemblage of large herbivores (e.g. cervids, rhinoceros, elephants) and their predators (tigers and smaller felines), which are now replaced by domestic cattle. Introduced plants species such as *Bursera* spp. (Burseraceae) *Jatropha gossypifolia* and *Euphorbia neriifolia* (Euphorbiaceae) occur in some of the remnants.

This ecosystem is important habitat for endemic and near-endemic birds including Burmese Collared-dove *Streptopelia xanthocycla,* Jerdon's Minivet *Pericrocotus albifrons* (NT), Hooded Treepie *Crypsirina cucullate* (NT) Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler *Chatarrhaea gularis.* It also supports remnant populations of the Endangered Eld's Deer *Rucervus eldii* (EN); (Thu et al., 2019) and Burmese Star Tortoise *Geochelone platynota* (CR).

Abiotic environment

Mean annual rainfall may be as low as 700 mm, and no more than 1,000 mm. A regular rainless period extends from October, reaching a peak in late May when monsoonal rains arrive. Temperatures are hot, with little seasonal variation. Sha thorny scrub is closely associated with the dry typically gypseous "Peguan" loams but also extends onto the Ayeyarwady sands. It occurs on flat terrain on low rises and other sites that drain relatively freely in the wet season.

Key processes and interactions

Rainfall gradients define the distribution of this ecosystem in the rain shadow of Myanmar's central Ayeyarwady valley. The amount and timing of monsoonal rains determine annual flushes of productivity in vegetation and the appearance and abundance of some of the component ground layer plants. Plants and animals have varied life history, morphological and ecophysiological traits for persistence through seasonal drought, including deep roots architecture, C4 photosynthetic pathways, succulent tissues and thermoregulatory behaviour.

Grazing and fire regimes shape the composition and structure of the vegetation. Prior to human occupation a diverse assemblage of megafauna is likely to have driven top-down ecosystem regulation. These animals were extirpated as human land use intensified in the region, and domestic cattle now graze in a more intense and sedentary grazing regime unregulated by predators.

Major threats

The ecosystem has been highly fragmented by intensive agricultural land uses (cattle grazing and some cropping; Ashton 2014). Only very small patches remain and these are in varying states of degradation due to overgrazing, legacies of past ploughing or earthworks (e.g. quarrying or roads) and invasions of exotic species. Recurring fires potentially threaten the persistence of succulent elements such as *Euphorbia* spp.

Ecosystem collapse definition

A historical ecosystem resembling the contemporary one, but including a full suite of biota and trophic functions, has collapsed due to loss of large native mammalian herbivores and their predators. The time of collapse is uncertain, but likely to have been after the widespread development of cultivation agriculture by indigenous peoples, and probably after British colonisation in 1824. Sha thorny scrub assessed here is a derived ecosystem that replaced the historic one. It shares many, species with the antecedent ecosystem but has a reduced trophic structure and lacks the large mammalian herbivores, their predators and some associated species, while grazing patterns and biomass accumulation have also been transformed.

Sha thorny scrub, derived from the collapse of the antecedent ecosystem, is now highly fragmented within a largely anthropogenic landscape and, itself, may be threatened with collapse. However, it retains much of the unique biota of the antecedent ecosystem whose closest relatives occur in Acacia savannas on the Indian Peninsula, another region that has been highly transformed by human activity (Mani 1974a, Mani 1974b).

Sha thorny scrub is regarded as collapsed when its distribution has declined to zero or when key structural elements of vegetation (native woody plants or C4 grasses) have declined below 5 % cover within a patch.

Assessment summary

Sha thorny scrub is distributed across the rolling hills of Myanmar's central dry zone. However, the ecosystem is restricted and range size estimates indicate that it meets the category threshold for Vulnerable under Criterion B1 and ongoing threats, including grazing and fragmentation, meet two of the subcriteria. Little other information was found on this ecosystem, so further research to estimate ecosystem degradation is recommended. **Vulnerable.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i), B1b(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Vulnerable

Year Published

2020

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. We expect that this ecosystem one occupied a very broad area of the dry non-floodplain areas of central Myanmar (most likely areas <1,000 mm mean annual rainfall). Further analyses of this potential distribution are recommended to allow assessments of Criterion A3. **Data Deficient.**

Criterion B

AOO and EOO were measured as 206 10 x 10 km grid cells (100 with one-percent rule invoked) and 44,613 km^2, respectively. Ongoing threats, particularly conversion to agriculture and degradation by sedentary livestock grazing are likely to cause continuing declines throughout its range. With an EOO of < 50,000 km^2 and meeting subcriteria for continuing decline in both extent (B1a(i)), the ecosystem is assessed as **Vulnerable** under Criterion B1.

Criterion C

We were unable to run a climate suitability model for this ecosystem, and no other information on environmental degradation was found during the assessment process. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. Field work suggested this ecosystem is extensively degraded, and we therefore recommend further work to better elucidate the extent and severity of degradation of this ecosystem. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0	8.7	39.13	52.17	0.05
Status (D3)	LC	LC	LC	-	-

Criterion E

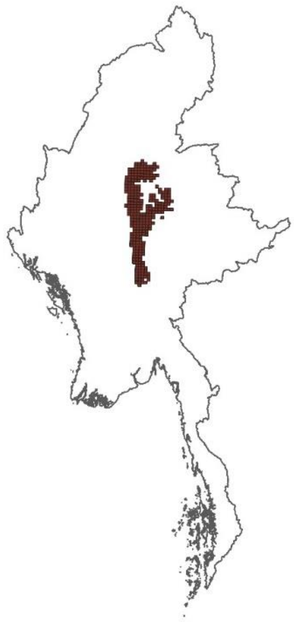
No models were used to assess Criterion E. **Data Deficient.**

Shan foothills Than-Dahat grassy forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Than-Dahat, Dry Diosporos forest (Oo and Koike, 2015)
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.7
IUCN Status **Vulnerable**

Description

Shan foothills Than-Dahat grassy forest is an open woodland dominated by *Tectona hamiltoniana* (Dahat) and *Terminalia oliveri* (Than). This ecosystem occurs around the eastern margin of the central dry zone, particularly on clay soils that form in the foothills of the Shan Hills (Davis, 1960). Trees in Than-Dahat grassy forests are rarely greater than 10 metres tall, and have an open semi-continuous canopy that defoliates in the dry season. An open shrub layer and semi-continuous ground cover of C4 grasses is present, and bamboo may occur (Oo and Koike, 2015). Two other Than-Dahat ecosystems are recognised to occur around the fringes of the central dry zone in Myanmar. All Than-Dahat ecosystems in Myanmar have been subject to extensive fragmentation as a result of human population growth and conversion of dry zone ecosystems to agriculture.



Distribution

Restricted to the eastern foothills of the dry zone and dry hilly areas in eastern Shan.

Characteristic native biota

Although dominated by deciduous *Terminalia oliveri* (Combretaceae) and *Tectona hamiltoniana* (Lamiaceae), Than-Dahat forest may also include evergreen *Acacia catechu* (Fabaceae) and bamboo (*Dendrocalamus strictus,* Poaceae), particularly in the drier areas. Undergrowth is mostly andropogonoid grass (Poaceae).

This ecosystem is important habitat for endemic and near-endemic birds including Burmese Collared-dove *Streptopelia xanthocycla,* Jerdon's Minivet *Pericrocotus albifrons* (NT), Hooded Treepie *Crypsirina cucullate* (NT) Burmese Bushlark *Mirafra microptera,* Burmese Prinia *Prinia* *cooki,* Ayeyarwady Bulbul *Pycnonotus blanfordi* and White-throated Babbler *Chatarrhaea gularis.* It also supports remnant populations of the Endangered Eld's Deer *Rucervus eldii* (EN); (Thu et al., 2019) and Burmese Star Tortoise *Geochelone platynota* (CR).

Abiotic environment

Mean annual rainfall of between about 800 mm and 1,000 mm (Stamp, 1924).

A seasonally dry period occurs from October to late May when monsoonal rains arrive. Temperatures are hot, with little seasonal variation. Generally, occurs on clays (such as Peguan Clay) and seasonally dry soils, mostly on low rolling rises and foothills. Distribution is largely a result of the occurrence of this dry soil type (Stamp, 1924a).

Key processes and interactions

As a xerophilous forest, rainfall gradients and soil type define the distribution of this ecosystem. Recurring dry season fires are critical in maintaining coexistence of grasses and woody plants. It was probably once heavily grazed by native herbivores before they were extirpated, and now may include grazing ruminants and cattle. Termites also play a role in cycling of organic material and nutrients.

Major threats

Widespread cutting for fuel and uses in machinery remains one of the major threats to this ecosystem. Earthworks and clearing for infrastructure such as roads occur throughout its range. Changed fire regimes are also likely to influence the persistence of characteristic native species. In some areas, the construction of dams has resulted in drowning of this ecosystem type.

Ecosystem collapse definition

Shan foothills Than-Dahat grassy forest scrub is considered collapsed when its area has declined to zero or when cover of either grass or woody plant decline below 2% per hectare.

Assessment summary

This ecosystem is restricted to the foothills along the Shan escarpment. Ongoing threats, particularly fuelwood cutting and infrastructure development within its range, suggest this ecosystem is undergoing a continuing decline, and therefore qualifies for listing under criterion B1. **Vulnerable.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i), B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Vulnerable

Year Published

2019

Date Assessed

5th December 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Jose Ferrer-Paris, Adam Duncan

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 287 10 x 10 km grid cells and 44,730 km^2, respectively. Ongoing threats, particularly conversion to agriculture, shifting cultivation, livestock grazing and road development projects (Oo and Koike, 2015) have been observed within its range. With an EOO of < 50,000 km^2 and meeting subcriteria for continuing decline in both extents due to infrastructure development and small-scale expansion of agriculture (B1a(i)) and biotic disruption due to livestock grazing (B1a(iii)), the ecosystem is assessed as **Vulnerable** under Criterion B1.

Criterion C

A climate suitability model implemented for this system (Ferrer-Paris et al., 2019, see methods) showed low predictive performance for this ecosystem and was considered too unreliable to assess Criterion C. Further studies of the impact of climate change on this ecosystem are recommended. No other information was found that was suitable for assessing Criterion C. **Data Deficient.**

Criterion D

Our analysis of the Forest Landscape Integrity Index (see methods) suggested that for this ecosystem, no combination of extent and relative severity met the category thresholds for threatened (see table below). Even with a sensitivity analysis on health index thresholds for relative severity (+0.25 and -0.25) the ecosystem did not meet the category thresholds to qualify as threatened under criterion D3. **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	0.29	1.55	10.01	88.16	76.44
Status (D3)	LC	LC	LC	-	-

Criterion E

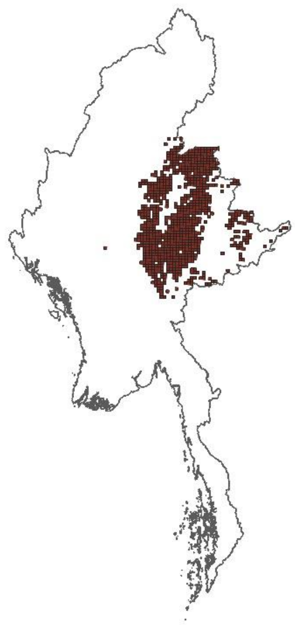
No models were used to assess Criterion E. **Data Deficient.**

Shan hills pine savanna

Authors Murray, N.J., Grantham, H., Keith, D.A.
Myanmar ecosystem names Mountain pine forest, sub-tropical pine forest (Kingdon-Ward, 1944).
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.8
IUCN Status **Endangered**

Description

Pine savanna is an open to closed evergreen needleleaf savanna ecosystem that occurs in four to five regions across Myanmar, with each currently being a separate ecosystem given geographical barriers between them. Further investigation is needed to identify the major features that distinguish these regional variants. Shan hills pine savanna can be found in the rolling hills of Shan State and extends into western Thailand and southern China (ECVMC-CAS, 2007). The ecosystem tends to occur on hill tops, where it is more exposed to drying than surrounding evergreen or semi-evergreen forests. Pines have a grassy understory, and require fire for natural regeneration, and can be invaded from other forest types when fire is suppressed (Ratnam et al., 2016). In many areas Shan hills pine savanna may be a secondary forest with canopy <15 m (Several similar pine savannas occur throughout Myanmar, including in the Chin Hills, Sagaing Region and Kachin State.



Distribution

Shan hills pine savanna occurs throughout Shan State, where it is patchily distributed across the hilly plateau at elevations over about 1,200 m (Collet, 1890), such as around Kalaw, and up to about 2,000 m near Taungyii. We were unable to visit the east and northeastern parts of Shan State during fieldwork, so we are unable to confirm this ecosystem in these inaccessible regions. The China vegetation map (ECVMC-CAS, 2007) suggests this ecosystem may not be as extensive in the north of Shan as depicted by our models.

Characteristic native biota

Shan hills pine savanna has a open tree canopy dominated by near-monotypic stands of Pinus species, which hare probably *Pinus merkusii* or *Pinus kesiya* (Pinaceae).

Field work could not be conducted in this region to identify the primary species of *Pinus.* Canopy height may approach around 30 m, although there is considerable variation with local climate and soil conditions. (Ashton, 2014). Hardwoods are near absent, although may occur where the savanna ecosystem meets surrounding evergreen forests, which is normally associated with wetter gullies, or hardwood forest at greater elevations. The ground layer is characterised by a semi-continuous cover of tussock grasses.

Abiotic environment

Pine savanna is found at moderate altitudes across the Shan Plateau (1,200-2,000 m above sea level). In these areas temperatures are typically more exposed and drier than surrounding areas, and likely receive rainfall typically greater than 1,000 mm per annum. They occur on low-nutrient and well-draining soils such as sand or loam (Davis, 1960).

Key processes and interactions

Pine savanna ecosystems are thought to be maintained by fire (Ratnam et al., 2016; Van Zonneveld et al., 2009). The ground layer is dominated by fire-adapted tussock grasses and characteristic pine trees that are well adapted to surviving both low and high intensity fires because their thick bark insulates vital meristematic and vascular tissues and the canopies of mature trees are generally above scorch height (Ratnam et al., 2016). Where fires are rare or supressed, pine savanna ecosystems may be invaded by hardwood forest species from surrounding ecosystems.

Major threats

Threats to this ecosystem include deforestation for slash and burn agriculture (Tun, 2016), felling for firewood, and fire suppression (Farjon, 2019, Ratnam et al., 2016, Van Zonneveld et al., 2009). Climate envelope models suggest that climate change is not expected to affect *P kesiya* significantly, primarily because the species has been shown to occur in a very wide range of climatic conditions (Van Zonneveld et al., 2009)

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2, when the proportion of the ecosystem considered primary forest declines to 0, or when broad-leaf species dominate and pines account for less than 10% of the tree canopy cover.

Assessment summary

Shan hills pine savanna is broadly distributed across Shan, and also occurs in neighbouring countries. A climate simulation model suggests that suitable environmental conditions for this ecosystem may reduce in area over the next 30 years, although further work is suggested to confirm this assessment outcome. Primary forest data suggests widespread degradation of this ecosystem has occurred since 1750, with only 16% of this ecosystem estimated to remain in a primary state. **Endangered**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**VU (LC-EN)**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**VU (LC-VU)**
	D3	**EN**
Criterion E	E	**DD**

Assessment Outcome

Endangered

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray, Hedley Grantham

Reviewed by: David Keith

Contributions by: Kyle Tomlinson, Jose-Rafael Ferrer-Paris

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

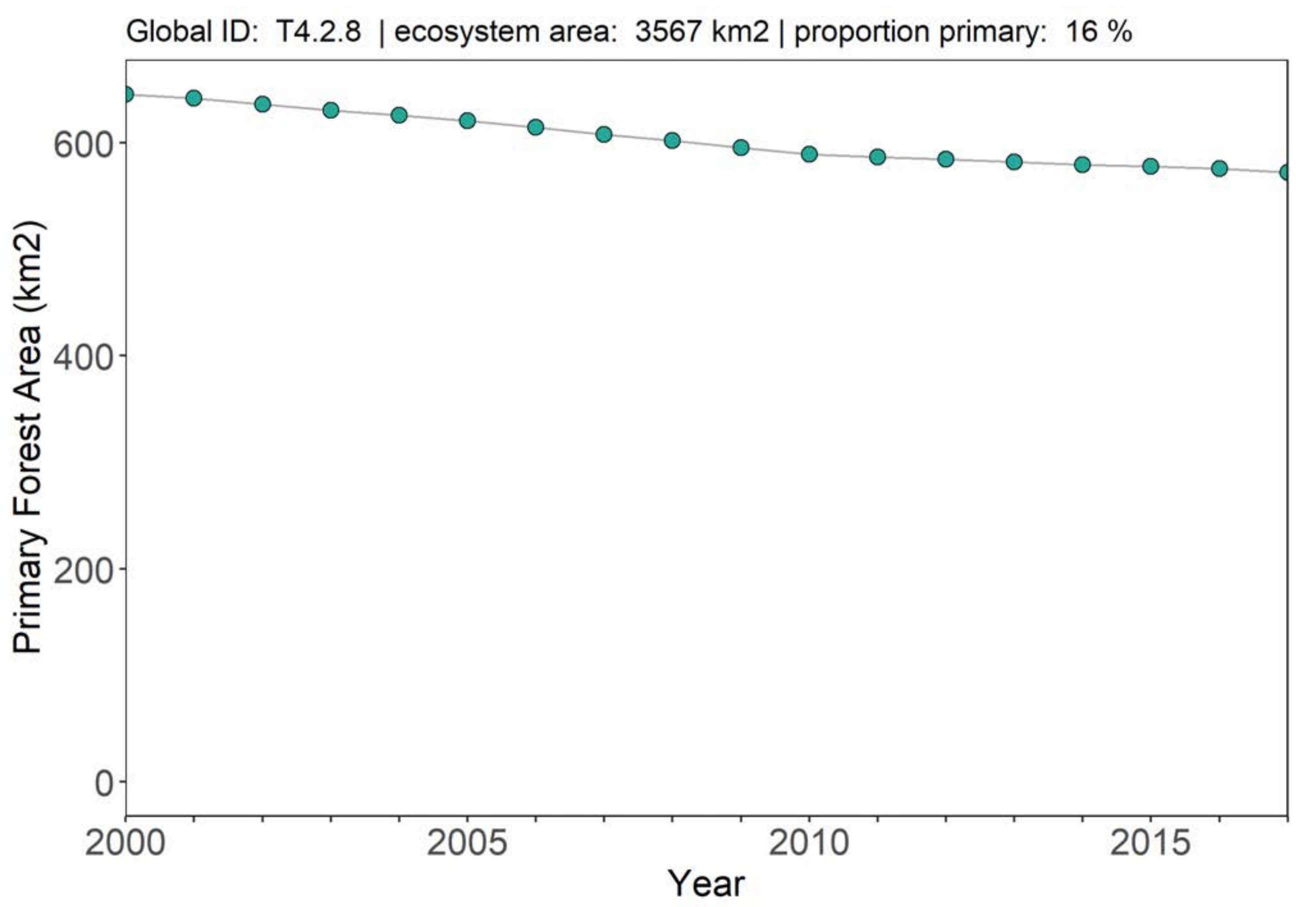
AOO and EOO were measured as 840 10 x 10 km grid cells and 200,821 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will not occur with an extent and severity to meet the category thresholds for Criterion C2a. Nevertheless, several of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Endangered, and therefore the ecosystem is assessed as Vulnerable (the most commonly returned result), with plausible bounds of Least Concern – Endangered. We do note that the outcome may be impaired by low predictive performance of the model, further studies are recommended to confirm this result. **Vulnerable (Least Concern – Endangered).**

Criterion D

Remote sensing analyses suggest that only 16% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 84% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is estimated as greater than 70% but less than 90% since 1750, meeting D3 category thresholds for Endangered. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 11.2% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will occur to an extent that exceeds D2b category thresholds for Vulnerable over a 50 year period (1984-2034). Confidence intervals suggest a bounded estimate of Least Concern to Vulnerable. The ecosystem is assessed as Vulnerable (Least Concern-Vulnerable) under Criterion D2b. **Endangered.**



Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

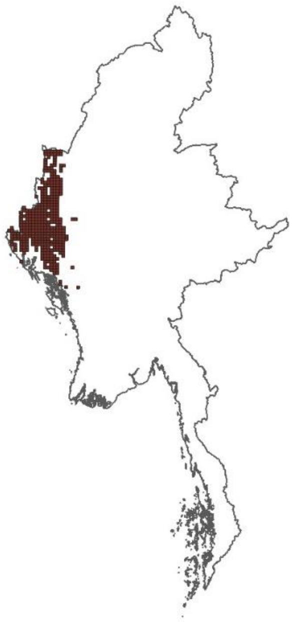
Chin Hills pine savanna

Authors Murray, N.J., Grantham, H., Keith, D.A.
Myanmar ecosystem names Mountain pine forest, sub-tropical pine forest (Kingdon-Ward, 1944).
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.9
IUCN Status **Least Concern**

Description

Pine savannas are grassy ecosystems with open to closed evergreen needleleaf tree canopies. They occur in four to five regions across Myanmar, with each currently recogised as a separate ecosystem type, subject to further research on geographical barriers to dispersal of biota. Chin Hills pine savanna occurs patchily at higher altitudes along the western border of Myanmar. The ecosystem is dominated by *Pinus kesiya* (Khasia Pine), with a canopy height up to around 30 metres, and a grass-dominated understorey (Davis, 1960). It is thought to occur in seasonally dry habitats on well-drained soil between about 800 m and 1,500 m (Davis, 1960, Farjon, 2013).

Distribution



Chin Hills pine savanna occurs along the Chin Hills in western Myanmar, where it is patchily distributed along the range between around 800 to 1,500 m (Davis, 1960) and perhaps up to 2,000 m (Farjon, 2013).

Characteristic native biota

This ecosystem is dominated by near-monotypic stands of Khasia Pine, *Pinus kesiya* (Pinaceae), local name Tinyu. The ecosystem is generally less biodiverse than surrounding hardwood forests. Hardwoods are mostly absent, although mixed stands with *Quercus* (Fagaceae), *Shorea and Dipterocarpus* (Dipterocarpaceae) can occur, particularly in the absence of fire (Davis, 1960). The understorey is dominated by a mixture of C4 and C3 grass species with small forbs. Shrubs are sparse. Several near-endemic and endemic taxa of birds range between *Rhododendron* (Ericaceae), *Quercus* (Fagaceae) and *Pinus* (Pinaceae).

Mrs Hume's Pheasant *Syrmaticus humiae* (NT), Black-bibbed Tit *Poecile hypermelaenus*, Yellow-billed Blue Magpie *Urocissa flavirostris* and Yellow-breasted Greenfinch *Chloris spinoides* are often seen in this habitat but only the local subspecies of Bar-tailed Treecreeper *Certhia himalayan ripponi* is actually restricted to mature pines (Harrap 2019).

Abiotic environment

The Chin Hills pine savanna is found at altitudes of 800 – 1,500 m, possibly up to 2,000 m, where temperatures are cooler than on adjacent lowlands where other savanna ecosystems occur. They occur on low-nutrient and well-draining soils with sandy or loamy texture (Davis, 1960). Rainfall is typically greater than 1,000 mm per annum and highly seasonal due to the monsoons.

Key processes and interactions

Pine savanna ecosystems are thought to be maintained by fire (Ratnam et al., 2016; Van Zonneveld et al., 2009). The ground layer is dominated by fire-adapted grasses, which propagate fire when they cure in the dry season. The characteristic pines survive low and relatively high intensity fires due to their thick bark, which insulates sensitive cambial and vascular tissues form fire temperatures (Ratnam et al., 2016). Most broad-leaf tree species lack such traits, and have lower survival rates post-fire. Where fires are rare or supressed, Asian pine savanna ecosystems tend to be invaded by hardwood forest species from surrounding ecosystems.

Major threats

Threats to this ecosystem include deforestation for agriculture, felling for firewood, and fire suppression (Farjon, 2013, Ratnam et al., 2016, Van Zonneveld et al., 2009). Climate envelope models suggest that climate change is not expected to affect *P. kesiya* significantly, primarily because the species has been shown to occur in a very wide range of climatic conditions (Van Zonneveld et al., 2009)

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2 or when the proportion of the ecosystem considered primary forest declines to 0.

Assessment summary

Remote sensing models suggest this ecosystem is relatively broadly distributed across the Chin Hills. No historical information on the distribution of this ecosystem was found, and an assessment of primary forest within the extant distribution suggests degradation has not occurred to an extent sufficient to meet category thresholds for Criterion D. Climate change is not expected to significantly affect the primary species of *Pinus,* but we do recommend further work to assess climate change impacts for this ecosystem. **Least Concern.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

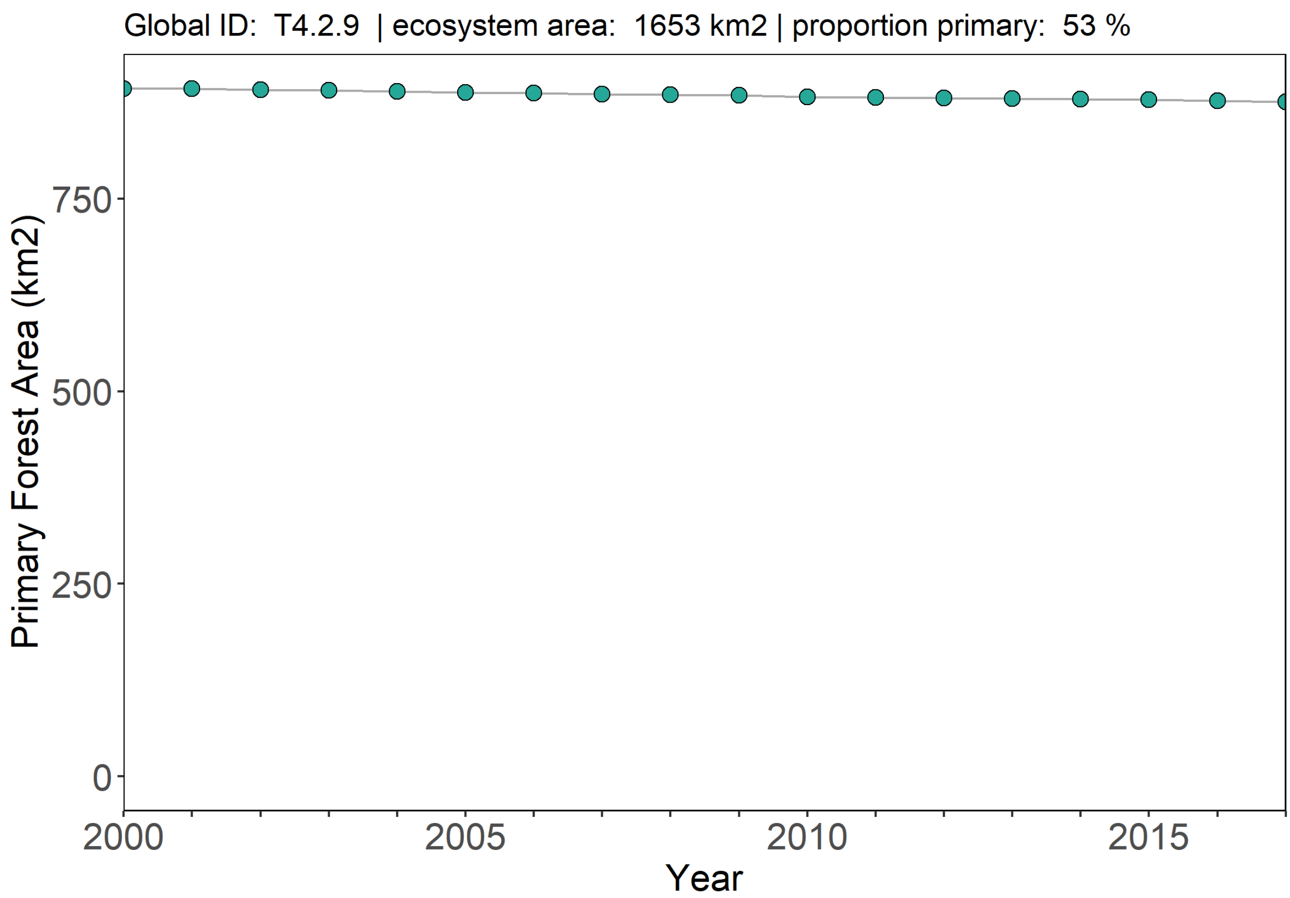
AOO and EOO were measured as 371 10 x 10 km grid cells and 71,265 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

A climate suitability model implemented for this system (Ferrer-Paris et al., 2019, see methods) showed low predictive performance and was considered too unreliable to assess Criterion C. Further studies of the impact of climate change on this ecosystem are recommended. No other information was found that was suitable for assessing Criterion C, despite discussions with experts familiar with Pine Savanna ecosystems. **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 53% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 47% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is estimated as less than 50% since 1750, not meeting any D3 category thresholds and assessed as Least Concern. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 1.9% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Sagaing hills pine savanna

Authors Murray, N.J., Grantham, H., Keith, D.A.
Myanmar ecosystem names Mountain pine forest, sub-tropical pine forest (Kingdon-Ward, 1944).
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.10
IUCN Status **Least Concern**

Description

Pine savanna is an open to closed evergreen needleleaf savanna ecosystem that occurs in four to five regions across Myanmar, with each currently being a separate ecosystem given their geographical barriers. Further investigation is needed to quantify the distinctive features of pine savannas in each region (K. Tomlinson, pers.comm.). Sagaing hills pine savanna is an open evergreen needleleaf savanna ecosystem that occurs across the Sagaing hills. It has a non-continous canopy primarily of *Pinus kesiya* (Khasia Pine) and a grassy understory. Fire is a key process that maintains the ecosystem, serving to suppress the incursion of surrounding hardwood forest ecosystems. Examples of this ecosystem can be found in Alaungdaw Kathapa National Park. Several similar pine savannas occur throughout Myanmar, including in the Chin Hills, Shan Region and Kachin State.

Distribution

Sagaing hills pine savanna occurs along the north-west border with India, where it is patchily distributed at elevations above around 800 m.

Characteristic native biota

This ecosystem is dominated by near-monotypic stands of Khasia Pine, *Pinus kesiya* (Pinaceae). Hardwoods are near absent, although may occur where the savanna ecosystem meets surrounding hardwood ecosystems.

Abiotic environment

Pine savanna is found at altitude in the Sagaing Hills, where temperatures are typically cooler than surrounding lowland areas, and rainfall is greater than about 1,200 mm per annum. Asian pine savannas typically occur on low-nutrient and well-draining soils such as sand or loam (Davis, 1960).

Key processes and interactions

Pine savanna ecosystems are thought to be maintained by periodic fire (Ratnam et al., 2016; Van Zonneveld et al., 2009). The ground layer is dominated by fire-adapted grasses and characteristic pine species are well adapted to surviving both low and high intensity fires (Ratnam et al., 2016). Thick bark protects the living stem tissues of pines enabling them to survive fires, so long as most of the canopy is not scorched.

Where fires are rare or supressed, pine savanna ecosystems tend to be invaded by hardwood forest species and undergo transition to a tropical dry forest ecosystem. The pine savannas are likely to provide open habitat for birds, ground mammals and invertebrates that are not common in rainforests.

Major threats

Threats to this ecosystem include deforestation for agriculture, felling for firewood and hardwood, and fire suppression (Farjon, 2013, Ratnam et al., 2016, Van Zonneveld et al., 2009). Climate envelope models suggest that climate change is not expected to affect *P. kesiya* significantly, primarily because the species has been shown to occur in a very wide range of climatic conditions (Van Zonneveld et al., 2009).

Ecosystem collapse definition

This system is considered collapsed when its distribution declines to 0 km^2, when the proportion of the ecosystem considered primary forest declines to 0, or when broad-leaf species dominate and pines account for less than 10% of the tree canopy cover.

Assessment summary

This ecosystem is relatively broadly distributed in northern Myanmar. Literature searches indicated that it is a poorly known ecosystem, but it appears sufficiently broadly distributed and ongoing threats are expected to be relatively benign. The ecosystem is assessed as **Least Concern**.

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

AOO and EOO were measured as 58 10 x 10km grid cells and 61,907 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

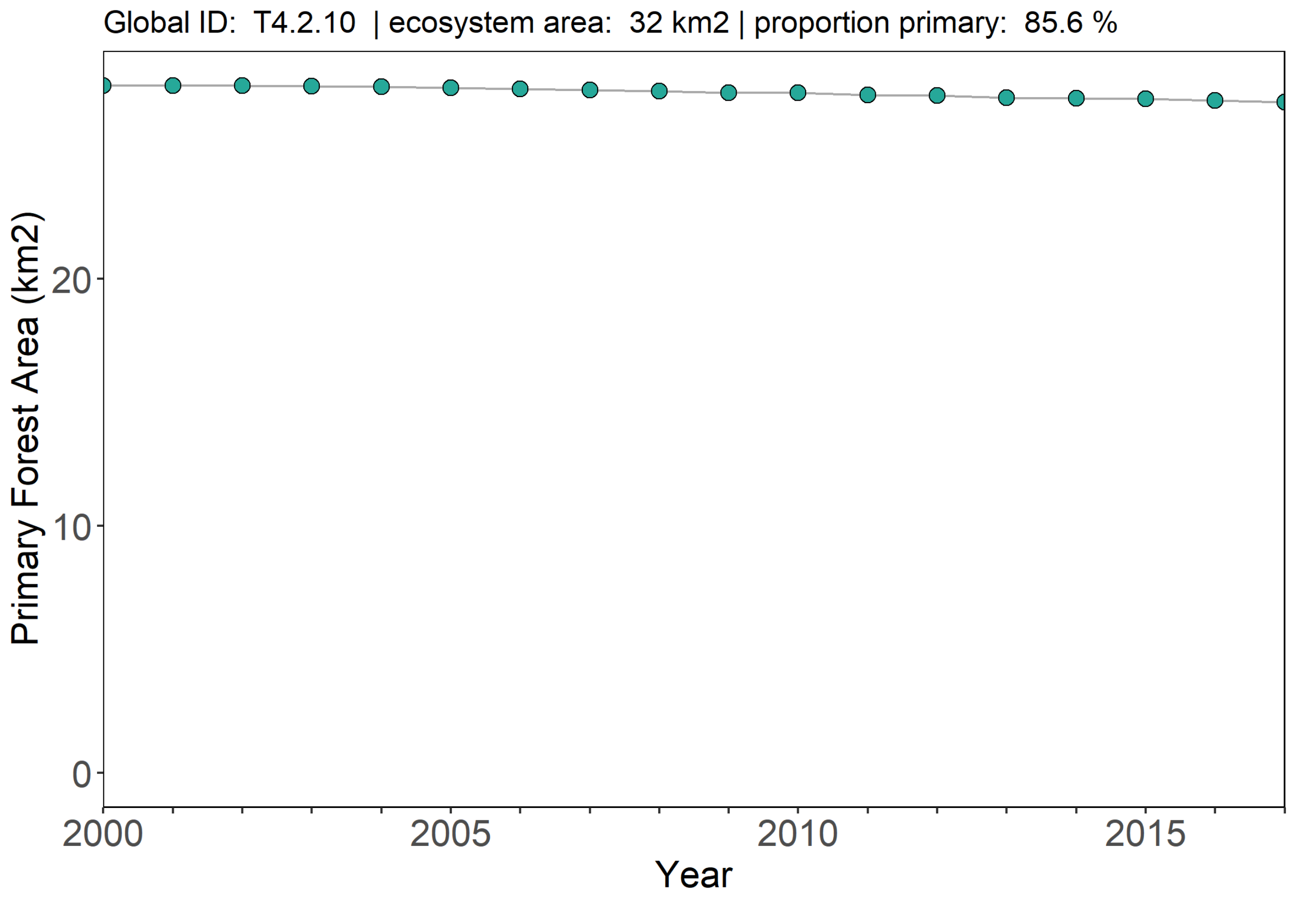
Criterion C

Despite reviews of the literature and discussion with ecosystem experts familiar with Myanmar's savanna ecosystems, no data suitable for assessing criterion D was found. Our climate simulation model had low predictive performance and results were considered unreliable, so this ecosystem is assessed as **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 85.6% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest

in 1750, there has been an assumed 14.4% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is estimated as less than 50% since 1750, not meeting any D3 category thresholds and assessed as Least Concern. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 2.4% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Kachin pine savanna

Authors., Grantham, H., Murray, N.J., Keith, D.A.
Myanmar ecosystem names Mountain pine forest, sub-tropical pine forest (Kingdon-Ward, 1944).
Biome Savannas and grasslands (T4)
Ecotype Pyric tussock savannas (T4.2)
Global classification MMR-T4.2.11
IUCN Status **Least Concern**

Description

Pine savanna is an open evergreen needleleaf savanna ecosystem that occurs in four to five regions across Myanmar, with each currently being a separate ecosystem given their geographical barriers. But further research is needed. This ecosystem in dominated primarily by pines, and has a grass and bracken understory. Kingdon-Ward (1945) suggests that this might be a sub-component of the Kachin sub-tropical rainforest as it is sometimes found intermixed with that rain forest ecosystem type found within the gullies and the savanna likely occupy more fire-prone ridges and drier south facing hill sides. This savanna ecosystem relies on periodic fire to maintain open conditions suitable for recruitment of pine seedlings, and. There is similar pine savanna found in other regions within the country and in neighbouring countries. There are few epiphytes.

Distribution

Kachin pine savanna is scattered in very small patches in northern Kachin state, typically between about 1,000 to 2,000 m in elevation. It also occurs in surrounding countries to the south-east (Ratnam et al., 2016). Considerable uncertainty remains in the distribution of this ecosystem due to a lack of access, so further work (including field work) is recommended to refine the distribution map of this ecosystem type.

Characteristic native biota

The trees include pines particularly *Pinus* species (either *P yunnanensis* or *P. kesiya*, Pinaceae). These forests are very poorly known in Myanmar and the dominant pine species needs further investigation (K. Tomlinson pers. comm.). In adjacent areas of China, *Pinus yunnanesis* is mapped with *Lithocarpus truncatus* *Quercus monimotricha* (Fagaceae) and *Schima wallichii* (Theaceae) (ECVMC-CAS, 2007).

In Myanmar, pine savannas may also include oaks *Quercus* may also include oaks *Quercus incana, Q. serrata* and *Q. griffithi* (Fagaceae); with shrubs including *Pieris ovalifolia* (Ericaceae), *Wendlandia speciosa* (Rubiaceae), *Vernonia clivorum* and *V. adenophylla* (the latter semi-scandent) (Asteraceae), *Dipentodon sinicus* (Dipentodonaceae), *Gaultheria grifjithiana* and *G. yunnanensis* (Ericaceae), *Litsea euosma, L. moupinensis* and *L. forrestii* (Lauraceae).

Abiotic environment

Kachin pine savanna is found predominantly on south facing slopes and sandy soils between around 700-2,000 m with a mainly sub-tropical climate.

Key processes and interactions

Periodic fire is important in maintaining the grassy character of this ecosystem and the dominance of pines. Thick bark protects the living stem tissues of pines enabling them to survive fires, so long as most of the canopy is not scorched. Without fire, it is likely that recruitment and establishment of broad-leaf evergreen trees will increase canopy cover, reduce light penetration and drying in the ground layer and promote transition to warm temperate rainforest

The pine savannas are likely to provide open habitat for birds, ground mammals and invertebrates that are not common in rainforests.

Major threats

The main threats likely include fire exclusion, frequent fire regimes, shifting cultivation, infrastructure development and possibly grazing (Ratnam et al., 2016). However, none of these are currently severe or extensive.

Ecosystem collapse definition

This ecosystem is collapsed when its distribution declines to zero, when the proportion of the ecosystem considered primary forest declines to 0, or when broad-leaf species dominate and pines account for less than 10% of the tree canopy cover.

Assessment summary

This ecosystem could not be visited during field work, but remote sensing models suggest that it is sparsely distributed in very small patches across much of Myanmar's north-east. Despite a restricted EOO, there is no evidence to suggest that this ecosystem is undergoing continuing declines and therefore the ecosystem is assessed as **Least Concern**. Further work is suggested to confirm the occurrence and distribution of pine savanna throughout Kachin state, and reassessing with refined distribution maps. **Least Concern.**

Assessment summary

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

5th December 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No time-series map data was available for assessing reduction in distribution of this ecosystem over any of the assessment time frames. **Data Deficient.**

Criterion B

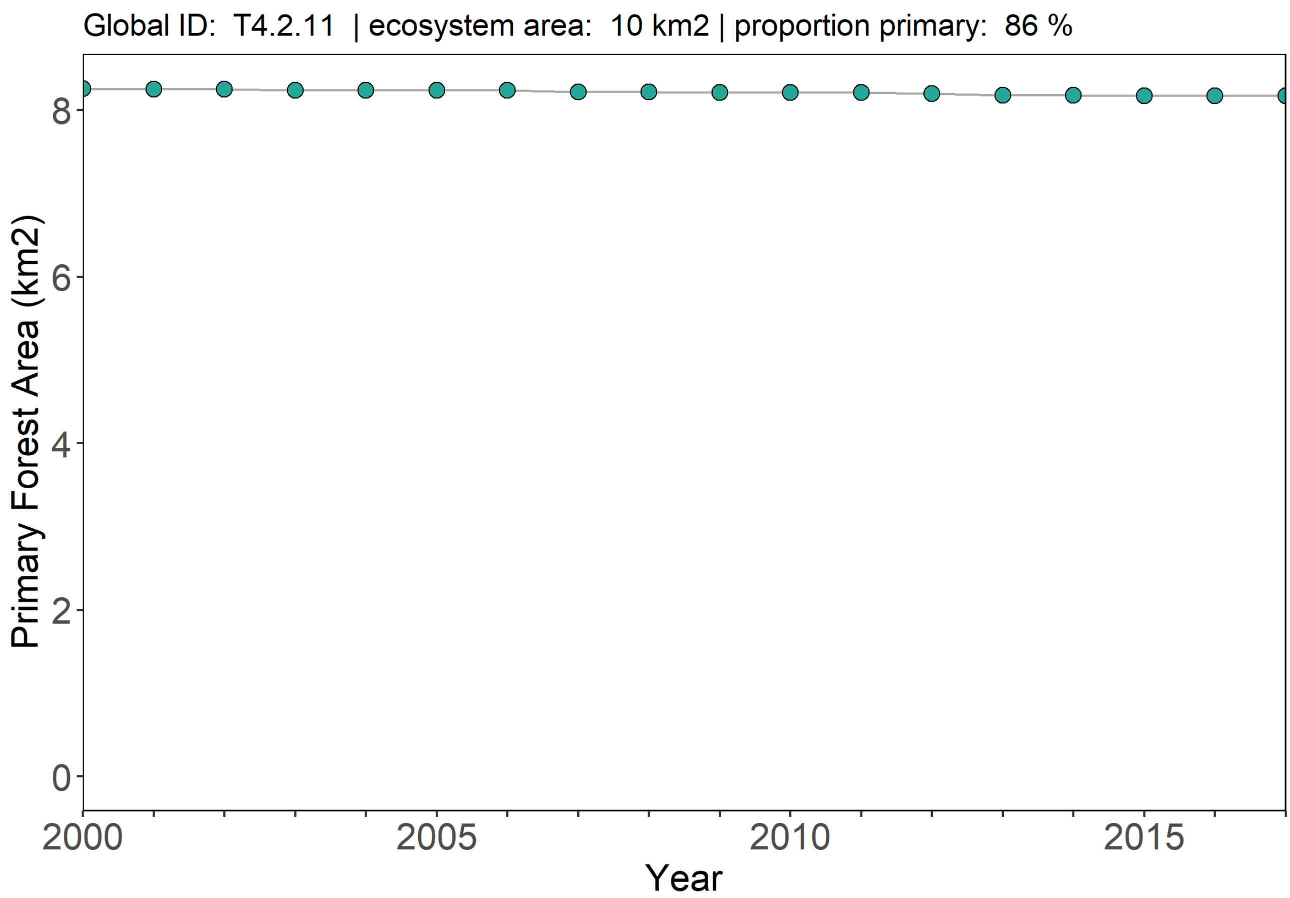
AOO and EOO were estimated as 72 10 x 10km grid cells and 45,063 km^2, respectively. An AOO with one per cent rule invoked of 0 suggests this ecosystem occurs as very small patches across its distribution. We found no information suggesting this ecosystem qualifies for any of the subcriteria related to continuing decline for B1, threats that may cause such declines or restricted distribution. The ecosystem is therefore assessed as **Least Concern**.

Criterion C

Despite reviews of the literature, attempts to run a climate simulation of future distributions (which was not possible due to low predictive performance) and discussion with ecosystem experts familiar with Myanmar's savanna ecosystems, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Remote sensing analyses suggest that 86% of the remaining extent of this ecosystem meets criteria to be classified as primary forest (Potapov et al., 2019). If 100% of the ecosystem is assumed to be primary forest in 1750, there has been an assumed 14% loss in primary forest extent since 1750. We assume that loss of primary forest has a relative severity of >90%, and use the extent of primary forest loss as a biotic variable for assessing extent of ecosystem degradation for Criterion D. Thus, degradation of this ecosystem is estimated as less than 50% since 1750, not meeting the D3 category threshold and assessed as Least Concern. Analyses of the time-series of primary forest data (n = 18 time points) indicate that there has been a 1.1% reduction in primary forest cover over the period 2000-2017. A linear model fit to this dataset, assuming that collapse occurs at 100% loss of primary forest cover, suggests that primary forest loss in this ecosystem will not occur to an extent to meet any category thresholds over a 50 year period (1984-2034). The ecosystem is assessed as Least Concern under Criterion D2b. **Least Concern**.



Criterion E

No models were used to assess Criterion E. **Data Deficient.**

Shan limestone grasslands

Authors Grantham, H., Tizard, R., Murray, N.J., Keith, D.A.

Myanmar ecosystem names Mountain grassland (Stamp, 1924b)
Biome Savannas and grasslands (T4)
Functional Group Temperate grasslands (T4.5)
Global classification MMR-T4.5.1
IUCN Status **Data Deficient**

Description

Very poorly known grasslands apparently existed on the limestones of the Shan Plateau 100 years ago when they were described by Stamp (1924b). Consistent with grasslands recorded in analogous environments in other parts of the world, Shan plateau grasslands likely occurred on heavy-textured soils in topographic depressions that receive cold air drainage from surrounding hills rising well above 1000 m elevation. Although limestone areas on the Shan plateau occur at subtropical latitudes, the temperatures may resemble those of temperate climates due to the elevation and cold air drainage. Owing to travel restrictions, it is not possible to provide a photo or accurate distribution map for this ecosystem.

Distribution

Poorly known but apparently restricted to undulating limestone landscapes on the Shan plateau. No distribution map is available for this ecosystem, although it is expected to occur across Shan State.

Characteristic native biota

The biota is very poorly known, but vegetation is likely to have been dominated by a mixture of C3 and C4 tussock grasses with interstitial forbs in plant taxa such as Asteraceae, Ranuncuaceae, Caryophyllaceae, Convolvulaceae, Lamiaceae, Onagraeae, Liliales (including Orchidaceae), Junaceae and Cyperaceae. The biota is likely to have included large herbivores such as deer (Cervidae), Rhinoceros, Elephant, and their predators including Tiger and other felines.

Abiotic environment

Mild to cool temperatures and moderate to high precipitation, including occasional snow. Likely to have occurred on heavy-textured clay alkaline soils derived from limestone in low-relief topographic depressions and valleys.

Key processes and interactions

Grazing and recurring fires are likely to have been important in maintaining the open grassy structure of this ecosystem.

Major threats

Conversion to crops and pastures is the major threat, as well as hunting of vertebrate fauna.

Ecosystem collapse definition

This ecosystem is collapsed when its distribution declines to 0 km^2 (Criterion A) or when species composition is predominantly introduced species.

Assessment summary

There are currently no known extant occurrences of this ecosystem, although the potential habitat on Shan plateau has not been systematically searched. Shan plateau grasslands are likely to have collapsed sometime in the twentieth century, but they are currently listed as **Data Deficient** until thorough surveys are undertaken.

Assessment information

Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**DD**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient

Year Published

2019

Date Assessed

17th November 2019

Assessment Credits

Assessed by: Hedley Grantham, Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No information on the distribution and change of this ecosystem was found during extensive literature reviews. **Data Deficient.**

Criterion B

Without data on the spatial distribution of this ecosystem, no assessment of Criterion B could be made. **Data Deficient.**

Criterion C

No information was found that could be used to assess Criterion C for this ecosystem**. Data Deficient.**

Criterion D

No information was found that could be used to assess Criterion D for this ecosystem. **Data Deficient.**

Criterion E

No model was used to assess the risk of collapse of this ecosystem. **Not Evaluated.**

Kachin snowfields

Authors Murray, N.J., Grantham, H., Keith, D.A.
Myanmar ecosystem names Snowbanks, snowcapped mountain
Biome Polar/Alpine (T6)
Functional Group Ice sheets, glaciers and perennial snowfields (T6.1)
Global classification MMR-T6.1.1
IUCN Status **Near Threatened (Near Threatened – Vulnerable)**

Description

Kachin snowfields are characterised by perrenial snow and ice that do not entirely melt over the warmer summer months. They therefore consist of masses of snow and ice that accumulate and compact over many years, but unlike glaciers do not become thick enough to flow with gravity. They are crucial for regulating water availability for ecosystems occuring downstream and at lower altitude.

Distribution

Kachin snowfields occur in the high mountain northeast region over around 3,750 m. They may fluctuate in distribution slightly between years due to varying climatic conditions.

Characteristic native biota

There may be some low growing forbs, sedges and grasses at the snow margins. However, owing to a very hostile abiotic environment, the biota of this ecosystem is characterised only by microbial fauna and microscopic algae. Vertebrates such as Red Fox *Vulpes vulpes* and Blue Sheep *Pseudois nayaur* could be itinerants in this ecosystem but are rarely seen. Snow Leopard *Panthera uncia* (VU) is the known predator for Blue Sheep so could be an itinerant but there are no confirmed records in Myanmar yet.

Abiotic environment

Persistently very cold with high annual precipitation. Topography is generally flat enough to sustain snow without leading to glacial flow. Owing to lower incident radiation throughout the year, persistent snowfields tend to occur more on poleward (northern) aspects of mountains.

Key processes and interactions

Persistent freezing conditions are driven primarily by high altitude, and the distribution of snow may be influenced by fine-scale topographic conditions, such as aspect and gullies. High winds redistribute surface snow, generally to leeward slopes, before it consolidates as ice.

Major threats

Global warming poses a very serious threat to this ecosystem, which is expected to cause widespread melting of snow patches and will drive a substantial decline of the extent of the ecosystem. Reduced snow cover will result in increased exposure to frosts, making the snowfields less suitable for habitation by biota that shelter from extreme temperatures in voids beneath the snow.

Ecosystem collapse definition

This system is considered collapsed when there is no longer a year-round cover of snow; the distribution of perennial snow declines to 0 km^2. We also follow the definition of Williams et al. (2015), which considered snowfield ecosystems collapsed if the 10-year running mean depth of the snowpack is zero.

Assessment summary

No data were used to assess trends in snow cover, despite data possibly being available to develop time-series estimates of snow cover change in the region where our remote sensing models suggest perennial snowfields occur (Not Evaluated, A1, A2a, A2b). Our map data suggests this ecosystem is broadly distributed and does not meet category thresholds for Criterion B1 or B2. However, climate warming is expected to impact this ecosystem at its single threat-defined location (see assessment information), and it is therefore listed tentatively as **Near Threatened – Vulnerable** under B3**.** We recommend urgent further work to refine this assessment based on analyses of time-series earth observation data.

Assessment information

Criteria		Status
Criterion A	A1	**NE**
	A2a	**NE**
	A2b	**NE**
	A3	**NE**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**-**
	B3	**NT (NT-VU)**
Criterion C	C1	**NE**
	C2a	**LC (LC-VU)**
	C2b	**NE**
	C3	**NE**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Near Threatened (Near Threatened – Vulnerable)

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Robert Tizard

Criterion A

Remote sensing snow cover time-series data may be suitable for conducting this assessment. However, owing to uncertainty in the distribution of this ecosystem no time-series modelling has been conducted to date. The ecosystem is therefore listed as **Not Evaluated** under Criterion A1, A2a and A2b. No historical data is available to assess the past extent of this ecosystem, **Data Deficient**, A3.

Criterion B

AOO was estimated to be 145 10 x 10 km grid cells and EOO 44,492 km^2, and therefore this ecosystem is listed as Least Concern for Criteria B1 and B2. Climate warming is an ongoing threat to this ecosystem that could result in widespread melting of perennial snowfield ecosystems worldwide. Given warming is likely to operate across the Himalayas, this ecosystem is assessed as occupying one threat-defined location. There is considerable uncertainty around the time-frames in which snowfields may collapse in the Himalayas, despite the role of climate change in the decline of snow cover in the Himalaya's being well established (e.g. Bolch et al., 2012). Nonetheless, rapid and irreversible contraction of permanent snow in the next two-three decades is a plausible scenario if positive feedbacks drive regional climate warming. Therefore, the ecosystem is tentatively assessed as **Vulnerable** under Criterion B3. **Near Threatened - Vulnerable.**

Criterion C

No data was used to assess observed temperature or precipitation trends for this ecosystem, and we recommend such an analysis in future red list assessments for Myanmar. An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will not occur with an extent and severity that meets any category thresholds for Criterion C2a. Several of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Vulnerable, and therefore the ecosystem is assessed as **Least Concern**, with plausible bounds of **Least Concern – Vulnerable**.

Criterion D

Despite literature searches and liaison with ecosystem experts in Myanmar, no data suitable for assessing this criterion was found. **Data deficient.**

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Alpine cliffs and screes

Authors Murray, N.J., Grantham, H., Tizard, R., Keith, D., Armstrong, K.E.
Myanmar ecosystem names Alpine rockface (Kingdon-Ward, 1944)
Biome Polar/Alpine (T6)
Functional Group Polar/alpine rocky outcrops (T6.2)
Global classification MMR-T6.2.1
IUCN Status **Least Concern**

Description

Alpine cliffs and screes are bare, icy, rocky areas amongst permanent snow fields. Vascular vegetation is low and sparse or absent, and the most common plants are crustose lichens and bryophytes (Keith et al., in review).

Distribution

This ecosystem occurs on the steep upper slopes of the highest mountain peaks amongst glaciers and permanent snowfields, of northern Myanmar and adjacent countries.

Characteristic native biota

The extreme conditions limit the expression of life in these ecosystems, which are characterised by low species diversity, low biomass and low productivity. Lichens, bryophytes and cyanobacteria are the primary producers that inhabit rock surfaces although non-woody vascular plants may be found in crevices where shallow soil accumulates. Other microbes and a small number of insect species likely perform functions as decomposers and detritivores. No information was found on the identity of species that characterise these assemblages in Myanmar. Tussocks of *Diapensia himalaica* (Diapensiaceae), *Androsace*, and primulas, such as the endemic *Primula vaginata* subsp. *eucyclia,* and *P. agleniana* var. *thearosa* (Primulaceae), and woolly plants such as *Saussurea* (Asteraceae), as well as cushion-forming plants like *Arenaria polytrichoides* (Caryophyllaceae) can be found at the highest elevations, growing in scree just below the snow line.

The ecosystem supports a small range of specialized birds more widespread in southwest china and the Tibetan Plateau including Grandala

Grandala coelicolor, Alpine Accentor *Prunella collaris,* and Red-fronted Rosefinch *Carpodacus puniceus* one of the world's highest ranging passerines.

Abiotic environment

This ecosystem is found at very high altitudes (approximately >4,500 m above sea level) and is characterised by extremely steep slopes (50-90°), extreme cold, exposure to high winds and periodic desiccation. Soils are essentially absent due to steep slopes or else skeletal and confined to crevices amongst rock.

Key processes and interactions

Extremely steep slopes promote erosion, prevent soil development and facilitate periodic mass movement through landslides and avalanches which remove living biomass. High altitudes and steep slopes, together with very low temperatures exacerbated by wind chill associated with periodically high velocity winds. Frosts and ice promote weathering through frost heave and limit the inhabitability of rock surfaces. Mutualisms within lichens are important but otherwise biotic interactions are weak.

Major threats

The most plausible threat is global warming, which may elevate temperatures, alter frequencies of snow cover and desiccation regimes. The magnitude of these changes is uncertain, as is the response of the sparse biota, but is likely to be negligible. If desiccation is significant, however, it could have an impact on the cover of bryophytes and lichen.

Ecosystem collapse definition

The system reaches a collapsed state when exposed rock is covered permanently by snow or by vascular vegetation.

Assessment summary

This ecosystem is restricted to small areas in northern Myanmar, but inferred threatening processes are unlikely to cause continuing declines of a non-negligible magnitude in extent. **Least Concern.**

Assessment information

Criteria		Status
Criterion A	A1	**LC**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

26th November 2019

Assessment Credits

Assessed by: David Keith, Nicholas Murray

Reviewed by: Hedley Grantham

Contributions by: Robert Tizard, Kate Armstrong

Criterion A

The distribution of Alpine cliffs and screes is unlikely to have changed appreciably in recent decades but may have increased due to snow melt in recent decades. Although no quantitative data are available, the likely status under criterion A1 is **Least Concern**

Criterion B

Our map data suggest that this ecosystem has an AOO of 45 10 x 10 km grid cells and an EOO of 51,924 km^2. Despite having an AOO of <50 10 x 10 km grid cells, there is no evidence of continuing decline and threats appear to be negligible. Therefore, this ecosystem does not meet the additional subcriteria and is assessed as **Least Concern.**

Criterion C

Despite literature searches and liaison with ecosystem experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite literature searches and discussion with ecosystem experts from Myanmar, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

No model was used to assess Criterion E. **Not Evaluated.**

High mountain scrub

Authors Armstrong, K.E., Grantham, H., Tizard, R., Murray, N.J., Keith, D.A.,
Myanmar ecosystem names Alpine scrub, Subalpine Rhododendron scrub (UNESCO, 2014), highest mountain sub-alpine scrub (Davis, 1960), scrub (Kingdon-Ward, 1944)
Biome Polar/Alpine
Functional Group Temperate alpine meadows and shrublands (T6.4)
Global classification MMR-T6.4.1
IUCN Status **Least Concern**

Description

High mountain scrub is a shrubby formation characterized by a great variety of *Rhododendron* species from large trees to dwarf undershrubs (comprising 75% of the vegetation), intermixed with other shrubby genera (e.g. *Salix*, *Berberis*, *Euonymus*) and stands of dwarf bamboo. According to Kingdon-Ward (1948) this is a *Rhododendron* climax formation with more species growing in this zone (20+) than any other of equal depth. There are c.130 species recorded from Myanmar – mostly from the far north with c. 30% being endemic (UNESCO, 2014).

This zone marks the transition between silver fir forest and alpine areas. From just within and extending beyond the silver fir forest, 3-5 m tall tree-like rhododendrons (*R. beesianum*, often mixed with *R. uvariifolium*) predominate, giving way to stands of *R. praestans* and *R. selense*, a small tree or large bushy shrub growing gregariously, which dominates the scene (Kingdon-Ward, 1944).

Distribution

This vegetation type occurs in high mountain regions of Northern Kachin State and neighboring Himalayan regions. It is found at elevations of c. 3,400-4,000 m.

Characteristic native biota

According to Kingdon-Ward (1948), typical species of *Rhododendron* in this zone include *R. anthopogon, R. arizelum, R. campylogynum, R. cerasinum, R. chryseum, R. crebreflorum, R. eclecteum, R. hypolepidotum, R. luridum, R. niphargum, R. praestans, R. pruniflorum, R. pumilum, R. repens, R. saluense, R. sanguineum, R. selense, R. tephropeplum, R. trichocladum, R. tsarongense* together with endemics such as *R.*

calostrotum, R. chamaetortum and *R. keleticum* (Ericaceae). Just twenty-five percent of the woody plants in the high mountain scrub are genera other than *Rhododendron*. They include *Salix* (Salicaceae), *Spiraea*, *Cotoneaster, Rosa, Sorbus wardii* (Rosaceae), *Ribes* (Grossulariaceae), *Viburnum*, (Adoxaceae), *Lonicera* (Caprifoliaceae), *Berberis burmanica* (Berberidaceae), *Euonymus* (Celastraceae), *Ilex* (Aquifoliaceae), *Vaccinium*, *Gaultheria minuata, Cassiope* (Ericaceae), and *Juniperus* (Cupressaceae). On exposed mountain ridges, dense stands of dwarf bamboo also occur. Herbs growing amongst the shrubs include *Codonopsis* (Campanulaceae) *Euphorbia sikkimensis* (Euphorbiaceae) and *Gentiana* (Gentianaceae).

This ecosystem supports Himalayan Monal *Lophophorus impejanus,* Temminck's Tragopan *Tragopan temminckii,* Blood Pheasant *Ithaginis cruentus;* a wide range of palearctic tits including Coal Tit *Periparus ater,* Rufous-vented Tit *Periparus rubidiventris,* Grey-crested Tit *Lophophanes dichrous* as well as breeding Leaf-warblers (Phylloscopidae), Old World Warblers and Parrotbills (Sylviidae), Fire-tailed Myzornis *Myzornis pyrrhoura,* White-eyes and Yuhinas (Zosteropidae), and Alpine Thrush *Zoothera mollissima.*There are also significant populations of high-elevation mammals including Red Panda *Ailurus fulgens* (EN), Takin *Budorcas taxicolor* (VU), Red Goral *Naemorhedus baileyi* (VU) and Moupin Pika *Ochotona thibetana.*

Abiotic environment

High mountain scrub occurs between the seasonal and permanent snowlines, where winter temperatures fall well below 0°C, often on steep and/or rocky areas.

Key processes and interactions

A minimal growing season of three months enables recruitment and slow growth of shrubs and low trees. Heavy snowfalls may occur in winter and, with wind shear, limit the stature of woody vegetation. Birds migrate to lower elevations in winter, while mammals, such as Himalayan mammoths, and invertebrates hibernate among rocks.

Major threats

This ecosystem is threatened by changes in the frequency and persistence of snow cover, as well as upward migration of forest species as a result of climate warming.

Ecosystem collapse definition

This ecosystem is considered collapsed when it's distribution reduces to 0 km^2.

Assessment Summary

No data suitable for assessing the majority of the criteria were found during the assessment process. However, our map data indicates this ecosystem is highly restricted to high mountain regions of northern Myanmar. Despite its restricted distribution, threats to the ecosystem appear relatively benign, and therefore the ecosystem did not meet subcriteria for Criterion B. We recommend further work to fill knowledge gaps on biotic and environmental degradation, particularly in relation to climate change, as well as work to estimate historical distributions required to assess Criterion A. The ecosystem is assessed as **Least Concern** under Criterion B.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

20th January 2020

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Kate Armstrong

Criterion A

No time-series map data was available to assess this ecosystem under Criterion A. **Data Deficient.**

Criterion B

High mountain scrub is highly restricted in distribution in northeastern Myanmar. AOO is 200 10 x 10 km grid cells and EOO was 90,294 km^2. There is no evidence to suggest ongoing decline to this ecosystem, although changes in snow cover frequency and other threats such as increased numbers of landslide events should be monitored over the next few years. The ecosystem is listed as **Least Concern.**

Criterion C

Despite targeted searches and liaison with ecosystem experts familiar with Myanmar's northern regions, no information was found that was suitable for assessing Criterion C. Further work to assess the impact of climate warming, in particular, to this ecosystem is recommended to fill this knowledge gap. **Data Deficient.**

Criterion D

Despite targeted searches and liaison with ecosystem experts familiar with Myanmar's northern regions, no information was found that was suitable for assessing Criterion D. **Data Deficient.**

Criterion E

No models were used to assess Criterion E. **Data Deficient.**

Alpine herbfield

Authors Armstrong, K.E., Grantham, H., Tizard, R., Murray, N.J., Keith, D.A.
Myanmar ecosystem names Alpine vegetation (UNESCO, 2014), alpine scrub (Kingdon-Ward, 1944)
Biome Polar/Alpine (T6)
Functional Group Temperate alpine meadows and shrublands (T6.4)
Global classification MMR-T6.4.2
IUCN Status **Endangered**

Description

Alpine herbfield is one of the rarest ecosystems in Myanmar, occurring from c. 3,500-4,200 m in steep mountainous areas of Kachin State, where snow persists into the growing season (i.e. April-May). This ecosystem is of outstanding integrity and represents some of the only undisturbed or lightly disturbed alpine vegetation of this size in the Himalaya (UNESCO, 2014).The flora is of Sino-Himalayan origin, and is comprised of herbaceous plants, which form alpine meadows interspersed with patches of matted *Rhododendron* and other prostrate Ericaceae (e.g. *Cassiope*)

Distribution

This ecosystem occurs below the permanent snowline in the high-altitude areas of northern Myanmar and adjacent countries.

Characteristic native biota

Alpine herbfield can be found at 3,500 m and above. Characteristic herbaceous plants in this ecosystem include numerous species of *Primula*, such as *P. serratifolia*, *P. capitata*, *P. triloba*, *P. dickieana, P. chamaethauma,* and *P. fea* as well as *Omphalogramma souliei* (Primulaceae), various gentian species, including *Gentiana wardii* and *Gentiana sino-ornata* (Gentianaceae), *Cremanthodium*, *Lactuca*, the woolly *Saussurea gossypiphora* (Asteraceae) and *Eriophyton wallichii* (Lamiaceae), *Cyananthus* (Campanulaceae), *Polygonum griffithii* (Polygonaceae), *Saxifraga* (Saxifragaceae), *Corydalis cashmeriana*, the endemic blue poppy *Meconopsis violacea* and other *Meconopsis* species (Papaveraceae), *Pedicularis* species including the endemic *Pedicularis nana* (Orobanchaceae), *Astragalus* (Fabaceae), *Ranunculus*, *Caltha paulustris* (Ranunculaceae), *Cyprepedium tibeticum* (Orchidaceae), *Iris*

(Iridaceae), bulbous species of *Fritillaria, Nomocharis souliei, Gagea* (Liliaceae) and *Allium* (Amaryllidaceae), as well as numerous grass (Poaceae) rush (*Luzula*, Juncaceae) and sedge (*Carex,* Cyperaceae) species. The shrubs that occur here are dwarf forms including numerous species of *Rhododendron*, such as *R. anthopogon*, *R. repens, R. campylogynum* and the two endemic species *R. crebreflorum* and *R. riparium* (Ericaceae). Thin mats of dwarf *Rubus* and *Potentilla fruticosa* (Rosaceae), *Cassiope* and *Diplarche* (Ericaceae) also occur in the upper ecotone.

Alpine herbfield supports Snow Partridge *Lerwa lerwa,* Himalayan Monal *Lophophorus impejanus,* Wood Snipe *Gallinago nemoricola* (VU), Grandala *Grandala coelicolor,* Alpine Thrush *Zoothera mollissima,* Chinese Rubythroat *Calliope tschebaiewi* and Rufous-breasted Accentor *Prunella strophiata.* During the summer months Takin *Budorcas taxicolor* (VU) gather in large groups above treeline and give birth to a single kid along the edge with high mountain scrub.

Abiotic environment

Low temperatures throughout the year and high rates of precipitation. The duration of snow persistence constrains a very short growing season, and is likely a key environmental determinant of the distribution of this ecosystem, in which there is limited incursion of most plant species that occur at lower elevations.

Key processes and interactions

Temperature limitations (Williams et al., 2015) and variation in the persistence of snow throughout the year are key factors that influence the processes and interactions in this ecosystem. Variation in moisture as a result of variation in snow persistence influences the distribution of plant species, as well as the level of shrub encroachment from adjacent shrubby ecosystem types. Thick snow drifts can also generate a sheer force which may cause local disturbances to this ecosystem, resulting in land slips, loss of vegetation and substantial soil movement (Williams et al., 2015).

Major threats

Alpine herbfields are visited each summer by local people from Myanmar and surrounding countries, and are often used for grazing Yaks. They come to harvest a variety of medicinal plants as well as *Cordyceps* (shi ba di) for traditional use and sale. Many species are hunted during this time for food while searching for medicine. Alpine ecosystems are thought to be particularly sensitive to climate change, because the fine-scale distribution of plant species is frequently related directly to climate or climate-influenced factors (Pickering et al., 2008), and a warming climate may increase the rates of encroachment by plant species from surrounding ecosystems (Williams et al., 2015). Upward migration has been observed in many Himalayan species (Telwala et al., 2013; Padma, 2014; Dolezal et al., 2016). However, there is high uncertainty about many important factors in the Himalaya that are likely to be influencing this ecosystem, including the distribution of precipitation, and snow and ice melt (Bolch et al., 2012).

Ecosystem collapse definition

This ecosystem is considered to have collapsed when its distribution declines to 0 km^2 (Criterion A). In addition, following Williams et al (2010) this ecosystem is considered collapsed when the 10-year running mean depth of snow is zero, indicating no persistent snow cover at any time of year (Criterion C) or when woody shrub invasion results in shrub dominance and transition to an alpine shrubland ecosystem type (Criterion D).

Assessment summary

This ecosystem is highly restricted to the mountainous northern region and tends to occur where snow persists well into the growing season. Although data searches highlighted a paucity of knowledge about change in key components of this ecosystem, our remote sensing data was sufficient to assess Criterion B. The ecosystem is so restricted and is considered to be threatened over the next twenty years that it qualifies for listing under Criterion B1. **Endangered**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**EN**
	B2	**VU**
	subcriteria	**B1(b), B2(b)**
	B3	**LC**
Criterion C	C1	**NE**
	C2a	**VU (LC-EN)**
	C2b	**NE**
	C3	**NE**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Endangered

Year Published

2019

Date Assessed

17th November 2019

Assessment Credits

Assessed by: Hedley Grantham, Nicholas Murray

Reviewed by: David Keith

Contributions by: Kate Armstrong

Criterion A

Despite extensive searches, no in situ time-series data suitable for assessing the change in distribution of this ecosystem type was available. **Data Deficient.**

Criterion B

Based on a remote sensing map of this ecosystem produced for the Myanmar National Ecosystem Assessment, Area of Occupancy (AOO) is 26 10 x 10 km grid cells (Vulnerable, B2) and Extent of Occurrence (EOO) 3,847 km^2 (Endangered, B1). The role of climate change in the decline of snow cover in the Himalaya's is well established, with evidence including loss of glaciers (e.g. Bolch et al., 2012). There is also evidence of compositional shifts in plant communities due to upward species migrations in similar Himalayan ecosystems (Telwala et al., 2013; Padma, 2014; Dolezal et al., 2016), suggesting that transition is underway. This ecosystem is therefore considered to meet the subcriterion B2 that threatening processes (climate warming) is likely to cause continuing declines in geographic distribution (as a result of shrub invasion), environmental quality (lower persistence of snow) and biotic interactions (increased woody shrub cover) within the next twenty years. **Endangered.**

Criterion C

An environmental suitability model (Ferrer-Paris et al., 2019; see methods) suggests that reductions in climate suitability will not occur with an extent and severity to meet the category thresholds for Criterion C2a. Nevertheless, several of the modelled scenarios suggested that the ecosystem could potentially meet thresholds for Vulnerable, and therefore the ecosystem is assessed as Least Concern, with plausible bounds of Least Concern – Vulnerable. We do note that the outcome may be impaired by low predictive performance of the model, further studies are recommended to confirm this result. **Least Concern (Least Concern – Vulnerable).**

Criterion D

Although shrub encroachment is considered to contribute to increased risk of collapse, no data was available to assess Criterion D. **Data Deficient.**

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

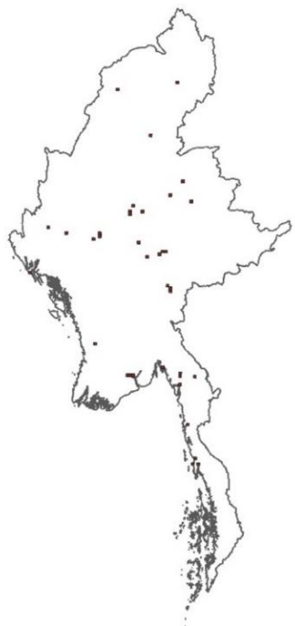
Aerobic karst caves

Authors Murray, N.J., Keith, D.A., Grismer., L., Stidham, T.
Myanmar ecosystem names Caves, limestone caves
Biome Dry subterranean (S1)
Functional Group Subterranean lithic systems (S1.1)
Global classification MMR-S.1.1
IUCN Status **Least Concern**

Description

Aerobic karst caves are dark subterranean limestone caves that are air-filled and support simple, low productivity ecosystems (Keith et al., 2019). Owing to light limitation, there is a distinct lack of photosynthentic primary producers and herbivores, and Karst cave biota is therefore typically dominated by detritivores and a few predators. In Myanmar Karst caves are widespread (Waltham and Eavis, 2004). Subterranean streams and pools also occur within Karst voids. These are transitional subterranean-freshwater ecosystems that are distinct from the aerobic ecosystems with which they co-occur, and outside the scope of this assessment.

High degrees of endemism within, and diversity among isolated karstic hills, caves, and towers result from a multitude of ecological niches afforded by their complex terrain along with their highly fragmented habitat-island nature. The high levels of biodiversity and site-specific endemism in karst habitats rival those of most other habitats throughout the tropics, yet karstic regions are rapidly becoming some of the most imperilled ecosystems on the planet (Clements et al., 2006). Southeast Asia harbors more karst habitat than anywhere else on earth (Day and Ulrich, 2000) but unregulated and unsustainable quarrying practices continue to threaten their integrity and are the primary threat to the survival of karst-associated species.



Distribution

An estimated 80,000 km^2 of Myanmar consists of Karst environments (Day and Urich, 2000).

A recent assessment of bat caves recorded 66 bat caves distributed across Myanmar, which is the best available indicative of the distribution of karst cave ecosystems in Myanmar, but likely underestimates the total number of Karst caves by a substantial margin. The distribution of karst caves follows the distribution of karst, which is primarily located in the Shan plateau, Kayin State, Mon State and Taninthyari Region.

Characteristic native biota

Native biota include invertebrates, fungi, bacteria and some vertebrates, notably bats. One hundred and thirteen species of bat have been recorded in Myanmar, including recently discovered endemics such as the Kachin Woolly Bat (*Kerivoula kachinensis;* Bates et al, 2004; Darwin Initiative, 2005, Francis, 2019). There is a single near-endemic bird, Greyish Limestone-babbler *Turdinus crispifrons* restricted to karst in Myanmar and neighboring Thailand. Most biota are well-adapted to light scarcity, including reduced eyes, pigmentation and wings, and specialised non-visual sensory organs (Keith et al., 2019).

Beyond bats, no publications were found to further identify the characteristic biota of karst caves in Myanmar.

Abiotic environment

Karst caves form in rocky karst environments from the chemical weathering of limestone by surface water or by phreatic sources (Keith et al., 2019). They are characterised by lack of light, except at their openings, and low variability in temperature and humidity.

Key processes and interactions

The availability of light and nutrients is a key ecological driver in cave ecosystems. Energy and nutrients are imported from seepage, tree roots, bats and birds, supporting a biota consisting mainly of detritovores and predators. Karst caves are normally insular in distribution with poor connectivity, and therefore frequently have very high levels of local endemism.

Major threats

Bird nests from karst caves in the Myeik Archipelago are harvested and sold for human consumption (Dreybrodt, 2019). In Thailand and Indonesia, bats are hunted for human consumption, although the extent of this practice in Myanmar is unknown (Clements et al 2006). Cement production is a threat to karst landscapes (Clements et al 2006), and quarrying may threaten caves in nearby areas.

Ecosystem collapse definition

Karst caves are considered collapsed when their total volume reduces to 0 m^3 through a process of collapse or weathering. In addition, karst cave ecosystems have collapsed if sufficient light is available at all parts in the cave system to limit the persistence of characteristic cave dwelling organisms.

Assessment summary

Although restricted across Myanmar, inferred threatening processes are unlikely to cause continuing declines of a non-negligible magnitude in extent. Limestone quarrying is a highly localised threat that warrants ongoing monitoring in this regard. **Least Concern.**

Assessment information

Criteria		Status
Criterion A	A1	**LC**
	A2a	**LC**
	A2b	**LC**
	A3	**LC**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**-**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

7th August 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Lee Grismer, Stidham, T.

Criterion A

There is no evidence that Karst Caves are declining in extent over any of the assessment time frames. **Least Concern.**

Criterion B

According to a dataset of bat caves in Myanmar, Karst Caves have an AOO of 37 10 x 10 km grid cells and an EOO of 440,849 km^2. Despite having an AOO of <50 10 x 10 km grid cells, there is no evidence of continuing decline or non-negligible threats to meet the additional subcriteria. Therefore, the ecosystem is assessed as **Least Concern.**

Criterion C

Despite extensive reviews of the literature, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite extensive reviews of the literature, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Ayeyarwady kanazo swamp forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Swamp forest, Kanazo forest, mangrove forest
Biome Palustrine wetlands (TF1)
Functional group Tropical flooded forests and peat forests (TF1.1)
Global classification MMR-TF1.1.1
IUCN Status **Critically Endangered (Critically Endangered – Collapsed)**

Description

Ayeyarwady kanazo swamp forest is an intertidal forest type dominated by the Endangered species *Heritiera fomes* ('kanazo', Stamp, 1925a). It occurs in the upper intertidal zone, normally above true mangroves, where the influence of freshwater is greater and water salinity is much lower than in seawater due to freshwater influx from the floodplain (Kathiresan et al., 2010). The ecosystem is characterised by a tree canopy of up to 25 m, the presence of pneumatophores and occasional flooding by fresh or saltwater (Stamp, 1925a; Davies et al., 2004). Ayeyarwady kanazo swamp forest once occupied very large areas of the Ayeyarwady delta, but its utility for construction, use for fuel wood and close proximity to Yangon, and expansion of rice cropping led to widespread declines of this ecosystem (Stamp, 1924).

Distribution

Suitable habitat and historical records for this ecosystem occurs along the inland edge of the mangrove forest in the Ayeyarwady delta, and fragments may be expected to remain. However, no recent distribution data for this ecosystem exists, although small patches may be confound within mangrove forest maps. Broad species range maps of *Heritiera fomes* suggest it follows the broad distribution of mangroves in the Ayeyarwady delta and southern Rakhine, possibly also with small occurrences on deltas of the Tanintharyi coast (Kathiresan et al., 2010, Davies et al., 2004). One record of *Heritiera fomes* is recorded in the Global Biodiversity Information Facility (GBIF), located just north of Yangon.

Characteristic native biota

The characteristic dominant tree species of Ayeyarwady kanazo swamp forest is *Heritiera fomes,* in association with *Aglaia cucullata*, *Intsia bijuga* and *Barringtonia acutangula* (Davies et al., 2004). These are freshwater mangroves and have morphological and ecophysical traits, such as pneumatophores, to tolerate substrate anoxia. Other woody species include *Lagerstroemia speciosa*, *Hibiscus tiliaceus*, and the palm *Phoenix paludosa* (Davis, 1960). At its lower elevation margins there are likely true mangrove species, including *Sonneratia apetala.*

Abiotic environment

This ecosystem occurs in the low elevation coastal zone where it typically fringes the upper margins of the intertidal zone where waters may be mildly brackish to fresh (Kress et al., 2003). Continual inundation, particularly in the monsoon season, results in substrate anoxia and peat accumulation. The ecosystem can tolerate low levels of salinity, but generally occurs in the high intertidal zone, above true mangroves, where there is abundant freshwater inflow and groundwater seepage, and saltwater incursion is limited. Ayeyarwady kanazo swamp has very similar dynamics to adjacent Ayeyarwady delta mangrove forest. However, Stamp (1925) notes that kanazo typically requires daily tidal flooding, but must also completely dry for several hours at least twice daily. It does occur in areas that are flooded by freshwater for several months of the year, however, and therefore tends to occur as a fringing forest between mangroves and floodplain ecosystems (Stamp, 1924).

Key processes and interactions

Ayeyarwady kanazo swamp forest has similar processes and interactions as adjacent mangrove forests. It occurs on a marine-freshwater transition, upslope and inland of mangrove, where salinity is low, but varies according to seasonal monsoonal influx of freshwater from the river catchment, and daily tidal influence. Mangroves, particularly *Sonneratia apetala* occur in the transition zone, but diminish with increasing freshwater influence (Stamp, 1924b). As silt is collected by this vegetation and the sediment elevation increases, *Sonneratia apetala* is replaced by Kanazo (*Heritiera fomes*) in the higher elevation intertidal zone (Stamp, 1924). Therefore, continued processes of deposition and a dominance of freshwater inputs over tidal influence are required to sustain this gradient-driven system (Stamp 1924).

Major threats

Due to its occurrence around the upper intertidal zone, remaining Ayeyarwady kanazo swamp forest is highly threatened by coastal development for agriculture and aquaculture (Polidoro et al., 2010). *Hertiera fomes* is highly valued as timber, for which it is used for house building and boat building. It has also been widely used as fuelwood for more than a century and is considered the most favoured species for charcoal making. One estimate suggests that in 1919-1920, at least 250,000 tons of kanazo was illegally extracted from delta forest reserves (Bryant, 1996). These factors suggest it has probably been more widely deforested than adjacent mangrove forest ecosystems.

According to the IUCN Red List of Threatened Species, *Hertiera fomes* has quickly disappeared due to coastal development, particularly for aquaculture and rice farming, reductions in water flow regimes, and from timber extraction (Kathiresan et al., 2010). This species is also threatened by disease and sea level rise, which will increase salinity levels in the muddy substrate. Consequently, the species is listed as Endangered on the IUCN Red List of Threatened Species (Kathiresan et al., 2010).

Ecosystem collapse definition

This ecosystem is collapsed when its area has declined to 0 km^2.

Assessment summary

Ayeyarwady Kanazo Swamp Forest is thought to have undergone a major decline in extent around the early 20th century in response to overexploitation for fuelwood and proximity to Yangon (Stamp, 1924). It continues to be threatened by coastal development for aquaculture and agriculture, sea level rise and fuelwood extraction. Although no reliable data on its distribution is available, our broad analysis of global mangrove distribution data occurring within the area mapped as 'Tropical Swamp Forest' by Davis (1960) suggests that as little as 2.6% of this ecosystem may remain. With only one record in GBIF and no confirmed on-ground records, our estimate may be considered conservative. Thus, Ayeyarwady Kanazo Swamp Forest is considered **Critically Endangered**, with plausible bounds **Critically Endangered – Collapsed**.

Assessment Information

Criteria		Status
Criterion A	A1	**CR (CR-CO)**
	A2a	**NE**
	A2b	**NE**
	A3	**CR (CR-CO)**
Criterion B	B1	**DD**
	B2	**DD**
	Subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered (Critically Endangered – Collapsed)

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

6th August 2019

Assessment Credits

Assessed by: Nicholas J. Murray

Reviewed by: David Keith

Contributions by: Robert Tizard

Criterion A

This ecosystem has undergone large but unquantifiable declines in extent since 1750, and no reliable map data was found to support this assessment. However, we assessed the magnitude of the potential reduction in distribution by digitising the area mapped as ‘tropical swamp forest’ by Davis (1960) and comparing with a 2010 distribution map of mangroves produced by global mangrove watch (Bunting et al., 2018). The maps produced by Davis (1960) suggested that about 9,000 km^2 of the delta was considered swamp forest which, for the purposes of this assessment, is assumed to be Kanazo swamp forest. The 2010 mangrove distribution map indicates nearly all of this area has been deforested for agriculture, and only about 236 km^2 of the area remains as mangrove. Thus, our estimate of loss is 97.4% since the Davis maps were produced 1960 (A1), which we also use to represent the possible historical distribution of this ecosystem. The ecosystem is therefore assessed as **Critically Endangered**, with an upper bound of **Collapsed** (A1, A3) due to uncertainty in the remaining distribution.

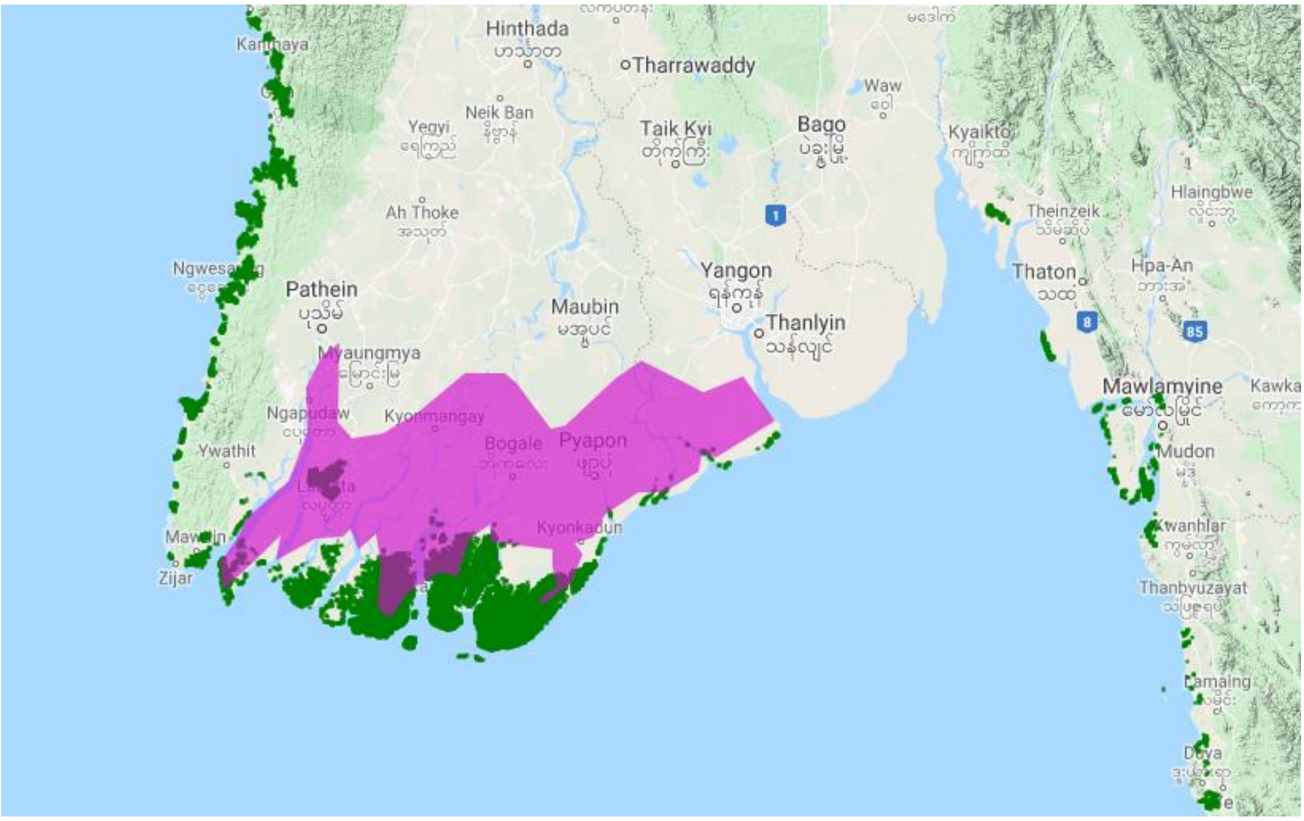


Figure 1. Distribution of 'tropical swamp forest' (pink) as mapped by Davis (1960) against mangroves (green) mapped by the Global Mangrove Watch (Bunting et al., 2018).

Criterion B

There is no distribution map for this ecosystem to serve as a basis for estimating AOO and EOO. **Data Deficient**.

Criterion C

Despite literature searches and discussion with coastal ecosystem experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite an extensive literature review and discussion with experts, no data suitable for assessing Criterion D were found. **Data Deficient.**

Criterion E

No model of Kanazo swamp forest ecosystems suitable for assessing Criterion E was identified, although models to assess the potential distribution of mangrove ecosystems do exist**. Not evaluated.**

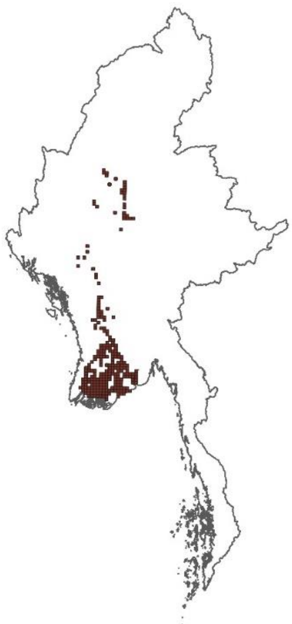
Central dry evergreen riparian forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Riparian forest, Swamp forest (Kress et al., 2003).
Biome Palustrine wetlands (TF1)
Functional group Tropical flooded forests and peat forests (TF1.1)
Global classification MMR-TF1.1.2
IUCN Status **Critically Endangered**

Description

An evergreen forest consisting of large rainforest trees that fringe the rivers and major streams of Myanmar's central dry zone. This ecosystem is heavily degraded and only small fragments in various states were found during our field studies. This ecosystem is likely to occur along major streams throughout the Ayeyarwady floodplain in Sagaing, Mandalay and possibly Bago. Buttressed trees are probably present in remnant vegetation (Davis, 1960), although much of these ecosystems are probably replaced now with village forests and plantings.

Distribution



Central dry evergreen riparian forest has not been mapped. However, it is likely to occur throughout the central dry zone along permanent waterways where remnant vegetation still exists. We estimated the broad extent of this ecosystem by buffering large rivers and streams (200 m) and identifying areas covered in trees. Although there is likely large error to this estimate due to including gardens and planted tree, we expect riparian forest to follow this broad distribution.

Characteristic native biota

This ecosystem occurs above the upper limit of mangrove forests (Stamp 1925). Tree species may include *Elaeocarpus hygrophilus* (Elaeocarpaceae), *Lagerstroemia speciosa* (Lythraceae), *Mangifera caloneura* (Anacardiaceae), *Calophyllum sp.* (Calophyllaceae), *Litsea nitida* and *Aglaia cucullata* (Meliaceae). A variety of cane species may also be present (Stamp 1925). No field work was conducted in this ecosystem type, so an extensive inventory of characteristic biota has not been developed.

Vines (particularly in family Fabaceae) are common in the understorey and in the tree canopies. The groundlayer includes abundant ferns and forbs.

Abiotic environment

This ecosystem occurs along permanent lowland waterways where there is a reliable year-round water supply. Typically, it occurs on riparian levees, where the forest is seasonally flooded during the monsoon, which occurs between May and October.

Key processes and interactions

Most species in this ecosystem are adapted to periodic flooding and frequent inundation is a key process that maintains this ecosystem. Floods transport and deposit woody debris and alluvium, promoting habitat diversity for birds and invertebrates, and replenishing soil nutrients. Floods may also create forest gaps enabling tree recruitment. Physical disturbance associated with floods can lead to changes in growth, community composition, light penetration and structure, altering the input of nutrients, organic matter and other detritus.

Major threats

This ecosystem has been extensively cleared for agriculture, access to waterways and urban development. Likely to have been heavily cut in historical times for timber, which could be used locally or floated downstream. The remaining fragments are very small, continually disturbed by human access and flooding, which promote the invasion of introduced plant species dispersed by floodwaters from disturbed areas upstream. Exotic trees such as *Samanea saman* (rain tree) are also extensively planted throughout the distribution of this ecosystem type.

Ecosystem collapse definition

Central dry evergreen riparian forest is considered collapsed when its area has declined to 0 km^2, all characteristic native species have been replaced by invasive or garden species, or when inundation events are completely removed from the system.

Assessment summary

We used a broad estimate of the former distribution of riparian forest and a recently developed dataset of tree cover to infer that up to 97.4% of this ecosystem has been lost since 1750. Remaining patches of this ecosystem are very small (often single remnant trees) and ongoing urbanisation and hardening of waterways is likely to be causing ongoing declines. **Critically Endangered.**

Assessment Information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**CR**
Criterion B	B1	**LC**
	B2	**EN**
	Subcriteria	**B2a(i)** **B2a(ii)** **B2a(iii)** **B2b**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

25th November 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Adam Duncan

Criterion A

We estimated the remaining extent of riparian forests in the Ayeyarwady delta floodplain using the 2018 GLAD tree cover data (Potapov et al., 2019). We assumed riparian forests occur within a 200 m buffer of rivers within the delta, which we identified in the ASTER river dataset (Nardi et al., 2019; NASA/METI/AIST/Japan Space systems, and U.S./Japan ASTER Science Team, 2019). To estimate the current extent of riparian forests, central dry evergreen riparian forest, we calculated the area of tree cover that met a canopy cover threshold of >= 20% within the 200 m buffer. This analysis suggested that the total remaining forested area within the 200 m buffer is 154.7 km^2. We do note that some of this forested area could be village forest or other managed forest types, but in the absence of any other data opted to use this as a broad estimate of riparian forest extent.

To assess historical losses of this ecosystem, we assumed that the full extent of the buffered area was once forested (605.2 km^2). We used this broad estimate of total riparian forest lost since around 1750 (97.4%) to assess criterion A3, which met criteria for Critically Endangered. **Critically Endangered.**

Criterion B

The ecosystem is broadly distributed throughout the central valley of Myanmar, although it now occurs in very small patches and frequently is represented by single remnant trees. Using the dataset described in the assessment of criterion A (existing tree cover within 200 m of streams in the central valley), AOO was estimated as 263 10 x 10 km grid cells and EOO 132,004 km^2. However, because single trees and very small patches are not considered to provide any risk spreading for this ecosystem, we applied the 1 per cent rule to assess Criterion B. Only 22 10 x 10 km grid cells had >1 km^2 of this ecosystem occurring within them, and the ecosystem is highly likely to be undergoing ongoing losses of extent (B2a(i)), hardening of waterways (B2a(ii)) and disruption of biotic processes (B1a(iii)). In addition, this ecosystem is likely to impacted by ongoing urbanisation and population growth along waterways within the next 20 years (B2b). **Endangered.**

Criterion C

Despite literature searches and discussion with ecosystem experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

We assessed the use of the recently developed Forest Landscape Integrity Index to assess the extent of degradation and its severity for this ecosystem type (Grantham et al., 2020). The index integrates maps of changes in forest connectivity with data on human pressures known to result in ecosystem degradation to compute a continuous value of contemporary forest degradation at high resolution. We assumed that the index is relative to a natural (historical) state, and therefore used it to assess criterion D3. However, owing to our lack of map data for this ecosystem (see Criterion A) and only a small proportion of this ecosystem covered by Forest Landscape Integrity Index Data (<2%; see table below), we assessed this ecosystem as **Least Concern**.

Ecosystem	Proportion of ecosystem extent > 90 % relative severity (%)	Proportion of ecosystem extent > 70 % relative severity (%)	Proportion of ecosystem extent > 50 % relative severity (%)	Proportion of ecosystem extent < 50 % relative severity (%)	Proportion of ecosystem with degradation data (%)
Extent and severity of biotic degradation (as mapped by Forest Landscape Integrity Index)	5.9	23.55	20.32	50.23	1.2
Status (D3)	LC	LC	LC	-	-

Criterion E

No model suitable for estimating the risk of collapse of this ecosystem was found. **Not Evaluated.**

Mixed delta scrub

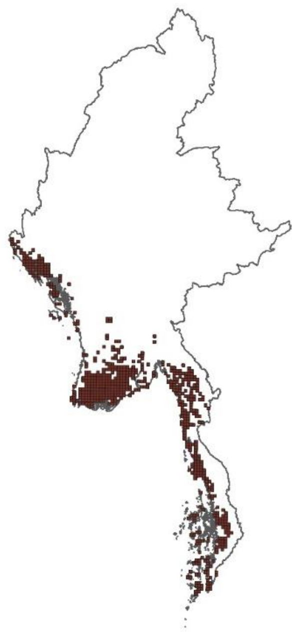
Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Byaik (Stamp, 1924b)
Biome Palustrine wetlands (TF1)
Functional group Tropical flooded forests and peat forests (TF1.1)
Global classification MMR-TF1.1.3
IUCN Status **Least Concern**

Description

Mixed delta scrub occurs above the upper limit of Kanazo swamps, on clay soil and where influence of salt water is largely absent. In this area it may be regularly flooded with freshwater. The shrub layer may be cane dominated, which forms very dense thickets, under a canopy of species including *Elaeocarpus hygrophils* and *Lagerstroemia speciosa*. Tree cover is relatively low, and thick grassy or cane thickets occur.

Distribution

Stamp (1925) states that this ecosystem occurs in association with Ayeyarwady Kanazo swamp forest and covers large areas of the Ayeyarwady delta and possibly parts of Tanintharyi. Our remote sensing analysis also suggests a non-mangrove coastal ecosystem with similar spectral properties on a coastal floodplain in northern Rakhine and scattered throughout the lowlands of Tanintharyi.



Characteristic native biota

This ecosystem occurs above the upper limit of mangrove forests (Stamp, 1924b). Tree species may include *Elaeocarpus hygrophilus*, *Lagerstroemia speciosa*, *Mangifera caloneura, Calphyllum sp., Litsea nitida* and *Amoora cucullata.* A variety of canes may also be present (Stamp, 1924b). No field work was conducted in this ecosystem type, so an extensive inventory of characteristic biota has not been developed.

Abiotic environment

Mixed delta scrub occurs in the low elevation coastal zone, at elevations above mangrove and tropical flooded forests, largely free from saltwater incursion.

It is thought to occur primarily on clay soils (Stamp, 1924b), and may be regularly flooded with freshwater during the monsoon. Mean annual temperature is 26.7° C, with highly seasonal patterns of rainfall averaging to around 3,000 mm per year.

Key processes and interactions

This ecosystem is likely to be flooded annually with freshwater during the monsoon. Soils may be waterlogged and generally poor. Potentially flooded infrequently by saltwater during storm surges.

Major threats

The majority of this ecosystem type has been cleared for the development of rice agriculture. It is likely that it was cut for fuelwood and timber, and in some areas this may still occur.

Ecosystem collapse definition

This ecosystem is considered collapsed when its area has declined to 0 km^2.

Assessment summary

Very little information was available for assessing this ecosystem. However, broad distribution maps developed from a remote sensing baseline suggested that this ecosystem is sufficiently broadly distributed to not meet any category thresholds for Criterion B. **Least Concern.**

Assessment Information

Criteria		Status
Criterion A	A1	DD
	A2a	DD
	A2b	DD
	A3	DD
Criterion B	B1	LC
	B2	LC
	Subcriteria	NA
	B3	LC
Criterion C	C1	DD
	C2a	DD
	C2b	DD
	C3	DD
Criterion D	D1	DD
	D2a	DD
	D2b	DD
	D3	DD
Criterion E	E	NE

Assessment Outcome

Least Concern

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

25th November 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

No information on the distribution and change of this ecosystem was found during extensive literature reviews. Owing to a lack of occurrence records to use as training data we were unable to model the present distribution of this ecosystem. **Data Deficient.**

Criterion B

We made a preliminary estimate of the distribution of this ecosystem by selecting all forested ecosystems that occur in the delta, which are not currently mapped as mangrove by the Global Mangrove Watch (Bunting et al., 2018). Area of Occupancy (AOO) was 644 10 x 10 km grid cells and Extent of Occurrence (EOO) was 363,006 km^2. The ecosystem was therefore assessed as **Least Concern**.

Criterion C

Despite literature searches and liaison with wetland experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite literature searches and liaison with wetland experts from Myanmar, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

No model was used to assess Criterion E. **Not Evaluated.**

Ayeyarwady floodplain wetlands

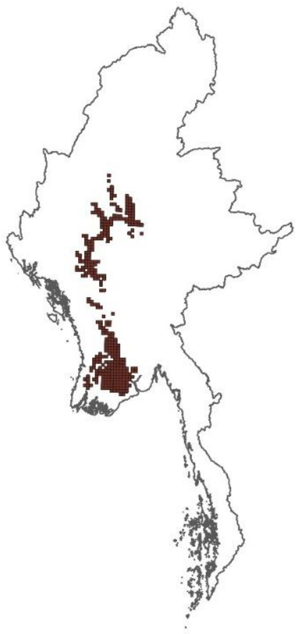
Authors Murray, N.J., Tizard, R., Keith, D.A.
Myanmar ecosystem names Wetlands, freshwater marsh
Biome Palustrine wetlands (TF1)
Functional group Seasonal floodplain marshes (TF1.4)
Global classification MMR-TF1.4.1
IUCN Status **Endangered**

Description

Ayeyarwady floodplain wetlands are shallow, often small, lakes that occur across the Ayeyarwady floodplain. They can be fully vegetated with non-woody vegetation or occur as patches of open water, and undergo regular seasonal drying and filling with monsoonal rain. Generally, they maintain some permanent water in at least part of their distribution throughout the year in most years.

Distribution

Scattered across the Ayeyarwady floodplain.



Characteristic native biota

Resident aquatic species are adapted to drying and wetting, enabling them to persist through extended dry periods. Grasses dominate including *Phragmtes australis*, other canegrasses, *Leersia* and *Cynodon dactylon*. Aquatic herbs such as *Persicaria* and *Ludwigia* are common. *Ottelia alismoides* is abundant in most permanent and seasonal wetland ecosystems across the Ayeyarwady floodplain (Kress et al., 2003).

There is a very high abundance and diversity of wetland bird species, including migratory birds, waterbirds and specialist passerines such as Jerdon's Babbler *Chrysomma altirostre* (VU), Asian Golden Weaver *Ploceus hypoxanthus* (NT), Streaked Weaver *Ploceus manyar,* and Yellow-throated Bunting *Emberiza elegans* (CR). Waterbird species include Lesser Whistling-duck *Dendrocygna javanica,* Cotton Pygmy-goose *Nettapus coromandelianus,* Little Grebe *Tachybaptus ruficollis,* Purple Swamphen *Porphyrio porphyrio,* Asian Openbill *Anastomus oscitans,* Glossy Ibis *Plegadis falcinellus,* Little Cormorant *Microcarbo niger,* Oriental Darter *Anhinga melanogaster* (NT), Pheasant-tailed Jacana *Hydrophasianus chirurgus,* Bronze-winged Jacana *Metopidius indicus* and Black-winged Kite *Elanus caeruleus.* There is also a very broad range of Herons (Ardeidae), Sandpipers, Snipes and Phalaropes (Scolopacidae). This ecosystem also supports an important population of Fishing Cat *Prionailurus viverrinus* (VU).

Abiotic environment

This ecosystem occurs as small wetland lakes in shallow depressions and catchments across the flat, sandy Ayeyarwady floodplain. During the monsoon, from May to October, these lakes fill with direct rainfall and from upstream and overbank flows, often increasing the size of open water patches by an order of magnitude. The pronounced dry season, lasting up to 6 months causes significant drying, with deeper wetlands acting as dry season refuge for a wide range of native fauna.

Key processes and interactions

Filling and drying between wet and dry seasons drive a highly variable ecosystem, with considerable variability in water quality, temperature, dissolved oxygen and nutrients. Depth is shallow (generally <2 m). Some wetlands may retain standing water year-round, within minimal depth in the dry season. They are often isolated for long periods of each year, and may be considerable variability between individual lakes across the distribution of this ecosystem.

Major threats

Conversion to rice paddies and aquaculture, and water extraction threaten this ecosystem throughout its range. Engineered drainage channels are also a key threat, diverting seasonal waterflows away from the wetlands.

Ecosystem collapse definition

This ecosystem is considered collapsed when its area has declined to 0 km^2, when regular inundation by freshwater ceases or all characteristic native biota (particularly plants) cease to occur.

Assessment summary

This ecosystem is widespread with EOO and AOO not meeting category thresholds for threatened. However, an assessment of present distribution (~2016) against an assumed historical distribution that approximates the same distribution as rice-paddies today, suggests that at least 70.1% of this ecosystem has been transformed to agriculture since the 1750s. The ecosystem therefore qualifies as **Endangered** under Criterion A3.

Assessment Information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**EN**
Criterion B	B1	**LC**
	B2	**LC**
	Subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Endangered

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

21st November 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Adam Duncan

Criterion A

To estimate the present distribution of Ayeyarwady floodplain wetlands, we first delineated the Ayeyarwady floodplain using GFPLAIN250 (Nardi et al., 2019). Within the floodplain area, we identified floodplain wetlands according to the following conditions:

- Were classified as water in our remote sensing classification;
- Were not identified as dams (Lehner et al., 2011);
- Did not occur within a 500 m of a river centreline, to avoid mapping rivers (NASA/METI/AIST/Japan Space systems, and U.S./Japan ASTER Science Team, 2019);
- Were not known to be under rice cultivation, which we identified using the NASA Cropland Extent data (412 km^2, Oliphant et al., 2017)

This process suggested that the total area of remaining floodplain wetlands in 2016 was 243 km^2 (811 km^2 identified as surface water, minus 156 km^2 identified as disappearing water, minus 412 km^2 identified as cropland).

To assess historical loss of this ecosystem type (A3), we assumed that the sum of rice paddies and remaining wetland ecosystems represents the full extent of this ecosystem prior to widespread rice cultivation catalysed by machinery, circa 1750. Since 1750, possibly before, rice paddies would have been developed in places that were flat and regularly flooded throughout the monsoon season; these areas are likely to have been a seasonally inundated floodplain wetland ecosystem (Torbick et al., 2017). We estimated the current extent of rice cultivation in the Ayeyarwady floodplain with the USGS croplands data (Oliphant et al., 2017).

After accounting for disappearing water and cropland extent, we estimate a 70.1% decline of this ecosystem since circa 1750. The ecosystem therefore qualifies as **Endangered** under A3.

Criterion B

This ecosystem has an AOO of 356 10 x 10 km grid cells and EOO of 128,014 km^2. **Least Concern**.

Criterion C

Despite literature searches and liaison with wetland experts from Myanmar, no data suitable for assessing criterion C were found. **Data Deficient.**

Criterion D

Despite literature searches and liaison with wetland experts from Myanmar, no data suitable for assessing criterion D were found. **Data Deficient.**

Criterion E

No model was used to assess Criterion E. **Not Evaluated.**

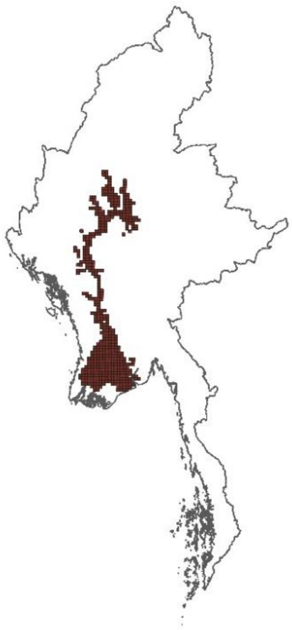
Central Ayeyarwady floodplain grasslands

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Seasonal marshes, rice paddies, seasonally inundated marshland
Biome Palustrine wetlands (TF1)
Functional group Seasonal floodplain marshes (TF1.4)
Global classification MMR-TF1.4.2
IUCN Status **Critically Endangered**

Description

Central Ayeyarwady floodplain grasslands have been almost entirely converted to rice paddies. It formerly occurred over vast areas of the flat Ayeyarwady floodplain where it was seasonally inundated with monsoonal rain between about May and October. Now, extensive engineering of levee banks and drainage channels have dramatically altered the majority of this ecosystem type. Floodplain grasslands lack woody vegetation and are completely dominated by grasses that persist through dry periods, although in some areas may remain nearly permanently inundated depending on rainfall patterns. In its natural state, this ecosystem supports a very high abundance of waterbirds, including bitterns, herons, egrets, ibis.

Distribution



Occurs across the majority of the mid- and elevated portions of the Ayeyarwady floodplain. Most have been converted to rice agriculture.

Characteristic native biota

Consists of mostly elephant grass *Saccharum arundinaceum*, (Kress et al., 2003), but also shorter grasses including *Paspalum* spp. and *Cynodon dactylon* (Poaceae). These seasonally wet grasslands support very high abundance and diversity of wetland bird species, including migratory birds, waterbirds and passerines such as Asian Golden Weaver *Ploceus hypoxanthus* (NT), Streaked Weaver *Ploceus manyar* and Red Avadavat *Amandava amandava*.

Waterbird species in the wet season include Lesser Whistling Duck *Dendrocygna javanica*, Asian Openbill *Anastomus oscitans*, Little Cormorant *Microcarbo niger*, Yellow Bittern *Ixobrychus sinansis*, Cinnamon Bittern *Ixobrychus cinnamomeus*, Intermediate Egret *Ardea intermedia*, and Little Egret *Egretta garzetta*.

Abiotic environment

Flat areas of the Ayeyarwady floodplain, slightly more elevated than Ayeyarwady foodplain wetlands and sometimes on slightly sloping surfaces enabling slow drainage. Regular inundation during the monsoonal months of May to October, primarily fed by local rainfall and overbank river flows from upstream, but drying rapidly over the dry season.

Key processes and interactions

Regular inundation is the primary driver of ecosystem dynamics in this system. A regular influx of water, along with nutrients and aquatic species, supports an assemblage of predator species including migratory waterbirds. During dry periods, mobile fauna migrate to nearby floodplain wetlands that tend to hold water throughout the year.

Major threats

Owing to frequent inundation by freshwater and occurring on flat landforms, the majority of this ecosystem is now converted to rice paddies. Invasion by exotic plants is promoted by eutrophication and soil disturbance. Increasing control of water flows throughout flat areas of Myanmar, including levees, dams and engineered river banks

Ecosystem collapse definition

This ecosystem is considered collapsed when its area has declined to 0 km^2, when regular inundation by freshwater ceases or all characteristic native biota (particularly plants) cease to occur.

Assessment summary

Satellite derived data on the extent of seasonal surface water in the Ayeyarwady floodplain suggests that only 190 km^2 of this ecosystem has not been converted to cropland. Assuming all seasonally inundated areas of the floodplain were once the Central Ayeyarwady floodplain grassland ecosystem, an estimate 92.4% of this ecosystem has now been converted to cropland. No data on other components of ecosystem degradation was available. Thus, the ecosystem is listed as **Critically Endangered** (A3).

Assessment Information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**CR**
Criterion B	B1	**LC**
	B2	**LC**
	Subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

25 November 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Adam Duncan

Criterion A

To estimate the present distribution of floodplain wetlands, we used the JRC Global Surface Water dataset, which is an analysis of surface water developed at 30-m resolution from Landsat data over a c. 30 year period (Pekel et al., 2016). To identify areas of floodplain grassland, we used the 'seasonal layer' of this dataset, which identifies pixels that are underwater for <12 months per year. This seasonal inundation of floodplain grasslands during the monsoon distinguishes this ecosystem from floodplain wetlands, which tend to maintain at least some permanent water throughout the dry season.

We clipped the seasonal water layer to the Ayeyarwady floodplain (Nardi et al., 2019) and removed any pixels mapped as rice, rivers or dams by global datasets (dams, Lehner et al., 2011; rivers, 500 m buffer to NASA/METI/AIST/Japan Space systems and U.S./Japan ASTER Science Team, 2019; rice, Oliphant et al., 2017). We also removed any pixels where water has not been recorded since 2010.

(1) Present extent of Central Ayeyarwady floodplain grassland = Landsat estimate of seasonal surface water – (water lost since 2016 + cropland)

(2) Present extent of Central Ayeyarwady floodplain grassland = 2,334.3 km^2 – (11.5 km^2 + 2,144 km^2)

(3) Present extent of Central Ayeyarwady floodplain grassland = 189.7 km^2.

The analysis suggested that the extent of the floodplain grassland ecosystem in 2016 was 189.7 km^2:

To assess historical loss of this ecosystem type, we assumed that any pixels identified as seasonal water in the Ayeyarwady floodplain was likely once a floodplain grassland ecosystem. Thus, the historical reduction in geographic distribution since 1750 is estimated to be:

(1) Historical reduction in geographic distribution = (water lost since 2016 + cropland) / (Landsat estimate of seasonal surface water) * 100

(2) Historical loss = (11.5 km^2 + 2,144 km^2) / (2,334.3 km^2) * 100

(3) Historical loss = 92.4%

This analysis suggests that 92.4% of this ecosystem has been converted to rice since around 1750. The ecosystem therefore qualifies as **Critically Endangered** under A3.

Criterion B

This ecosystem has an AOO of 504 10 x 10 km grid cells and EOO of 138,490 km^2. **Least Concern**.

Criterion C

Despite extensive literature searches and liaison with wetland experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite extensive reviews of the literature and input from wetland experts across Myanmar, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

No model was used to assess Criterion E. **Not Evaluated.**

Glacial Lakes

Author: Murray, N.J., Tiwari, A., Keith, D.A.
Myanmar ecosystem names High-altitude mountain lakes
Biome Lakes (F2)
Functional Group Freeze-thaw freshwater lakes (F2.4)
Global classification MMR-F2.4.1
IUCN Status **Least Concern**

Description

Glacial lakes are waterbodies formed by glaciation that are supplied with meltwater from snowpack (Allen et al., 2019). They tend to be located at the terminus, lateral area or beyond the mouth of a glacier (Yao et al., 2018). Two types of glacier lakes occur in Myanmar, those fed directly by glaciers and those that are non-glacier fed; both of these occur in valleys formed by glaciation (Maharjan et al., 2018). The Global Land Ice Measurements from Space (GLIMS) dataset holds 148 glacier records that are within or intersect Myanmar's border. According to the International Centre for Integrated Mountain Development (ICIMOD) reports, there are 267 glacier lakes in Myanmar of which 257 are bedrock-dammed, eight are moraine-dammed and 2 are classified as 'other' (Maharjan et al., 2018). In the Himalayas, the size distribution of glacial lakes is typically highly left-skewed as a result of the majority of lakes being smaller than 0.1 km^2 (Maharjan et al., 2018, Shukla et al., 2019).

Distribution

Glacial lakes occur in high mountain glacial valleys along the northwest and northeast border in Kachin State.

Characteristic native biota

Very little is known or published about the characteristic native biota and ecology of Myanmar's glacial lakes, and no information biota was found during the assessment process.

Abiotic environment

Glacial lakes occur in high mountain regions where low temperature and relatively higher precipitation support the formation of glaciers. In Myanmar, the average altitude of glacial lakes is 4,290 m (Maharjan et al., 2018). Their surface is wholly frozen during winter months and undergo thawing during the warmer months.

Lakes closer to glaciers are typically fed by glacial meltwater, whereas lakes further down the valley are fed by both glacier meltwater and rainfall, but all occur in steep-sided mountain valleys that have formed as a result of glaciation.

Key processes and interactions

Glacial lakes are fed by glacier meltwater, and are therefore highly sensitive to changes in climate. The higher confidence of warmer temperature increase and uncertainty of future precipitation patterns as indicated by IPCC (2014) would contribute to the formation of many glaciers in the high mountains of Myanmar. Increases in temperature can lead to increased volume of meltwater while glaciers decline in size, which can lead to an increased risk of glacial lake outburst floods (GLOFs) (Khanal et al., 2015).

Major threats

Climate change is the principal threat to glacial lakes. There is some evidence that both the number and size of glacial lakes are increasing in response to climate warming as a result of increased rates of glacial melt (Maharjan et al., 2018). The increasing size of glacial lakes in many areas has led to an increased risk of outburst floods, although the risk of these hazards in Myanmar has not been assessed.

Ecosystem collapse definition

Glacial lakes are considered ecologically collapsed when no water remains in the system. This may occur as inflows from glaciers cease, such as when a glacier melts completely, or after a GLOF event.

Assessment summary

Glacial lakes across the Himalaya are reported to be expanding in area in response to increased rates of glacier melt (Maharjan et al., 2018), contributed by warming temperature and higher elevation. However, there is a lack of data available to quantify these potential increases. Similarly, no adequate information was found to assess whether there has been a Myanmar-wide decline in extent. Despite being restricted to a small area in northern Myanmar, there was no evidence of ongoing decline in extent, environmental quality or biotic interactions (Criteria A-D). The ecosystem is therefore assessed as **Least Concern**.

ECOSYSTEM DESCRIPTION

Assessment Information

Criteria		Status
Criterion A	A1	**LC**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Least Concern

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

14th March 2019

Assessment Credits

Assessed by: Nicholas Murray, David Keith

Reviewed by: Hedley Grantham

Contributions by: Achyut Tiwari

Assessment Summary

Glacial lakes across the Himalaya are reported to be expanding in area in response to increased rates of glacier melt (Maharjan et al., 2018). No data were available to quantify these potential increases. Similarly, no information was found that suggests a Myanmar wide decline in extent. Despite being restricted to a small area in northern Myanmar, there was no evidence of ongoing decline in extent, environmental quality or biotic interactions (Criteria A-D). The ecosystem is therefore assessed as **Least Concern**.

Criterion A

No data was found that was suitable for assessing the change in extent of glacial lakes in Myanmar. It should be noted that with accelerated snow melt under climate warming, glacial lakes often increase in area, that are accompanied by an increased risk of catastrophic flood outburst events (Wang and Zhang, 2013). In the Koshi basin, Nepal, to the west of the study area. Shrestha et al. (2017) found that area of glacial lakes increased by 35% between 1977 and 2010. Similar remote sensing data and geospatial analysis methods are available for Myanmar, but have not been applied in this assessment (e.g. Richardson and Reynolds, 2000, King et al., 2018, Wang and Zhang, 2013). Nonetheless, given the similar environment and close proximity of the Koshi basin, similar rates and direction of change are likely in Myanmar and there is very unlikely to have been a decline in lake extent over the past 50 years (criterion A1). **Least Concern.,**

Criterion B

Distribution data provided by ICIMOD (Maharjan et al., 2018) indicates that the EOO of glacial lakes in Myanmar is 3,738 km^2 and AOO is 28 10 x 10 km^2 grid cells. However, there is no evidence of a continuing decline in spatial extent, environmental quality or disruption to biotic interactions. On the contrary, trends in glacial lakes to the west in Nepal suggest an increase in extent (Shrestha et al., 2017). Therefore, the ecosystem does not meet the criterion of evidence of an ongoing decline. **Least Concern**.

Criterion C

Despite an extensive literature review, no data was found that could be used to assess changes in the abiotic environment of glacial lakes over the time-periods specified in the IUCN Red List of Ecosystems categories and criteria. **Data Deficient.**

Criterion D

Despite an extensive literature review, no data that could be used to assess disruption of biotic processes over the time-periods. **Data Deficient.**

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

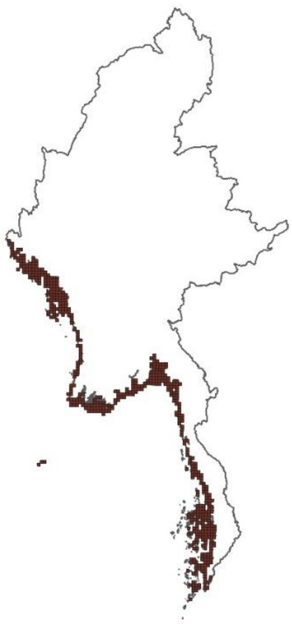
Coastal mudflat

Authors Murray, N.J., Mundkur, T.A.
Myanmar ecosystem names Tidal flat, mudflat
Biome Shoreline systems (MT1)
Functional group Muddy shores (TM1.2)
Global classification MMR-MT1.2.1
IUCN Status **Least Concern**

Description

Coastal mudflat is the low-sloping, sediment dominated ecosystem that occurs between the high and low spring tides (Dyer, 1998; Healy et al., 2002). In Myanmar, it occurs primarily as extensive unvegetated tidal flats of fine-grained silt and mud that occur in low energy coastal environments (Bird, 2010). Coastal mudflat is an exceptionally dynamic ecosystem, constantly changing in extent through the processes of sediment erosion, deposition and subsidence, compaction that are mostly driven by tidal dynamics and, to a lesser extent, the impacts of the annual monsoon (Murray et al., 2019).

Distribution



Coastal mudflat occurs along the majority of the Myanmar coastline, particularly in sheltered bays and along low energy, low-sloping regions of the coastline (MacKinnon et al., 2012). The flats are largest where there are large sediment outflows from nearby river systems, large macro-tidal ranges and extensive low-sloping areas of the coastal shelf. A 2016 estimate of the full extent of tidal flats in Myanmar from Landsat data indicated that approximately 3,316 km^2 of mudflat occurs along the Myanmar coastline, primarily in the Gulf of Martaban, Tanintharyi coastline and in the sheltered bays and inlets of the Rakhine coast (Murray et al., 2019).

An analysis of habitat for migratory shorebirds suggested that there are nine major coastal mudflat complexes that occur in all coastal provinces, including (from north to south), Nan Thar Island, Hunters Bay, Natkan, the Ayeyarwady Delta (east and west), the area around the outer islands, the Gulf of Mottama, Ahlat and the mudflats around Bilugyun Island

and, in the south, the Dawei River mouth and mudflats south of Myeik in Tanintharyi (Zöckler et al., 2014). Furthermore, the Myanmar directory of important wetlands indicates that most of the 19 coastal sites identified as being national and regionally important contain large areas of coastal mudflat (Zöckler et al., 2018).

Characteristic native biota

Coastal mudflat is typically non-vegetated, but the sediments contain microalgae and benthic diatoms, and potentially some seagrass in low abundance. They support numerous burrowing invertebrates, including clams, worms, shrimp, crabs and amphipods (Healy et al., 2002). Despite extensive literature searches, detailed information on diversity, relative abundance and community composition of the benthos in Myanmar was not found.

A wide variety of predatory vertebrates are dependent on this benthic biota, including birds, fish, aquatic and terrestrial mammals and reptiles. It supports a variety of resident, local migratory and long-distance waterbird species, including herons, egrets, storks, gulls and terns. Several of these are IUCN listed globally threatened species, including Spoon-billed Sandpiper *Calidris pygmea* (CR), Spotted Greenshank *Tringa guttifer* (EN) and Lesser Adjutant *Leptoptilos javanicus* (VU) (Naing 2006). The most visible and perhaps most studied biota in coastal mudflat is the seasonal influx of migratory shorebirds including Whimbrel *Numenius phaeopus*, Eurasian Curlew *Numenius arquata* (NT), and Curlew Sandpiper *Calidris ferruginea* (NT), that often occur in huge flocks of up to 40,000 individuals (Zockler et al., 2010; Zöckler et al., 2014). Migratory shorebirds are being monitored annually through the Asian Waterbird Census (Mundkur et al., 2017), surveys of the Spoon-billed Sandpiper Task Force and others.

Various species of marine mammals including dolphin feed in the coastal waters over the mudflats at high tide, especially, the Irrawaddy Dolphin *Orcaella brevirostris* (EN). Mammals like Crab-eating Macaque *Macaca fascicularis*, and Smooth Otter *Lutra perspicillata* (VU) and reptiles like Estuarine Crocodile (LC) are recorded in Meinmahlakyun Wildlife Sanctuary (also Ramsar Site and East Asian-Australasian Flyway Partnership Network Site) in the mouth of the Ayeyarwady Delta.

Abiotic environment

Coastal mudflats undergo regular tidal inundation, and therefore typically occur a few metres above and below mean sea-level, typically in low-sloping, low-energy coastal environments with relatively large tidal ranges (Murray et al., 2014). The sediments are continually waterlogged and maintain salinity levels approximately the same as seawater, increasing as waters evaporate at low tide. The low-energy abiotic environment is necessary to maintain their fine sediment substrate (Fan, 2012; Murray et al., 2015).

Key processes and interactions

Coastal mudflats maintain a fine balance of sediment erosion and deposition, whereby tidal currents and waves both deposit and erode fine-scale sediments (Fan, 2012). This process is generally governed by wave dynamics, the benthic community, sediment texture, sediment size, occurrence of vegetation (Healy et al., 2002; Adam, 2009). Regular tidal inundation regulates salinity levels within the sediment. Benthic biota support local bioturbation, biodeposition and biotransportation (Kuwae et al., 2012; Murray et al., 2015). Tidal ranges across Myanmar are typically about 2 m but increase to over 6 m in areas where there are major complexes of tidal flat, such as the Gulf of Martaban (Bird, 2010).

Major threats

Coastal mudflat in Myanmar is threatened by coastal development, harvesting, hunting and bycatch of native biota, sea-level rise, particularly where they are adjacent to coastal developments (MacKinnon et al., 2012; Kirwan and Megonigal, 2013; Murray et al., 2019). In many regions, housing is built directly on mudflat (Satake et al., 2006). Coastal vegetation loss has also been shown to threaten coastal mudflat ecosystems elsewhere in the world, with mechanistic models suggesting that it drives increased erosion and is therefore a plausible pathway to loss of area and ecosystem collapse (Mariotti and Fagherazzi, 2013; Weston, 2014). Although losses of tidal flats to reclamation and coastal development in Myanmar is estimated at <5% of their total extent since 1970, there is growing concern about the impact of proposed coastal developments, including port developments, infrastructure associated with oil and gas extraction, aquaculture and hydropower plants (MacKinnon et al., 2012; Zöckler et al., 2013; Mentaschi et al., 2018).

Ecosystem collapse definition

Coastal mudflats are collapsed when their area has declined to 0 km^2 (Criterion A; Murray et al., 2015) or when tidal inundation frequency has been reduced sufficiently to limit the ability for the ecosystem to support its characteristic native biota and processes (nominally to <2 tide-driven saltwater inundation events per month; Criterion D).

Assessment summary

The ecosystem is widely distributed along Myanmar's coastline and exceeds the range size thresholds in Criterion B. An analysis of time-series spatial data (Murray et al., 2019), which was only available for 26% of the Myanmar coastline (only central-northern Rakhine State), indicated tidal flats expanded between 1992 and 2016 at a rate of 3.36 % per year, meeting none of the reduction in geographic distribution criteria. No data or models were available to be used for assessing Criteria C, D or E. The ecosystem is therefore assessed as **Least Concern**.

Assessment Information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**NE**
	A2b	**LC**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	Subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

7th August 2019

Assessment Credits

Assessed by: Nicholas J. Murray, Taej A. Mundkur

Reviewed by: David Keith

Contributions by: Robert Tizard, Doug Watkins

Criterion A

We used a recently developed global time-series of the extent of tidal flats to analyse change in area over a 50 year period (Murray et al., 2019). Time-series data for Myanmar were only available for 26% of the Myanmar coastline, only within Rakhine state. In this area the data suggested tidal flats in Myanmar have expanded at a rate of 3.36% per year since 1992 (Figure 1). Murray et al. (2019) suggests this a result of increasing sediment flux to the coastal ocean as a result of land clearing (Murray et al., 2019). Owing to the relatively small proportion of the coastline for which there is time-series data, it is recommended that a national scale remote sensing analysis be conducted to estimate rates of change. Nevertheless, extrapolating this rate of change to a 50-year period (1992-2042) and assuming a proportional rate of change (Bland et al., 2017), we found that coastal mudflat does not meet the category thresholds for Criterion A2b, and is therefore **Least Concern**.

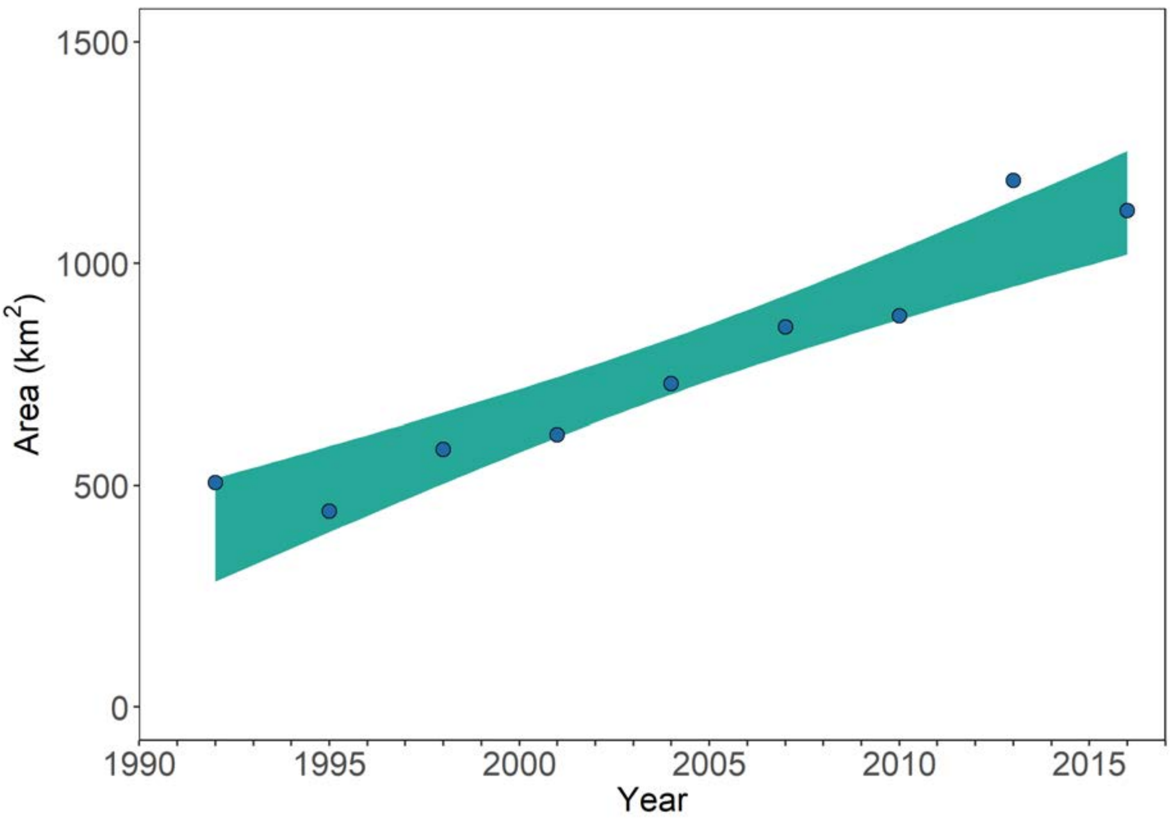


Figure 1. The area of coastal mudflats in Myanmar, derived from an analysis of time-series Landsat imagery. Source: (Murray et al., 2019).

Criterion B

Based on the 2016 map of coastal mudflat produced for Myanmar (Murray et al., 2019), Area of Occupancy (AOO) was 566 10 x 10 km grid cells and Extent of Occurrence (EOO) was 455,575 km^2. The ecosystem was therefore assessed as **Least Concern**.

Criterion C

Coastal mudflat ecosystems around the world are threatened by sea level rise, reduced sediment flux to the coastal zone and interruption of natural coastal processes (Murray et al., 2019). However, despite an extensive literature review and discussion with experts, no data suitable for assessing Criterion C were found. **Data Deficient.**

Criterion D

Despite an extensive literature review and discussion with experts, no data suitable for assessing Criterion D were found. Some data may exist under the Asian Waterbird Census, but this was not available at the time of the assessment. **Data Deficient.**

Criterion E

Several models exist that may allow a quantitative ecosystem model to be developed for Myanmar's coastal wetlands (Kirwan and Murray, 2007; Craft et al., 2008; Mariotti and Fagherazzi, 2013; Spencer et al., 2016; Schuerch et al., 2018). However, to our knowledge none of these have been adapted for coastal mudflat ecosystems, despite suitable spatial data being available. **Data Deficient.**

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Sandy shoreline

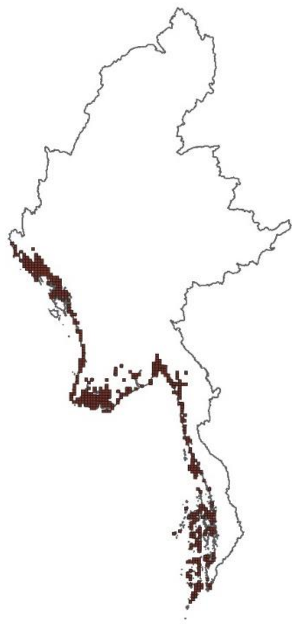
Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Beach, sandy beach
Biome Shoreline systems (MT1)
Functional Group Sandy shores (MT1.3)
Global classification MMR-MT1.3.1
IUCN Status **Least Concern**

Description

Sandy shoreline is an exposed, physically dynamic ecosystem consisting of a surf zone, sandy beach and sand dune systems (Brown and McLachlan, 2002). Owing to its unstable substrate, sandy shoreline is a dynamic ecosystem that is typically hostile to biota. Biotic assemblages are primarily structured by physical forces, which include erosion, deposition of sediment throughout the adjacent surf, beach and dune zones (Defeo et al., 2009; Luijendijk et al., 2018).

Distribution

In Myanmar, sandy shorelines are scattered along the coastlines of Rakhine State, Ayeyarwady Region, Mon State and Tanintharyi Region (Bird, 2010). Along the west-facing Rakhine and Ayeyrawady coasts, sandy beaches most commonly occur in large sandy bays, before changing to long sandy beaches of the south-facing Ayeyrawady coastline, and may be particularly extensive at low tide due to large tidal range (Bird, 2010). Sandy shorelines also occur over much of the open coast of Mon and Tanintharyi, where they are interspersed with coastal mudflat and tropical mangrove ecosystems (Zöckler et al., 2013). A recent analysis suggested less than 5% of the Myanmar coastline is sandy (Luijendijk et al., 2018).



Characteristic native biota

Sandy beaches in Myanmar harbour epifauna such as crabs, molluscs, isopods and amphipods, as well as infauna such as bivalves and polychaetes (Whitten and Damanik, 2012). These avoid desiccation and predation by burrowing. Most are detritivores or filter feeders. Diperterans and other insects live off wrack of seagrass and kelp deposited at the high water mark. Sandy beach ecosystems also support a wide variety resident and migratory birds, including migratory shorebirds, waterbirds, gulls and terns. There are five species of sea turtle that regularly breed on Myanmar's beaches, Olive Ridley *Lepoideochely olivacea* (VU), Loggerhead *Caretta caretta* (NT), Green *Chelonia mydas* (EN), Hawksbill *Eretmochelys imbricate* (CR) and Leatherback *Dermochelys coriacea* (CR) (Zöckler et al., 2013).

Abiotic environment

A dynamic environment with unstable coarse-grained substrates, sandy shoreline consists of accumulations of wave deposited particles that are sourced from inland erosion and sub-aqueous sedimentary environments. It may also include marine biogenic sources, such as coral skeletons, shells and sponges. They are found on higher-energy coastlines than mudflats. Sandy shorelines do not typically depend on any particular temperature or precipitation regime, although they tend to have a greater extent outside of tropical regions where low-energy coastlines frequently support extensive mangrove ecosystems (Luijendijk et al., 2018).

Key processes and interactions

The primary processes and interactions in sandy shoreline ecosystems relate to waves, tidal regimes and sediment availability (Whitten et al., 2000). Tidal regimes create strong desiccation gradients, which are tolerated through a range of behavioural and physiological traits in the fauna. Water movement and its influence on sediment deposition is a key factor that determines the physical states of sandy shorelines, which in turn governs the dynamics of the ecological community. Periodic storms cause major mobilisation of sand, which may take months or years for replacement.

Major threats

Sandy shoreline ecosystems in Myanmar may be threatened by coastal development, particularly for tourism resorts, quarrying sand for roads and construction, and beach erosion (Schlacher et al., 2007; Zöckler et al., 2013; Luijendijk et al., 2018). Vehicle use may be an increasing threat. Some may be subject to overharvest of invertebrates, such as bivalves.

Ecosystem collapse definition

Sandy shorelines are collapsed when their area has declined to 0 km^2.

Assessment summary

Although restricted to the coastline, this ecosystem is widely distributed and appears to be mostly stable in extent. Transect-based remote sensing assessments of beach erosion indicate that, despite a median net erosion of --0.044m/yr occurring across all sandy shoreline transects in Myanmar (n = 961 transects), no more than 19.5% of transects met erosion thresholds to qualify as threatened. The ecosystem is therefore assessed as **Least Concern**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**NA**
	B3	**LC**
Criterion C	C1	**LC**
	C2a	**LC**
	C2b	**LC**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Least Concern

Year Published

2019

Date Assessed

5th August 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Arjen Luijendijk

Criterion A

No time series data suitable for assessing the changing extent of sandy beach ecosystems was available for this assessment. **Data deficient.**

Criterion B

Although restricted to the narrow band of coastline, Myanmar's Sandy Shoreline ecosystem is sufficiently broadly distributed to not meet any category thresholds for Criterion B1 and B2 (AOO is 1,356 10 x 10 km grid cells and EOO is 548,470 km^2). Similarly, the number of threat defined locations is far greater than 5. **Least Concern.**

Criterion C

Coastal erosion was assessed using a transect-based remote sensing approach. Transects placed perpendicular to the coastline every 500-m along the 8,800 km long coastline, indicated that only ~5% of transects in Myanmar were detected as sandy (n = 961 transects; Luijendijk et al., 2018). Of these sandy shoreline transects, the median rate of change over a 33-yr period (1984-2016) was -0.044 m/yr (mean = -0.65, range = -91.5 to +76.8 m/yr, n = 961). For the purposes of this assessment, we assume the rates of change per year remain the same in the past (C1), present (C2) and future (C3) time periods (Bland et al., 2017).

Sandy shores (as depositional ecosystems) cannot maintain function under extreme rates of erosion, and hence were assumed to be collapsed when those rates are sustained. We therefore adopted a widely used extreme erosion rate of -5 m/yr as the collapse threshold for this ecosystem (Esteves and Finkl, 1998). Accordingly, the category thresholds for relative severity per transect were:

- VU <−1.5 m/yr (30% of collapse threshold)
- EN <−2.5 m/yr (50% of collapse threshold)
- CR <−4 m/yr (80% of collapse threshold)

The data indicates that 97 (10.1%) of transects met the threshold for Critically Endangered, 4.5% for Endangered and 4.9% for Vulnerable. In total, no more than 19.5% of transects were categorised in the >30% relative severity category. Therefore, the ecosystem does not meet any category thresholds for Criteria C1, C2a or C2b. No historical data was available for Criterion C3. **Least Concern.**

Criterion D

Despite targeted searches, no data suitable for assessing change in the Myanmar sandy shoreline ecosystem was found. The assessment is therefore Data Deficient for Criterion D1, D2a, D2b, D3. **Data Deficient.**

Criterion E

No model suitable for estimating the probability of ecosystem collapse over the next 50-100 years was found, and the ecosystem is assessed as Data Deficient for Criterion E. **Data Deficient.**

Tanintharyi coastal dune forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Coastal forest
Biome Supralittoral coastal systems (MT2)
Functional Group Coastal shrublands and grasslands (MT2.1)
Global classification MMR-MT2.1.1
IUCN Status **Data Deficient**

Description

Tanintharyi coastal dune forest occurs as a thin band of vegetation along the Tanintharyi coastline. The coastal dune forest primarily occurs in sheltered hind-dune locations where it tolerates salt spray, exposed conditions, and nutrient deficient soil (Stamp, 1924b). However, despite tolerating salt spray, it is beyond the influence of tidal inundation and cannot occur in areas regularly inundated by high tides.

Distribution

In Tanintharyi, coastal dune forest occurs as a thin strip behind sandy beaches on the summit of foredunes and sandbars, scattered along the entire Tanintharyi coastline (Stamp, 1924b; Kress et al., 2003). Its distribution typically follows the distribution of sandy beaches. No map data is available for this ecosystem.

Characteristic native biota

Stamp (1924b) reports that Taninthyari coastal dune forest is dominated by *Casuarina equisetifolia*, which is more abundant than any other tree species. The groundlayer includes the creeping *Ipomea pes-caprae* and salt-tolerant coastal grasses (Stamp, 1924b; Kress et al., 2003). *Casuarina* is generally more abundant than Coconut Palm *Cocos nucifera* in this ecosystem.

Abiotic environment

Coastal dune forest occurs in sandy soils directly adjacent to sandy shorelines, saltmarsh and coastal mudflat. This pioneering zone is exposed to coastal winds, sand deposition and salt spray. It occurs above the highest spring tide line due to an intolerance of saltwater inundation (Stamp, 1924b).

Key processes and interactions

Rapidly draining sandy soils, which may be unstable and easily mobilised, contribute to the dry, harsh environment that this ecosystem occupies. Few grazing animals are likely present, with most dispersal being driven by coastal winds and marine currents. Periodic storms disturb vegetation cover and mobilise sands, fueling continual dynamics and turnover in the ecosystem.

Major threats

This ecosystem is threatened by the expansion of agriculture, particularly for rice farming, rubber plantations, coconut farms and oil palm. Coastal development for the construction of roads and establishment of coastal resorts may also threaten this ecosystem.

Ecosystem collapse definition

This ecosystem is collapsed when total ecosystem area has declined to 0 km^2.

Assessment summary

Tanintharyi coastal dune forest is listed as Data Deficient because of a lack of information on its distribution, change in area over time and the impact of threatening processes. It is thought to occur across much of the Tanintharyi coastline but studies targeting its distribution and change are required to conduct a detailed red list of ecosystems assessment of this ecosystem. **Data Deficient.**

ECOSYSTEM DESCRIPTION

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

5th August 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

There is no information on the change in distribution of this ecosystem. **Data Deficient.**

Criterion B

No information on the distribution of this ecosystem was found during this assessment. **Data Deficient.**

Criterion C

Despite exhaustive reviews of the literature and discussion with coastal ecosystem experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite exhaustive reviews of the literature and discussion with coastal ecosystem experts from Myanmar, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

No model of coastal dune forests suitable for assessing Criterion E was identified. **Data Deficient.**

Rakhine coastal dune forest

Authors Murray, N.J., Keith, D.A.
Myanmar ecosystem names Coastal forest
Biome Supralittoral coastal systems (MT2)
Functional Group Coastal shrublands and grasslands (MT2.1)
Global classification MMR-MT2.1.2
IUCN Status **Data Deficient**

Description

Rakhine Coastal dune forests occur as a thin band of trees and shrubs, mostly <100 m wide, behind sandy shoreline ecosystems across South-East Asia (Whitten and Damanik, 2012). In this part of the coastal zone, coastal dune forest must tolerate salt spray, seasonally dry conditions, and nutrient deficient soil, but cannot tolerate continued inundation during the tidal cycle. They therefore occur beyond the influence of tides primarily on sandy soils.

Distribution

Rakhine coastal dune forest occurs adjacent to sandy beaches along much of the Rakhine and Ayeyarwardy coastline that fringes the Bay of Bengal (Stamp, 1924b). The distribution of this ecosystem type therefore closely follows the distribution of sandy shorelines and coastal mudflats, mainly along the western coast of Ayeyarwady province. No map data is available for this ecosystem.

Characteristic native biota

Characteristic species include coconut palm *Cocos nucifera, Terminalia* sp, Fabaceae spp*.,* and scattered *Casuarina equisetifolia* (rarely dominant as in Tanintharyi, Kress et al., 2003). Introduced tree species are common, including *Tamarindus indica* and *Samanea saman* (raintree). The shrub layer includes *Gardenia* spp. and *Fabaeae* spp. a ground layer of creeping species including *Ipomea pes-caprae* and *Fabaceae* spp. and herbs of the Asteraceae and Solanaceae.

Abiotic environment

Coastal dune forest occurs in sandy soils and dunes directly adjacent to sandy shoreline ecosystems and coastal mudflats (Whitten and Damanik, 2012). This pioneering zone is highly exposed to coastal winds, sand deposition and salt

spray. They occur above the highest spring tide line. Moving away from the coast, the coastal dune forest would typically transition into savanna and semi-evergreen forest ecosystems further inland or wetlands in adjacent depressions. However, owing to extensive deforestation, the remaining coastal dune forests occurring in Rakhine are typically bounded by cropland (particularly rice and coconut) that has been developed along the flat coastal plain.

Key processes and interactions

This ecosystem occurs in harsh, salty coastal environments behind dynamic sandy beaches. It occurs in areas of fast-draining and highly mobile sandy substrates, where an ability to tolerate hot and dry conditions enables this ecosystem to persist. Periodic storms cause physical disturbance to vegetation and occasionally result in storm surge, inundating the soils with salt water, which may kill some of the standing vegetation.

Major threats

Threats to Rakhine coastal dune forest are mostly related to the expansion of agriculture and coastal development, including residential and tourist infrastructure across Rakhine's coastal zone. The incursion of rice farming and other agricultural activities may lead to deforestation of this ecosystem type. Physical disturbance promotes invasion of introduced plant species. Similarly, coastal development for roads, resorts and urban expansion also threaten this ecosystem type. Sea level rise could threaten this ecosystem, but its potential impacts are considered highly uncertain due to a lack of information on the distribution and dynamics of this ecosystem.

Ecosystem collapse definition

This ecosystem is collapsed when total ecosystem area has declined to 0 km^2.

Assessment summary

Rakhine coastal dune forest is listed as Data Deficient because of a lack of information on its distribution, change in area over time and the impact of threatening processes. It is thought to be scattered across much of the Rakhine coastline but studies targeting its distribution and change are required to fill a range of knowledge gaps regarding the status of this ecosystem. **Data Deficient.**

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**NA**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

5th August 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

There is no information on the change in distribution of this ecosystem and no maps suitable for assessing the criteria were found. **Data Deficient.**

Criterion B

No maps of this ecosystem were found during the assessment, and therefore Criterion C is assessed as **Data Deficient.**

Criterion C

Despite reviews of the literature and discussion with coastal ecosystem experts from Myanmar, no data suitable for assessing criterion C was found. **Data Deficient.**

Criterion D

Despite reviews of the literature and discussion with coastal ecosystem experts from Myanmar, no data suitable for assessing criterion D was found. **Data Deficient.**

Criterion E

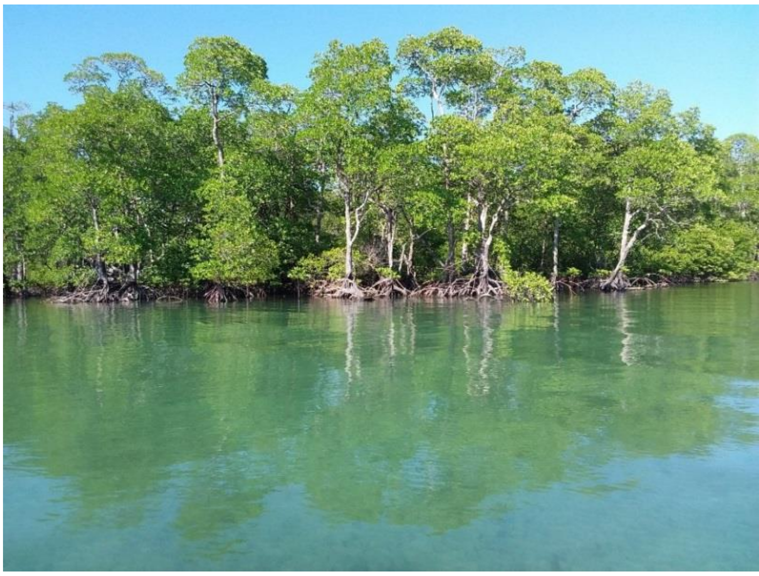
No model of coastal dune forests suitable for assessing Criterion E was identified. **Data Deficient.**

Tanintharyi mangrove forest

Author: Murray, N.J., Worthington, T.A., Keith, D.A.
Myanmar ecosystem names Mangroves, tropical mangrove forest
Biome Brackish tidal systems (MFT1)
Functional Group Intertidal forests and shrublands (MFT1.2)
Global classification MMR-MFT1.2.1
IUCN Status **Least Concern (Least Concern – Near Threatened)**

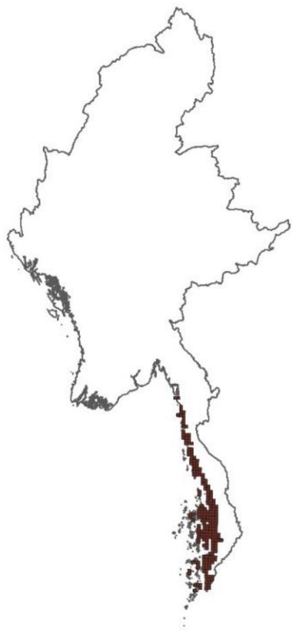
Description

Myanmar tropical mangrove forests have a closed canopy that are predominantly evergreen. Tanintharyi mangrove forests occur from 9°N up to approximately latitude 16°N. They typically occur along open-coast and sheltered areas of soft-sediment (Bird, 2010). In Tanintharyi, mangroves are estimated to occupy approximately 2,500 km^2 (Gaw et al., 2018).



Distribution

This ecosystem occurs along the west facing coastline of Tanintharyi, and are delimited in this assessment by the Salween (Thanlwin) River to the north in southern Mon State.



Characteristic native biota

These are the most botanically diverse mangrove forests in Myanmar. WWF ecoregion description lists *Rhizophora mucronata, Rhizophera apiculata*, *Sonneratia caseolaris*, *Ceriops tegal*, *Xyloxarpus granatum*, *Avicennia officinalis*, and *Bruguiera spp.* as key species in this ecosystem type. The diversity of tree species makes the canopy structurally complex. Stilt roots create additional structural complexity beneath the canopy. There is a small group of mangrove specialized breeding birds including Brown-winged Kingfisher *Pelargopsis amauroptera* (NT), Ruddy Kingfisher *Halcyon coromanda*, Mangrove Pitta *Pitta megarhyncha* (NT), Golden-bellied Gerygone *Gerygone sulphurea*, and Mangrove Whistler *Pachycephala cinereal* (Rasmussen and Anderton, 2012). Migratory shorebirds may also be present in this ecosystem, utilising vegetation for roosting habitat and foraging among the aerial roots and pneumatophores at low tide (Hogarth, 2015).

Abiotic environment

Tanintharyi mangrove forests occur in low energy coastal areas where soft sediments are regularly inundated throughout the tidal cycle. Regular tidal inundation leads to a highly saline environment.

Key processes and interactions

Tidal inundation is the most important process occurring in tropical mangrove ecosystems. The regular influx of saline water serves to mobilise detritus (leaf litter etc.), which is broken down by macro- and micro-organisms (Whitten and Damanik, 2012).

These macro and microorganisms form an important food source for crustaceans and fish, which in turn are important food sources for larger predators.

The mangroves also play a significant role in ecosystem functioning, serving as nursery habitat for fish, influencing sediment dynamics and producing organic matter (Figure 1).

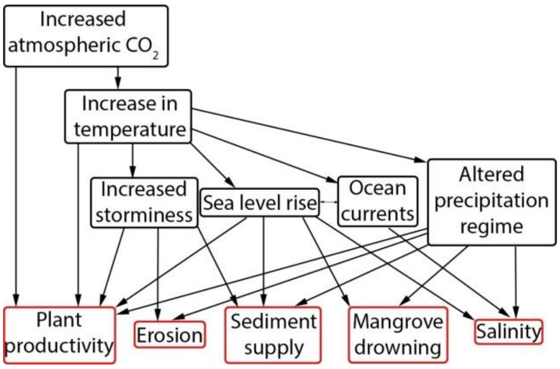


Figure 1. Conceptual model of the impacts of climate change on mangrove ecosystems. Note that in sea level rise is likely to lead to erosion of sediment patches on shingle and, with an absence of sediment replenishment, drowning of mangrove ecosystems. Source: (Ward et al., 2016)

Major threats

Palm oil is emerging as a key threat to tropical mangrove forest in Myanmar, where suitable soil and climatic conditions exist for the industry to expand (Gaw et al., 2018). Indeed, a recent remote sensing analysis showed that 432 km^2 of mangroves in Tanintharyi were transformed into oil palm plantation between 1995 and 2015 (De Alban et al., 2018). Myanmar has set an ambitious target to become self-sufficient in palm oil production, and Tanintharyi is the only region suitable for palm oil production (Friess et al., 2019). Other threats include overharvesting for charcoal and firewood and deforestation for rice production, aquaculture and infrastructure. Recent reports suggest that sand mining is rapidly increasing in the region, which may cause the erosion of estuarine mangroves.

Ecosystem collapse definition

We follow the collapse definition of Marshall et al. (2018), where an absence of true mangrove species signifies transition to a collapsed or novel ecosystem. Therefore, this system is considered collapsed when the distribution of mangroves declines to 0 km^2.

Assessment summary

Although Tanintharyi mangrove forests are considered fairly stable, they have undergone recent deforestation, primarily as a result of agricultural development for palm oil, aquaculture and rice production, their losses do not yet meet category thresholds for a reduction in geographic distribution. Similarly, models of biotic and abiotic degradation suggest the ecosystem does not meet any category thresholds for Criteria C or D. The ecosystem is assessed as **Least Concern** under A1**.** However, net stability of mangrove extent and functionality measures hides substantial gains and losses (Gaw et al., 2018), highlighting issues with using one area metric alone. For example, 384 km^2 of mangroves were lost between 1989 and 2014, but this was offset by gains of 302 km^2. Substantial gains are seen in major estuaries such as the Dawei River, where land use change has increased fluvial sedimentation, and mangroves have colonised newly emerged mudbanks in the estuary (Gaw et al., 2018). These young mangrove forests are likely to be structurally simpler and less diverse than long established forests that are undergoing declines in extent through land use intensification. Thus, if we assume compensated losses slow, due to lack of accommodation space or intensifying coastal land use (particularly oil palm), the ecosystem is listed as **Near Threatened** under A2a.

Assessment Information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**LC (LC-NT)**
	A2b	**LC**
	A3	**DD**
Criterion B	B1	**LC**
	B2	**LC**
	subcriteria	**-**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**LC**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC**
	D3	**DD**
Criterion E	E	**NE**

Assessment Outcome

Least Concern – Near Threatened

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

12th July 2019

Assessment Credits

Assessed by: Nicholas Murray, Thomas Worthington

Reviewed by: David A. Keith

Contributions by: Dan Friess, Minerva Singh

Criterion A

Time-series remote sensing data for the state of Tanintharyi, where the majority of tropical mangrove forests occur (the remainder occur in Mon State), show that net losses of mangrove cover were relatively low. A recent analysis by Gaw et al., (2018) indicated that only 3.2% of tropical mangrove forest was lost in Tanintharyi Region over a 25 year period. This relatively low estimate of change, particularly compared to Myanmar's other mangrove ecosystems, is assumed to be similar in Mon State and therefore low across the extent of this ecosystem. The low net losses of Tanintharyi mangrove forests (about 0.1 per cent per year) is considered a result of increases in mangrove area offsetting those losses caused by deforestation (Gaw et al., 2018). These increases were due to forest clearing in stream catchments, which resulted in sedimentation of estuaries, with these new substrates colonised by mangroves, offsetting the direct removal of mangroves for palm oil plantations and sand mining. This rate of loss across the ecosystem does not meet any category thresholds for the past 50 years due to compensatory effects in recent years, suggesting **Least Concern** status for criterion A2a and A2b. However, these compensatory effects appear unlikely to continue into the future and we therefore consider this ecosystem **Near Threatened**.

Criterion B

AOO and EOO were measured as 224 10 x 10 km grid cells and 52,577 km^2, respectively. The ecosystem is assessed as Least Concern under Criterion B1 and B2. **Least Concern.**

Criterion C

A model that synthesises the effects of sediment supply and accelerating rates of sea level rise was used to assess the likely impacts of sea level rise (SLR) on the ecosystem (Lovelock et al., 2015). The model has several known limitations and assumptions, including that no landward migration can occur, and that sea level rise is uniform across the world. However, the model suggests Tanintharyi Mangrove Forests are likely to be robust to SLR with little or no areas of the ecosystem predicted to become submerged by 2060. Specifically, the model indicates that less than 1% under all scenarios may become submerged by 2060. This is because suspended sediment concentrations are relatively high along this coastline, allowing mangrove to keep pace with moderate rates of SLR. Even assuming a relative severity of this impact to be >80%, because no mangrove recruitment can occur in a submerged system, the ecosystem remains **Least Concern** under C2b. **Least Concern**.

Criterion D

We used the same approach for assessing criterion D as for Ayeyarwady delta and Rakhine mangrove ecosystems. Twelve vegetation indices (measures of NDVI, SAVI, EVI and NDMI) that represent vegetation greenness and vegetation moisture content were used to assess the extent of mangrove degradation under Criterion D (Worthington and Spalding, 2018). Individual pixels that are (i) currently mapped as mangrove, and (ii) decreased in the majority of index values (at least 10 of the 12 indices) by >40% relative to the reference time period (pre the year 2000) were considered degraded. We assumed that meeting these criteria indicated that degradation, such as mangrove die-back or small-scale cutting for firewood, had occurred.

This analysis suggested that, over an 18 year period since 2000, only 0.7% of the 2,697 km^2 Tanintharyi mangrove ecosystem met the criteria to be classified as degraded. Extrapolating to the 50-year time frame required in IUCN Red List of Ecosystems assessments suggests that less than 30% of the ecosystem will meet the category thresholds for Criterion D. This result agrees with other studies of mangrove condition in Tanintharyi, which suggest that mangroves that have been degraded can re-establish themselves on newly accreted mud banks and offset the process of degradation (Gaw et al., 2018). The ecosystem is therefore assessed as **Least Concern** under Criterion D2b. **Least Concern.**

Criterion E

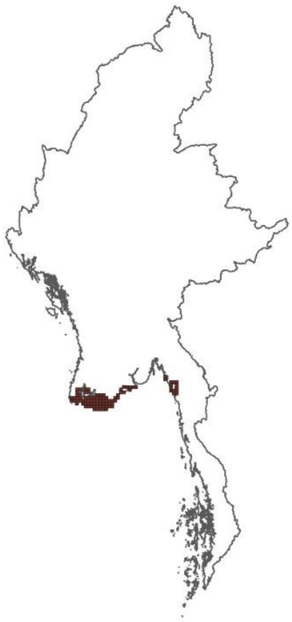
No model was used to quantitatively assess the risk of ecosystem collapse for this ecosystem. **Not Evaluated.**

Ayeyarwady delta mangrove forest

Authors: Murray, N.J., Worthington, T.A., Keith, D.A.
Myanmar ecosystem names Mangroves, delta mangrove forest, Irrawaddy mangrove forest
Biome Brackish tidal systems (MFT1)
Functional Group Intertidal forests and shrublands (MFT1.2)
Global classification MMR-MFT1.2.2
IUCN Status **Endangered**

Description

Ayeyarwady delta mangrove forest is dominated by trees tolerant of salinity, tidal inundation and substrate anoxia. Salt tolerance is conferred by osmotic regulation and salt excretion. Specialised structure such as aerial stilt roots, lenticels and aerenchymatous tissues transport oxygen to roots. High primary productivity and litter fall sustains a web of detritivores and their predators. At high tide, mangroves are important nursery grounds for juvenile fish (Spalding, 2001).



Distribution

Ayeyarwady delta mangrove forest occurs in the intertidal zone across the Ayeyarwady Delta, which is defined by Cape Negrais in the west and the Thanlwin (Salween) River in the east. This ecosystem was originally the largest tract of mangroves in Myanmar (Webb et al., 2014). The earliest reliable area estimate (1978) for the total mangrove distribution in the Ayeyarwady Delta was 2,623 km^2 (Webb et al., 2014), though other accounts suggest that mangroves may have covered 2,345 km^2 in 1954 (Oo, 2002).

Characteristic native biota

Complex forest composed of trees from multiple taxa including *Rhizophora apiculata*, *Avicennia officinalis, Bruguiera sexangular, Excoecaria agallocha* and *Sonneratia caseolaris*. Up to 33 mangrove species have been recorded in this system (U Win Maung, pers. comm.) out of a total of 34 recorded nationally (Aye et al., 2019). *Nypa fruticans* may occur in the upper intertidal zone where there is more freshwater influence, although its presence may have increased in response to human disturbance. The area provides habitat for several threatened vertebrates, including Irrawaddy dolphin *Orcaella brevirostris* (EN), Estuarine crocodile *Crocodylus porosus* and Mangrove Terrapin *Batagur baska* (CR). There is a small group of mangrove specialized breeding birds including Brown-winged Kingfisher *Pelargopsis amauroptera* (NT), Ruddy Kingfisher *Halcyon coromanda*, Mangrove Pitta *Pitta megarhyncha* (NT), and Mangrove Whistler *Pachycephala cinereal* (Rasmussen and Anderton, 2012). Migratory shorebirds may also be present in this ecosystem, utilising vegetation for roosting habitat and foraging among the aerial roots and pneumatophores at low tide (Hogarth, 2015). There are relatively few mammals in the area but Smooth Otter *Lutrogale perspicillata* (VU) and Fishing Cat *Prionailurus viverrinus* (VU) have both been recorded (Francis, 2019).

Abiotic environment

Mangroves occur in coastal areas where they are inundated by seawater during the diurnal tidal cycle. This high salinity environment generally occurs along the coastal fringe, and is important for reducing incursion of other non-halophytic vascular plants (Marshall et al., 2018). Being well adapted to highly saline environments, mangroves also tend to occur in anaerobic and waterlogged soil, although not exclusively (Hogarth, 2015).

Key processes and interactions

The mangrove trees drive most of the processes and functions in this ecosystem, providing nursery habitat for fish and shrimp, controlling and responding to sedimentation processes and generating organic matter that contribute to carbon and nutrient cycles (Marshall et al., 2018). In general, mangrove distribution is constrained by cool temperatures (Figure 1), but these are not limiting in Myanmar. They are also regulated by wave action, tides and sea level (Figure 1).

Major threats

The Ayeyarwady Delta has undergone extensive deforestation as a result of high human population (around 8 million people) and widespread agricultural development (Oo, 2002; Webb et al., 2014). The delta region hosts around 14% of Myanmar's population and is responsible for around 35% of the country's rice production (Webb et al., 2014). Rice is thus a well-documented threat to mangroves in the region, primarily driving widespread deforestation and modification of hydrology (Webb et al., 2014; Richards and Freiss, 2016). Mangrove deforestation as a result of aquaculture, salt farming and fuelwood extraction have also been documented throughout the Ayeyarwady delta region (Webb et al., 2014; De Alban et al., 2020).

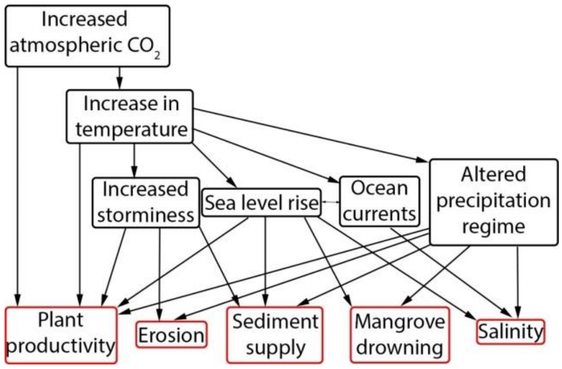


Figure 1. Conceptual model of the impacts of climate change on mangrove ecosystems. Note that in sea level rise is likely to lead to erosion of sediment patches on shingle and, with an absence of sediment replenishment, drowning of mangrove ecosystems. Source: (Ward et al., 2016)

Ecosystem collapse definition

We follow the collapse definition of Marshall et al. (2018), where an absence of true mangrove species signifies transition to a collapsed or novel ecosystem. Therefore, this system is considered collapsed when the distribution of mangroves declines to 0 km^2. This is a conservative threshold because established trees may persist for some years after the site becomes unsuitable for reproduction and recruitment.

Assessment summary

Published estimates of the reduction in geographic distribution suggest that extensive losses of this ecosystem have occurred. Using rates of change from a long-term time-series remote sensing dataset suggests that a decrease in extent of around 79.5% is expected over a 50 year period between 1978 and 2028. However, there are challenges in linear extrapolations from historical data into the future, since the Ayeyarwady is undergoing rapid socioeconomic changes which may mean a non-linear response in the future. Even with this uncertainty, the ecosystem qualifies as **Endangered** under criterion A2b, and just under the threshold for Critically Endangered. **Endangered.**

Assessment Information

Criteria		Status
Criterion A	A1	**EN**
	A2a	**DD**
	A2b	**EN**
	A3	**EN**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i)** **B1b**
	B3	**LC**
Criterion C	C1	**LC**
	C2a	**DD**
	C2b	**LC**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC (LC-VU)**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Endangered

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

12th July 2019

Assessment Credits

Assessed by: Nicholas Murray, Thomas Worthington

Reviewed by: David Keith

Contributions by: Dan Freiss, Calvin Lee, Ruth Reef, Cath Lovelock

Criterion A

Oo (2002) reported that up to around 1924, mangroves in Myanmar remained in a relatively undisturbed state, before being over-exploited during the second world war to satisfy military demands for timber. According to Oo (2002), the total area of mangroves forests in the Ayeyarwady Delta was estimated to be 2345.15 km^2 (234,515 ha) in 1954, declining to 1786.42 km^2 in 1984. The source data used by Oo (2002) for these estimates is not known.

Other estimates suggesting a decline from 2,623 km^2 in 1978 to 938 km^2 in 2011 were made from Landsat MSS, TM, and ETM by Webb et al. (2014). Assuming the methods of the two studies produced compatible estimates, yields an annualised proportional rate of decline of ln(938/2345)/(2011-1954) = 0.016 over the 57 years 1954 to 2011. If the methods are not compatible, the annualised proportional rate of decline based on Webb's et al. (2014) data alone is ln(938/2623)/(2011-1978) = 0.031 over the 33 years 1978 to 2011. Assuming similar rates of decline occurred between 1969 and 2019, the estimated decline in extent of Ayeyarwady mangrove forest over the past 50 years is 55-79% (best estimate 67%), indicating **Endangered** status under criterion A1.

A linear projection suggested that areas outside of protected areas, which protect around 14.6% of the Ayeyarwady's mangroves (in 2011), could be completely deforested by 2019 (worst-case scenario) and 2044 (best-case scenario). However, future changes in extent of Ayeyarwady mangrove forest are likely to be non-linear, given uncertainty in socio-economic scenarios for Myanmar in the coming years. Factors such as commitments to conservation initiatives, increasing preservation of remaining patches, development of dams in the Ayeyarwady catchment, population trajectories in the delta region and changing frequency and intensity of typhoons under climate change could all affect the extent of delta mangroves.

Based on analysis of Landsat MSS, TM, and ETM + data, the Ayeyarwady Delta Mangrove Forest was reported to have declined from 2,623 km^2 in 1978 to 938 km^2 in 2011 (Webb et al., 2014). This equates to a 64.2% decline at a rate of 3.1% per year over the 33 year period (n = 6 area estimates, Figure 2). Assuming a proportional rate of decline (Lee et al., 2019; Lee and Murray, 2017), the ecosystem is expected to decline by 78.9% between 1978 and 2028, and is therefore assessed as **Endangered** under A2b.

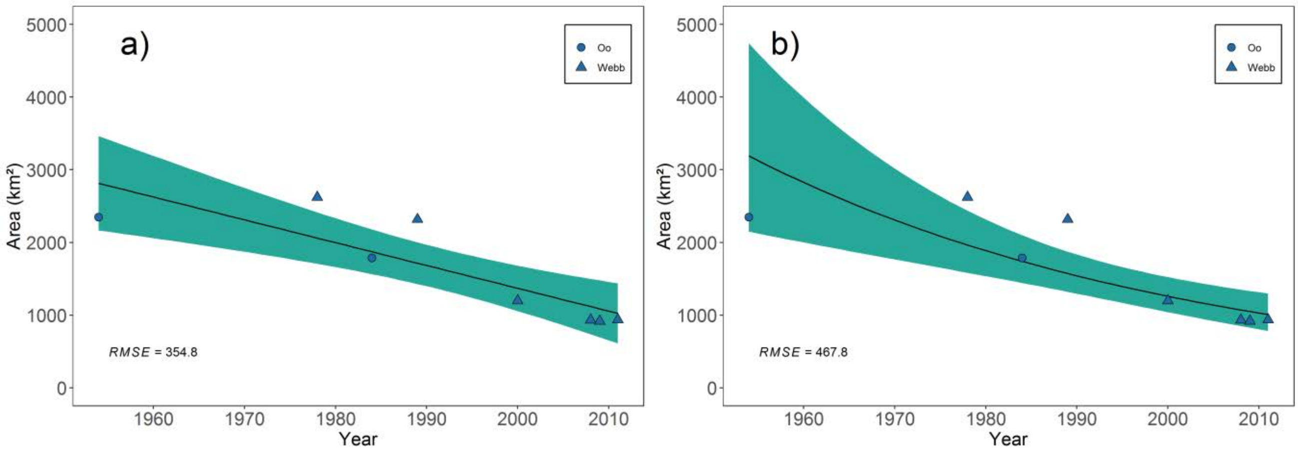


Figure 2. The area of Ayeyarwady delta mangrove forest in Myanmar with 95% confidence intervals. Points in circle are reported by Oo (2002) and points in triangle are reported by Webb et al. (2014). a) Fitting a linear model to all available data; b) Fitting an exponential model to all available data.

Aung et al. (2013) suggested that the Ayeyarwady delta mangrove forest has been reduced to half of their original extent. However, the underlying data was not consistent with this estimate. Estimates reported by Oo (2002) and Webb et al. (2014) suggest a decline of at least 60-65% since the 1950s or 1970s, and neither of these estimates took account of anecdotal reports of a large reduction in extent due to mangrove timber extraction during WWII. This suggests that the decline in extent of the ecosystem since 1750 is very likely to exceed 70%. Hence, its status under criterion A3 is likely to be at least Vulnerable, and more likely **Endangered**.

Criterion B

EOO is 24,390 km^2 and AOO is 93 10 x 10 km grid cells. There is a strong body of evidence indicating that the Ayeyarwady Delta mangrove forest are subject to a range of ongoing threats, including widespread cutting for fuelwood, deforestation for agriculture and salt farming. These threatening processes have (i) led to a continuing decline of spatial extent (B1a(i)), and (ii) will likely cause a continuing reduction in geographic distribution, environmental quality and biotic interactions in the next 20 years. The ecosystem is therefore listed as **Vulnerable** under Criterion B1a(i) and B1b. **Vulnerable**.

Criterion C

A model that synthesises the effects of sediment supply and accelerating rates of sea level rise was used to assess the likely impacts of sea level rise on the ecosystem (Lovelock et al., 2015). The model has several known limitations and assumptions, including that no landward migration can occur, that sea level rise is uniform across the world and it is expected to be limited in accuracy when applied to small geographic regions due to low resolution elevation data. It also ignores local sediment dynamics, which influence habitat suitability and potential compensatory changes. However, in the absence of any other forecasts of the impact of SLR on this ecosystem, we adopt a precautionary approach and use it to assess the expected area to be submerged by 2060. Three SLR scenarios were simulated in the model: Representative Concentration Pathway (RCP) 6, (RCP 6, 0.48 m SLR by 2100), RCP 8.5 (0.63 m SLR by 2100) and a more extreme scenario (1.4 m SLR by 2100. Results of the model suggest that under all scenarios <1% the delta mangrove ecosystem is expected to become submerged by 2060. The ecosystem is assessed as **Least Concern** under C2b. **Least Concern.**

Criterion D

We used a recently developed remote-sensing method to identify areas of mangrove forests that have undergone apparent ecosystem degradation (Worthington and Spalding, 2018). The approach utilises several vegetation indices (NDVI, SAVI, EVI and NDMI) that represent vegetation greenness and vegetation moisture condition. The indices are derived from Landsat time-series data and identify pixels that have undergone decreases in the index values of >40% relative to the reference period (pre 2000) and had not recovered to within <20% of the reference value. The analysis suggested that, over an 18 year period since 2000, about 12.95% of remaining mangroves met criteria to be classified as having undergone degradation.

No time-series is available for extrapolating this estimate with certainty. However, a simple extrapolation whereby the rate of change (12.95% divided by 18 years = 0.72% per year) suggests that, if past trends continue linearly into the future, 35.97% of the extent of ecosystem would be classified as degraded in fifty years. If we assume a proportional rate of decline instead, rate of loss is 0.77% per year, with 31.97% of the extent classified as degraded in fifty years. If relative severity of the decline is assumed to be more than 50% but less than 80% (equating to collapse threshold of NDVI = 0.2), the ecosystem is assessed as **Least Concern**. However, if relative severity is assumed to be greater than or equal to 80%, which we consider unlikely given the system remains mapped as mangroves, the ecosystem is assessed as **Vulnerable**. **Least Concern (Least Concern – Vulnerable)**.

Figure 3.
Raw Google Earth Imagery for Southern Ayeyarwady Delta at the Ayeyarwady River Mouth (at right).

Figure 4.
Mangrove distribution as mapped by the Global Mangrove Watch (version 2).

Figure 5.
Mangrove degradation as identified by analyses of Landsat data, where at least 10 of 12 vegetation indices underwent a >40% decline when compared to a historical reference value (computed before 2000).

Criterion E

No models were used to assess Criterion E. **Not Evaluated.**

Dwarf mangrove (shrubland) on shingle

Author: Murray, N.J., Keith, D.A.
Myanmar ecosystem names Dwarf mangroves
Biome Brackish tidal systems (MFT1)
Functional Group Intertidal forests and shrublands (MFT1.2)
Global classification MMR-MFT1.2.3
IUCN Status **Critically Endangered**

Description

Sparsely vegetated coastal ecosystem, characterised by dwarf *Avicennia* shrubs growing on intertidal shingle and rocky tidal flats. This environment tends to occur in areas exposed to low-moderate wave action that have not accumulated deep sediments characteristic of other mangrove ecosystems.

Distribution

No maps of dwarf mangrove shrubland on shingle exist, but this ecosystem may occur in very small patches along the Myanmar coastline where large rock platforms and suitable environmental conditions allow. Only two confirmed patches are currently known, one in Rakhine State and one in Tanintharyi state (Zaw Myo Hein, pers. comm).

Characteristic native biota

Primarily composed of *Avicennia officinalis* (Acanthaceae) shrubs growing to <1.5 m in height. Intertidal fauna includes migratory shorebirds and other waterbirds, such as Striated Heron *Butorides striata,* Little Egret *Egretta garzetta* and Pacific Reef-egret *Egretta sacra.*

Abiotic environment

Dwarf mangrove on shingle occurs on rock platforms where it undergoes regular tidal inundation. Individual trees typically grow in depressions on the tidal platform above the surf zone. Dwarfism in mangroves is most likely linked with hydroedaphic conditions, where very low soil moisture at low tide leads to severe water stress (Naidoo, 2006). High soil salinity and nutrient limitation are also likely, resulting from the location of this ecosystem in the rocky intertidal zone (Naidoo, 2006).

Key processes and interactions

Dwarfism in mangroves is a widespread phenomenon that is commonly attributed to high salinity, poor aeration, waterlogging, compaction, and nutrient limitation (Naidoo, 2006). However, in rocky areas it is also likely related to shallow sediment and associated desiccation, preventing establishment of individuals of normal height. *Avicennia* is a halophytic species, and therefore requires ongoing tidal inundation by saltwater.

Major threats

Dwarf mangrove ecosystems in Myanmar are subject to a relatively low number of anthropogenic threats, owing to occurring in rocky intertidal zones that are generally not converted to other land uses. Sea-level rise and severe tropical cyclones are likely to influence the ability of this ecosystem to persist into the future (Alongi, 2002; Thompson et al., 2002; Cazenave and Le Cozannet, 2013) (Figure 1). A single occurrence of a severe tropical storm could results in total loss of a patch of this ecosystem, and therefore this ecosystem may be restricted to as few as two threat-defined locations.

Ecosystem collapse definition

We follow the collapse definition of Marshall et al. (2018), where an absence of true mangrove species signifies transition to a collapsed or novel ecosystem. Therefore, this system is considered collapsed when the distribution of mangroves declines to 0 km^2 or when seedling recruitment declines to 0.

Assessment summary

Conceptual models suggest this ecosystem is threatened by sea level rise and will likely be drowned as result of erosion of substrate and lack of accommodation space to support ecosystem migration. Furthermore, it is highly restricted and occurs as two very small patches that are considered at risk of collapse when subject to catastrophic tropical storms, which are known to occur in the region. The time taken for re-establishment may extend beyond decades, given the slow growth rates on rocky substrates, during which time increasingly frequent storms and sea-level rise could disrupt the regeneration process. The ecosystem therefore qualifies as **Critically Endangered** under Criterion B1 and B2.

Assessment Information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**CR**
	B2	**CR**
	subcriteria	**B1b** **B1c** **B2b** **B2c**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**LC**
Criterion E	E	**DD**

Assessment Outcome

Critically Endangered

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

12th July 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Nil

Criterion A

Owing to their sparse and small vegetation structure, dwarf mangrove (shrubland) on shingle are unlikely to be mappable using satellite remote sensing. Field reconnaissance, supplemented by airborne image monitoring (e.g. UAVs), is essential to estimate change in spatial extent. Despite a targeted literature search, no information on the spatial distribution and change of this ecosystem was found. **Data Deficient.**

Criterion B

This ecosystem is highly restricted to coastal areas dominated by rocky shingle. Two very small patches of this ecosystem have been identified in Myanmar, one on the Rakhine coast and the other on the Tanintharyi coast. This ecosystem is highly susceptible to sea level rise and severe storms, and is considered to occur at two threat defined locations (storms). Dwarf mangrove (shrubland) on shingle therefore qualifies for listing as **Critically Endangered** under criterion B2b, c based on an estimated AOO of 2 10 x 10 degree grid cells and ongoing plausible threats. It also meets criterion B1b, c for **Critically Endangered** status based on an estimated EOO of 331 km^2 and ongoing plausible threats. **Critically Endangered.**

Criterion C

Unlike the other three mangrove ecosystem types in Myanmar, Dwarf mangrove (shrubland) on shingle occurs in environments with very little sediment. Therefore, the impact of sea level rise on mangrove ecosystems, often showing that mangroves can migrate or actively control their own elevation by capturing sediment, are unlikely to be applicable for this ecosystem (Lovelock et al., 2015; Rogers et al., 2019). With such small patches of sediment substrate and few areas with undeveloped and unvegetated adjacent rock platforms, the lack of accommodation space suggests that this ecosystem will be drowned from sea level rise. Indeed, conceptual models (Figure 1) of the impact of climate change on mangrove ecosystems suggest that climate change will drive increased erosion (via increased storminess) and sea level rise will lead to loss of sediment supply and mangrove drowning. However, with a lack of spatial data, and no information found in the literature on the status of dwarf mangrove (shrubland) on shingle, it is not possible to make a quantitative assessment of Criterion C. **Data Deficient.**

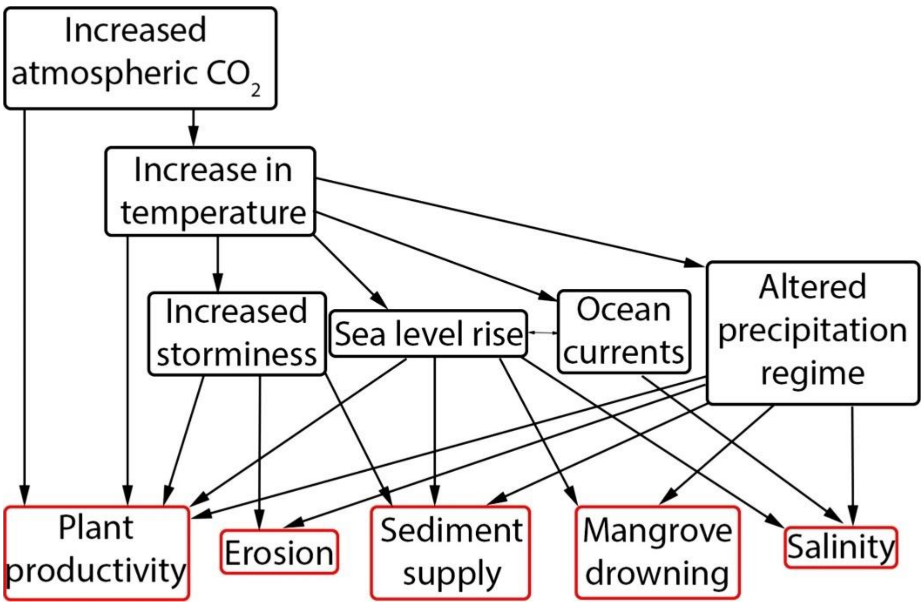


Figure 1. Conceptual model of the impacts of climate change on mangrove ecosystems. Note that sea level rise is likely to lead to erosion of sediment patches on shingle and, with an absence of sediment replenishment, drowning of mangrove ecosystems. Source: (Ward et al., 2016)

Criterion D

According to expert information, there is no evidence that biotic degradation is occurring in this ecosystem. **Least Concern.**

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

Rakhine mangrove forest on mud

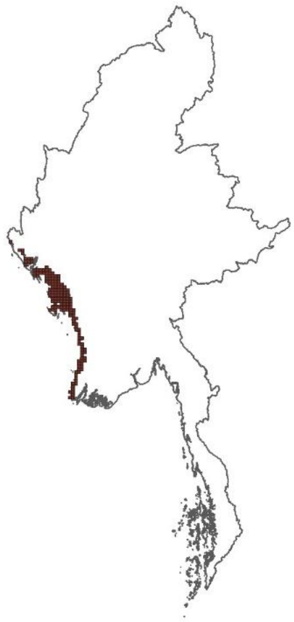
Authors Murray, N.J., Worthington, T.A., Lee, C., Keith, D.A.
Myanmar ecosystem names Mangroves
Biome Brackish tidal systems (MFT1)
Functional Group Intertidal forests and shrublands (MFT1.2)
Global classification MMR-MFT1.2.4
IUCN Status **Critically Endangered (Vulnerable – Critically Endangered)**

Description

Rakhine mangrove forest on mud occupies the intertidal zone of the Rakhine coastline. In this region, mangroves occur on soft, muddy, waterlogged sediments, primarily within sheltered bays and inlets. They are exposed to very high water salinity as a result of regular tidal incursion (Spalding, 2001) and are often fringed by groves of *Nipa* palms, which mark the transition to other ecosystems.

Distribution

Occurs along the Bay of Bengal coastline of Myanmar, encompassing the entire Rakhine coastline and into far west Ayeyarwady state. The southern distributional limit is Cape Negrais.



Characteristic native biota

Based on the Wunbaik mangrove forest reserve, a region with the most preserved mangrove forests within Rakhine, there are 28 observed mangrove species, including the critically endangered *Bruguiera hainseii* (Myint and Stanley, 2011). Species include *Aegialitis rotundifolia, Aegiceras corniculatum, Avicennia alba, Avicennia marina, Avicennia officinalis, Bruguiera cylindrical, Bruguiera gymnorrhiza, Bruguiera hainesii, Bruguiera parviflora, Bruguiera sexangula, Ceriops decandra, Ceriops tagal, Excoecaria agallocha, Heritiera fomes, Heritiera littoralis, Kandelia candel, Lumnitzera littorea, Lumnitzera racemose, Nypa fruticans, Rhizophora apiculate, Rhizophora mucronata, Scyphiphora hydrophyllacea, Sonneratia alba, Sonneratia apetala, Sonneratia caseolaris, Sonneratia griffithii, Xylocarpus granatum, Xylocarpus moluccensis (*Myint and Stanley, 2011*).*

There is a small group of mangrove specialized breeding birds including Brown-winged Kingfisher *Pelargopsis amauroptera* (NT), Ruddy Kingfisher *Halcyon coromanda*, Mangrove Pitta *Pitta megarhyncha* (NT), and Mangrove Whistler *Pachycephala cinereal* (Rasmussen and Anderton, 2012). This is supplemented with migratory shorebirds roosting in the mangroves during high tides between October and April. Migratory shorebirds may also be present in this ecosystem, utilising vegetation for roosting habitat and foraging among the aerial roots and pneumatophores at low tide (Hogarth, 2015).

Abiotic environment

In Rakhine, mangrove forest on mud occurs in areas where soft sediments are regularly inundated throughout the tidal cycle. They occur primarily in sheltered saline waters of embayments and estuaries with low wave energy, where recruitment of mangroves can naturally occur (Hogarth 2015).

Key processes and interactions

As with all mangrove ecosystems, the mangrove species themselves drive the majority of ecosystem processes, including providing nursery habitat for fish and crustaceans, controlling sedimentation processes that enables them to maintain their elevation and generating organic matter that contribute to carbon and nutrient cycles. In general mangrove distributions are limited by cool temperatures (Figure 1), but these are not limiting in Myanmar. They are also regulated by wave action, tides and sea level (Figure 1).

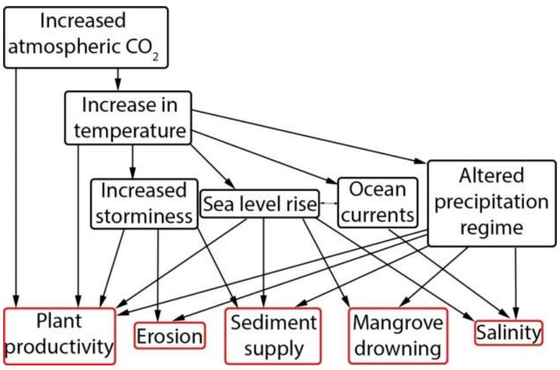


Figure 1. Conceptual model of the impacts of climate change on mangrove ecosystems. Note that sea level rise is likely to lead to erosion of sediment patches on shingle and, with an absence of sediment replenishment, drowning of mangrove ecosystems. Source: (Ward et al., 2016)

Major threats

Deforestation is the primary threat to mangroves along the Rakhine Coast, with this being considered a hotspot for mangrove deforestation in Southeast Asia after losing >10% of mangrove forest per 1 degree grid cell in many parts of the state between 2000-2012 (Richards and Friess, 2016). Drivers of deforestation include conversion into settlements, shrimp farms and rice paddies, with degradation attributed to wood cutting, brick-baking and bark peeling in some areas (Saw and Kanzaki, 2015; ; De Alban et al., 2020). The region is also periodically exposed to cyclones (Storey, 2015), causing physical damage and altering sedimentation supply (Ward et al., 2016)

Ecosystem collapse definition

We follow the collapse definition of Marshall et al. (2018), where an absence of true mangrove species signifies transition to a collapsed or novel ecosystem. Therefore, this system is considered collapsed when the distribution of mangroves declines to 0 km^2.

Assessment summary

This ecosystem is distributed along a narrow band of the western Myanmar coastline, and remote sensing data indicates extensive declines in its extent. When extrapolated to 2038, there will be an estimated 38% reduction in geographic distribution. Furthermore, an estimate of the current range versus that around 1800 suggests that less than 10% of the original extent remains. Owing to non-citation of source information, there is some uncertainty around this historical figure but this estimate was deemed plausible with a spatial model of pre-human extent (Murray, unpub. data). An assessment of time-series vegetation indices suggests a 12% degradation of the ecosystem since 2000, and projected to a 50 year time frame about 40% of the ecosystem may become degraded by 2050. Given uncertainty around the historical estimate, the ecosystem is assessed within the plausible range of **Vulnerable – Critically Endangered** and assigned a status of **Critically Endangered**.

Assessment information

Criteria		Status
Criterion A	A1	**NE**
	A2a	**NE**
	A2b	**VU**
	A3	**CR (VU-CR)**
Criterion B	B1	**VU**
	B2	**LC**
	subcriteria	**B1a(i)** **B1a(iii)**
	B3	**LC**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**LC**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**LC (LC-VU)**
	D3	**LC**
Criterion E	E	**NE**

Assessment Outcome

Critically Endangered (Vulnerable – Critically Endangered)

IUCN Red List of Ecosystems Categories and Criteria

Version 2.2

Year Published

2019

Date Assessed

8th March 2019

Assessment Credits

Assessed by: Nicholas Murray, Thomas Worthington

Reviewed by: David Keith

Contributions by: Calvin Lee

Criterion A

A remote sensing analysis of mangroves in Rakhine state indicated that, between 1988 and 2015, there was a decline in mangrove extent of 20.45% (Storey, 2015). Using estimates of area for 1988, 2000 and 2015, the forecast loss of mangroves between 1988 and 2038 is estimated to be 34.6% (proportional rate of decline, 1988 and 2015 data only). Assuming this trend from Rakhine state also applies to the mangroves in Western Ayeyarwady state (the southern part of this ecosystem), the ecosystem is assessed as **Vulnerable** under Criterion A2b.

According to a socio-economic analysis undertaken in Northern Rakhine State, mangrove ecosystems began to be deforested in the late 1800s and early 1900s as a result of British demands for firewood to support steam vessels and the salt industry (Storey, 2015). However, the most rapid loss of mangrove coverage occurred in the late 1960s and 1970s, driven by development policies aiming to increase the area of land under rice production, as well as harvesting for timber and charcoal. Storey (2015) estimates that in 1900, approximately 70% of original mangrove cover remained, but by 2015 this had reduced to less than 6%.

Although no information on the reliability of this estimate is available, a simple spatial distribution model of habitat suitability suggests that the 1900 estimated extent is plausible (Murray, unpub. data.). If this estimate of historical loss is applied to the full geographic range of Rakhine mangrove on mud, the ecosystem qualifies for listing as **Vulnerable-Critically Endangered** under Criterion A3.

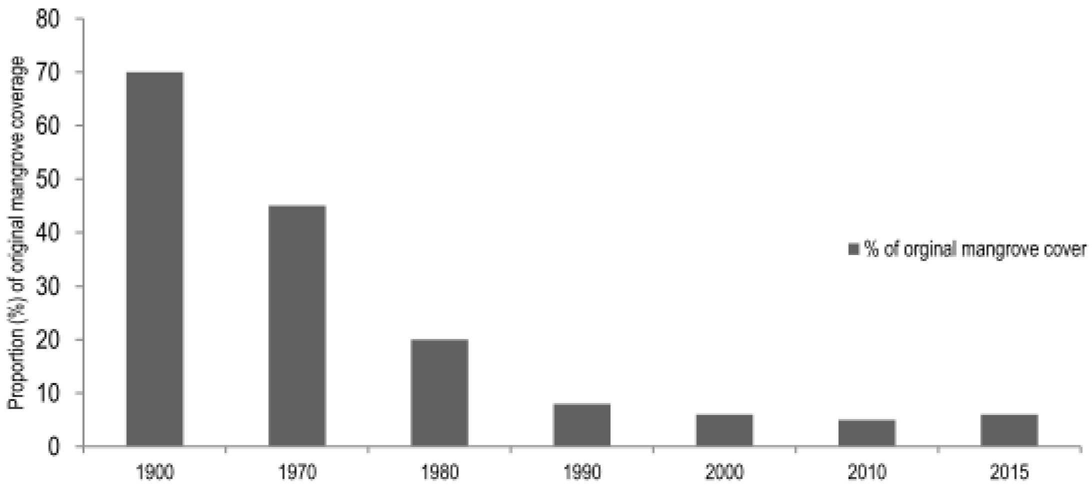


Figure 2. Estimates of the change in mangrove coverage from the original mangrove cover. Source: (Storey, 2015)

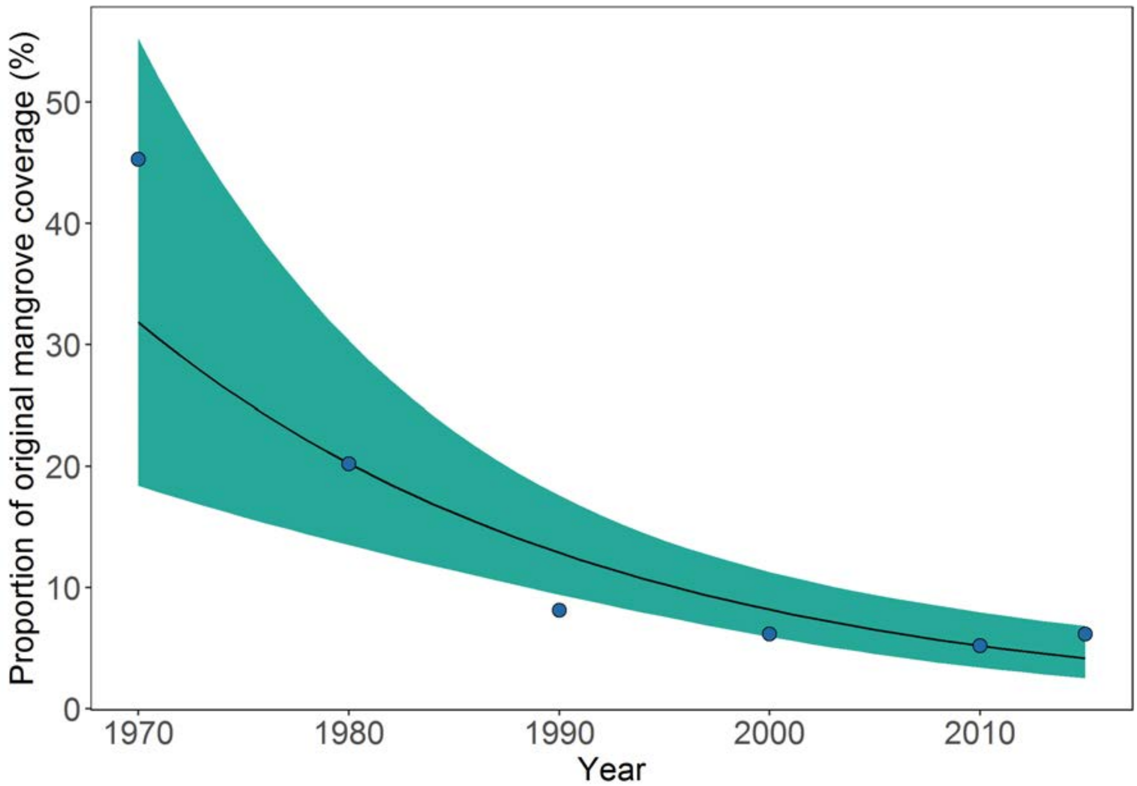


Figure 3. Data on mangrove extent plotted on a continuous x-axis, with an exponential line fitted.

Criterion B

The ecosystem is widely distributed across the western coast of Myanmar. However, due to being restricted to a narrow coastal band, the ecosystem has an AOO of 158 10 x 10 km grid cells and an EOO of 48,253 km^2.

Ongoing threats, particularly cutting for fuelwood, are reportedly causing continued decline in biotic processes (see ecosystem description). With an EOO of < 50,000 km^2 and meeting subcriteria for continuing decline in both extent (B1a(i)) and biotic disruption (B1a(iii)), the ecosystem is assessed as **Vulnerable** under Criterion B1.

Criterion C

A model that synthesises the effects of accelerating rates of sea level rise while accounting for changes in sediment supply was used to assess the likely impacts of SLR on the ecosystem (Lovelock et al., 2015). Although the model has several known limitations and assumptions, including that no landward migration can occur, that sea level rise is uniform across the world and that the elevation data is not high-resolution, it suggests that a small proportion of Rakhine Mangrove Forest on mud may be submerged by 2060. Specifically, the model indicates that up to 2.3% of mangroves may be lost under an extreme SLR scenario of 1.4 m SLR by 2100. Given the conservative assumptions, and even assuming a relative severity of the change in sea levels of >80%, because no mangrove recruitment can occur in a submerged system, the ecosystem remains **Least Concern** under C2b. **Least Concern**.

Criterion D

We used the same approach for assessing criterion D as for Ayeyarwady delta mangrove forest. A total of 12 vegetation indices (including NDVI, SAVI, EVI and NDMI) that represent vegetation greenness and vegetation moisture content were used to assess condition trends across the geographic distribution of this ecosystem. Each 30-m pixel that (i) is currently mapped as mangrove and (ii) has undergone >40% decreases in at least 10 of the 12 remote sensing indices since the beginning of the time-series (the year 2000) were considered degraded. Validation data suggests that the process of degradation detected with this method includes mangrove die-back or small-scale clearing for firewood (Worthington and Spalding, 2018). The analysis suggested that, over a 16 year period since 2000, about 12.23% of the 1,871 km^2 of mangroves along the Rakhine coastline met criteria to be classified as degraded.

No time-series is available for extrapolating this estimate with certainty. However, a simple extrapolation whereby the rate of change (12.23% divided by 16 years = 0.76% per year) suggests that, if past trends continue, 38.2% of the extent of ecosystem are expected to be classified as degraded in 2050. Using proportional rate of decline, the rate of decline is estimated to be 0.72% per year, reaching 30.40% of extent degraded in fifty years. If the relative severity of these declines are assumed to be more than 50% but less than 80%, the ecosystem is assessed as **Least Concern** under Criterion D2b. However, if relative severity is assumed to be greater than or equal to 80%, suggesting near ecosystem collapse in the degraded pixels, the ecosystem is assessed as **Vulnerable**. (**Least Concern – Vulnerable)**.

Criterion E

No model was used to quantitatively assess the risk of ecosystem collapse for this ecosystem. **Not Evaluated.**

Grassy saltmarsh

Authors Murray, N.J.
Myanmar ecosystem names Saltmarsh, intertidal marsh
Biome Brackish tidal systems (MFT1)
Functional Group Coastal saltmarshes (MFT1.3)
Global classification MMR-MFT1.3.1
IUCN Status **Data deficient**

Description

Saltmarshes are vegetated coastal ecosystems that undergo periodic flooding by saline water (Adam, 1993). They typically border saline water bodies, where water fluctuations (either tidal or non-tidal) flood the vegetation, which is dominated by grasses, sedges or herbs, but trees are absent or very sparse. In coastal environments, coastal saltmarshes are highly dynamic and typically fringe low energy coastlines, often occurring above areas of coastal mudflat, seagrass or mangroves.

Distribution

Saltmarshes are very poorly known in Myanmar and, to our knowledge, no confirmed occurrences of saltmarsh ecosystems have been recorded. However, given that they occur along the nearby coasts and rivers of Bangladesh (Siddique et al., 2012), as well as other tropical regions, they are likely to occur in coastal areas not dominated by mangroves or dynamic sediment-dominated systems such as sandy shorelines and coastal mudflats. In this environment they would probably consist of grasses and herbs in flat areas adjacent to saline waterbodies (P. Adam*, pers. comm.*). It is possible that saltmarshes in Myanmar have been wholly converted to agricultural land for aquaculture and rice farming.

Characteristic native biota

Saltmarshes typically have low plant diversity and are dominated by a few species, tending to increase in diversity further away from the seaward margin. Invertebrate and microbial species richness can be very high. Saltmarshes are poorly known in Myanmar, and no information is available on their characteristic biota.

Abiotic environment

Although they are exposed to air for the majority of the time, saltmarshes undergo periodic flooding from saline water sources, mostly as a result of tidal fluctuations in coastal environments. They therefore occur up to about the highest astronomical tide, and rarely below mean high water neap tide (Adam 1993). Saltmarsh soils are frequently waterlogged and anaerobic, primarily owing to slow drainage after inundation as a result of low-sloping topography. The soils may accumulate very high concentrations of salt during dry phases, until flushed by tides or overland flow after rains. Saltmarshes may also occur where there is significant influence of salt spray or increased salinity due to evapotranspiration, but are not tidally inundated (P. Adam, *pers. comm.*). Intertidal saltmarsh fauna is typically absent in these non-tidal saltmarshes.

Key processes and interactions

The interaction between biota and physical processes is a key feature of saltmarsh ecosystems. Salt tolerant vegetation plays an essential role in trapping sediment, which maintains their elevation and extent, and balances the physical process of erosion. Ongoing sediment supply offsets erosion and contributes to their ability to maintain extent with sea level rise. Salinity levels may fluctuate widely in response to the timing of tidal submergence, freshwater influx and drying.

Major threats

With little known about grassy saltmarsh ecosystems in Myanmar, it is difficult to assess major threats to this ecosystem. However, its habitat along rivers, around estuaries and in flat coastal areas is particularly threatened by conversion to agriculture, changing flood and sedimentation regimes of rivers and sea level rise (Adam, 2002).

Ecosystem collapse definition

Grassy saltmarsh are collapsed when their area has declined to 0 km^2 or when saline water ceases to inundate the system.

Assessment summary

Despite targeted searches, no data were found that could be used to perform an assessment of ecosystem collapse risk. We recommend further targeted field work and reviews to confirm the occurrence of this ecosystem in Myanmar. The ecosystem is therefore assessed as **Data Deficient**.

Assessment information

Criteria		Status
Criterion A	A1	**DD**
	A2a	**DD**
	A2b	**DD**
	A3	**DD**
Criterion B	B1	**DD**
	B2	**DD**
	subcriteria	**-**
	B3	**DD**
Criterion C	C1	**DD**
	C2a	**DD**
	C2b	**DD**
	C3	**DD**
Criterion D	D1	**DD**
	D2a	**DD**
	D2b	**DD**
	D3	**DD**
Criterion E	E	**DD**

Assessment Outcome

Data Deficient

Year Published

2019

Date Assessed

5th August 2019

Assessment Credits

Assessed by: Nicholas Murray

Reviewed by: David Keith

Contributions by: Paul Adam

Assessment Summary

Grassy saltmarsh is a very poorly known ecosystem in Myanmar. There have been reports that small pockets occur in estuaries and river mouths along the Rakhine coastline. Despite extensive searches of the literature and other information sources, no information suitable for conducting an ecosystem risk assessment was found. The ecosystem is **Data Deficient**.

Criterion A

No information on the distribution and change of this ecosystem was found during extensive literature reviews. **Data Deficient.**

Criterion B

Without data on the spatial distribution of this ecosystem, no assessment of Criterion B could be made. **Data Deficient.**

Criterion C

Saltmarshes are considered susceptible to sea level rise and the impacts of climate change (Deegan et al., 2012; Fagherazzi et al., 2012; Kirwan et al., 2016). However, no information on Myanmar's grassy saltmarsh ecosystem was found during this assessment. **Data Deficient.**

Criterion D

A range of threats have been shown to cause disruption of biotic processes and interactions in saltmarsh ecosystems, included loss of vegetation, elevated erosion rates and excessive input of pollutants (Deegan et al., 2012). However, no data for this system occurs in Myanmar, and therefore the ecosystem is assessed as **Data Deficient**.

Criterion E

No model suitable for quantitatively assessing the risk of ecosystem collapse for this ecosystem was found. **Data Deficient.**

4. Assessment outcomes

4.1 Overall status of Myanmar ecosystems

A total of 64 ecosystem types were identified and evaluated under the IUCN Red List of Ecosytems categories and criteria (Table 4.1, Table 4.2). Twenty-nine (45.3%) were assigned a threatened status, consisting of 8 (12.5%) Critically Endangered ecosystem types, 9 (14.1%) Endangered and 12 (18.8%) Vulnerable ecosystem types. Accounting for uncertainty in assessment outcomes indicates that, across Myanmar, 45.3% (42.2%-50.0%) of ecosystem types qualify for threatened status (Table 4.1). One ecosystem type, Central Ayeyarwady Palm Savanna ecosystem types was confirmed as Collapsed (Table 4.2). A further two ecosystem types, Ayeyarwady kanazo swamp forest and Southern Rakhine hills evergreen rainforest, were assessed with an upper plausible status outcome of Collapsed, although their final assessment was Critically Endangered.

Twenty-eight (43.8%) ecosystem types were assessed as Near Threatened or Least Concern. However, a post-assessment expert review by experts suggested that 11 of the 25 (44%) Least Concern ecosystems could qualify for a different assessment outcome if more data was available. These 11 ecosystems were reclassified to Data Deficient.

Seventeen (26.6%) of Myanmar's ecosystem types were classified as Data Deficient (Table 4.2). Data deficient ecosystem types were primarily ecosystems for which there were historical records, but with insufficient published information to assess the criteria (e.g. Rocky Tanintharyi karst). Alternatively, there were insufficient distribution records to incorporate into our mapping workflow to allow assessments of Criterion A and B (e.g. Grassy saltmarsh). Data deficient ecosystems also tended to occur in regions that were inaccessible to field researchers due to travel restrictions (e.g. Shan limestone grasslands). Urgent further work to confirm the distribution and assess the status of these data deficient systems is recommended.

Table 4.1 Number of ecosystems in each IUCN Red List of Ecosystems conservation status category. Lower bound and upper bound reflect uncertainty in assessments of the criteria.

IUCN Category	Overall outcome		Lower bound		Upper bound	
	No. of Ecosystems	% of Ecosystems	No. of Ecosystems	% of Ecosystems	No. of Ecosystems	% of Ecosystems
Collapsed	1	1.6	1	1.6	3	4.7
Critically Endangered	8	12.5	6	9.4	7	10.9
Endangered	9	14.1	10	15.6	9	14.1
Vulnerable	12	18.8	11	17.2	16	25.0
Near Threatened	3	4.7	4	6.3	2	3.1
Least Concern	14	21.9	15	23.4	10	15.6
Data Deficient	17	26.6	17	26.6	17	26.6

*Table 4.2 The status of terrestrial ecosystems in Myanmar. Note: status assignments denoted by a * indicate a post-assessment reclassification to Data Deficient due to an expert judgement that there was insufficient data to confirm a Least Concern assessment outcome.*

Code	Biome / Functional Group / Ecosystem Type	Status
T	*TERRESTRIAL*	
T1	***Tropical and subtropical forests***	
T1.1	*Tropical/subtropical lowland rainforests*	
MMR-T1.1.1	Tanintharyi island rainforests	Vulnerable (Least Concern - Vulnerable)
MMR-T1.1.2	Tanintharyi Sundaic lowland evergreen rainforest	Vulnerable
MMR-T1.1.3	Tanintharyi limestone tropical evergreen forest	Endangered
MMR-T1.1.4	Tanintharyi upland evergreen rainforest	Data Deficient *
MMR-T1.1.5	Kayin evergreen tropical rainforest	Endangered
MMR-T1.1.6	Southern Rakhine hills evergreen rainforest	Critically Endangered (Critically Endangered – Collapsed)
MMR-T1.1.7	Western Shan Plateau subtropical evergreen rainforest	Vulnerable
MMR-T1.1.8	Kachin-Sagaing low elevation subtropical rainforest	Data Deficient *
MMR-T1.1.9	Kachin-Sagaing mid elevation subtropical rainforest	Data Deficient *
MMR-T1.1.10	Kachin hills subtropical rainforest	Data Deficient *
T1.2	*Tropical/subtropical dry forests and scrubs*	
MMR-T1.2.1	Tanintharyi semi-evergreen forest	Data Deficient *
MMR-T1.2.2	Rocky Tanintharyi karst	Data Deficient
MMR-T1.2.3	Mixed cane break	Least Concern
MMR-T1.2.4	Bago semi-evergreen forest	Critically Endangered (Endangered - Critically Endangered)
MMR-T1.2.5	Dry zone foothills spiny scrub	Data Deficient *
MMR-T1.2.6	Rakhine hills bamboo brake	Least Concern
MMR-T1.2.7	Rakhine hills semi-evergreen dry forest	Vulnerable
MMR-T1.2.8	Magway dry cycad forest	Endangered (Endangered - Critically Endangered)
MMR-T1.2.9	Magway semi-evergreen dry gully forest	Vulnerable (Near Threatened - Vulnerable)
MMR-T1.2.10	East Myanmar dry valley forest	Vulnerable
MMR-T1.2.11	Eastern Shan semi-evergreen forest	Vulnerable
MMR-T1.2.12	Western Shan semi-evergreen forest	Vulnerable
MMR-T1.2.13	Indaing forest	Endangered
MMR-T1.2.14	Northern semi-evergreen forest	Data Deficient *
T1.3	*Tropical/subtropical moist montane rainforests*	
MMR-T1.3.1	Tanintharyi cloud forest	Critically Endangered

T2	***Temperate-boreal forests and woodlands***	
T2.1	*Boreal and temperate montane forests and woodlands*	
MMR-T2.1.1	Kachin mountain conifer forest	Data Deficient *
T2.4	*Warm temperate rainforests*	
MMR-T2.4.1	Shan Warm Temperate Rainforest	Endangered
MMR-T2.4.2	Chin Hills warm temperate rainforest	Vulnerable
MMR-T2.4.3	Sagaing Warm Temperate Rainforest	Near Threatened
MMR-T2.4.4	Kachin Warm Temperate Rainforest	Data Deficient *
MMR-T2.4.5	Mountain bamboo brake	Data Deficient
MMR-T2.4.6	Kachin Montane Temperate Broadleaf Forest	Data Deficient *
T4	***Savannas and grasslands***	
T4.2	*Pyric tussock savannas*	
MMR-T4.2.1	Rakhine coastal savanna	Data Deficient *
MMR-T4.2.2	Central Ayeyarwady Than-Dahat grassy forest	Vulnerable
MMR-T4.2.3	Central Ayeyarwady Palm Savanna	Collapsed
MMR-T4.2.4	Shwe Settaw Sha-Bamboo thicket	Near Threatened
MMR-T4.2.5	Magway Than-Dahat dry grassy forest	Least Concern
MMR-T4.2.6	Sha Thorny Scrub	Vulnerable
MMR-T4.2.7	Shan foothills Than-Dahat grassy forest	Vulnerable
MMR-T4.2.8	Shan hills pine savanna	Endangered
MMR-T4.2.9	Chin hills pine savanna	Least Concern
MMR-T4.2.10	Sagaing hills pine savanna	Least Concern
MMR-T4.2.11	Kachin pine savanna	Least Concern
T4.5	*Temperate grasslands*	
MMR-T4.5.1	Shan limestone grassland	Data Deficient
T6	***Polar/alpine***	
T6.1	*Ice sheets, glaciers and perennial snowfields*	
MMR-T6.1.1	Kachin snowfields	Near Threatened (Near Threatened - Vulnerable)
T6.2	*Polar/alpine rocky outcrops*	
MMR-T6.2.1	Alpine cliffs and screes	Least Concern
T6.4	*Temperate alpine meadows and shrublands*	
MMR-T6.4.1	High mountain scrub	Least Concern
MMR-T6.4.2	Alpine herbfield	Endangered
S	***SUBTERRANEAN***	
S1	***Dry subterranean***	
S1.1	*Subterranean lithic systems*	
MMR-S1.1.1	Aerobic karst caves	Least Concern
TF	***FRESHWATER/TERRESTRIAL***	

TF1	***Palustrine wetlands***	
TF1.1	*Tropical flooded forests and peat forests*	
MMR-TF1.1.1	Ayeyarwady kanazo swamp forest	Critically Endangered (Critically Endangered - Collapsed)
MMR-TF1.1.2	Central dry evergreen riparian forest	Critically Endangered
MMR-TF1.1.3	Mixed delta scrub	Least Concern
TF1.4	*Seasonal floodplain marshes*	
MMR-TF1.4.1	Ayeyarwady floodplain wetlands	Endangered
MMR-TF1.4.2	Central Ayeyarwady floodplain grasslands	Critically Endangered
F	***FRESHWATER***	
F2	***Lakes***	
F2.4	*Freeze-thaw freshwater lakes*	
MMR-F2.4.1	Glacial Lakes	Least Concern
MT	***MARINE/TERRESTRIAL***	
MT1	***Shoreline systems***	
MT1.2	*Muddy shores*	
MMR-MT1.2.1	Coastal mudflats	Least Concern
MT1.3	*Sandy shores*	
MMR-MT1.3.1	Sandy shoreline	Least Concern
MT2	***Supralittoral coastal systems***	
MT2.1	*Coastal shrublands and grasslands*	
MMR-MT2.1.1	Tanintharyi coastal dune forest	Data Deficient
MMR-MT2.1.2	Rakhine coastal dune forest	Data Deficient
MFT	***MARINE/FRESHWATER/TERRESTRIAL***	
MFT1	***Brackish tidal systems***	
MFT1.2	*Intertidal forests and shrublands*	
MMR-MFT1.2.1	Tanintharyi mangrove forest	Near Threatened (Least Concern - Near Threatened)
MMR-MFT1.2.2	Ayeyarwady delta mangrove forest	Endangered
MMR-MFT1.2.3	Dwarf mangrove (shrubland) on shingle	Critically Endangered
MMR-MFT1.2.4	Rakhine mangrove forest on mud	Critically Endangered (Vulnerable - Critically Endangered)
MFT1.3	*Coastal saltmarshes*	
MMR-MFT1.3.1	Grassy saltmarsh	Data Deficient

4.2 Types of threatened ecosystems

Myanmar's *Terrestrial* realm had the greatest number of threatened ecosystems, which included 22 ecosystem types (45.8% of Myanmar's ecosystem types) that were assigned to a threatened category (Table 4.3). As a proportion of the number of ecosystems within a realm, *Freshwater/Terrestrial* (FT) was the most threatened with 80% (4 out of 5 freshwater/terrestrial ecosystem types) meeting the category thresholds for threatened criteria (VU, EN, CR).

At a Biome level, *Tropical and subtropical forests* accounted for the majority of threatened ecosystems types (15 ecosystem types, 23% of all of Myanmar's ecosystems), followed equally by *Palustrine wetlands* (4 ecosystem types, 6.3% of total) and *Savannas and grasslands* (4 ecosystem types, 6.3% of total; Table 4.4). As a proportion of each biome, the assessment indicated that *Palustrine wetlands* is the most threatened realm, with 80% of Myanmar's *Palustrine wetlands* ecosystem types assigned to a threatened category. *Tropical and subtropical forests* (60%, 15 ecosystem types) and *Brackish tidal systems* (60%, 3 ecosystem types) are also highly threatened biomes in Myanmar.

At the Ecosystem Functional Group level, the greatest number of threatened ecosystems were *Tropical/subtropical dry forests and scrubs* (8 ecosystem types, 12.5% of total) followed by *Tropical/subtropical lowland rainforests* (6 ecosystem types, 9.4% of total; Table 4.5).

Table 4.3 Realm summary of the threatened ecosystems of Myanmar. Note that area and % of landmass estimates only include ecosystems that were mapped.

Realm	Area (km^2)	% of Myanmar landmass	No. of natural ecosystems	No. of threatened ecosystems	% of ecosystems (Myanmar) threatened	% of ecosystems (Realm) threatened
Freshwater	21.52	0.00	1	0	0.0	0.0
Freshwater/Terrestrial	4,077.67	0.61	5	4	6.3	80.0
Marine/Freshwater/Terrestrial	6,314.57	0.94	5	3	4.7	60.0
Marine/Terrestrial	4,459.07	0.67	4	0	0.0	0.0
Subterranean	0.38	0.00	1	0	0.0	0.0
Terrestrial	411,875.14	61.54	48	22	34.4	45.8

Table 4.4 Biome summary of the threatened ecosystems of Myanmar. Note that area and % of landmass estimates only include ecosystems that were mapped. Biomes with a dash not mapped.

Biome	Area (km^2)	% of Myanmar landmass	No. of natural ecosystems	No. of threatened ecosystems	% of ecosystems (Myanmar) threatened	% of ecosystems (Biome) threatened
Brackish tidal systems	6,314.57	0.94	5	3	4.7	60.0
Dry subterranean	0.38	0.00	1	0	0.0	0.0
Lakes	21.52	0.00	1	0	0.0	0.0
Palustrine wetlands	4,077.67	0.61	5	4	6.3	80.0
Polar/alpine	3,810.93	0.57	4	1	1.6	25.0
Savannas and grasslands	29,269.40	4.37	12	4	6.3	33.3
Shoreline systems	4,459.07	0.67	2	0	0.0	0.0
Supralittoral coastal systems	-	-	2	0	0.0	0.0
Temperate-boreal forests and woodlands	46,959.73	7.02	7	2	3.1	28.6
Tropical and subtropical forests	331,835.08	49.58	25	15	23.4	60.0

Table 4.5. Ecosystem functional group summary of the threatened ecosystems of Myanmar. Note that area and % of landmass estimates only include ecosystems that were mapped. Ecosystem functional groups with a dash not mapped.

Ecosystem functional group	Area (km^2)	% of Myanmar landmass	No. of natural ecosystems	No. of threatened ecosystems	% of ecosystems (Myanmar) threatened	% of ecosystems (Biome) threatened
Boreal and temperate montane forests and woodlands	490.07	0.07	1	0	0.0	0.0
Coastal saltmarshes	-	-	1	0	0.0	0.0
Coastal shrublands and grasslands	-	-	2	0	0.0	0.0
Freeze-thaw freshwater lakes	21.52	0.00	1	0	0.0	0.0
Ice sheets, glaciers and perennial snowfields	3,142.03	0.47	1	0	0.0	0.0
Intertidal forests and shrublands	6,314.57	0.94	4	3	4.7	75.0
Muddy shores	2,997.83	0.45	1	0	0.0	0.0
Polar/alpine rocky outcrops	296.36	0.04	1	0	0.0	0.0
Pyric tussock savannas	29,269.40	4.37	11	4	6.3	36.4
Sandy shores	1,461.24	0.22	1	0	0.0	0.0
Seasonal floodplain marshes	3,145.55	0.47	2	2	3.1	100.0
Subterranean lithic systems	0.38	0.00	1	0	0.0	0.0
Temperate alpine meadows and shrublands	372.54	0.06	2	1	1.6	50.0
Temperate grasslands	-	-	1	0	0.0	0.0
Tropical flooded forests and peat forests	932.12	0.14	3	2	3.1	66.7
Tropical/subtropical dry forests and scrubs	290,069.80	43.34	14	8	12.5	57.1
Tropical/subtropical lowland rainforests	41,739.60	6.24	10	6	9.4	60.0
Tropical/subtropical moist montane rainforests	25.68	0.00	1	1	1.6	100.0
Warm temperate rainforests	46,469.66	6.94	6	2	3.1	33.3

4.3 Distribution of threatened ecosystems

Myanmar's ecosystem diversity is highest along the Himalayas and foothills in the north (Kachin State), where the Shan plateau meets the central dry zone, along the Rhakine range in the west and much of the Tanintharyi lowlands (Figure 4.1, Figure 4.2). Threatened ecosystem richness was highest in the lower Ayeyarwady delta (Figure 4.1). The principal geographic correlates of the number of threatened ecosystems were:

- Areas of high agricultural intensity. Areas such as the Ayeyarwady floodplain, coastal plains and parts of the Shan Plateau have been almost entirely converted for commodity-driven agriculture over the past 200 years, and have had a dramatic impact on ecosystem functional groups such as intertidal forests, floodplain marshes, lowland rainforests and tropical flooded forests.

- Areas where shifting agriculture and forestry has caused widespread loss of primary forests. These regions include most of Tanintharyi, Rakhine range, forested areas of the Shan plateau and the far north-east.

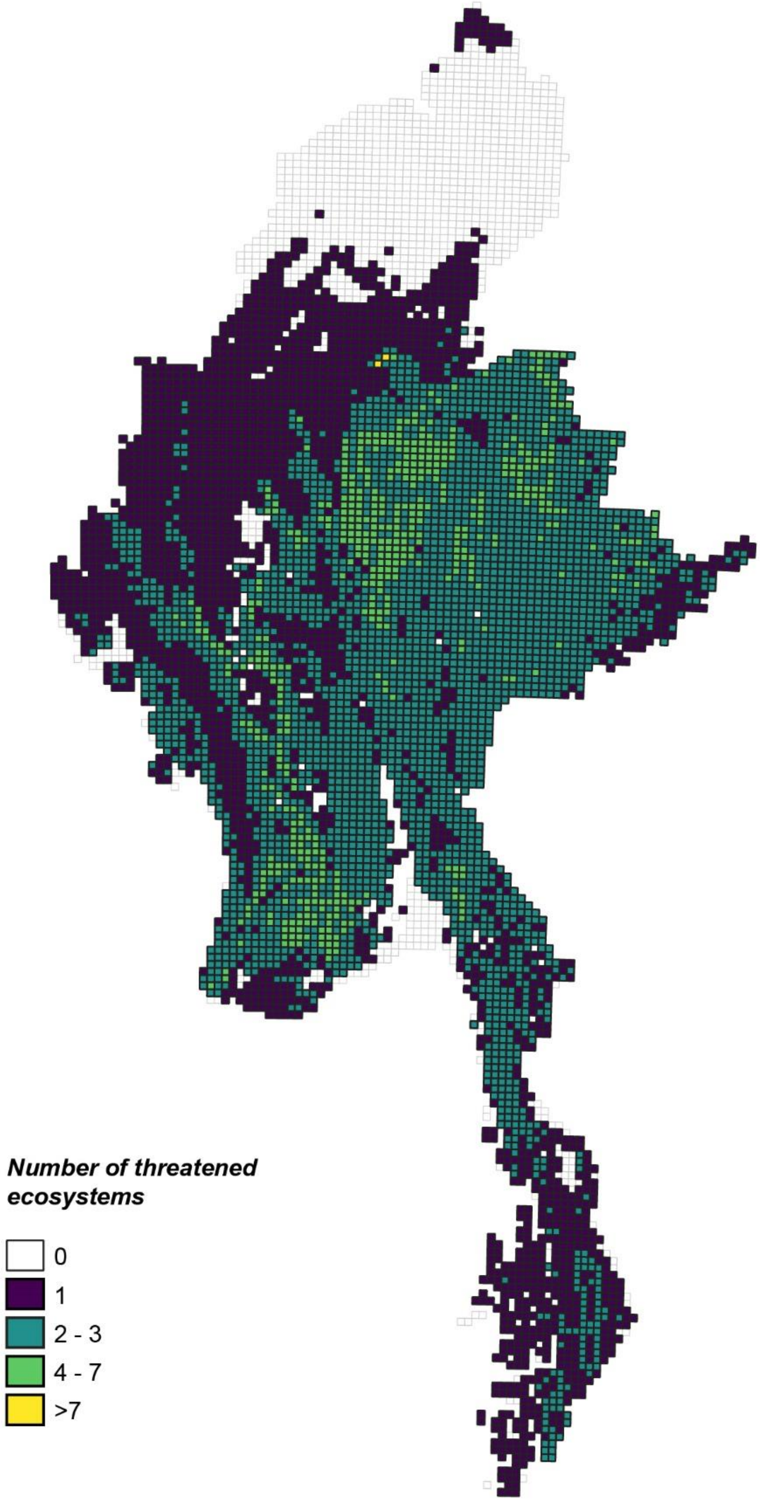


Figure 4.1 Summary of the distribution of all mapped ecosystems (left) and threatened ecosystems (CR, EN, VU; right). Each 10 x 10 km grid cell is coloured by the number of threatened ecosystems that intersect it.

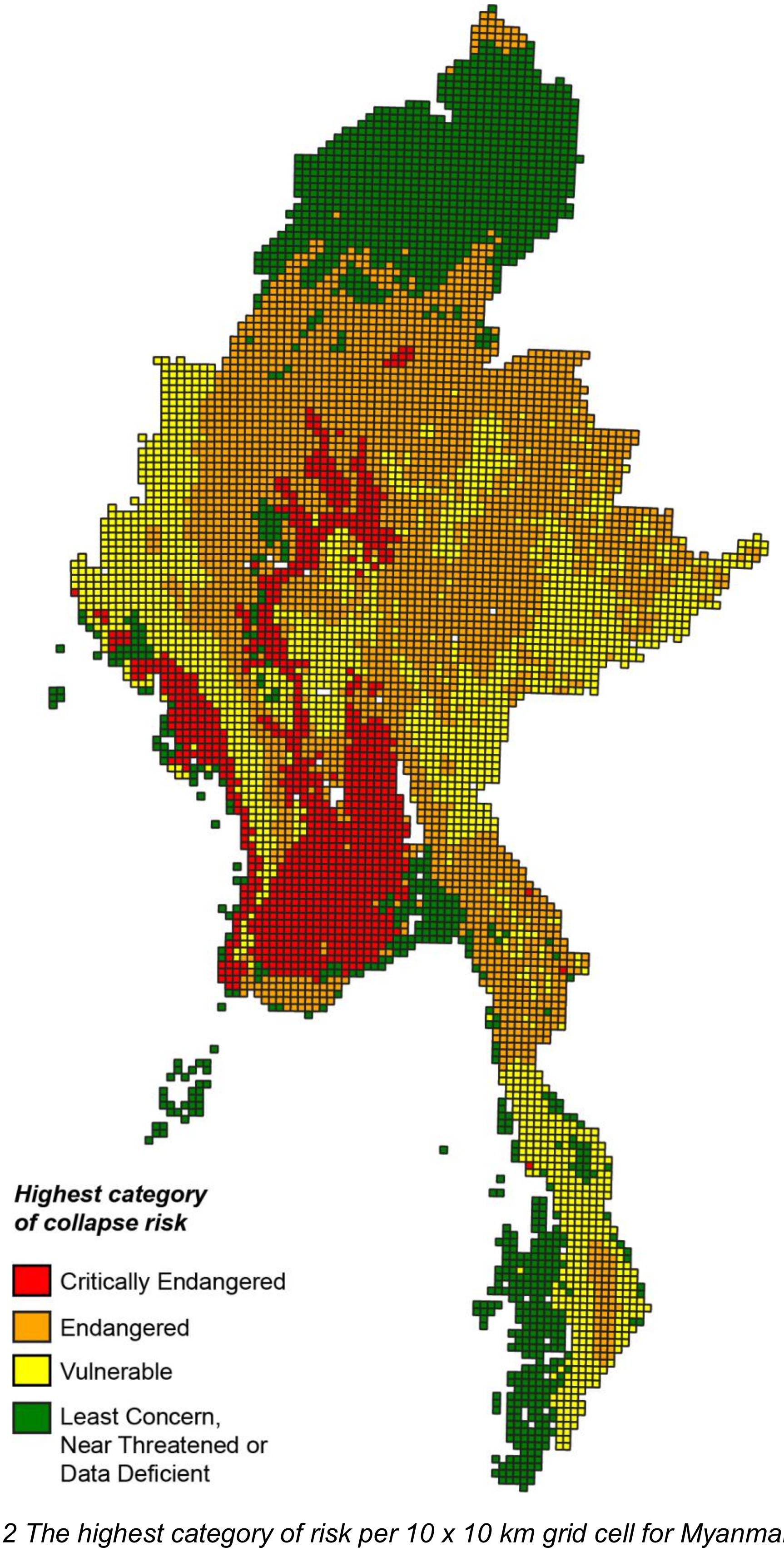


Figure 4.2 The highest category of risk per 10 x 10 km grid cell for Myanmar.

4.4 Threats to ecosystems

This assessment indicated that, while some of Myanmar's most threatened ecosystems, such as the two *Palustrine wetlands*, have undergone extensive fragmentation and conversion as a result of human impacts, others remain as some of the most important intact examples of their kind in Asia. Nevertheless, the majority of Myanmar's natural ecosystems are at risk from a range of threatening processes which appear to be accelerating in intensity and expanding in footprint over recent years (Figure 4.3). We list the major threats to Myanmar's natural ecosystems by biome in Table 4.1.

Figure 4.3 Examples of major threats to ecosystems in Myanmar.

Infrastructure development, such as the construction of new roads, can have a severe impact on Myanmar's threatened ecosystems. Below, Western Shan semi-evergreen forest (Vulnerable; MMR-T1.2.12) is intersected by a new road connecting the central dry zone to the Shan Plateau.

Targeted logging for high value timber, such as this example illegal logging detected in Alaungdaw Kathapa National Park, is widespread through the majority of tropical and subtropical forest ecosystems in Myanmar.

Grazing by livestock reduces recruitment and degrades natural ecosystems in Myanmar's central dry zone, as observed here in Sha thorny scrub (MMR T4.2.6).

Widespread conversion of the Ayeyarwady floodplain to rice agriculture has led to the listing of several formerly widespread ecosystems as threatened, including Central Ayeyarwady floodplain grasslands (MMR 1.4.2).

Cutting of natural ecosystems for construction timber and other uses is widespread across Myanmar.

Rice agriculture across the coastal plains of Rakhine state have severely reduced the extent of ecosystems such as Rakhine Coastal Savanna (MME4.2.1) and Rakhine hills semi-evergreen dry forest (MMR-1.2.7)

Shifting agriculture is among the most widespread threats to Myanmar's tropical and subtropical forests, such as Western Shan semi-evergreen forest (MMR-T1.2.12). Remote sensing methods to quantify the extent of this threat across Myanmar are improving and will allow better assessments of ecosystem degradation in future assessments.

Table 4.6. Major threats to ecosystems identified in the red list assessment by Biome.

Biome	Major threats
Tropical and subtropical forests	• Infrastructure development for a growing road network across the country • Defaunation (hunting) still occurs across most of Myanmar's tropical and subtropical forests. • Commercial plantations of crops such as oil palm (particularly in Tanintharyi) • Conversion to betel nut, rubber, sugar cane, banana, cassava (across the country) • Shifting cultivation is widespread across all tropical and subtropical forests, driving loss of primary forest, degradation and establishment of bamboo-dominated secondary forests. The extent of this impact is difficult to quantify due to remote sensing limitations in accurately identifying the distribution of shifting agriculture. • Open-pit and illegal surface mining for gold and amber, particularly in the north and affecting ecosystems including Kachin-Sagaing low elevation subtropical rainforest and Northern semi-evergreen forest • Ongoing fragmentation and pressure of edge affects impact remaining patches at the local scale. • Timber production
Temperate-boreal forests and woodlands	• Timber cutting for high value wood products • Shifting agriculture • Defaunation (hunting) still occurs across most of Myanmar's forests.
Savannas and grasslands	• Changes in fire regimes via increased or decreased fire management can have a strong influence on the distribution of savannas by promoting the incursion of adjacent semi-evergreen ecosystems. • Agriculture conversion, particularly for rice and nuts along Myanmar's western range and in areas surrounding Myanmar's pine savanna ecosystems • High intensity grazing can reduce recruitment and lead to losses of understorey grasses.
Polar/alpine	• Climate warming is the principal threat to Myanmar's alpine ecosystems
Dry subterranean	• Cement production • Changes in water chemistry
Palustrine wetlands	• Ongoing land conversion for agriculture such as rice farming • Changes water flooding regimes as a result of land use change and alterations to flow pathways • Urban expansion, particularly along waterways • Infrastructure development for a growing road network across the country

Lakes	• Climate change is expected to have a very high impact on freeze-thaw lake ecosystems, with increasing snowmelt resulting in an increase risk of break out floods
Shoreline systems	• Coastal development, particularly for tourism, transport infrastructure and port construction • Interrupted coastal processes • Sea level rise
Supralittoral coastal systems	• Coastal development, particularly for tourism, transport infrastructure and port construction • Infrastructure development (roads) • Change in freshwater flooding regimes • Cutting for fuelwood, charcoal and construction timber • Sea level rise • Conversion to agriculture (including coconut plantations, palm oil)
Brackish tidal systems	• Coastal development, particularly for tourism, transport infrastructure and port construction • Infrastructure development (roads) • Change in freshwater flooding regimes • Cutting for fuelwood, charcoal and construction timber • Sea level rise • Conversion to agriculture (including coconut plantations, rice paddies, palm oil) • Aquaculture development, particularly between since 1990

5. Recommendations

5.1 Major recommendations

The assessment process for the IUCN Red List of Ecosystems for Myanmar revealed widespread data deficiency and a poor-understanding of the majority of Myanmar's terrestrial ecosystems. In this section we provide specific recommendations to fill key knowledge gaps and allow a complete reassessment of Myanmar's ecosystems in the future.

5.1.1 Continued improvement to the ecosystems typology

We recommend continued review and improvement with the ecosystem typology with botanists and other experts in the region. They could help review and improve the current descriptions, help determine some of the current splits (e.g. pine savannas), and potentially identify ecosystems that might have been missed, despite our best efforts. Some more specific recommendations are noted in Table 5.1.

5.1.2 Improvements in understanding ecosystems (extent, biotic and abiotic processes)

Ecosystem mapping to assess spatial criteria (A and B)

Resource limitations in this project allowed only a single ecosystem map to be produced, reducing our ability to assess recent reductions in the geographic distribution of the majority of ecosystems in Myanmar. We recommend further work to develop time-series maps of ecosystem in Myanmar with map accuracies sufficient to analyse the change in geographic distribution of ecosystems over a 50 year period (such as Lee et al., 2020). Such maps may be developed as a single wall-to-wall mapping effort, such as the map produced in this project for the majority of terrestrial ecosystems, or as ecosystem-specific maps that enable increased accuracy through the implementation of customised mapping workflows, such as maps used to assess Coastal mudflats.

Models of historical ecosystem distributions c. 1750

Ecosystem assessments conducted in other countries, such as Finland and Colombia, have been able to utilise 'potential' or 'pre-human' ecosystem maps to assess Criterion A1. An effort to produce this type of product for Myanmar that aligns with the ecosystem typology would allow assessments of Criterion A1, which could only be applied for 5 ecosystem types (7.8% of assessed ecosystems) in this assessment.

Models of biotic and abiotic processes

The focus of this assessment was around determining the extent of ecosystems (criteria A and B), but we also produced models that informed criterion C (e.g. forest degradation) and criterion D (climate change effects within mountainous areas). Again it is important in the future to review the accuracy of these models and improve on them where possible.

Ground truthing

It will be important in the future to further ground truth the ecosystem distribution maps to gain a better understanding of the accuracy of the models and to increase our understanding of the extant distributions of each Myanmar ecosystem type. Some specific ecosystem types require urgent targeted ecological research due to being at imminent risk of collapse, or due to extremely limited knowledge of their distribution, characteristic biota and status. For instance, Southern Rakhine hills evergreen rainforest was recorded nearly 100 years ago by Stamp (1924) and our remote sensing models indicated it may still exist in very small fragments. However, further work to confirm its presence is required.

5.1.3 Central database of ecosystem data to support re-assessment

Several recent initiatives, such as OneMap Myanmar, appear promising for collating environmental spatial data in a single place to support assessments of environmental change. Other data, such as time-series data of river flows and spatial data on recent land development approvals that result in losses of natural ecosystems, would allow assessments of the red list criteria and increase the efficiency of conducting assessments such as this. A central database would also support the compilation of species inventories for each ecosystem identified in this assessment.

5.1.4 Expand IUCN Red List of Ecosystems assessment to surrounding countries

Results of this assessment suggest ecosystems in surrounding countries, including China and India, are similarly at risk from threatening processes that cause ecosystem loss and degradation. We recommend conducting IUCN Red List of Ecosystems assessments, with reference to the typology developed in this project and an effort to crosswalk to existing typologies, in surrounding countries. This will ultimately contribute to an IUCN Red List of Ecosystems of South-east Asia, as well as continental Asia.

5.1.5 Reassess Red List Criteria within 5 years

This assessment revealed widespread data deficiency, so we recommend a reassessment of the red list criteria to better refine the list of threatened ecosystems in Myanmar in a time-frame of not more than 5 years.

5.1.6 Develop a marine and a freshwater red list of ecosystems of Myanmar

A full assessment of Myanmar's marine and freshwater ecosystems to accompany this assessment would provide a comprehensive view of the risk of ecosystem collapse in Myanmar, supporting improved protected area planning and natural resource management.

5.1.7 Integrate ecosystems within policy and planning

Adoption of the ecosystem typology, data and results by the government and other stakeholders into their planning and monitoring systems. Also it would be valuable to have a system like this noted within legislation and policy. For example, when developing the updated Convention on Biological Diversity (CBD) 2020-2030 National Strategy and Action Plans for Biodiversity (NBSAPs).

5.2 Recommendations by Biome

With data deficient the most common assessment outcome in this Red List of Ecosystems national assessment, we recommend a range of further work to better estimate risks to Myanmar's natural ecosystems (Table 5.1).

Table 5.1 Recommendations for further work to reduce data deficiency and reassess the Red List of Ecosystems criteria within a period not exceeding 5 years.

Biome	Major recommendations
Tropical and subtropical forests	• Further work in inaccessible areas to assess data deficient criteria, particularly in Shan (Shan semi-evergreen forests, east Myanmar dry valley forest), Tanintharyi, northern Rakhine and Kachin. • Estimate ecosystem degradation per ecosystem using field-based methods, which include quantifying the extent and impact of shifting agriculture. • Delineate Karst landscapes in the Tanintharyi region to better delineate karst ecosystems from surrounding ecosystems. • Refine estimates of the distribution of Western Shan Plateau subtropical evergreen rainforest. • Improve the data used to split the Tanintharyi limestone tropical evergreen forest. • Confirm the presence of Southern Rakhine evergreen rainforest • Improve estimates of the distribution threatened dry zone ecosystems through targeted field searches in agricultural landscapes. • Confirm presence of Tanintharyi cloud forest and search similar mountain tops in regions identified as having a high probability of cloud forest. • Improve maps of Indaing and Northern semi-evergreen forest • Confirm the distributional differences between Tanintharyi Sundaic lowland and Tanintharyi semi-evergreen. Similarly review the threshold used between upland and lowland Tanintharyi evergreen rainforests. • Confirm presence through ground truthing of Southern Rakhine hills evergreen rainforest.
Temperate-boreal forests and woodlands	• Confirm distributions of northern warm temperate forests along the India border, as well as throughout Shan • Confirm presence of mountain bamboo brake in the north • Crosswalk ecosystem typology with Indian and Chinese ecosystem maps/typologies (e.g. Tan et al, 2017)
Savannas and grasslands	• Use burned area products to further refine distribution estimates of savanna ecosystems. • Targeted searches for data deficient ecosystems, including Shan limestone grasslands. • Analyse fire frequencies for assessments of Criterion C for fire-dependent ecosystems.

	• Confirm the presence and map the distribution of Kachin Pine Savanna when access becomes viable. • Improve maps of Than-Dahat forests through field work and targeted mapping work.
Polar/alpine	• Analyse time-series data of snow cover to assess temporal trends in alpine ecosystems. • Field work to better delineate cliffs and screes, alpine herbfield and high mountain scrub. • Glacier assessments using time-series data from relevant sensors.
Dry subterranean	• Continue to improve the cave inventory in Myanmar. • Assess where and how quarrying is impacting limestone caves across their range.
Palustrine wetlands	• Targeted field work to search for Ayeyarwady Kanazo swamp forest and refine estimates of its current and past extent. • Improve the estimate of historical and extant distributions of Central dry evergreen riparian forest. • Confirm the distribution of Mixed Delta scrub. • More detailed assessments of ecosystem degradation following methods developed in other Red List of Ecosystems assessments, such as Australia’s connected wetlands of the Lake Eyre basin (Pisanu et al., 2015)
Lakes	• Apply simulation models of glacier lakes to better investigate the impact of increasing snowmelt on collapse risk • Develop a red list of freshwater ecosystems and cross-walk with Ramsar national wetland inventory
Shoreline systems	• Detailed analyses of coastal mudflat and sandy shoreline ecosystems, including species inventories • Develop local models of distribution of sandy shoreline extent and change
Supralittoral coastal systems	• Coastal dune forests are not mapped due to their linear nature. Develop maps of these ecosystems by completing a coastal transect of Myanmar to document the presence of these ecosystems
Brackish tidal systems	• Search for other occurrences of dwarf mangrove on shingle. • Apply existing scenario and/or simulation models to mangrove ecosystems to estimate future risk of collapse (Criterion A1). • Improve spatial models of mangrove degradation to allow assessments of Criterion C and D. • Utilise recently developed global mangrove watch data to better quantify recent reductions of mangrove extent. • Field work to search for and confirm the presence of grassy saltmarsh in Myanmar

5.3 Recommendations for conservation

This IUCN Red List of Ecosystems assessment has shown a dire situation for Myanmar's ecosystems. Of the area assessed, we found that nearly two-thirds (64%) is mapped as a natural ecosystem type, but of this over half (57.8%, 24,750 km^2) of remaining area contains a threatened ecosystem type (CR, EN and VU). This means over one third of Myanmar's land area contains threatened ecosystems. There needs to be an increase in conservation efforts to reverse this situation and slow the trajectory towards collapse for ecosystems that are not currently threatened. Conservation planning will be key to identify what are the best conservation actions and where to apply them to reduce the risk of collapse for Myanmar's natural ecosystems.

5.3.1 Key regions to target for conservation action

Critically endangered ecosystems are found within the Bago Yoma and central coast of Rakhine, along with small pockets in the central dry zone and around the edge of the dry zone is where vulnerable ecosystems can also be found (Figure 5.1). While a lot of the country contains threatened ecosystems (CR, EN and VU), they are skewed towards particular areas including the eastern and western parts of the country, with some concentrations in the centre around Bago, and in the south within Tanintharyi (Figure 5.1). The political regions and states with the highest proportion and amounts of threatened ecosystems that could be the focus of conservation planning processes including Shan, Kayah and Nay Pyi Taw in addition to those with the great extents of threatened ecosystems Rakhine, Chin, Bago, and Tanintharyi (Figure 5.2).

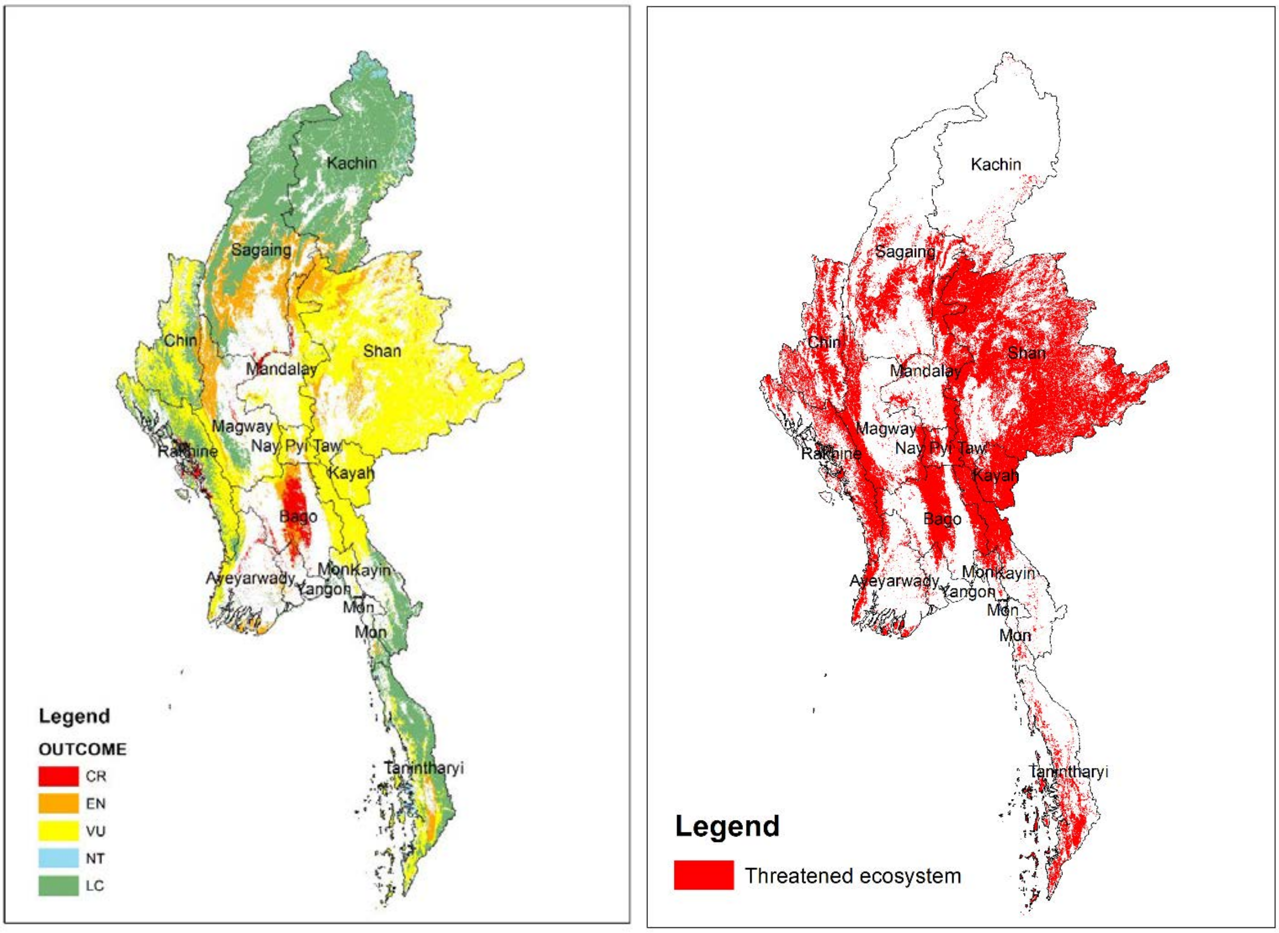


Figure 5.1. Distribution of different categories of threatened ecosystems (left), and the distribution of all threatened ecosystems (right). Threatened ecosystems included CR, EN, and VU.

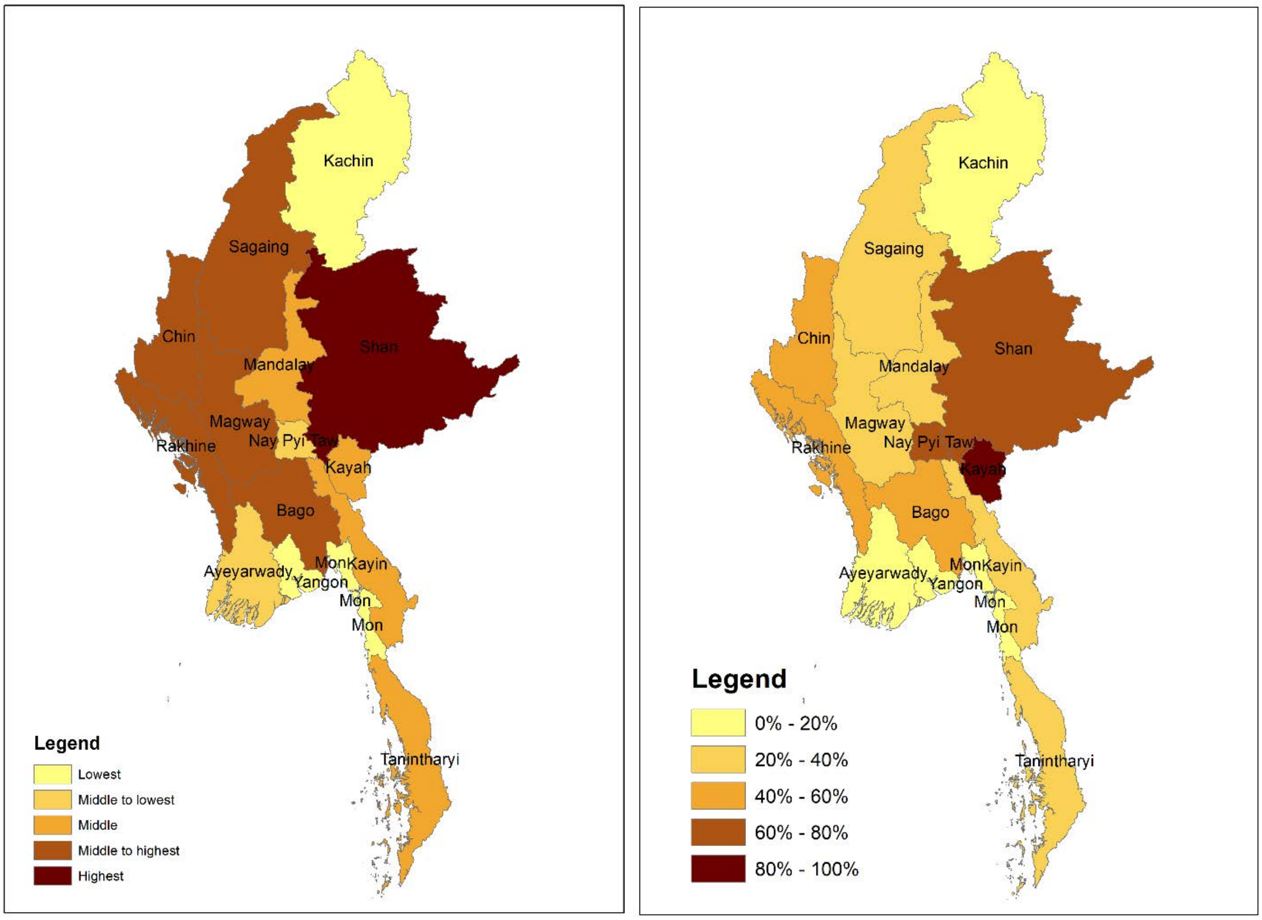


Figure 5.2. The number of threatened ecosystems within each state or region. Left is comparing the states and regions with the highest versus lowest area of threatened ecosystems. Right is measuring the proportion of that state or region that is covering its jurisdiction with threatened ecosystems.

5.3.2 Expand conservation network

A key conservation action for ecosystem conservation is going to be the expansion of protected areas, both formal and OECM (Other Effective Conservation Measures). One of the key global conservation policy targets has been to build a representative protected area network. The Convention on Biological Diversity (CBD) Aichi targets require 17% of ecosystems be protected within protected areas.

Formal protected areas

The assessment showed that only 1.9% of the extent of ecosystems identified as threatened occur within protected areas. There are significant gaps in the current protected areas and Figure 5.3 shows the degree to which the current extent of threatened ecosystems are protected. There are a few areas with ecosystems with no current protection, including mangroves in Rakhine state and Tanintharyi limestone tropical evergreen forest (Figure 5.3). Most of the areas with threatened ecosystems have some level of protection, but have not reached the 17% target of the CBD (Figure 5.3). This does increase when proposed protected areas are included (Figure 5.3). Non-threatened ecosystem types, which occur particularly in the north, are fairly well protected (Figure 5.4). Those in the south become better represented when the proposed protected areas are also included (Figure 5.4).

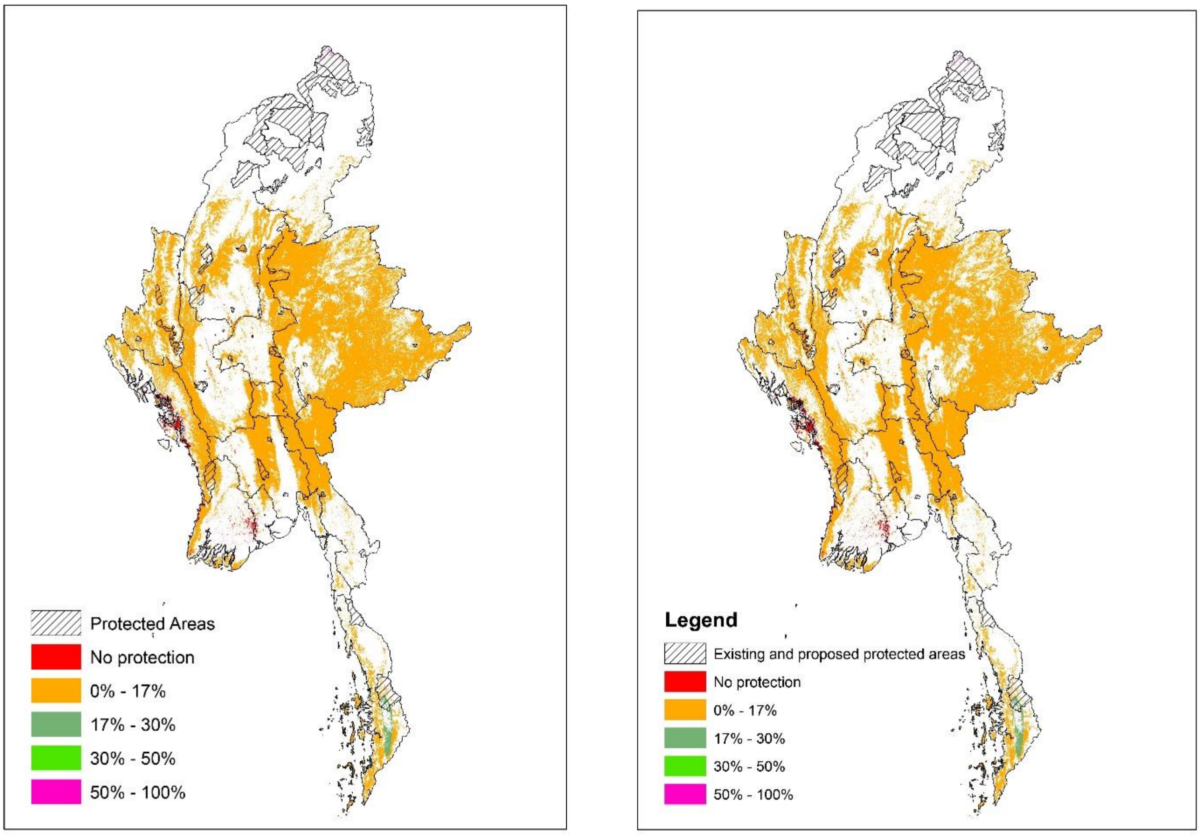
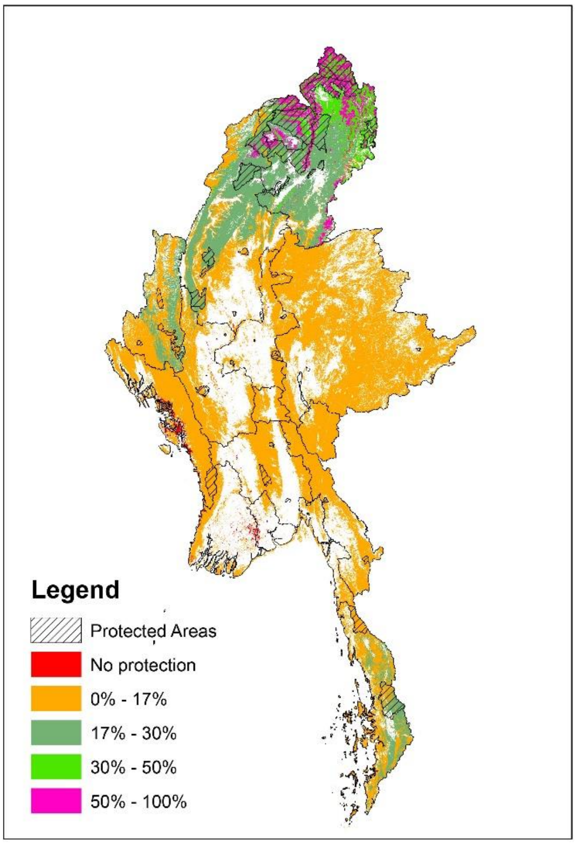


Figure 5.3. Proportion of threatened ecosystem protected for: existing protected areas (left), and existing and proposed (right).



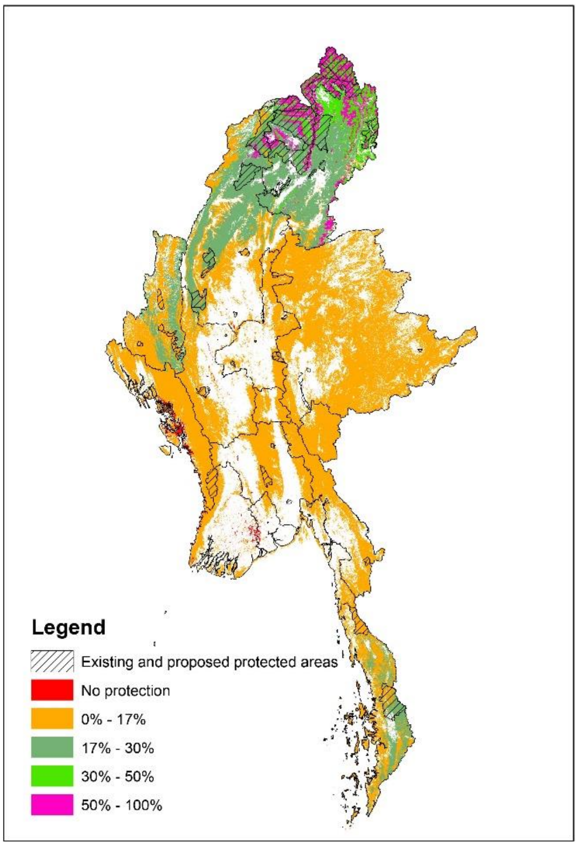


Figure 5.4. Proportion of ecosystem protected for: existing protected areas (left), and existing and proposed (right).

Forest Management Units

Forest management units administered by the Forestry Department cover a large area of Myanmar's forests. There is an opportunity for conservation management within some of the key forest units important to help conserve threatened ecosystems. Figure 5.5 shows the proportion of an ecosystem within forest management units and we found that for threatened ecosystems, those management units within the centre of the country could really contribute towards their conservation, often covering between 50-100% of the entire ecosystem remaining (Figure 5.5). It also shows additional opportunities within the east and west of the country, typically covering around 17-50% of the entire remaining ecosystems. When considering all ecosystems, there are few differences with large areas of no to low coverage in the north and south of the country (Figure 5.5). In general, forest management units are skewed towards threatened ecosystems in the centre, east and west of the country that were commercially developed during the colonial era.

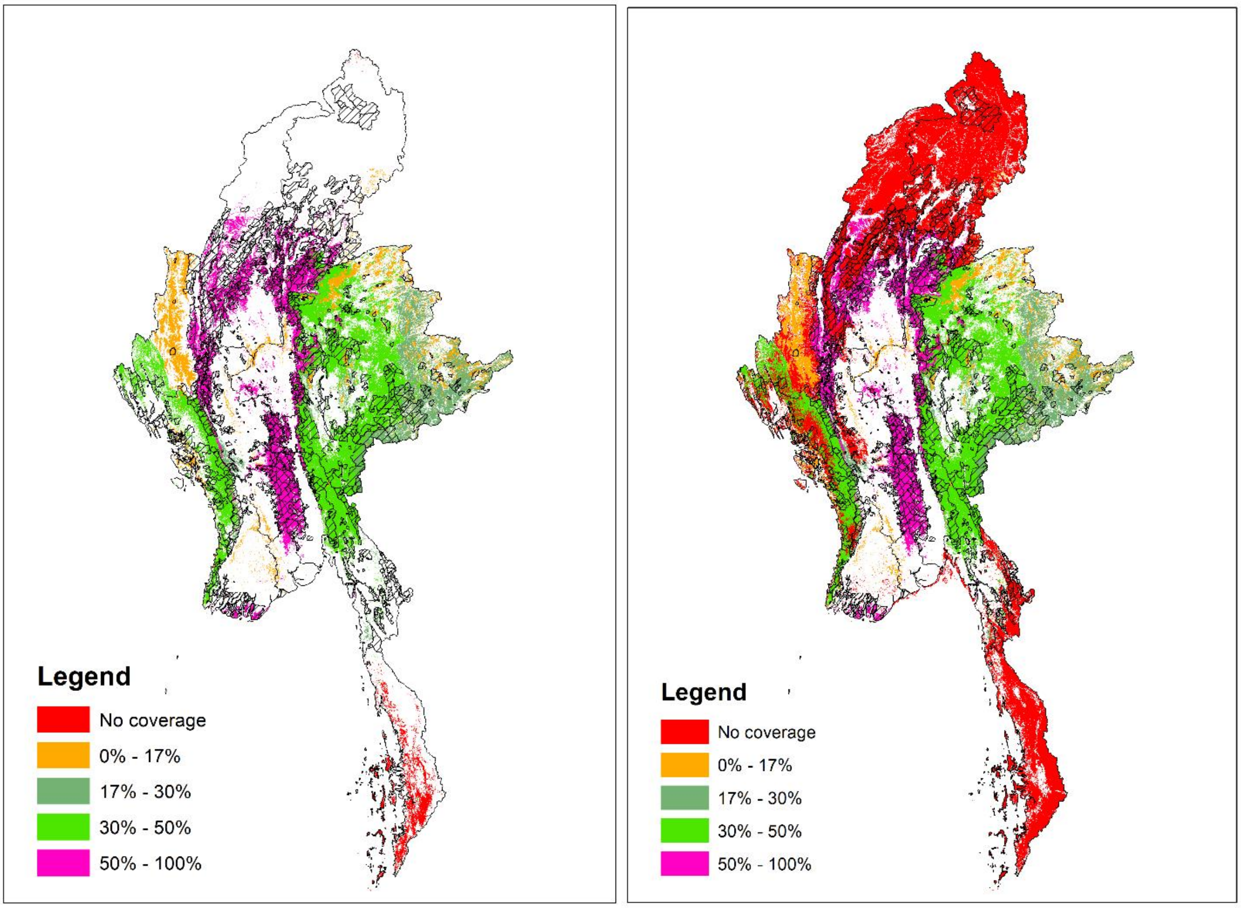


Figure 5.5. The proportion of each ecosystems area within forest management units: 1) threatened ecosystems, and 2) all ecosystems.

Community based conservation

Myanmar supports an incredible diversity of ecosystems and an equally incredible ethnic diversity of over 135 distinct ethnic groups. This diversity has also come with a long history of ethnic conflicts over a dramatic political, social and economic past. These conflicts have been integral to the threats and opportunities to conserve Myanmar's ecosystems into the next century. Since many parts of the country are still in active conflict it is unlikely that a centrally managed protected area system can cover all conservation needs.

There is a clear need for localized management systems based on community-centered conservation to expand and strengthen the country's conservation needs. Armitage et al. (2020) have identified the following principles for governance of community-centered conservation in the post-2020 global biodiversity framework:

- Build multilevel networks and collaborative relationships needed to coproduce conservation solutions that provide social and ecological outcomes;
- Promote equity and opportunity for all, recognizing specifically the role of women as agents of change in community-centered conservation;
- Reframe conservation action through the lens of reconciliation and redress (e.g., injustices from land grabs and territorial enclosures);

- Adopt a rights-based approach to conservation action in which community access and decision-making autonomy are emphasized; and
- Revitalize the customary and local institutions that provide legitimate adaptive strategies for the stewardship of biodiversity.

In May 2018, the Myanmar Government passed the Conservation of Biodiversity and Protected Area Law that formally recognizes Local Community Protected Areas as a new mechanism to secure community rights for community-centered conservation, broadly following the international concept of Indigenous Community Conservation Areas. This new law has already resulted in serval new areas being recognized based on community requests these have included areas of karst, hill forest and offshore islands. Communities in Kayin State have delegated an area of 5,485 km^2 as the Salween Peace Park a bottom-up, people-centered process to protect the resources of the Karen People. Garnett et al. (2018) has recognized that about 40% of ecologically intact landscapes are managed or tenure held by indigenous people and this needs to be an essential part of Myanmar reaching their conservation goals.

5.3.3 Threatened ecosystem recovery plans

A recovery plan for threatened ecosystems would be useful to outline actions across the ecosystems distribution that address threats to its survival, such as habitat loss and unsustainable use. The documents are usually co-developed by various government departments and ideally include the cost estimate of management actions. These documents might find specific conservation actions such as key restoration or conservation management areas or improved fire regimes.

5.3.4 Biodiversity priority areas available for other planning processes

Clear areas identified as biodiversity priority areas considering threatened ecosystems will help mainstream the recognition of those key places into various types of decision making processes to help avoid harmful development. One methodology which has previously been applied in Myanmar has been the Key Biodiversity Areas (KBAs) method. There is an ongoing process to review the current KBAs as there are now a new set of criteria that was not used to previously to identify KBAs (IUCN 2016). Two sets of criteria can be triggered ecosystem data; *A2 Threatened ecosystem types*, which requires a RLE to be completed, and *A4 geographically restricted ecosystem types.* This assessment will be a useful input into the assessment of these KBA criteria. To help justify current KBAs, we identified those which might meet the KBA criteria for ecosystems, and also how well the current network of KBAs covers the threatened ecosystems (Figure 5.6).

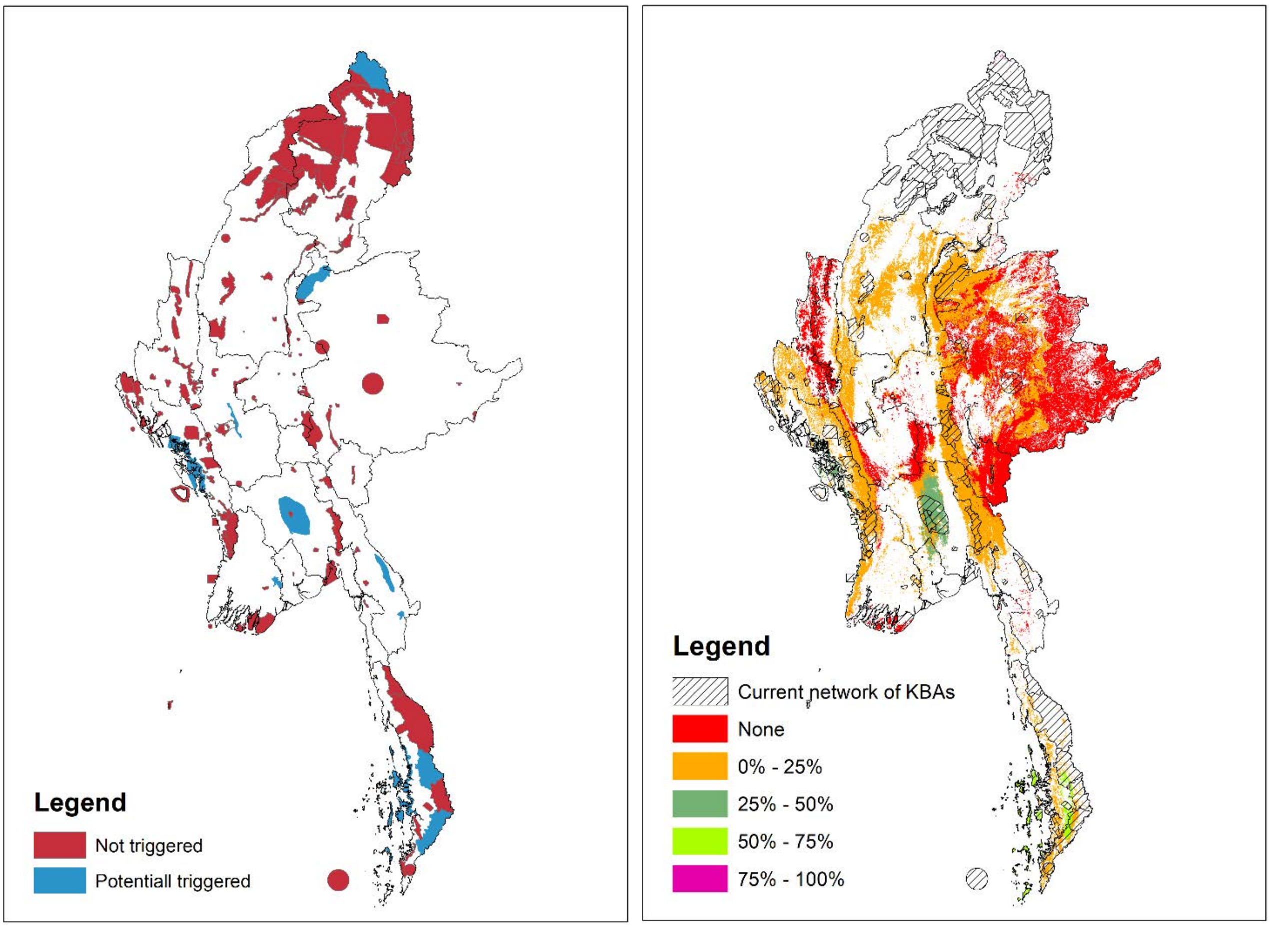


Figure 5.6. Existing KBAs and that are likely to meet criteria triggered by threatened ecosystems (left), Proportion of threatened ecosystem covered by existing KBAs.

6. References

Adam, P. (1993). Saltmarsh ecology. Cambridge University Press.

Adam, P. (2002). Saltmarshes in a time of change. *Environmental conservation*, *29*(1), 39-61.

Adam, S. (2009). Bio-physical characterization of sediment stability indicators for mudflats using remote sensing.

Allen, S. K., Zhang, G., Wang, W., Yao, T., and Bolch, T. (2019). Potentially dangerous glacial lakes across the Tibetan Plateau revealed using a large-scale automated assessment approach. *Science Bulletin*, *64*(7), 435-445.

Alongi, D. M. (2002). Present state and future of the world's mangrove forests. *Environmental conservation*, *29*(3), 331-349.

Armitage D, Mbatha P, Muhl E-K, Rice W, Sowman M. (2020). Governance principles for community-centered conservation in the post-2020 global biodiversity framework. *Conservation Science and Practice*, 2:e160.

Ashton, P. S. (2017). Patterns of variation among forests of tropical Asian mountains, with some explanatory hypotheses. *Plant Ecology and Diversity*, *10*(5-6), 361-377.

Ashton, P. S., and Seidler, R. (2014). *On the forests of tropical Asia: lest the memory fade*. Kew Publishing.

Aung, T. T., Mochida, Y., and Than, M. M. (2013). Prediction of recovery pathways of cyclone-disturbed mangroves in the mega delta of Myanmar. *Forest ecology and management*, *293*, 103-113.

Aung, M., Swe, K. K., Oo, T., Moe, K. K., Leimgruber, P., Allendorf, T., ... and Wemmer, C. (2004). The environmental history of Chatthin Wildlife Sanctuary, a protected area in Myanmar (Burma). *Journal of Environmental Management*, *72*(4), 205-216.

Auld, T. D., and Leishman, M. R. (2015). Ecosystem risk assessment for Gnarled Mossy Cloud Forest, Lord Howe Island, Australia. *Austral Ecology*, *40*(4), 364-372.

Bates, P. J., Struebig, M. J., Rossiter, S. J., Kingston, T., Oo, S. S. L., and Mya, K. M. (2004). A new species of Kerivoula (Chiroptera: Vespertilionidae) from Myanmar (Burma). *Acta Chiropterologica*, *6*(2), 219-226.

Banda, K., Delgado-Salinas, A., Dexter, K. G., Linares-Palomino, R., Oliveira-Filho, A., Prado, D., ... and Weintritt, J. (2016). Plant diversity patterns in neotropical dry forests and their conservation implications. *Science*, *353*(6306), 1383-1387.

Bhagwat, T., Hess, A., Horning, N., Khaing, T., Thein, Z. M., Aung, K. M., ... and Neil, A. (2017). Losing a jewel – Rapid declines in Myanmar's intact forests from 2002-2014. *PloS one*, *12*(5), e0176364.

Bird, E. (Ed.). (2010). *Encyclopedia of the world's coastal landforms*. Springer Science & Business Media.

BirdLife/FFI/IUCN/WWF (2014). Joint Briefing Paper on Extraction and Biodiversity in Limestone Areas'. Cambridge, UK.

Bland, L.M., Rowland, J., Regan, T.J., Keith, D. A., Murray, N. J., Lester. R.E., Linn, M., Rodriguez, J.P., and Nicholson, E. (2018). Defining ecosystem collapse for biodiversity risk assessment. *Frontiers in Ecology and the Environment*.

Bland, L. M., Keith, D. A., Miller, R. M., Murray, N. J., and Rodríguez, J. P. (2017). Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria, version 1.1. *International Union for the Conservation of Nature, Gland, Switzerland*.

Bland, L. M., Regan, T. J., Dinh, M. N., Ferrari, R., Keith, D. A., Lester, R., ... and Nicholson, E. (2017). Using multiple lines of evidence to assess the risk of ecosystem collapse. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1863), 20170660.

Bolch, T., Kulkarni, A., Kääb, A., Huggel, C., Paul, F., Cogley, J. G., ... and Bajracharya, S. (2012). The state and fate of Himalayan glaciers. *Science*, *336*(6079), 310-314.

Bowler, D. E., Nilsen, E. B., Bischof, R., O'Hara, R. B., Yu, T. T., Oo, T., ... and Linnell, J. D. (2019). Integrating data from different survey types for population monitoring of an endangered species: the case of the Eld's deer. *Scientific reports*, *9*(1), 1-14.

Brown, A. C., and McLachlan, A. (2002). Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation*, *29*(1), 62-77.

Bryant, R. L. (1996). Romancing colonial forestry: The discourse of'forestry as progress' in British Burma. *Geographical Journal*, 169-178.

Bunting, P., Rosenqvist, A., Lucas, R. M., Rebelo, L. M., Hilarides, L., Thomas, N., ... and Finlayson, C. M. (2018). The global mangrove watch – a new 2010 global baseline of mangrove extent. *Remote Sensing*, *10*(10), 1669.

Bystriakova, N. (Ed.). (2003a). *Bamboo biodiversity: information for planning conservation and management in the Asia-Pacific region*. UNEP World Conservation Monitoring Centre.

Bystriakova, N., Kapos, V., Lysenko, I., and Stapleton, C. M. A. (2003b). Distribution and conservation status of forest bamboo biodiversity in the Asia-Pacific Region. *Biodiversity & Conservation*, *12*(9), 1833-1841.

Campos-Arceiz, A., Larrinaga, A. R., Weerasinghe, U. R., Takatsuki, S., Pastorini, J., Leimgruber, P., ... and Santamaría, L. (2008). Behavior rather than diet mediates seasonal differences in seed dispersal by Asian elephants. *Ecology*, *89*(10), 2684-2691.

Cazenave, A., and Cozannet, G. L. (2014). Sea level rise and its coastal impacts. *Earth's Future*, *2*(2), 15-34.

Clements, G. R., Lynam, A. J., Gaveau, D., Yap, W. L., Lhota, S., Goosem, M., ... and Laurance, W. F. (2014). Where and how are roads endangering mammals in Southeast Asia's forests? *PloS one*, *9*(12).

Clements, R., Sodhi, N. S., Schilthuizen, M., and Ng, P. K. (2006). Limestone karsts of Southeast Asia: imperiled arks of biodiversity. *Bioscience*, *56*(9), 733-742.

Collett, H., and Hemsley, W. B. (1890). On a collection of plants from Upper Burma and the Shan States. Linnean Society London.

Connette, G. M., Oswald, P., Thura, M. K., Connette, K. J. L., Grindley, M. E., Songer, M., ... and Mulcahy, D. G. (2017). Rapid forest clearing in a Myanmar proposed national park threatens two newly discovered species of geckos (Gekkonidae: Cyrtodactylus). *PloS one*, *12*(4).

Connette, G., Oswald, P., Songer, M., and Leimgruber, P. (2016). Mapping distinct forest types improves overall forest identification based on multi-spectral Landsat imagery for Myanmar's Tanintharyi Region. *Remote Sensing*, *8*(11), 882.

Craft, C., Clough, J., Ehman, J., Joye, S., Park, R., Pennings, S., ... and Machmuller, M. (2009). Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services. *Frontiers in Ecology and the Environment*, *7*(2), 73-78.

Davies, J., Sebastian, A. C., and Chan, S. (2004). *A wetland inventory for Myanmar*. Ministry of the Environment, Japan.

Davis, J. H. (1960). *The forests of Burma* (pp. 1-41). University of Florida, USA.

Darwin Initiative. (2005). Biodiversity assessment of limestone karst dependent bats in Myanmar (Burma). Darwin Initiative.

Day, M., and Urich, P. (2000). An assessment of protected karst landscapes in Southeast Asia. *Cave and Karst Science*, *27*(2), 61-70.

De Alban, J. D. T., J. Jamaludin, D. Wong de Wen, M. M. Than and E. L. Webb (2020). Improved estimates of mangrove cover and change reveal catastrophic deforestation in Myanmar. *Environmental Research Letters* 15(3): 034034.

De Alban, J. D. T., Connette, G. M., Oswald, P., and Webb, E. L. (2018). Combined Landsat and L-band SAR data improves land cover classification and change detection in dynamic tropical landscapes. *Remote Sensing*, *10*(2), 306.

Deegan, L. A., Johnson, D. S., Warren, R. S., Peterson, B. J., Fleeger, J. W., Fagherazzi, S., and Wollheim, W. M. (2012). Coastal eutrophication as a driver of salt marsh loss. *Nature*, *490*(7420), 388-392.

Defeo, O., McLachlan, A., Schoeman, D. S., Schlacher, T. A., Dugan, J., Jones, A., ... and Scapini, F. (2009). Threats to sandy beach ecosystems: a review. *Estuarine, coastal and shelf science*, *81*(1), 1-12.

Dolezal, J., Dvorsky, M., Kopecky, M., Liancourt, P., Hiiesalu, I., Macek, M., ... and Borovec, J. (2016). Vegetation dynamics at the upper elevational limit of vascular plants in Himalaya. *Scientific reports*, *6*(1), 1-13.

Dreybrodt, J. (2019). Myanmar Cave Documentation Project: Myeik Archipelago Caves and Fauna. Myanmar Caves.

Dyer, K. R. (1998). The typology of intertidal mudflats. *Geological Society, London, Special Publications*, *139*(1), 11-24.

Eames, J. C., Hla, H., Leimgruber, P., Kelly, D. S., Aung, S. M., Moses, S., and TIN, U. S. N. (2005). Priority contribution. The rediscovery of Gurney's Pitta Pitta gurneyi in Myanmar and an estimate of its population size based on remaining forest cover. *Bird Conservation International*, 15(1), 3-26.

ECVMC-CAS (The editorial committee of vegetation map of China, Chinese Academy of Sciences). (2007). Vegetation of China and Its' Geographic Pattern: Illustration of the Vegetation Map of the People's Republic of China 1:1.000.000. Geological Publishing House, Beijing, China (in Chinese).

Esteves, L. S., and Finkl, C. W. (1998). The problem of critically eroded areas (CEA): An evaluation of Florida beaches. *Journal of Coastal Research*, 11-18.

Fagherazzi, S., Kirwan, M. L., Mudd, S. M., Guntenspergen, G. R., Temmerman, S., D'Alpaos, A., ... and Clough, J. (2012). Numerical models of salt marsh evolution: Ecological, geomorphic, and climatic factors. *Reviews of Geophysics*, *50*(1).

Fan, D. (2012). Open-coast tidal flats. In *Principles of tidal sedimentology* (pp. 187-229). Springer, Dordrecht.

Farjon, A. (2013). Pinus kesiya. The IUCN Red List of Threatened Species 2013: e.T42372A2975925. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T42372A2975925.en. Downloaded on 05 June 2019.

Fava, F., and Colombo, R. (2017). Remote Sensing-Based Assessment of the 2005–2011 Bamboo reproductive event in the Arakan Mountain range and its relation with wildfires. *Remote Sensing*, *9*(1), 85.

Fawthrop, T. (2019). Myanmar's Myitsone Dam Dilemma. *The Diplomat. March*, *11*.

Ferrer-Paris, J. R., Zager, I., Keith, D. A., Oliveira-Miranda, M. A., Rodríguez, J. P., Josse, C., ... and Barrow, E. (2019). An ecosystem risk assessment of temperate and tropical forests of the Americas with an outlook on future conservation strategies. *Conservation Letters*, *12*(2), e12623.

Ford, D., and Williams, P. D. (2013). *Karst hydrogeology and geomorphology*. John Wiley and Sons.

Forest Department (2015) National Biodiversity Strategy and Action Plan. The Republic of the Union of Myanmar, Ministry of Environmental Conservation and Forestry.

Francis, C. M. (2019). *Field Guide to the Mammals of South-East Asia.* Second Edition. Bloomsbury Wildlife. UK.

Friess, D. A., Rogers, K., Lovelock, C. E., Krauss, K. W., Hamilton, S. E., Lee, S. Y., ... and Shi, S. (2019). The State of the World's Mangrove Forests: Past, Present, and Future. *Annual Review of Environment and Resources*, *44*, 89-115.

Garnett, S.T., Burgess, N.D., Fa, J.E. *et al.* (2018). A spatial overview of the global importance of Indigenous lands for conservation. *Nat Sustain***1,** 369–374.

Gaw, L. Y., Linkie, M., and Friess, D. A. (2018). Mangrove forest dynamics in Tanintharyi, Myanmar from 1989–2014, and the role of future economic and political developments. *Singapore Journal of Tropical Geography*, *39*(2), 224-243.

Geissmann, T., Grindley, M., Momberg, F., Lwin, N., and Moses, S. (2009). Hoolock gibbon and biodiversity survey and training in southern Rakhine Yoma, Myanmar. *Gibbon Journal*, (5), 7-27.

Global Witness. (2009). A disharmonious trade: China and the continued destruction of Burma's northern frontier forests. Retrieved from https://www.globalwitness.org/en/archive/disharmonious-trade-china-and-continued-destruction-burmas-northern-frontier-forests/

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., and Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote sensing of Environment*, *202*, 18-27.

Grantham, H. S., A. Duncan, T. D. Evans, K. Jones, H. Beyer, R. … and J. E. M. Watson (2020). Modification of forests by people means only 40% of remaining forests have high ecosystem integrity. *bioRxiv.* DOI: 10.1101/2020.03.05.978858

Grismer, L. L., Wood Jr, P. L., Thura, M. K., Zin, T., Quah, E. S., Murdoch, M. L., ... and Lwin, N. (2018). Twelve new species of Cyrtodactylus Gray (Squamata: Gekkonidae) from isolated limestone habitats in east-central and southern Myanmar demonstrate high localized diversity and unprecedented microendemism. *Zoological Journal of the Linnean Society*, *182*(4), 862-959.

Grismer, L. L., Wood Jr, P. L., Thura, M. K., Quah, E. S., Murdoch, M. L., Grismer, M. S., ... and Kyaw, H. (2018). Three more new species of Cyrtodactylus (Squamata: Gekkonidae) from the Salween Basin of eastern Myanmar underscore the urgent need for the conservation of karst habitats. *Journal of Natural History*, *52*(19-20), 1243-1294.

Grismer, L. L., Wood, P. J., Thura, M. K., Quah, E. S., Grismer, M. S., Murdoch, M. L., ... and Lin, A. (2018). A new Cyrtodactylus Gray, 1827 (Squamata, Gekkonidae) from the Shan Hills and the biogeography of Bent-toed Geckos from eastern Myanmar. *Zootaxa*, *4446*(4), 477-500.

Grismer, L. L., Wood Jr, P. L., Quah, E. S., Murdoch, M. L., Grismer, M. S., Herr, M. W., ... and Lin, A. (2018). A phylogenetic taxonomy of the Cyrtodactylus peguensis group (Reptilia: Squamata: Gekkonidae) with descriptions of two new species from Myanmar. *PeerJ*, *6*, e5575.

Grismer, L. L., Wood Jr, P. L., Thura, M. K., Win, N. M., Grismer, M. S., Trueblood, L. A., and Quah, E. H. S. (2018). A re-description of Cyrtodactylus chrysopylos Bauer (Squamata: Gekkonidae) with comments on the adaptive significance of orange coloration in hatchlings and descriptions of two new species from eastern Myanmar (Burma). *Zootaxa*, *4527*(2), 151-185.

Grismer, L. L., Wood Jr, P. L., Thura, M. K., Win, N. M., and Quah, E. S. (2019). Two more new species of the Cyrtodactylus peguensis group (Squamata: Gekkonidae) from the fringes of the Ayeyarwady Basin, Myanmar. *Zootaxa*, *4577*(2), 274-294.

Grismer, L.L., Wood, P.L., Jr., Quah, E.S.H., Grismer, M.S., Thura, M. K., Oaks, J.R., Lin, A. (2019). Two new species of Cyrtodactylus Gray, 1827 (Squamata: Gekkonidae) from a karstic archipelago in the Salween Basin of southern Myanmar (Burma). Zootaxa.

Grismer, L. L., Wood, P. L. J., Quah, E. S., Thura, M. K., Herr, M. W., and Lin, A. K. (2019). A new species of forest-dwelling Cyrtodactylus Gray (Squamata: Gekkonidae) from the Indawgyi Wildlife Sanctuary, Kachin State, Myanmar. *Zootaxa*, *4623*(1), zootaxa-4623.

Grismer, L. L., Wood, P. L. J., Quah, E. S., Thura, M. K., Oaks, J. R., and Lin, A. (2019). A new species of Bent-toed Gecko (Squamata, Gekkonidae, Cyrtodactylus) from the Shan Plateau in eastern Myanmar (Burma). *Zootaxa*, *4624*(3), zootaxa-4624.

Harrap, S. (2019). Bar-tailed Treecreeper (Certhia himalayana). In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A. & de Juana, E. (eds.). Handbook of the Birds of the World Alive. Lynx Edicions, Barcelona. Retrieved from https://www.hbw.com/node/59946 on 5 July 2019.

Hogarth, P. J. (2015). *The biology of mangroves and seagrasses*. Oxford University Press.

Healy, T., Wang, Y., and Healy, J. A. (Eds.). (2002). *Muddy coasts of the world: processes, deposits and function*. Elsevier.

IUCN (2016). A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. First edition. Gland, Switzerland: IUCN.

International Rivers (2013). *World Rivers Review – Sept. 2013: Focus on World Bank and Dams*. Retrieved from https://www.internationalrivers.org/world-rivers-review/world-rivers-review-%E2%80%93-sept-2013-focus-on-world-bank-and-dams

IPCC (2014). Synthesis Report. *Contribution of working groups i, ii and iii to the fifth assessment report of the intergovernmental panel on climate change*, *138*.

Jarvis, A., and Mulligan, M. (2011). The climate of cloud forests. *Hydrological Processes*, *25*(3), 327-343.

Kathiresan, K., Salmo III, S.G., Fernando, E.S., Peras, J.R., Sukardjo, S., Miyagi, T., … and Ngoc Nam, V. (2010). Heritiera fomes. The IUCN Red List of Threatened Species 2010: e.T178815A7615342. http://dx.doi.org/10.2305/IUCN.UK.2010-2.RLTS.T178815A7615342.en

Keith, D. A., Ferrer, J.R., Nicholson, E., Bishop, M.J., Polidoro, B.A., Ramirez-Lodra, E.,…and Kingsford, R.T. (In review). Earth's ecosystems: a function-based typology for conservation and sustainability. *Nature*.

Keith, D. A., Ferrer, J.R., Nicholson, E., Bishop, M.J., Polidoro, B.A., Ramirez-Lodra, E., …and Kingsford, R.T. (2019). Indicative distribution maps for Ecological Functional Groups - Level 3 of IUCN Global Ecosystem Typology (Version 0.0.1). *Zenodo*. http://doi.org/10.5281/zenodo.3546514

Keith, D. A., Akçakaya, H. R., and Murray, N. J. (2018). Scaling range sizes to threats for robust predictions of risks to biodiversity. *Conservation Biology*, *32*(2), 322-332.

Keith, D. A., Rodríguez, J. P., Brooks, T. M., Burgman, M. A., Barrow, E. G., Bland, L., ... and Miller, R. M. (2015). The IUCN red list of ecosystems: motivations, challenges, and applications. *Conservation Letters*, *8*(3), 214-226.

Keith, D. A., Rodríguez, J. P., Rodríguez-Clark, K. M., Nicholson, E., Aapala, K., Alonso, A., ... and Benson, J. S. (2013). Scientific foundations for an IUCN Red List of Ecosystems. *PLOS one*, *8*(5).

Khaine, I., Woo, S. Y., Kang, H., Kwak, M., Je, S. M., You, H., ... and Yang, L. (2017). Species diversity, stand structure, and species distribution across a precipitation gradient in tropical forests in Myanmar. *Forests*, *8*(8), 282.

Khaing, T. T., Pasion, B. O., Lapuz, R. S., and Tomlinson, K. W. (2019). Determinants of composition, diversity and structure in a seasonally dry forest in Myanmar. Global Ecology and Conservation, 19, e00669.

Khanal, N. R., Mool, P. K., Shrestha, A. B., Rasul, G., Ghimire, P. K., Shrestha, R. B., and Joshi, S. P. (2015). A comprehensive approach and methods for glacial lake outburst flood risk assessment, with examples from Nepal and the transboundary area. *International Journal of Water Resources Development*, *31*(2), 219-237.

King, O., Dehecq, A., Quincey, D., and Carrivick, J. (2018). Contrasting geometric and dynamic evolution of lake and land-terminating glaciers in the central Himalaya. *Global and Planetary Change*, *167*, 46-60.

Kingdon-Ward, F. (1944). A sketch of the botany and geography of north Burma. *Journal of Bombay Natural History Society*, *45*, 16-30.

Kingdon-Ward, F. *Burma's Icy Mountains* (1949) Jonathan Cape.

Kirwan, M. L., and Megonigal, J. P. (2013). Tidal wetland stability in the face of human impacts and sea-level rise. *Nature*, *504*(7478), 53-60.

Kirwan, M. L., and Murray, A. B. (2007). A coupled geomorphic and ecological model of tidal marsh evolution. *Proceedings of the National Academy of Sciences*, *104*(15), 6118-6122.

Kirwan, M. L., Temmerman, S., Skeehan, E. E., Guntenspergen, G. R., and Fagherazzi, S. (2016). Overestimation of marsh vulnerability to sea level rise. *Nature Climate Change*, *6*(3), 253-260.

Kress, W. J., DeFilipps, R. A., Farr, E., and Kyi, D. Y. Y. (2003). A checklist of the trees, shrubs, herbs, and climbers of Myanmar. *A checklist of the trees, shrubs, herbs, and climbers of Myanmar*. Contributions from the United States National Herbarium, 45,1-90.

Kuwae T, Miyoshi E, Hosokawa S, Ichimi K, Hosoya J, Amano T, Moriya T, Kondoh M, Ydenberg RC, Elner RW. 2012. Variable and complex food web structures revealed by exploring missing trophic links between birds and biofilm. Ecology Letters 15:347-356.

Lee, C. K., Keith, D. A., Nicholson, E., and Murray, N. J. (2019). Redlistr: tools for the IUCN Red Lists of ecosystems and threatened species in R. *Ecography*, *42*(5), 1050-1055.

Lee, C., and Murray, N. (2017). Redlistr: Tools for the IUCN Red List of Ecosystems and Species. R package version 1.0.3. https://CRAN.R-project.org/package=redlistr

Lee, C. K., Nicholson, E., Duncan, C., & Murray, N. J. (2020). Estimating changes and trends in ecosystem extent with dense time-series satellite remote sensing. *Conservation Biology*.

Lehner, B., Liermann, C. R., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., ... and Nilsson, C. (2011). High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. *Frontiers in Ecology and the Environment*, *9*(9), 494-502.

Liu, X., Feng, Z., Jiang, L., Li, P., Liao, C., Yang, Y., and You, Z. (2013). Rubber plantation and its relationship with topographical factors in the border region of China, Laos and Myanmar. *Journal of Geographical Sciences*, *23*(6), 1019-1040.

Lim, C. L., Prescott, G. W., De Alban, J. D. T., Ziegler, A. D., and Webb, E. L. (2017). Untangling the proximate causes and underlying drivers of deforestation and forest degradation in Myanmar. *Conservation Biology*, *31*(6), 1362-1372.

Lo, T. W., Siegel, D., and Kwok, S. I. (Eds.). (2019). *Organized Crime and Corruption Across Borders: Exploring the Belt and Road Initiative*. Routledge.

Lovelock, C. E., Cahoon, D. R., Friess, D. A., Guntenspergen, G. R., Krauss, K. W., Reef, R., ... and Saintilan, N. (2015). The vulnerability of Indo-Pacific mangrove forests to sea-level rise. *Nature*, *526*(7574), 559-563.

Luijendijk, A., Hagenaars, G., Ranasinghe, R., Baart, F., Donchyts, G., and Aarninkhof, S. (2018). The state of the world's beaches. *Scientific reports*, *8*(1), 1-11.

MacKinnon, J., Verkuil, Y. I., and Murray, N. (2012). IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea). *Occasional paper of the IUCN species survival commission*, *47*.

Maharjan, S. B., Mool, P. K., Lizong, W., Xiao, G., Shrestha, F., Shrestha, R. B., ... and Baral, P. (2018). The status of glacial lakes in the Hindu Kush Himalaya-ICIMOD Research Report 2018/1 (2018). *ICIMOD Research Report*, (2018/1).

Mani, M. S. (1974a). Biogeography of the Peninsula. In *Ecology and biogeography in India* (pp. 614-647). Springer, Dordrecht.

Mani, M. S. (1974b). Biogeography of the eastern Borderlands. In *Ecology and biogeography in India* (pp. 648-663). Springer, Dordrecht.

Mariotti, G., and Fagherazzi, S. (2013). Critical width of tidal flats triggers marsh collapse in the absence of sea-level rise. *Proceedings of the national Academy of Sciences*, *110*(14), 5353-5356.

Marshall, A., to Bühne, H. S., Bland, L., and Pettorelli, N. (2018). Assessing ecosystem collapse risk in ecosystems dominated by foundation species: the case of fringe mangroves. *Ecological indicators*, *91*, 128-137.

Mentaschi, L., Vousdoukas, M. I., Pekel, J. F., Voukouvalas, E., and Feyen, L. (2018). Global long-term observations of coastal erosion and accretion. *Scientific reports*, *8*(1), 1-11.

Mundkur, T., Langendoen, T., and Watkins, D. (2017). The Asian Waterbird Census 2008–2015-Results of Coordinated Counts in Asia and Australasia. *Wetlands International, Ede, 144pp*.

Murray, N. J., Clemens, R. S., Phinn, S. R., Possingham, H. P., and Fuller, R. A. (2014). Tracking the rapid loss of tidal wetlands in the Yellow Sea. *Frontiers in Ecology and the Environment*, 12(5), 267-272.

Murray, N. J., Keith, D. A., Bland, L. M., Ferrari, R., Lyons, M. B., Lucas, R., ... and Nicholson, E. (2018). The role of satellite remote sensing in structured ecosystem risk assessments. *Science of the Total Environment*, *619*, 249-257.

Murray, N. J., Keith, D. A., Bland, L. M., Nicholson, E., Regan, T. J., Rodríguez, J. P., and Bedward, M. (2017). The use of range size to assess risks to biodiversity from stochastic threats. *Diversity and Distributions*, *23*(5), 474-483.

Murray, N. J., Ma, Z., and Fuller, R. A. (2015). Tidal flats of the Yellow Sea: A review of ecosystem status and anthropogenic threats. *Austral Ecology*, *40*(4), 472-481.

Murray, N. J., Phinn, S. R., DeWitt, M., Ferrari, R., Johnston, R., Lyons, M. B., Clinton, N., Thau, D., and Fuller, R. A. (2019). The global distribution and trajectory of tidal flats. *Nature*, *565*(7738), 222.

Murray, N.J., Keith, D.A., Tizard, R., Duncan, A., Htut, W.T., Hlaing, N., Oo, A.H., Ya, K.Z., Grantham, H. (2020). Map of the terrestrial ecosystems of Myanmar, Version 1.0. *Figshare* DOI: https://doi.org/10.6084/m9.figshare.12364067.v1

Myint, W. & Stanley, D.O. (2011). The Mangrove Vegetation of Wubaik Reserved Forest. FAO-UN.

Naidoo, G. (2006). Factors contributing to dwarfing in the mangrove Avicennia marina. *Annals of botany*, *97*(6), 1095-1101.

Naing, T. Z. (2006). Waterbirds survey in mouth of Yangon River and Ayeyarwady (Irrawaddy) delta. *Indian Birds*, *2*(3), 65-71.

Nardi, F., Annis, A., Di Baldassarre, G., Vivoni, E. R., and Grimaldi, S. (2019). GFPLAIN250m, a global high-resolution dataset of Earth’s floodplains. *Scientific data*, *6*, 180309.

Nicholson, E., Keith, D. A., and Wilcove, D. S. (2009). Assessing the threat status of ecological communities. *Conservation Biology*, *23*(2), 259-274.

NASA/METI/AIST/Japan Spacesystems, and U.S./Japan ASTER Science Team (2019). ASTER Global Water Bodies Database V001 [Data set]. NASA EOSDIS Land Processes DAAC.

Oliphant, A. J., Thenkabail, P. S., Teluguntla, P., Xiong, J., Congalton, R. G., Yadav, K., ... and Smith, C. (2017). NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) Global Food Security-support Analysis Data (GFSAD) Cropland Extent 2015 Southeast Asia 30 m V001. NASA EOSDIS Land Processes DAAC, USGS Earth Resources Observation and Science (EROS).

Oo, N. (2002). Present state and problems of mangrove management in Myanmar. *Trees*, *16*(2-3), 218-223.

Oo, K. S., Win, H. L., Bates, P. J., and Pearch, M. (2017). The ecology and distribution of Flying Foxes (Chiroptera: Pteropodidae: Pteropus) in Tanintharyi Region, Myanmar with a first mainland record of Pteropus hypomelanus geminorum from Myeik. Journal of Threatened Taxa, 9(8), 10528-10537.

Oo, W. P., & Koike, F. (2015). Dry forest community types and their predicted distribution based on a habitat model for the central dry zone of Myanmar. *Forest Ecology and Management*, 358, 108-121.

Padma, T. V. (2014). Himalayan plants seek cooler climes: race is on to record mountain biodiversity before it is lost. *Nature*, *512*(7512), 359-360.

Papworth, S., Rao, M., Oo, M. M., Latt, K. T., Tizard, R., Pienkowski, T., and Carrasco, L. R. (2017). The impact of gold mining and agricultural concessions on the tree cover and local communities in northern Myanmar. *Scientific Reports*, *7*, 46594.

Pekel, J. F., Cottam, A., Gorelick, N., and Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. *Nature*, *540*(7633), 418-422.

Pickering, C., Hill, W., and Green, K. (2008). Vascular plant diversity and climate change in the alpine zone of the Snowy Mountains, Australia. *Biodiversity and Conservation*, *17*(7), 1627-1644.

Piman, T., Krittasudthacheewa, C., Apirumanekul, C., Vasconcelos, V., Bouckaert, F., Maung, W., ... and Ohnmar Htwe, K. (2017, April). Impacts of Changing Landscapes on Water Quality in Chindwin River. In *Proceedings of the 3rd International Conference on the Status and Future of the World's Large Rivers, New Delhi, India* (pp. 18-21).

Platt, S. G., Brantley, C. G., and Rainwater, T. R. (2001). Canebrake fauna: wildlife diversity in a critically endangered ecosystem. *Journal of the Elisha Mitchell Scientific Society*, 1-19.

Platt, S. G., Myo, K. M., Ko, W. K., Maung, A., and Rainwater, T. R. (2010a). Field observations and conservation of Heosemys depressa in the Rakhine Yoma Elephant Range of western Myanmar. *Chelonian Conservation and Biology*, *9*(1), 114-119.

Platt, S. G., Ko, W. K., Myo, K. M., Khaing, L. L., Platt, K., Maung, A., and Rainwater, T. R. (2010b). Notes on Melocanna baccifera and bamboo brakes in the Rakhine hills of western Myanmar. *Bamboo Science & Culture*, *23*(1).

Platt, S. G., Myo, K. M., Ko, W. K., Maung, A., and Rainwater, T. R. (2010c). Field observations and conservation of Heosemys depressa in the Rakhine Yoma Elephant Range of western Myanmar. Chelonian Conservation and Biology, 9(1), 114-119.

Platt, S. G., Swe, T., Ko, W. K., Platt, K., Myo, K. M., Rainwater, T. R., and Emmett, D. (2011). Geochelone platynota (Blyth 1863)–Burmese Star Tortoise, Kye Leik. *Rhodin, AGJ, Pritchard, PCH, van Dijk, PP, Saumure, RA, Buhlmann, KA*.

Platt, S. G., Platt, K., Khaing, L. L., Yu, T. T., Soe, M. M., Nwe, S. S., ... and Rainwater, T. R. (2014). Heosemys depressa in the southern Chin Hills of Myanmar: a significant range extension and traditional ecological knowledge. *Chelonian Conservation and Biology*, 13(2), 252-256.

Polidoro, B. A., Carpenter, K. E., Collins, L., Duke, N. C., Ellison, A. M., Ellison, J. C., ... and Livingstone, S. R. (2010). The loss of species: mangrove extinction risk and geographic areas of global concern. *PloS one*, *5*(4).

Ponce-Reyes, R., Nicholson, E., Baxter, P. W., Fuller, R. A., and Possingham, H. (2013). Extinction risk in cloud forest fragments under climate change and habitat loss. *Diversity and Distributions*, *19*(5-6), 518-529.

Potapov, P., Tyukavina, A., Turubanova, S., Talero, Y., Hernandez-Serna, A., Hansen, M. C., ... and Chishtie, F. (2019). Annual continuous fields of woody vegetation structure in the Lower Mekong region from 2000-2017 Landsat time-series. *Remote Sensing of Environment*, *232*, 111278.

Qi, X., Zhang, C., and Wang, K. (2019). Comparing Remote Sensing Methods for Monitoring Karst Rocky Desertification at Sub-pixel Scales in a Highly Heterogeneous Karst Region. *Scientific reports*, *9*(1), 1-12.

Rao, A. S. (1974). The vegetation and phytogeography of Assam-Burma. In *Ecology and biogeography in India* (pp. 204-246). Springer, Dordrecht.

Rasmussen, P. C. and Anderton, J. C. (2012). *Birds of South Asia. The Ripley Guide. Vols. 1 and 2.* Second Edition. National Museum of Natural History – Smithsonian Institution, Michigan State University and Lynx Edicions, Washington, D.C., Michigan and Barcelona.

Ratnam, J., Bond, W. J., Fensham, R. J., Hoffmann, W. A., Archibald, S., Lehmann, C. E., ... and Sankaran, M. (2011). When is a 'forest'a savanna, and why does it matter? *Global Ecology and Biogeography*, 20(5), 653-660.

Ratnam, J., Tomlinson, K. W., Rasquinha, D. N., and Sankaran, M. (2016). Savannahs of Asia: antiquity, biogeography, and an uncertain future. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1703), 20150305.

Reddy, C. S., Pasha, S. V., Satish, K. V., Unnikrishnan, A., Chavan, S. B., Jha, C. S., ... and Dadhwal, V. K. (2019). Quantifying and predicting multi-decadal forest cover changes in Myanmar: a biodiversity hotspot under threat. *Biodiversity and conservation*, 28(5), 1129-1149.

Richards, D. R., and Friess, D. A. (2016). Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences*, *113*(2), 344-349.

Richardson, S. D., and Reynolds, J. M. (2000). An overview of glacial hazards in the Himalayas. *Quaternary International*, *65*, 31-47.

Rodríguez, J. P., Keith, D. A., Rodríguez-Clark, K. M., Murray, N. J., Nicholson, E., Regan, T. J., ... and Brooks, T. M. (2015). A practical guide to the application of the IUCN Red List of Ecosystems criteria. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1662), 20140003.

Rodríguez, J. P., RODRÍGUEZ-CLARK, K. M., Baillie, J. E., Ash, N., Benson, J., Boucher, T., ... and Keith, D. A. (2011). Establishing IUCN red list criteria for threatened ecosystems. *Conservation Biology*, *25*(1), 21-29.

Rogers, K., Kelleway, J. J., Saintilan, N., Megonigal, J. P., Adams, J. B., Holmquist, J. R., ... and Woodroffe, C. D. (2019). Wetland carbon storage controlled by millennial-scale variation in relative sea-level rise. *Nature*, *567*(7746), 91-95.

Rundel, P. W. (2009). Vegetation in the Mekong basin. In *The Mekong* (pp. 143-160). Academic Press.

Sampson, C., McEvoy, J., Oo, Z. M., Chit, A. M., Chan, A. N., Tonkyn, D., ... and Wittemyer, G. (2018). New elephant crisis in Asia – Early warning signs from Myanmar. *PloS one*, *13*(3).

Satake, K., Aung, T. T., Sawai, Y., Okamura, Y., Win, K. S., Swe, W., ... and Oo, T. Z. (2006). Tsunami heights and damage along the Myanmar coast from the December 2004 Sumatra-Andaman earthquake. *Earth, planets and space*, *58*(2), 243-252.

Saw, A.A. & Kanzaki, M. (2015). Local Livelihoods and Encroachment into a Mangrove Forest Reserve: A Case Study of the Wunbaik Reserved Mangrove Forest, Myanmar. *Procedia Environmental Sciences*, 28, 483–492.

Saw Han, U., and Khaing, S.T. (2019) Southeastern Asia: Southern Myanmar. Ecoregion Description. World Widlife Fund.

Schlacher TA, Dugan J, Schoeman DS, Lastra M, Jones A, Scapini F, McLachlan A, Defeo O. 2007. Sandy beaches at the brink. Diversity and Distributions 13:556-560.

Schuerch, M., Spencer, T., Temmerman, S., Kirwan, M. L., Wolff, C., Lincke, D., ... and Hinkel, J. (2018). Future response of global coastal wetlands to sea-level rise. *Nature*, *561*(7722), 231-234.

Shimizu, K., Ahmed, O. S., Ponce-Hernandez, R., Ota, T., Win, Z. C., Mizoue, N., and Yoshida, S. (2017). Attribution of disturbance agents to forest change using a Landsat time series in tropical seasonal forests in the Bago Mountains, Myanmar. *Forests*, *8*(6), 218.

Shrestha, F., Gao, X., Khanal, N. R., Maharjan, S. B., Shrestha, R. B., Wu, L. Z., ... and Bajracharya, S. R. (2017). Decadal glacial lake changes in the Koshi basin, central Himalaya, from 1977 to 2010, derived from Landsat satellite images. *Journal of Mountain Science*, *14*(10), 1969-1984.

Shukla, A., Garg, P. K., and Srivastava, S. (2018). Evolution of glacial and high-altitude lakes in the Sikkim, Eastern Himalaya over the past four decades (1975–2017). *Frontiers in Environmental Science*, *6*, 81.

Siddique, M. A. M., Mustafa Kamal, A. H., and Aktar, M. (2012). Trace metal concentrations in salt marsh sediments from Bakkhali River estuary, Cox's Bazar, Bangladesh. *Zoology and Ecology*, *22*(3-4), 254-259.

Songer, M. A. (2006). *Endangered dry deciduous forests of Upper Myanmar (Burma): a multi-scale approach for research and conservation* (Doctoral dissertation).

Spalding, M.D. (2001). Mangroves. Pages 496-504 in Steele, J.H. editor. *Encyclopedia of Ocean Sciences* (Second Edition). Academic Press, Oxford.

Spencer, T., Schuerch, M., Nicholls, R. J., Hinkel, J., Lincke, D., Vafeidis, A. T., ... and Brown, S. (2016). Global coastal wetland change under sea-level rise and related stresses: The DIVA Wetland Change Model. *Global and Planetary Change*, *139*, 15-30.

Stamp, L. D. (1925). The Aerial Survey of the Irrawaddy Delta Forests (Burma): Notes Embracing The Observations of Messrs. AW Moodie CR Robbins and CW Scott, Compiled and Edited with Permission. *Journal of Ecology*, *13*(2), 262-276.

Stamp, L. D. (1924a). Notes on the Vegetation of Burma. *The Geographical Journal*, *64*(3), 231-237.

Stamp, L. D. (1924b). The vegetation of Burma from an ecological standpoint. Univ. Rangoon Res. Monogr., 1, 1-58.

Stamp, L. D., and Lord, L. (1923). The ecology of part of the riverine tract of Burma. *Journal of Ecology*, *11*(2), 129-159.

Storey, D. (2015). A Socio-Economic Assessment of Mangroves Areas in North Rakhine State. *REACH*.

Suzuki, R., Takeda, S., and Keh, S. K. (2004). The impact of forest fires on the long-term sustainability of taungya teak reforestation in Bago Yoma, Myanmar. *Tropics*, *14*(1), 87-102.

Tan, J., A. Li, G. Lei, J. Bian, G. Chen and K. Ma (2017). Preliminary assessment of ecosystem risk based on IUCN criteria in a hierarchy of spatial domains: A case study in Southwestern China. *Biological Conservation* 215: 152-161.

Tagane, S., Toyama, H., Tanaka, N., Aung, M. M., Nagahama, A., Win, A. K., ... and Yahara, T. (2019). Contributions to the flora of Myanmar III: New records of 10 woody species from the Mergui Archipelago of southern Myanmar. Natural History Bulletin of the Siam Society, 63(2), 141-151.

Telwala, Y., Brook, B. W., Manish, K., and Pandit, M. K. (2013). Climate-induced elevational range shifts and increase in plant species richness in a Himalayan biodiversity epicentre. *PloS one*, *8*(2).

Thaung, N. O., Lwin, K. O., and Yin, Y. K. (2006). Assessment on plant biodiversity of the Alaungdaw Kathapa National Park in Myanmar. In *Proceedings of the Annual Research Conference (Forestry Sciences), Yangon, Myanmar, 26-28 May, 2006* (pp. 19-90). Myanmar Academy of Agricultural, Forestry, Livestock and Fishery Sciences.

Thompson, R. C., Crowe, T. P., and Hawkins, S. J. (2002). Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. *Environmental Conservation*, *29*(2), 168-191.

Thu, A. M., Li, G. G., Zhang, M., Thang, T. H., Soe, A. M., Naing, W., and Quan, R. C. (2019). Group size and social organization of the endangered Eld's deer (Rucervus eldii thamin): Results from a long-term study in Myanmar. *Global Ecology and Conservation*, *18*, e00618.

Tian, Y., Wu, B., Zhang, L., Li, Q., Jia, K., and Wen, M. (2011). Opium poppy monitoring with remote sensing in North Myanmar. *International Journal of Drug Policy*, *22*(4), 278-284.

Torbick, N., Chowdhury, D., Salas, W., and Qi, J. (2017). Monitoring rice agriculture across myanmar using time series Sentinel-1 assisted by Landsat-8 and PALSAR-2. *Remote Sensing*, *9*(2), 119.

Tun, K. K. (2016). Sustainability in Pa-O forest: Will there be hope for the locals? In *Politics of Autonomy and Sustainability in Myanmar* (pp. 91-123). Springer, Singapore.

UNESCO. (2014). Tentative World Heritage Listing. URL: https://whc.unesco.org/en/tentativelists/5874/

Van Zonneveld, M., Koskela, J., Vinceti, B., and Jarvis, A. (2009). Impact of climate change on the distribution of tropical pines in Southeast Asia. *Unasylva*, 60(231/232), 24-28.

Veettil, B. K., Pereira, S. F. R., and Quang, N. X. (2018). Rapidly diminishing mangrove forests in Myanmar (Burma): a review. *Hydrobiologia*, *822*(1), 19-35.

Waltham, T., and Eavis, A. (2004). Caves in Myanmar. Cave and Karst Science, 31(1), 3-6.

Wang, C., and Myint, S. W. (2016). Environmental concerns of deforestation in Myanmar 2001–2010. *Remote sensing*, *8*(9), 728.

Wang, S. J., and Zhang, T. (2013). Glacial lakes change and current status in the central Chinese Himalayas from 1990 to 2010. *Journal of Applied Remote Sensing*, *7*(1), 073459.

Ward, R. D., Friess, D. A., Day, R. H., and MacKenzie, R. A. (2016). Impacts of climate change on mangrove ecosystems: a region by region overview. *Ecosystem Health and Sustainability*, *2*(4), e01211.

Webb, E. L., Jachowski, N. R., Phelps, J., Friess, D. A., Than, M. M., and Ziegler, A. D. (2014). Deforestation in the Ayeyarwady Delta and the conservation implications of an internationally-engaged Myanmar. *Global Environmental Change*, *24*, 321-333.

Weston, N. B. (2014). Declining sediments and rising seas: an unfortunate convergence for tidal wetlands. *Estuaries and Coasts*, *37*(1), 1-23.

Whitten, T., and Damanik, S. J. (2012). Ecology of Sumatra. Tuttle Publishing.

Whitten, T., Damanik, S. J., Anwar, J., and Hisyam, N. (2000). The ecology of Sumatra, vol. 1. *Hong Kong: Periplus Editions Ltd*.

Williams, R. J., Wahren, C. H., Stott, K. A. J., Camac, J. S., White, M., Burns, E., ... and Papst, W. A. (2015). An International Union for the Conservation of Nature Red List ecosystems risk assessment for alpine snow patch herbfields, South-Eastern Australia. *Austral Ecology*, *40*(4), 433-443.

Wilson, A. M., and Jetz, W. (2016). Remotely sensed high-resolution global cloud dynamics for predicting ecosystem and biodiversity distributions. *PLoS biology*, *14*(3), e1002415.

Wohlfart, C., Wegmann, M., and Leimgruber, P. (2014). Mapping threatened dry deciduous dipterocarp forest in South-east Asia for conservation management. *Tropical Conservation Science*, *7*(4), 597-613.

Worthington, T., and Spalding, M. (2018). Mangrove restoration potential: A global map highlighting a critical opportunity.

Yao, X., Liu, S., Han, L., Sun, M., and Zhao, L. (2018). Definition and classification system of glacial lake for inventory and hazards study. *Journal of Geographical Sciences*, *28*(2), 193-205.

Zaw Htun, N., Mizoue, N., and Yoshida, S. (2011). Classifying tropical deciduous vegetation: a comparison of multiple approaches in Popa Mountain Park, Myanmar. *International Journal of Remote Sensing*, *32*(24), 8935-8948.

Zöckler, C., Delany, S., and Barber, J. (2013). Sustainable Coastal Zone Management in Myanmar. ArcCona Ecological Consultants and Flora Fauna International. Cambridge, UK. 60pp Stilt 66:37-51.

Zöckler, C., Hla, T. H., Clark, N., Syroechkovskiy, E., Yakushev, N., Daengphayon, S., and Robinson, R. O. B. (2010). Hunting in Myanmar is probably the main cause of the decline of the Spoon-billed Sandpiper Calidris pygmeus. *Wader Study Group Bulletin*, *117*(1), 1-8.

Zöckler, C., Zaw Naing, T., Moses, S., Nou Soe, R., and Htin Hla, T. (2014). The importance of the Myanmar coast for Water Birds. *Stilt*, *66*, 37-51.

Zöckler, C., Aung, P.P, Grindley, M., and Aung, C. (2018). Coastal Wetlands in Myanmar – a directory of important sites for biodiversity. ArcCona Ecological Consultants, Cambridge, UK.

Appendix 1.
Expert group on Myanmar Ecosystem Assessment

Myanmar Government Institutions

Name	Affiliation
U Moe Aung	Dry Zone Greening Department, Forest Department
U Thet Naing Oo	Natural Forest and Planation Division, Forest Department
U Tun Tun Win	Forest Research Institute, Forest Department
U Phyo Thet Naing	Watershed Management Division, Forest Department
U Lamin Thu(2)	Planning and Statistics Division, Forest Department
U Kyaw Thet	GIS Section, Forest Department
Daw Nan Shwe Yi	Planning and Statistics Division, Forest Department
U Nyein Aung	Nature and Wildlife Conservation Division, Forest Department
Daw Wai Mon Thet	Nature and Wildlife Conservation Division, Forest Department
Daw Thaw Min Moe	Nature and Wildlife Conservation Division, Forest Department
U Sein Aung Min	Environmental Conservation Department
Daw Su Su Win	Environmental Conservation Department
U Soe Moe Kyaw	Survey Department
U Min Thet Htun	Survey Department
Dr. Rose Nay Win	University of Forestry and Environmental Science
Dr. Aung Swe	Geography Department, Yangon University
Dr. Aung Kyaw Myat	Geology Department, Yangon University
Dr. Aye Mi San	Zoology Department, Yangon University
Dr. Ko Myint	Zoology Department, Yangon University
Dr. Win Zaw	Zoology Department, Yangon University
Dr. Nyo Nyo Aung	Zoology Department, Yangon University
Dr. Soe Sandar San	Geography Department, Mandalay University
Dr. Soe Moe Lwin	Geology Department, Mandalay University
Dr. Sai Sein Lin Oo	Zoology Department, Kyaing Tone University
Dr. Moe Moe Khaing	Zoology Department, Sagaing University
Dr. Kyaw Aung Hein	Geography Department, Taunggyi University
Daw Ei Shwe Sin	Geology Department, Taunggyi University
Daw Yin Nwe Oo	Marine Science Department, Myeik University
U Aung Myo Hsan	Marine Science Department, Mawlamyaing University

National and International Non-governmental Organisations

Name	Affiliation
Carl Reeder	World Wide Fund for Nature (WWF)
Daw Zin Mar Hein	World Wide Fund for Nature (WWF)
Mark Grindley	Fauna and Flora International (FFI)
U Aung Lin	Fauna and Flora International (FFI)
U Myo Myint Aung	Fauna and Flora International (FFI)
U Thet Zaw	Istituto Oikos
U Toe Tat Zay Ya	Istituto Oikos
Dr. Nicolas Murray	James Cook University (JCU)
Dr. Hedley Grantham	Wildlife Conservation Society (WCS)
Robert Tizard	Wildlife Conservation Society (WCS)
Dr. Alex Diment	Wildlife Conservation Society (WCS)
Adam Duncan	Wildlife Conservation Society (WCS)
U Saw Htun	Wildlife Conservation Society (WCS)
U Kyaw Thinn Latt	Wildlife Conservation Society (WCS)
Dr. Naw May Lay Thant	Wildlife Conservation Society (WCS)
U Thet Zaw Naing	Wildlife Conservation Society (WCS)
U Kyaw Zaya	Wildlife Conservation Society (WCS)
U Nyan Hlaing	Wildlife Conservation Society (WCS)
U Aung Htet Oo	Wildlife Conservation Society (WCS)
U Kyaw Kaung Thant Zin	Wildlife Conservation Society (WCS)
U Htet Arkar Aung	Wildlife Conservation Society (WCS)
U Ye Linn Aung	Wildlife Conservation Society (WCS)
U Min Hein Htike	Wildlife Conservation Society (WCS)
U Htun Thu	Wildlife Conservation Society (WCS)
U Swan Htet Naing Aung	Wildlife Conservation Society (WCS)
Daw Theint Thandar Bol	Wildlife Conservation Society (WCS)
U Aung Kyaw Thu	The Regional Community Forestry Training Centre (RECOFTC)
Dr. Thiri Dawei Aung	Biodiversity and Nature Conservation Association (BANCA)
Daw Thiri Sandar Zaw	Biodiversity and Nature Conservation Association (BANCA)
U Myint Lwin	Myanmar Forest Association (MFA)
U Yan naing Kyaw	Myanmar Forest Association (MFA)
U Tint Tun	Marine Science Association Myanmar (MSAM)
U Aung Kyaw Myint	Friend of Wildlife (FOW)
U Kyaw Naing Win	One Map-Myanmar
U Shein Aung Khun Bo	Myanmar Environmental Rehabilitation-Conservation Network (MERN)
Daw Khay Mar Aye Mon	Advancing Life and Regenerating Motherland (ALARM)
U Soe Min Naing	Ecosystem Conservation and Community Development Initiative (ECCDI)

Appendix 2.
Translation of Ecosystem Names: English → Myanmar

ကုဒ်နံပါတ်	ဇီဝနယ်မြေ / လုပ်ဆောင်ချက် အုပ်စု / ဂေဟာစနစ် အမျိုးအစား	ကာကွယ်ထားမှု အခြေအနေ
T	ကုန်းမြေ	
T1	*အပူပိုင်း/ သမပိုင်း သစ်တောများ*	
T1.1	*အပူပိုင်း/သမပိုင်း မြေနိမ့် မိုးသစ်တော*	
MMR-T1.1.1	တနင်္သာရီကျွန်းစု မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ (ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး- ပျက်သုဉ်းရန် အန္တရာယ်ရှိ)
MMR-T1.1.2	တနင်္သာရီ ဆွန်းဒီယက်(စ) မြေနိမ့်ပိုင်း အမြဲစိမ်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.1.3	တနင်္သာရီ ထုံးကျောက်တောင် အပူပိုင်း အမြဲစိမ်းတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.1.4	တနင်္သာရီကုန်းမြင့် အမြဲစိမ်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T1.1.5	ကရင် အမြဲစိမ်း အပူပိုင်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.1.6	တောင်ပိုင်း ရခိုင်ကုန်းမြင့် အမြဲစိမ်း မိုးသစ်တော	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ (ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ – ပြိုကွဲ ပျက်သုဉ်း)
MMR-T1.1.7	အနောက်ပိုင်း ရှမ်းကုန်းပြင်မြင့် သမပိုင်း အမြဲစိမ်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.1.8	ကချင်-စစ်ကိုင်း ပင်လယ်ရေ မျက်နှာပြင်နိမ့် သမပိုင်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T1.1.9	ကချင်-စစ်ကိုင်း ပင်လယ်ရေ မျက်နှာပြင် အလယ်အလတ် သမပိုင်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T1.1.10	ကချင်ကုန်းမြင့် သမပိုင်း မိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
T1.2	*အပူပိုင်း/ သမပိုင်း ခြောက်သွေ့တောနှင့် ဆူးခြုံတောများ*	
MMR-T1.2.1	တနင်္သာရီ အမြဲစိမ်းဆန်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T1.2.2	ကျောက်ဆောင်ပေါ်သော တနင်္သာရီ ထုံးကျောက်ဂူများ	အချက်အလက် ပြည့်စုံမှုမရှိ
MMR-T1.2.3	ရေနောကြိမ်တောများ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T1.2.4	ပဲခူး အမြဲစိမ်းဆန်တော	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ (ပျက်သုဉ်းရန် အန္တရာယ်ရှိ- ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ)
MMR-T1.2.5	အပူပိုင်းဒေသ တောင်ခြေ ဆူးခြုံတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး

MMR-T1.2.6	ရခိုင်ကုန်းမြင့် ဝါးတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T1.2.7	ရခိုင်ကုန်းမြင့် အမြဲစိမ်းဆန် ခြောက်သွေ့တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.2.8	မကွေး ခြောက်သွေ့မုန်တိုင်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ (ပျက်သုဉ်းရန် အန္တရာယ်ရှိ- ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ)
MMR-T1.2.9	မကွေး အမြဲစိမ်းဆန် ခြောက်သွေ့ လျှိုမြောင်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ (ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး-ပျက်သုဉ်းရန် အန္တရာယ်ရှိ)
MMR-T1.2.10	မြန်မာ အရှေ့ပိုင်း ခြောက်သွေ့တောင်ကြားသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.2.11	ရှမ်း အရှေ့ပိုင်း အမြဲစိမ်းဆန်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.2.12	ရှမ်း အနောက်ပိုင်း အမြဲစိမ်းဆန်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.2.13	အင်တိုင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T1.2.14	မြောက်ပိုင်း အမြဲစိမ်းဆန်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
T1.3	အပူပိုင်း/သမပိုင်း စွတ်စို တောင်ပေါ် *မိုးသစ်*တော	
MMR-T1.3.1	တနင်္သာရီ မိုးတိမ်သစ်တောများ	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ
T2	**အအေးပိုင်း-ဆီးနှင်းဖုန်းလွှမ်းသော တောင်ပေါ်သစ်တောများ**	
T2.1	အအေးပိုင်း-ဆီးနှင်းဖုန်းလွှမ်းသော တောင်ပေါ်သစ်တောများ	
MMR-T2.1.1	ကချင် တောင်ပေါ် ထင်းရှူးတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
T2.4	အအေးပိုင်း ပူနွေးမိုးသစ်တော	
MMR-T2.4.1	ရှမ်း အအေးပိုင်း ပူနွေးမိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T2.4.2	ချင်းတောင်တန်း အအေးပိုင်း ပူနွေးမိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T2.4.3	စစ်ကိုင်း အအေးပိုင်း ပူနွေးမိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး
MMR-T2.4.4	ကချင် အအေးပိုင်း ပူနွေးမိုးသစ်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး (ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး- ပျက်သုဉ်းရန် အန္တရာယ်ရှိ)
MMR-T2.4.5	တောင်ပေါ်ဝါးတော	အချက်အလက် ပြည့်စုံမှုမရှိ

MMR-T2.4.6	ကချင် အအေးပိုင်း တောင်ပေါ် ရွက်ကျယ်တော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
T4	**မြက်ခင်းတောများနှင့် မြက်ခင်းလွင်ပြင်များ**	
T4.2	မီးလောင်ထားသော တူးဆော့ခ်မြက်ခင်းလွင်ပြင်များ	
MMR-T4.2.1	ရခိုင်ကမ်းရိုးတန်း မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T4.2.2	ဧရာဝတီမြစ် အလယ်ပိုင်း သန်း၊ ဒဟတ် မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T4.2.3	ဧရာဝတီမြစ် အလယ်ပိုင်း ထန်းနှင့် မြက်ခင်းတော	ပြိုကွဲ ပျက်သုဉ်း
MMR-T4.2.4	ရွှေစက်တော် ရှားနှင့်ဝါး ရောနှောတော	ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး
MMR-T4.2.5	မကွေး သန်း၊ ဒဟတ်နှင့် ခြောက်သွေ့မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T4.2.6	ရှား ဆူးခြုံတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T4.2.7	ရှမ်း တောင်ခြေ သန်း၊ ဒဟတ် မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T4.2.8	ရှမ်းတောင်တန်း ထင်းရှူးနှင့် မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-T4.2.9	ချင်းတောင်တန်း ထင်းရှူးနှင့် မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T4.2.10	စစ်ကိုင်းတောင်တန်း ထင်းရှူးနှင့် မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T4.2.11	ကချင် ထင်းရှူးနှင့် မြက်ခင်းတော	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
T4.5	အအေးပိုင်း မြက်ခင်းတောများ	
MMR-T4.5.1	ရှမ်း ထုံးကျောက်နှင့် မြက်ခင်းတော	အချက်အလက် ပြည့်စုံမှုမရှိ
T6	**ဝင်ရိုးစွန်းဒေသ/မြင့်မားသော တောင်တန်းများ**	
T6.1	**ရေခဲ အလွှာချပ်များ၊ ရေခဲမြစ်များ၊ နှစ်ရှည် ဆီးနှင်းဖုံးကွင်းပြင်များ**	
MMR-T6.1.1	ကချင် ဆီးနှင်းလွင်ပြင်	ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး (ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး- ပျက်သုဉ်းရန် အန္တရာယ်ရှိ)
T6.2	ဝင်ရိုးစွန်းဒေသ/မြင့်မားသော တောင်ပေါ်ဒေသရှိ ကျောက်တောင်စွန်းများ	
MMR-T6.2.1	မြင့်မားသော တောင်ပေါ်ဒေသကျောက်ကမ်းပါးစောက်များနှင့် ကျောက်ကျိုးပဲ့ပျက်နှာပြင်များ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး

T6.4	အအေးပိုင်း မြင့်မားသောတောင်ပေါ်ဒေသ မြက်ခင်းမြေများနှင့် ခြုံတောမြေများ	
MMR-T6.4.1	မြင့်မားသော တောင်ပေါ် ခြုံတောများ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MMR-T6.4.2	မြင့်မားသောတောင်ပေါ်ဒေသရှိဘယဆေးခင်းများ	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
S	**မြေအောက်လှိုဏ်ဂူများ**	
S1	**ခြောက်သွေ့သော မြေအောက် လှိုဏ်ဂူများ**	
S1.1	မြေအောက်ကျောက်လှိုဏ်များ	
MMR-S1.1.1	အောက်စီဂျင်ရနိုင်သော ထုံးကျောက်လှိုဏ်ဂူများ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
TF	**ရေချို/ကုန်း**မြေ	
TF1	**ရေငံစပ် ရေငြိမ်၊ ရေဝပ်ဒေသများ**	
TF1.1	အပူပိုင်း ရေလွှမ်းတောများနှင့် သစ်ဆွေးတောများ	
MMR-TF1.1.1	ဧရာဝတီ ကနစို စိမ့်တောများ	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ (ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ-ပြိုကွဲ ပျက်သုဉ်း)
MMR-TF1.1.2	အလယ်ပိုင်း ခြောက်သွေ့အမြဲစိမ်း မြစ်ချောင်းကမ်းနား သစ်တောများ	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ
MMR-TF1.1.3	မြစ်ဝကျွန်းပေါ် ရေနှော ခြုံတောများ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
TF1.4	ရာသီအလိုက် ရေလွှမ်း ရှံ့တောများ	
MMR-TF1.4.1	ဧရာဝတီ ရေလွှမ်းလွင်ပြင် ရေဝပ်ဒေသများ	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-TF1.4.2	ဧရာဝတီ အလယ်ပိုင်း ရေလွှမ်းလွင်ပြင် မြက်ခင်းတောများ	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ
F	**ရေချို**	
F2	**ကန်များ**	
F2.4	အေးခဲပြီး စိမ့်ဝင်နေသော ရေချိုကန်များ	
MMR-F2.4.1	ရေခဲမြစ်လက်ကျန် ရေကန်များ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MT	**အဏ္ဏဝါ/ကုန်းမြေ**	
MT1	**ကန်းရိုးတန်းများ** *Shoreline systems*	
MT1.2	ရွှံ့နွံထူထပ်သော ကမ်းခြေများ	

MMR-MT1.2.1	ကမ်းရိုးတန်း ရွှံ့ပြင်ကျယ်များ/ လဒါပြင်များ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MT1.3	သဲသောင်ပြင်များ	
MMR-MT1.3.1	သဲသောင်ပြင် ကမ်းရိုးတန်းများ	ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး
MT2	**ဒီရေအထက် ရေတင်စိုစွတ်နေသော ကမ်းရိုးတန်းများ**	
MT2.1	ကမ်းရိုးတန်း ခြုံတောများနှင့် မြက်ခင်းလွင်ပြင်များ	
MMR-MT2.1.1	တနင်္သာရီ ကမ်းရိုးတန်း သဲသောင်ခုံတောများ	အချက်အလက် ပြည့်စုံမှုမရှိ
MMR-MT2.1.2	ရခိုင် ကမ်းရိုးတန်း သဲသောင်ခုံတောများ	အချက်အလက် ပြည့်စုံမှုမရှိ
MFT	**အငန္တာဝါ/ရေချို/ကုန်းေြမ**	
MFT1	**ရေငန် ဒီရေတောများ**	
MFT1.2	ဒီရေတောများနှင့် ခြုံတောများ	
MMR-MFT1.2.1	တနင်္သာရီ ဒီရေတော	ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး (ပျက်သုဉ်းရန် အန္တရာယ်နည်းပါး- ပျက်သုဉ်းရန် အန္တရာယ် ကျရောက်လုနီးပါး)
MMR-MFT1.2.2	ဧရာဝတီ မြစ်ဝကျွန်းပေါ်ဒီရေတော	ပျက်သုဉ်းရန် အန္တရာယ်ရှိ
MMR-MFT1.2.3	ကျောက်စရစ်မြေပေါ် ရှိ ခြုံပုတ်ပု ဒီရေတောများ	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ
MMR-MFT1.2.4	ရခိုင် ရွှံ့ထူဒီရေတောများ	ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ (ပျက်သုဉ်းရန် အန္တရာယ်ရှိ- ပျက်သုဉ်းလုနီးပါး အန္တရာယ်ရှိ)
MFT1.3	ကမ်းရိုးတန်း ဒီရေလွှမ်း မြက်ခင်းတောများ	
MMR-MFT1.3.1	ဒီရေလွှမ်း မြက်ခင်းတောများ	အချက်အလက် ပြည့်စုံမှုမရှိ

Appendix 3.
Summary table of RLE Results

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
T	*TERRESTRIAL*																				
T1	*Tropical and subtropical forests*																				
T1.1	*Tropical/subtropical lowland rainforests*																				
MMR-T1.1.1	Tanintharyi island rainforests	DD	DD	DD	DD	LC	LC	NA	LC	DD	VU (LC-VU)	DD	DD	DD	DD	LC	LC	NE	VU	LC	VU
MMR-T1.1.2	Tanintharyi Sundaic lowland evergreen rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	VU	VU	NE	VU	VU	VU
MMR-T1.1.3	Tanintharyi limestone tropical evergreen forest	DD	DD	DD	DD	EN	LC	B1a(i), B1a(iii)	LC	DD	LC	DD	DD	DD	DD	LC	LC	NE	EN	EN	EN
MMR-T1.1.4 *	Tanintharyi upland evergreen rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD
MMR-T1.1.5	Kayin evergreen tropical rainforest	DD	DD	DD	DD	VU	LC	B1a(i), B1a(iii)	LC	DD	LC	DD	DD	DD	DD	LC	EN	NE	EN	EN	EN
MMR-T1.1.6	Southern Rakhine hills evergreen rainforest	DD	DD	DD	DD	CR	EN	B1a(i), B1a(iii)	NE	DD	DD	DD	DD	DD	DD	DD	DD	NE	CR	CR	CO
MMR-T1.1.7	Western Shan Plateau subtropical evergreen rainforest	DD	DD	DD	DD	LC	LC	NA	DD	DD	DD	DD	DD	DD	DD	LC	VU	NE	VU	VU	VU
MMR-T1.1.8 *	Kachin-Sagaing low elevation evergreen subtropical rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD
MMR-T1.1.9 *	Kachin-Sagaing mid elevation subtropical rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
MMR-T1.1.10 *	Kachin Hills subtropical rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD
T1.2	*Tropical/subtropical dry forests and scrubs (T1.2)*																				
MMR-T1.2.1 *	Tanintharyi semi-evergreen forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD
MMR-T1.2.2	Rocky Tanintharyi karst	DD	DD	DD	DD	DD	DD	NA	DD	DD	DD	DD	DD	DD	DD	DD	DD	NE	DD	DD	DD
MMR-T1.2.3	Mixed cane break	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	LC	NE	LC	LC	LC
MMR-T1.2.4	Bago semi-evergreen forest	DD	DD	DD	DD	EN	LC	B1a(i), B1a(iii)	LC	DD	CR (EN-CR)	DD	DD	DD	DD	LC	LC	NE	CR	EN	CR
MMR-T1.2.5 *	Dry zone foothills spiny scrub	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	NE	DD	DD	DD
MMR-T1.2.6	Rakhine hills bamboo brake	DD	DD	DD	LC	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	LC	NE	LC	LC	LC
MMR-T1.2.7	Rakhine hills semi-evergreen dry forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC (LC-VU)	DD	DD	DD	DD	LC	VU	NE	VU	VU	VU
MMR-T1.2.8	Magway dry cycad forest	DD	DD	DD	DD	VU	LC	B1a(i), B1a(iii)	LC	DD	EN (VU-CR)	DD	DD	DD	DD	LC	EN	NE	EN	EN	CR
MMR-T1.2.9	Magway semi-evergreen dry gully forest	DD	DD	DD	DD	NT	LC	B1b	LC	DD	VU (NT-VU)	DD	DD	DD	DD	DD	LC	NE	VU	NT	VU
MMR-T1.2.10	East Myanmar dry valley forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	VU	VU	NE	VU	VU	VU
MMR-T1.2.11	Eastern Shan semi-evergreen forest	DD	DD	DD	DD	DD	DD	NA	DD	DD	DD	DD	DD	DD	DD	LC	VU	DD	VU	VU	VU

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
MMR-T1.2.12	Western Shan semi-evergreen forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	LC	VU	NE	VU	VU	VU
MMR-T1.2.13	Indaing forest	DD	DD	EN	DD	LC	LC	NA	LC	DD	VU (NT-VU)	DD	DD	DD	DD	LC (LC-VU)	VU	NE	EN	EN	EN
MMR-T1.2.14 *	Northern semi-evergreen forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC (LC-VU)	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD
T1.3	*Tropical/subtropical moist montane rainforests*																				
MMR-T1.3.1	Tanintharyi cloud forest	DD	DD	DD	DD	CR	CR	B1a(iii)	CR	DD	DD	DD	DD	DD	DD	DD	LC	NE	CR	CR	CR
T2	*TEMPERATE-BOREAL FORESTS WOODLANDS*																				
T2.1	*Boreal and temperate montane forests and woodlands*																				
MMR-T2.1.1 *	Kachin mountain conifer forest	DD	DD	DD	DD	LC	LC	NA	DD	DD	DD	DD	DD	DD	DD	DD	LC	NE	DD	DD	DD
T2.4	*Warm temperate rainforests*																				
MMR-T2.4.1	Shan warm temperate rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC (LC-VU)	DD	DD	DD	DD	LC	EN	NE	EN	EN	EN
MMR-T2.4.2	Chin Hills warm temperate rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	LC	VU	NE	VU	VU	VU
MMR-T2.4.3	Sagaing warm temperate rainforest	DD	DD	DD	DD	LC	NT	B1a(i), B1a(iii)	LC	DD	LC (LC-VU)	DD	DD	DD	DD	LC	LC	NE	LC	LC	VU
MMR-T2.4.4 *	Kachin warm temperate rainforest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC (LC-VU)	DD	DD	DD	DD	LC	LC	NE	DD	DD	DD

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
MMR-T2.4.5	Mountain bamboo brake	DD	DD	DD	DD	DD	DD	NA	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
MMR-T2.4.6 *	Kachin montane temperate broadleaf forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	DD	LC	DD	DD	DD	DD
T4	*SAVANNAS AND GRASSLANDS*																				
T4.2	*Pyric tussock savannas*																				
MMR-T4.2.1 *	Rakhine coastal savanna	DD	DD	DD	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	DD	LC	NE	DD	DD	DD
MMR-T4.2.2	Central Ayeyarwady Than-Dahat grassy forest	DD	DD	DD	DD	VU	LC	B1a(i), B1a(iii)	LC	DD	DD	DD	DD	DD	DD	DD	LC	DD	VU	VU	VU
MMR-T4.2.3	Central Ayeyarwady Palm savanna	DD	DD	DD	CO	CO	CO	NA	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	CO	CO	CO
MMR-T4.2.4	Shwe Settaw Sha-Bamboo thicket	DD	DD	DD	DD	NT	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	LC	DD	NT	NT	NT
MMR-T4.2.5	Magway Than-Dahat dry grassy forest	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	LC	DD	LC	LC	LC
MMR-T4.2.6	Sha thorny scrub	DD	DD	DD	DD	VU	LC	B1a(i), B1a(iii)	LC	DD	DD	DD	DD	DD	DD	DD	LC	DD	VU	VU	VU
MMR-T4.2.7	Shan foothills Than-Dahat grassy forest	DD	DD	DD	DD	VU	LC	B1a(i), B1a(iii)	LC	DD	DD	DD	DD	DD	DD	DD	LC	DD	VU	VU	VU
MMR-T4.2.8	Shan hills pine savanna	DD	DD	DD	DD	LC	LC	NA	LC	DD	VU (LC-EN)	DD	DD	DD	DD	VU (LC-VU)	EN	DD	EN	EN	EN
MMR-T4.2.9	Chin hills pine savanna	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	LC	LC	DD	LC	LC	LC
MMR-T4.2.10	Sagaing hills pine savanna	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	LC	LC	DD	LC	LC	LC

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
MMR-T4.2.11	Kachin pine savanna	DD	DD	DD	DD	LC	LC	Not met	LC	DD	DD	DD	DD	DD	DD	LC	LC	DD	LC	LC	LC
T4.5	*Temperate grasslands*																				
MMR-T4.5.1	Shan limestone grasslands	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
T6	*POLAR/ALPINE*																				
T6.1	*Ice sheets, glaciers and perennial snowfields*																				
MMR-T6.1.1	Kachin snowfields	NE	NE	NE	NE	LC	LC	NA	NT-VU	NE	LC (LC-VU)	NE	NE	DD	DD	DD	DD	DD	NT	NT	VU
T6.2	*Polar/alpine rocky outcrops*																				
MMR-T6.2.1	Alpine cliffs and screes	LC	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	LC	LC	LC	LC
T6.4	*Temperate alpine meadows and shrublands*																				
MMR-T6.4.1	High mountain scrub	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	DD	LC	LC	LC
MMR-T6.4.2	Alpine herbfield	DD	DD	DD	DD	EN	VU	B1(b), B2(b)	LC	NE	VU (LC-EN)	NE	NE	DD	DD	DD	DD	NE	EN	EN	EN
S	*SUBTERRANEAN*																				
S1	*Dry subterranean*																				

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
S1.1	*Subterranean lithic systems*																				
MMR-S1.1.1	Aerobic Karst caves	LC	LC	LC	LC	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	NE	LC	LC	LC
TF	*FRESHWATER/TERRESTRIAL*																				
TF1	*Palustrine wetlands (TF1)*																				
TF1.1	*Tropical flooded forests and peat forests (TF1.1)*																				
MMR-TF1.1.1	Ayeyarwady kanazo swamp forest	CR-CO	NE	NE	CO (CR-CO)	DD	DD	NA	DD	DD	DD	DD	DD	DD	DD	DD	DD	NE	CR	CR	CO
MMR-TF1.1.2	Central dry evergreen riparian forest	DD	DD	DD	CR	LC	EN	B2a(i), B2a(ii), B2a(iii), B2b	LC	DD	DD	DD	DD	DD	DD	DD	LC	NE	CR	CR	CR
MMR-TF1.1.3	Mixed delta scrub	DD	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	NE	LC	LC	EN
TF1.4	*Seasonal floodplain marshes*																				
MMR-TF1.4.1	Ayeyarwady floodplain wetlands	DD	DD	DD	EN	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	NE	EN	EN	EN
MMR-TF1.4.2	Central Ayeyarwady floodplain grasslands	DD	DD	DD	CR	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	NE	CR	CR	CR
F	*FRESHWATER*																				
F2	*Lakes*																				

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
F2.4	*Freeze-thaw freshwater lakes*																				
MMR-F2.4.1	Glacial lakes	LC	DD	DD	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	NE	LC	LC	LC
M	*MARINE/TERRESTRIAL*																				
MT1	*Shoreline systems (MT1)*																				
MT1.2	*Muddy shores*																				
MMR-MT1.2.1	Coastal mudflats	DD	NE	LC	DD	LC	LC	NA	LC	DD	DD	DD	DD	DD	DD	DD	DD	DD	LC	LC	LC
MT1.3	*Sandy shores*																				
MMR-MT1.3.1	Sandy shoreline	DD	DD	DD	DD	LC	LC	NA	LC	LC	LC	LC	DD	DD	DD	DD	DD	DD	LC	LC	LC
MT2	*Supralittoral coastal systems*																				
MT2.1	*Coastal shrublands and grasslands*																				
MMR-MT2.1.1	Tanintharyi coastal dune forest	DD	DD	DD	DD	DD	DD	NA	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
MMR-MT2.1.2	Rakhine coastal dune forest	DD	DD	DD	DD	DD	DD	NA	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
MFT	*MARINE/FRESHWATER/TERRESTRIAL*																				
MFT1	*Brackish tidal systems*																				

Code	Ecosystem type	Criterion A				Criterion B				Criterion C				Criterion D				Criterion E	OUTCOME	LOWER	UPPER
		A1	A2a	A2b	A3	B1	B2	subcriteria	B3	C1	C2a	C2b	C3	D1	D2a	D2b	D3				
MFT1.2	*Intertidal forests and shrublands*																				
MMR-MFT1.2.1	Tanintharyi mangrove forest	LC	LC-NT	LC	DD	LC	LC	NA	LC	DD	LC	DD	DD	DD	DD	LC	DD	NE	NT	LC	NT
MMR-MFT1.2.2	Ayeyarwady delta mangrove forest	EN	DD	EN	EN	VU	LC	B1a(i), B1b	LC	LC	DD	LC	DD	DD	DD	LC (LC-VU)	LC	NE	EN	EN	EN
MMR-MFT1.2.3	Dwarf mangrove (shrubland) on shingle	DD	DD	DD	DD	CR	CR	B1(b,c), B2(b,c)	DD	DD	DD	DD	DD	DD	DD	DD	LC	DD	CR	CR	CR
MMR-MFT1.2.4	Rakhine mangrove forest on mud	NE	NE	VU	CR (VU-CR)	VU	LC	B1a(i), B1a(iii)	LC	DD	DD	LC	DD	DD	DD	LC (LC-VU)	LC	NE	CR	VU	CR
MFT1.3	*Coastal saltmarshes*																				
MMR-MFT1.3.1	Grassy saltmarsh	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	NE	DD	DD	DD

*Note: * indicates an ecosystem initially assessed as Least Concern, but a post-assessment review suggested there was sufficient evidence to suggest that further quantitative data could yield an alternative assessment outcome. These ecosystems were therefore assessed as Data Deficient.*

Appendix 4.
Biophysical ecosystem summaries

Code	Ecosystem type	Number dry months per annum (<100mm)	Mean elevation (m)	Annual mean temperature	Minimum temperature coolest month	Annual precipitation (mm)
MMR-T1.1.1	Tanintharyi island rainforests	4.7	132.0	26.1	20.0	4351.0
MMR-T1.1.2	Tanintharyi Sundaic lowland evergreen rainforest	5.4	97.0	26.3	19.4	3121.4
MMR-T1.1.3	Tanintharyi limestone tropical evergreen forest	5.3	171.2	26.0	19.3	2475.5
MMR-T1.1.4	Tanintharyi upland evergreen rainforest	5.5	416.0	24.9	17.5	2278.0
MMR-T1.1.5	Kayin evergreen tropical rainforest	6.0	371.7	25.2	15.2	2960.6
MMR-T1.1.6	Southern Rakhine hills evergreen rainforest	5.0	52.3	26.6	20.7	3125.6
MMR-T1.1.7	Western Shan Plateau subtropical evergreen rainforest	6.0	1195.0	20.0	6.1	1487.1
MMR-T1.1.8	Kachin-Sagaing low elevation evergreen subtropical rainforest	5.5	266.1	22.8	8.5	3093.8
MMR-T1.1.9	Kachin-Sagaing mid elevation subtropical rainforest	5.1	525.0	21.0	7.1	3252.2
MMR-T1.1.10	Kachin Hills subtropical rainforest	5.1	1060.2	18.8	4.8	2758.1
MMR-T1.2.1	Tanintharyi semi-evergreen forest	5.9	430.5	24.9	15.7	2524.6
MMR-T1.2.3	Mixed cane break	6.0	91.6	26.4	16.8	3526.3
MMR-T1.2.4	Bago semi-evergreen forest	6.0	224.8	26.2	14.5	2131.0
MMR-T1.2.5	Dry zone foothills spiny scrub	6.1	491.6	23.6	9.5	1279.1
MMR-T1.2.6	Rakhine hills bamboo brake	5.9	243.3	25.2	14.4	3116.0
MMR-T1.2.7	Rakhine hills semi-evergreen dry forest	5.9	428.0	24.3	13.4	2770.3
MMR-T1.2.8	Magway dry cycad forest	6.0	357.4	26.2	13.6	1367.7
MMR-T1.2.9	Magway semi-evergreen dry gully forest	6.0	164.0	25.5	14.0	1925.7
MMR-T1.2.10	East Myanmar dry valley forest	6.0	729.4	22.8	9.2	1450.3
MMR-T1.2.11	Eastern Shan semi-evergreen forest	6.0	981.4	21.7	8.2	1346.0
MMR-T1.2.12	Western Shan semi-evergreen forest	6.0	798.6	22.5	9.2	1695.5
MMR-T1.2.13	Indaing forest	6.0	254.5	24.8	11.6	1446.3
MMR-T1.2.14	Northern semi-evergreen forest	5.8	487.3	24.6	12.4	1957.2
MMR-T1.3.1	Tanintharyi cloud forest	6.0	2149.3	16.8	5.0	1336.1
MMR-T2.1.1	Kachin mountain conifer forest	7.1	3204.7	8.2	-5.5	1244.0
MMR-T2.4.6	Kachin montane temperate broadleaf forest	6.2	2541.8	12.0	-1.8	1534.1
MMR-T2.4.1	Shan warm temperate rainforest	6.0	1633.6	17.0	2.6	1708.8

Code	Ecosystem type	Number dry months per annum (<100mm)	Mean elevation (m)	Annual mean temperature	Minimum temperature coolest month	Annual precipitation (mm)
MMR-T2.4.2	Chin Hills warm temperate rainforest	6.0	1632.5	17.4	7.0	2186.6
MMR-T2.4.3	Sagaing warm temperate rainforest	5.7	1668.4	16.1	2.3	2106.4
MMR-T2.4.4	Kachin warm temperate rainforest	5.2	1542.7	16.5	2.5	2393.2
MMR-T4.2.1	Rakhine coastal savanna	5.7	54.0	25.8	15.1	4195.3
MMR-T4.2.2	Central Ayeyarwady Than-Dahat grassy forest	6.5	296.1	26.1	13.4	897.7
MMR-T4.2.4	Shwe Settaw Sha-Bamboo thicket	6.0	270.4	25.8	13.9	1471.2
MMR-T4.2.5	Magway Than-Dahat dry grassy forest	6.2	235.9	26.1	13.4	980.0
MMR-T4.2.6	Sha thorny scrub	6.5	109.1	27.0	13.4	852.2
MMR-T4.2.7	Shan foothills Than-Dahat grassy forest	6.1	388.9	24.5	10.8	1161.2
MMR-T4.2.8	Shan hills pine savanna	6.0	1290.9	19.3	6.3	1685.8
MMR-T4.2.9	Chin hills pine savanna	5.8	662.9	22.7	12.2	2932.1
MMR-T4.2.10	Sagaing hills pine savanna	5.1	1020.6	18.9	5.3	2828.6
MMR-T4.2.11	Kachin pine savanna	5.1	906.3	19.3	4.8	2334.1
MMR-T6.1.1	Kachin snowfields	8.0	3752.5	5.4	-8.3	975.1
MMR-T6.2.1	Alpine cliffs and screes	8.6	4021.0	3.7	-10.2	845.5
MMR-T6.4.1	High mountain scrub	6.6	2885.6	10.2	-3.5	1405.6
MMR-T6.4.2	Alpine herbfield	8.8	3888.9	4.2	-9.7	821.2
MMR-S1.1.1	Aerobic Karst caves	7.0	363.7	24.7	12.8	1987.9
MMR-TF1.1.2	Central dry evergreen riparian forest	6.0	15.3	26.8	17.5	2350.5
MMR-TF1.1.3	Mixed delta scrub	5.9	7.8	26.7	18.6	3037.3
MMR-TF1.4.1	Ayeyarwady floodplain wetlands	6.3	23.2	27.0	16.2	1804.5
MMR-TF1.4.2	Central Ayeyarwady floodplain grasslands	6.8	37.3	27.0	14.8	1491.3
MMR-F2.4.1	Glacial lakes	8.9	4285.9	2.1	-12.0	783.3
MMR-MT1.2.1	Coastal mudflats	5.8	0.8	26.2	16.7	4456.9
MMR-MT1.3.1	Sandy shoreline	5.8	3.9	26.4	17.5	3937.2

Code	Ecosystem type	Number dry months per annum (<100mm)	Mean elevation (m)	Annual mean temperature	Minimum temperature coolest month	Annual precipitation (mm)
MMR-MFT1.2.1	Tanintharyi mangrove forest	5.3	11.3	26.6	20.1	3787.7
MMR-MFT1.2.2	Ayeyarwady delta mangrove forest	6.0	5.9	26.9	20.2	2843.3
MMR-MFT1.2.3	Dwarf mangrove (shrubland) on shingle	6.0	6.1	26.6	18.9	5499.4
MMR-MFT1.2.4	Rakhine mangrove forest on mud	6.0	2.4	26.1	15.8	4202.6

Appendix 5.
Ecosystem area summaries

Code	Ecosystem Type	Area (km²)	Proportion protected * (%)	AOO (No. 10x10 km grid cells)	AOO 1% (No. 10x10 km grid cells with >1km²)	EOO (km²)
MMR-T1.1.1	Tanintharyi island rainforests	1936.7	27.46	206	133	50336.7
MMR-T1.1.2	Tanintharyi Sundaic lowland evergreen rainforest	7165.7	20.59	381	302	56208.7
MMR-T1.1.3	Tanintharyi limestone tropical evergreen forest	1935.9	55.53	56	53	3795.9
MMR-T1.1.4	Tanintharyi upland evergreen rainforest	7719.4	32.49	361	291	58256.4
MMR-T1.1.5	Kayin evergreen tropical rainforest	792.1	0.98	289	122	39269.4
MMR-T1.1.6	Southern Rakhine hills evergreen rainforest	32.1	0.00	18	5	1619.4
MMR-T1.1.7	Western Shan Plateau subtropical evergreen rainforest	7540.3	0.36	1644	914	288485.2
MMR-T1.1.8	Kachin-Sagaing low elevation evergreen subtropical rainforest	2699.5	51.23	559	99	68469.2
MMR-T1.1.9	Kachin-Sagaing mid elevation subtropical rainforest	4564.3	40.73	638	321	58922.0
MMR-T1.1.10	Kachin Hills subtropical rainforest	7353.5	33.90	684	583	132457.0
MMR-T1.2.1	Tanintharyi semi-evergreen forest	20501.8	17.17	729	564	139401.2
MMR-T1.2.3	Mixed cane break	249.0	1.55	311	56	105271.5
MMR-T1.2.4	Bago semi-evergreen forest	7058.4	9.00	193	148	19561.6
MMR-T1.2.5	Dry zone foothills spiny scrub	479.0	0.35	295	77	200013.6
MMR-T1.2.6	Rakhine hills bamboo brake	7562.1	6.28	390	290	92132.9
MMR-T1.2.7	Rakhine hills semi-evergreen dry forest	24884.1	5.22	649	539	112684.0
MMR-T1.2.8	Magway dry cycad forest	1107.8	1.72	118	82	24766.0

Code	Ecosystem Type	Area (km²)	Proportion protected * (%)	AOO (No. 10x10 km grid cells)	AOO 1% (No. 10x10 km grid cells with >1km²)	EOO (km²)
MMR-T1.2.9	Magway semi-evergreen dry gully forest	2241.9	1.96	264	122	54178.6
MMR-T1.2.10	East Myanmar dry valley forest	33946.6	0.19	1552	1044	426131.6
MMR-T1.2.11	Eastern Shan semi-evergreen forest	28713.4	0.21	630	605	124498.4
MMR-T1.2.12	Western Shan semi-evergreen forest	47563.6	0.88	1444	1272	177030.4
MMR-T1.2.13	Indaing forest	39026.9	2.70	1836	1220	380133.1
MMR-T1.2.14	Northern semi-evergreen forest	76735.2	17.62	1828	1622	276613.7
MMR-T1.3.1	Tanintharyi cloud forest	25.7	0.51	2	2	108.2
MMR-T2.1.1	Kachin mountain conifer forest	490.1	85.47	155	73	85269.5
MMR-T2.4.6	Kachin montane temperate broadleaf forest	10542.1	48.76	320	287	60480.3
MMR-T2.4.1	Shan warm temperate rainforest	7630.6	0.22	603	422	190658.4
MMR-T2.4.2	Chin Hills warm temperate rainforest	11188.0	13.09	303	264	57426.6
MMR-T2.4.3	Sagaing warm temperate rainforest	5838.5	17.02	202	163	50913.1
MMR-T2.4.4	Kachin warm temperate rainforest	11270.5	60.45	444	369	79334.4
MMR-T4.2.1	Rakhine coastal savanna	5091.8	0.04	420	296	77921.1
MMR-T4.2.2	Central Ayeyarwady Than-Dahat grassy forest	6838.4	1.12	337	217	37936.9
MMR-T4.2.4	Shwe Settaw Sha-Bamboo thicket	59.6	15.15	81	14	21475.9
MMR-T4.2.5	Magway Than-Dahat dry grassy forest	4977.6	6.35	322	174	63007.2
MMR-T4.2.6	Sha thorny scrub	653.5	0.19	206	100	44613.2

Code	Ecosystem Type	Area (km^2)	Proportion protected * (%)	AOO (No. 10x10 km grid cells)	AOO 1% (No. 10x10 km grid cells with >1km²)	EOO (km^2)
MMR-T4.2.7	Shan foothills Than-Dahat grassy forest	6387.4	4.38	287	210	44730.4
MMR-T4.2.8	Shan hills pine savanna	3566.9	0.54	840	361	200820.7
MMR-T4.2.9	Chin hills pine savanna	1653.0	2.97	371	200	71265.7
MMR-T4.2.10	Sagaing hills pine savanna	31.7	64.99	58	7	61907.1
MMR-T4.2.11	Kachin pine savanna	9.5	45.40	72	0	45063.4
MMR-T6.1.1	Kachin snowfields	3142.0	67.82	145	117	44492.0
MMR-T6.2.1	Alpine cliffs and screes	296.4	89.78	45	36	51924.3
MMR-T6.4.1	High mountain scrub	303.2	59.05	200	97	90293.8
MMR-T6.4.2	Alpine herbfield	69.3	97.35	26	17	3846.6
MMR-S1.1.1	Aerobic Karst caves	0.4	1.99	37	0	440849.5
MMR-TF1.1.2	Central dry evergreen riparian forest	87.1	0.03	263	22	132004.1
MMR-TF1.1.3	Mixed delta scrub	845.0	1.12	644	169	363005.8
MMR-TF1.4.1	Ayeyarwady floodplain wetlands	811.3	0.39	356	136	128014.0
MMR-TF1.4.2	Central Ayeyarwady floodplain grasslands	2334.3	2.69	504	222	138490.2
MMR-F2.4.1	Glacial lakes	21.5	67.85	28	4	3738.4
MMR-MT1.2.1	Coastal mudflats	2997.8	5.64	566	318	455574.7
MMR-MT1.3.1	Sandy shoreline	1461.2	10.39	1356	431	548469.5
MMR-MFT1.2.1	Tanintharyi mangrove forest	3273.7	0.74	224	184	52576.7
MMR-MFT1.2.2	Ayeyarwady delta mangrove forest	1239.0	12.35	93	74	24390.0
MMR-MFT1.2.3	Dwarf mangrove (shrubland) on shingle	0.5	0.00	2	0	331.4
MMR-MFT1.2.4	Rakhine mangrove forest on mud	1801.4	0.00	158	133	48252.3

** this analysis was conducted in Google Earth Engine with World Database on Protected Areas data dated 1/2/2019.*

Appendix 6.
Myanmar state summaries

State	Area of state (km²)	Number of ecosystems identified	Remaining natural ecosystems (km²)	Proportion remaining natural ecosystems (%)	Extent of protected areas (km²)	Protected area (%)	Proportion natural ecosystems protected * (%)
Ayeyarwady	33763	23	7394.7	21.9	166.4	0.49	1.93
Bago	38520	20	16335.8	42.41	963.8	2.5	6.24
Chin	36813	19	29646.0	80.53	1799.1	4.89	5.14
Kachin	88744	24	73534.0	82.86	27443.9	30.92	27.94
Kayah	11668	13	10538.1	90.31	17.0	0.15	0
Kayin	29954	18	19387.0	64.72	358.0	1.2	2.96
Magway	44010	23	18846.5	42.82	543.6	1.24	2
Mandalay	36424	21	16728.2	45.93	540.2	1.48	1.27
Mon	11549	20	4062.5	35.18	403.2	3.49	6.27
Naypyitaw	138	5	50.5	36.48	0.0	0	0
Rakhine	35449	21	27705.8	78.16	1696.2	4.79	6.12
Sagaing	95607	27	63604.8	66.53	12152.8	12.71	16.01
Shan	155755	25	96645.2	62.05	1244.8	0.8	0.5
Tanintharyi	41300	19	32971.7	79.83	9757.9	23.63	5.31
Yangon	9555	14	1173.2	12.28	6.1	0.06	0
Total (Myanmar)	669249	62	418623.9	62.55	57093.0	8.53	13.64

** this analysis was conducted in Google Earth Engine with World Database on Protected Areas data dated 1/2/2019.*

Appendix 7.
Status uncertainty

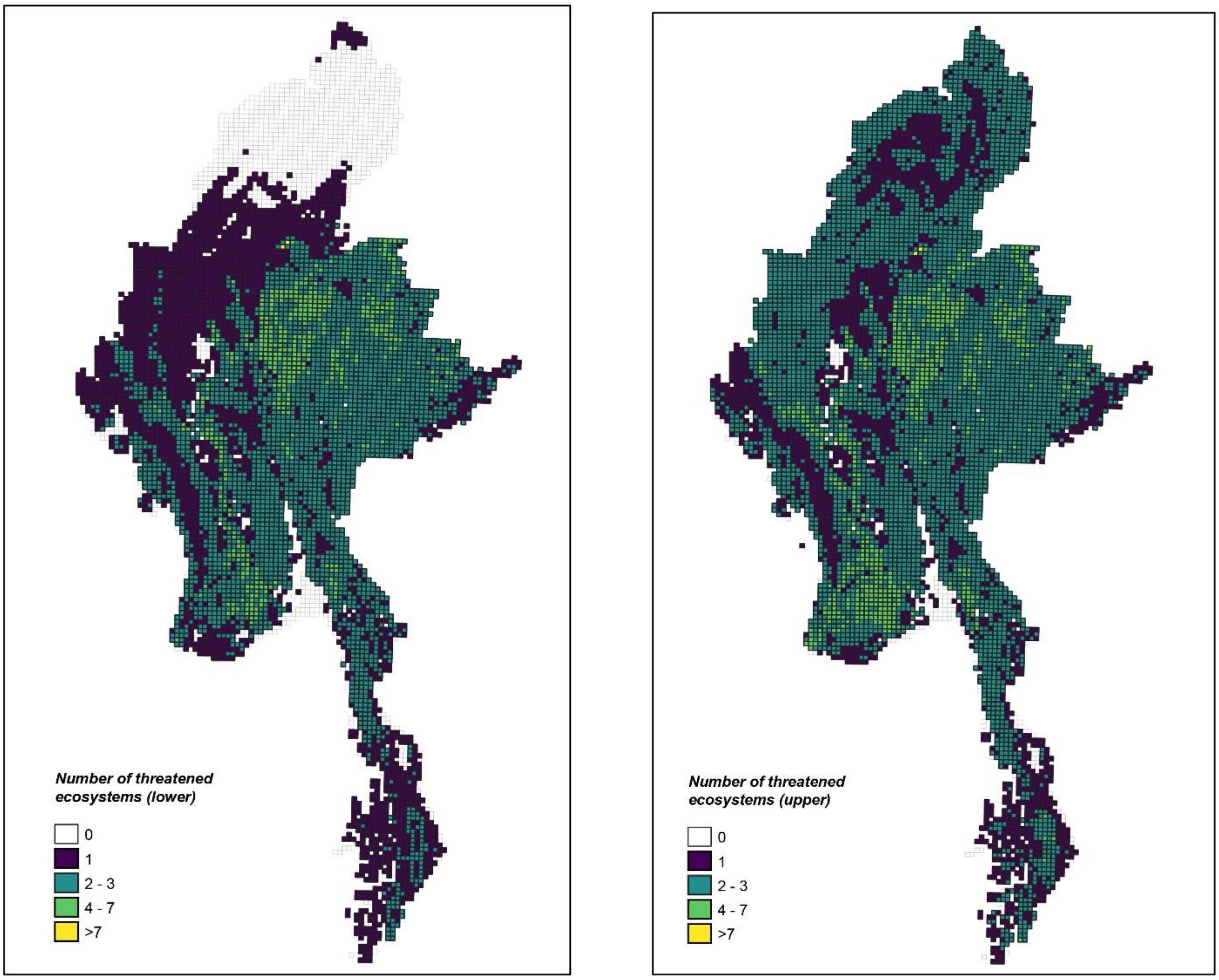


Figure A7.1 Plausible bounds of the distribution of threatened ecosystems (CR, EN, VU). Each 10 x 10 km grid cell is coloured by the number of ecosystems or threatened ecosystems that intersect it. Lower (left) and upper (right) plausible bounds reflect uncertainty in assessment outcomes as a result of lack of suitable data, model uncertainty, or expert judgement.

Appendix 8.
Expert assessment of Least Concern Ecosystems

The ecosystems listed this table were initially assessed as Least Concern using available published data. However, a post-assessment expert review highlighted that further information could lead to an alternative assessment outcome. Applying the precautionary principle, these ecosystems were assigned the status of Data Deficient and all are recommended for urgent further work to complete the assessment.

Code	Biome / Functional Group / Ecosystem Type	Justification
T	*TERRESTRIAL*	
T1	***Tropical & subtropical forests***	
T1.1	*Tropical/subtropical lowland rainforests*	
MMR-T1.1.4	Tanintharyi upland evergreen rainforest	This ecosystem type was initially assessed as Least Concern using published data. However, an expert review indicated that it is subject to a range of rapidly expanding and intensifying threats, including oil pipeline development, roads development and plantation development (Connette et al., 2016). The impacts of these threats have not yet been quantified, but it is likely that further work would lead to an assessment outcome other than Least Concern. It is therefore considered to not have met minimum evidence standards and assigned as Data Deficient. We recommend urgent further work to complete the assessment of this ecosystem type.
MMR-T1.1.8	Kachin-Sagaing low elevation subtropical rainforest	This ecosystem type was initially assessed as Least Concern using published data. However, an expert review identified a range of threats to this ecosystem that could lead to a status outcome other than Least Concern. Threats identified in the review include: land clearing for gold mining along the Chindwin and Uru rivers, leading to heavy metal contamination and silting (Bhagwat 2017, Lim et al 2017, Piman et al 2017, Lee et al 2020), extensive logging and mining in Tanai/Hukaung Valley (Bhagwat 2017) new gold mining concessions in the foothills around Putao, extensive clearing and secondary forest around Myitkyina and towards the Chinese border due to logging and agricultural expansion/plantation development (Bhagwat 2017, Wang & Myint 2016, Global Witness 2009), exacerbated by military conflict (Lim et al 2017), risk from potential Myitsone dam project (Fawthrop 2019, International

		Rivers 2013), risk from future roads linking to Chinese belt and road initiative, which would open access to further forest cutting (Lo 2019). These drivers of environmental degradation are likely to appreciably increase the risk of collapse of this ecosystem within the assessment time frame. The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to assess the impacts of these threats and enable a robust assessment.
MMR-T1.1.9	Kachin-Sagaing mid elevation subtropical rainforest	This ecosystem type was initially assessed as Least Concern using published data. However, there is extensive secondary forest in the Naga Hills due to slash and burn agricultural practices over many generations, mining for jade, gold and amber in many areas within the extent of this ecosystem, extensive clearing and secondary forest around Myitkyina and towards the Chinese border due to logging and agricultural expansion/plantation development (Bhagwat 2017, Wang & Myint 2016, Global Witness 2009), exacerbated by military conflict (Lim et al 2017), risk from future roads linking to Chinese belt and road initiative, which would open access to further forest cutting (Lo 2019). These observed drivers of environmental degradation suggest that, with sufficient data, this ecosystem may qualify for threatened status. Therefore, the ecosystem is assessed as Data Deficient and urgent work to gather data on the impacts of these threats is recommended to allow an assessment of the status of this ecosystem.
MMR-T1.1.10	Kachin Hills subtropical rainforest	This ecosystem type was initially assessed as Least Concern using published data. However, extensive illegal logging over a period of around 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009), concessions and land grabbing for agriculture, clearing and secondary forest around Myitkyina and towards the Chinese border, exacerbated by military conflict (Lim et al 2017), risk from future roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting. Work to assess the rate of loss of this ecosystem and enable an assessment of Criterion A may result in this ecosystem being assigned a status other than Least Concern. We recommend urgent work to gather data on the impacts of these threats to enable a robust assessment of the status of this ecosystem. It is therefore considered to have a Data Deficient status.
T1.2	*Tropical/subtropical dry forests and scrubs*	
MMR-T1.2.1	Tanintharyi semi-evergreen forest	This ecosystem type was initially assessed as Least Concern using published data. However, this ecosystem is subject to a range of rapidly expanding threats, including clearing for oil pipeline development, new roads

		and for rapid rubber and oil palm plantation development (Connette et al 2016, Bhagwat et al 2017). These threats have yet to be quantified sufficiently over a time-frame long enough to support a quantitative assessment but are very likely to result in extensive degradation of this ecosystem that could meet the category thresholds. Further work to quantify these threats and incorporate into the assessment are required, and therefore it is assigned a Data Deficient status.
MMR-T1.2.5	Dry zone foothills spiny scrub	This ecosystem type was initially assessed as Least Concern using published data. However, owing to a limited amount of training data the maps developed during this project may potentially overestimate the extent of the ecosystem and underestimate the amount of fragmentation of what remains. Further work to improve maps of this ecosystem, as well as develop a map time-series, may lead to an assessment outcome other than Least Concern. The ecosystem is therefore assessed as Data Deficient, and we recommend urgent further work to improve confidence in the assessment outcome and to establish whether there is appreciable edge effects from adjoining land uses.
MMR-T1.2.14	Northern semi-evergreen forest	This ecosystem type was initially assessed as Least Concern using published data. However, the extent of this ecosystem is likely to have reduced considerably over the past 50 years with expanding agriculture, mining and road development (Khaing et al., Ashton lest the memory fade book). The ecosystem is also likely to be subject to ongoing illegal logging, fragmentation, and road development. The extent and intensity of these threats is considered to be sufficient that, should detailed data become available, the ecosystem would receive a status other than Least Concern. Therefore, the ecosystem is assessed as Data Deficient and we recommend urgent further work to assess historical change in extent and assess extent and severity of degradation of this ecosystem.
T2	***Temperate-boreal forests & woodlands***	
T2.1	*Boreal and temperate montane forests and woodlands*	
MMR-T2.1.1	Kachin mountain conifer forest	This ecosystem type was initially assessed as Least Concern using published data. However, experts identified a range of threats that, if quantified, could lead to an assessment outcome other than Least Concern. These include: Illegal logging along the border with Yunnan over a period of 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009).

		Risk from roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting and over-extraction of resources such as medicinal plants and animal parts [e.g. adjacent to Hpimaw, Kanbaiti, Chipwi/Pianma, Khaunglanphu/ Fugong and Gongshan. The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem.
T2.4	*Warm temperate rainforests*	
MMR-T2.4.4	Kachin Warm Temperate Rainforest	This ecosystem type was initially assessed as Least Concern using published data. However, experts identified a range of threats that, if quantified, could lead to an assessment outcome other than Least Concern. These threats include illegal logging along the border with Yunnan over a period of 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009). Risk from roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting and over-extraction of resources such as medicinal plants and animal parts (e.g. adjacent to Hpimaw, Kanbaiti, Chipwi/Pianma, Khaunglanphu/ Fugong and Gongshan; Clements et al 2014.) The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem
MMR-T2.4.6	Kachin Montane Temperate Broadleaf Forest	This ecosystem type was initially assessed as Least Concern using published data. However, experts identified a range of threats that, if quantified, could lead to an assessment outcome other than Least Concern. These threats include Illegal logging along the border with Yunnan over a period of 15-20 years (Bhagwat et al 2017, Lim et al 2017, Global Witness 2009). Risk from roads linking to Chinese belt and road initiative (Lo 2019), which would open access to further forest cutting and extraction of resources such as medicinal plants and animal parts (e.g. adjacent to Hpimaw, Kanbaiti, Chipwi/Pianma, Khaunglanphu/ Fugong and Gongshan; Clements et al 2014.) The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem
T4	***Savannas and grasslands***	
T4.2	*Pyric tussock savannas*	
MMR-T4.2.1	Rakhine coastal savanna	Extreme fragmentation and loss of lowland areas of this ecosystem due to development of rice agriculture has likely occurred. However, an assessment of the amount of

	loss that has occurred over the past 50 years was not possible in this project. If data were available, experts suggest that the ecosystem would likely qualify for an assessment outcome other than Least Concern. The ecosystem is therefore listed as Data Deficient and we recommend urgent further work to quantify the impact of these threats and enable a robust assessment of the status of this ecosystem.

ISBN: 978-0-9903852-5-7