# Restoration Opportunities Assessment Methodology (ROAM) in Myanmar

Daniel Constable, Jake Brunner, Li Jia

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# Executive summary

The report summarizes the methodology and main outcomes of a national Restoration Opportunities Assessment Methodology (ROAM) process to identify Forest Landscape Restoration (FLR) opportunities in Myanmar. FLR is an integrated approach that seeks to ensure that forests, trees, and the functions that they provide are effectively conserved, restored, and employed on a landscape-scale to help secure ecological integrity and sustainable livelihoods.

Given rapid deforestation in Myanmar and the government's plan to restore ecosystems for the benefit of people and environment, IUCN conducted a national ROAM mapping process in 2017-2018 with support from funding from the UK Department for International Development (DFID) International Forestry Knowledge (KNOWFOR) programme, and the Nature Conservancy (TNC).

The process identifies strategically important geographical areas in Myanmar to address key FLR objectives, including

- supporting Myanmar to restore forest cover;
- protecting key watersheds, which are the foundation of production activities that support millions of rural residents; and
- protecting key biodiversity areas.

ROAM was applied in support of the Myanmar Reforestation and Rehabilitation Program (MRRP), which was approved in 2016, as well as other restoration efforts in Myanmar, including The Restoration Initiative (TRI) funded by the Global Environment Facility (GEF).

MRRP aims to restore over 1.2 million hectares of degraded and deforested land by 2026, through plantations, community forestry, agroforestry, natural forest regeneration, and enrichment planting. If MRRP can invest strategically in priority areas and adopt an FLR approach, implementation of such restoration plans will generate multiple benefits for Myanmar's people and biodiversity.

The resulting analysis identified up to 2.5 million hectares in Myanmar as FLR opportunity areas. However, after excluding areas where FLR is impractical (built-up areas, open water, etc.) or low priority (if they only deliver one rather than multiple benefits), 713,000 hectares were identified as priority FLR areas (red areas in Map 1, page 23). Priority watersheds (yellow areas in Map 1) were identified where there is at least 10% of the watersheds identified as FLR priority area, These watersheds cover 1.9 million hectares.

Priority FLR areas include the dry deciduous forest of central Sagaing Region, the mangroves of northern Rakhine State and the Ayeyarwady Delta, the lowland evergreen forest of southern Tanintharyi Region, and the mixed deciduous forest of the Bago Yoma. These FLR areas represent potential priorities for directing FLR activities and are shown in Map 1. The map is indicative only. The identification of specific FLR sites requires more detailed on-the-ground assessments.

# Acknowledgements

Degraded forest in Sagaing Region © Dr. Oliver Springate-Bagnisky


Degraded forest in Sagaing Region © Dr. Oliver Springate-Bagnisky

# 1 - Project background

## 1.1. Background

With over 45% forest cover, Myanmar has some of the largest remaining forest areas in Asia (Food and Agriculture Organization of the United Nations, 2015). However, in recent years, Myanmar has seen significant deforestation at an annual rate of 1%, among the world's highest (*Ibid.*). From 1975 to 2010, closed forest areas decreased almost by half (from 45% to 20%), while open forests increased by 8% (from 16% to 27%) (*Ibid.*). Over-exploitation and illegal logging, shifting cultivation, expansion of agricultural lands and rapid expansion of urban areas are all contributing to the degradation of Myanmar's forests, but the underlying degradation drivers are more to do with the institutional frameworks affecting people and forests, such as inadequate public participation, insufficient state budget, and absence of a clear, inclusive land-use policy (*Ibid.*).

To address the challenges of deforestation and forest degradation in Myanmar, the government has committed 30% of its land area to permanent forest estate. It also has a long history of reforestation activities, including mass plantation projects since the 1970s and community forestry developments. However, many of these efforts have experienced poor survival rates. In 2016, State Counsellor Daw Aung San Suu Kyi directed the Ministry of Natural Resources and Environmental Conservation (MONREC) to develop a new reforestation and restoration plan. The result was the Myanmar Reforestation and Restoration Program (MRRP).

A fresh look at restoration needs and strategies is particularly relevant in light of the MRRP, which is the main policy instrument for national restoration efforts. Lessons from other countries show that for FLR to be sustainable and scalable, an inclusive and participatory landscape approach is required. FLR is an integrated approach that seeks to ensure that forests, trees, and the functions they provide are effectively restored, conserved, and employed on a landscape-scale to help secure ecological integrity and sustainable livelihoods for the future. To help address this need, IUCN and World Resources Institute (WRI) developed the **Restoration Opportunities Assessment Methodology (ROAM)**,[1] a flexible and practical methodology that has been used across diverse biophysical and socio-economic settings to identify and analyse FLR opportunities that are ecologically, economically and socially feasible.

Successful FLR implementation will not only increase carbon sequestration and capacity to adapt to climate change through low-emission development strategies but also create multiple other benefits, such as expanding habitats and migration corridors for biodiversity, enhancing food production, reducing soil erosion, and yielding clean water supplies. FLR also helps combat poverty through the creation of rural jobs and improving access to natural resources.

Against this backdrop, IUCN and its partners facilitated a national ROAM process in Myanmar to identify FLR priorities. It is hoped that with this restoration effort Myanmar's restoration work can maximize the socio-economic and environmental benefits for society while helping the country recover from decades of forest loss.

## 1.2. Objectives

The objectives of national ROAM assessment in Myanmar were to:

- build common understanding of FLR and ROAM among stakeholders;
- identify and prioritize FLR opportunities in Myanmar; and
- provide knowledge support to enable future FLR action on the ground.

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[1] https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration/restoration-opportunities-assessment-methodology-roam

# 2 - Mapping methods and process

## 2.1. Myanmar National ROAM Mapping Process

In response to needs identified during the national workshop, a ROAM process was initiated to identify FLR priorities. In March and August 2017, two ROAM workshops were held that built on the momentum of a national ROAM workshop in November 2017. FLR specialists from the Forest Department, IUCN and TNC collaborated to refine the conceptual models and methodology to identify national FLR priorities and opportunities.

The mapping process prioritized FLR efforts for watershed protection needs, biodiversity conservation and implementation readiness (near medium-population density areas). The goal was to support forest recovery while protecting important ecosystem services (watershed values and biodiversity) and delivering livelihood benefits to local communities. Results were to be finalized in consultation with the FD, but initial mapping showed that over one million hectares of degraded land should be prioritized for FLR.

Based on input from the two workshops, IUCN and TNC carried out ROAM using spatial analysis tools. This analysis helped identify spatially-explicit areas of degradation and potential opportunities for FLR. Since it was carried out on a national scale, the outputs are more general than if done for a smaller area with more detailed, localized data. The following sections describe the data, methods, and results from this analysis.

## 2.2. Data sources and approach

A variety of data was considered for use in the ROAM analysis. Since this was a national-level analysis, a requirement was for data to cover the entire country. Due to limited data availability for some thematic data types, global data sets were used for many of the inputs. However, national or country-specific data was used when available.

The analysis was conducted by identifying (1) potential **degradation** areas, (2) identifying FLR **opportunity** that delivered the desired ecosystem services, (3) **excluding** areas unsuitable for FLR, and (4) **prioritizing** areas within the identified opportunity areas. Data used are described below (see Appendix A for data sources and citations).

### Degradation
1. Forest canopy cover loss from 1990-2015 (all forest types, inclusive of #1-2 below)
2. Mangrove loss from 1990-2015
3. Dry deciduous forest loss from 1990-2015

### Prioritization/Opportunity
1. Watersheds upstream of or surrounding waterbodies of at least 1,000 hectares, or at least 250 hectares and adjacent to another large lake, or waterbodies with a hydropower or irrigation dam (Ayeyarwady or Salween river basins[2] only).
2. River corridors, as mapped by Conservation International (2012).
3. Watersheds with at least 10% forest canopy cover in 1990, and at least 15% canopy cover loss from 1990-2015.
4. Key Biodiversity Areas, as identified by the Key Biodiversity Partnership (2016).
5. Watershed with at least 30% of their total area greater than 15 degrees slope.
6. Within 500 m of a road or 10 km of a populated place but excluding roadways or high population/urbanized areas.

### Exclusion
Areas that are assumed to be lower value or preclude land-based forest restoration activities were removed from the analysis.

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[2] Also known as watersheds, in this report the term basin is also used to refer to an area from which all water would theoretically flow to a single outlet.

1. Roads: Although areas adjacent to roads are accessible and may provide opportunities for FLR, roads plus a 100 m buffer were excluded because the data is one-dimensional (has no width) and this general area is assumed to include areas unsuitable for FLR or at higher risk to future clearing.
2. Open water: Areas of open water such as lakes and rivers.
3. Urban areas: Built-up areas and areas with high population density.
4. Irrigated agriculture. (Paddy was specifically considered for exclusion but no accurate data were identified.)

## Other data

Several data sources were considered that would have expanded the analysis to better address socio-economic, gender, and biodiversity issues. However, most of these had features that limited their utility, and they were not used in the final analysis. A subsequent analysis for FLR in Myanmar could be improved by expanding the use of such data. See Appendix D for a list of this data.

## Basemap data

Additional data were used to display as a reference basemap. These included administrative boundaries, terrain (hillshade), waterways (also used in analysis), villages, and a simplified road network. These data are not described further since they were not used in the analysis.

# 3 - Data processing and analysis

## 3.1. Pre-processing

All analyses were conducted using raster data, which represents data as a grid of values, rather than vectors. This was done because the original degradation data was provided in raster format and to speed up analyses. Data obtained in vector format, which includes most of the opportunity and prioritization data, was converted to raster data. All data was also resampled to a consistent and spatially-referenced 90 m raster cell size. Finally, all data was also projected to a standard equal area projection centred on Myanmar (the projection parameters are listed in Appendix C). This was done to ensure more accurate area calculations. An exception is slope, which was analysed using a conformal projection to avoid inaccuracies from distortion (Snyder, 1987).

All data was aligned ("snapped") so that raster cells overlay at the same location, which is critical for the analysis to ensure that overlaid layers correctly align. A resampled, 90 m resolution layer of forest canopy cover for the year 2010 (Sexton et al., 2013) was used as the standard to which all other layers were aligned (any similar layer could have been used for this purpose).

## 3.2. Degradation layers

Data on forest canopy cover loss were used as a primary input to the analysis. Each of these layers was given an alphanumeric code for example "D1", which is used as a reference in the data dictionary included in Appendix A.

### Forest canopy cover loss (D1)
Forest canopy cover loss was obtained from both national and global sources. The global data source (Hansen et al., 2013) technically provide data for "tree canopy cover" and "forest cover loss" separately. However, in this analysis the two data sets are used in conjunction to estimate tree canopy cover in the year 2015, and terms forest loss or forest canopy cover loss are used interchangeably.

Prior studies show significant forest loss prior to 2000, the earliest year for which global forest cover loss data are available (Hansen et al., 2013). To capture forest loss pre-2000, an older dataset was used. This data set from Leimgruber (Leimgruber et al., 2005) mapped forest loss (and other land cover changes) between 1990 and 2000. This data set was particularly important for mapping extensive mangrove loss in the Ayeyarwady Delta between 1990 and 2000.

The input forest canopy cover loss layer was created by adding forest loss from Leimgruber et al. (2005) and Hansen et al. (2013). The resultant data were resampled to a 90 m resolution raster layer with a binary value of 1 where forest loss occurred during this period, and 0 where no forest loss occurred. The resampling process introduced errors, especially where isolated 30 m cells were resampled to 90 m. To address this, data was expanded by two cells along the edges, shrunk by three cells, then expanded by one. This process removed a small number of isolated cells.[3]

Areas of forest regrowth reported by Hansen et al. (2013) appeared relatively minor and were not added back to areas of forest loss prior to 2000. This is in line with recommendations provided by Hansen et al., noting that canopy cover, loss, and regrowth layers use different methodology and should not be added directly to calculate total current forest canopy cover (Hansen et al., 2013).

### Dry deciduous forest loss (D2)
Dry deciduous forest (DDF) is highly threatened and provides important habitat for large mammals. DDF has suffered extensive clearing, with Myanmar having the largest remaining area of DDF in Southeast Asia (Wohlfart, Wegmann, & Leimgruber, 2014). A data set from Wohlfart et al. (2014) was considered for mapping DDF. However, the lower resolution (250 m) and a visual examination of alignment with satellite imagery showed that this data set could not be used for the intended purpose. Instead, data from Hansen et al. (2013) was selected for

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[3] http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/generalizing-zones-with-nibble-shrink-and-expand.htm

areas within the Central Dry Zone (CDZ). To carry this out, an outline of the CDZ was sketched based on annual precipitation patterns, with some deviation in the northernmost areas to include areas of known DDF. Any canopy cover loss within this area was considered to be loss of DDF.

### Mangrove forest loss (D3)
Mangrove forests provide a range of important environmental services. These include disaster risk reduction from storms and waves, fuelwood (charcoal), as well as a wide range of environmental benefits (Emerton & Aung, 2013). Because of their importance, mangrove forest loss was highlighted as a separate degradation layer. No georeferenced mangrove data set was identified prior to 2000. It was therefore necessary to use a proxy to identify potential mangrove loss since significant mangrove loss had occurred prior to 2000, especially in the Ayeyarwady Delta (Brunner, 2017; Leimgruber et al., 2005; Webb et al., 2014; Weber, Keddell, & Kemal, 2014). A proxy to estimate mangrove loss was created that used (1) forest loss during 1990-2015 that was (2) within 2 km of the ocean, and (3) below 5 m in elevation.

These thresholds were selected based on a visual examination of recent (c. 2015) satellite imagery and the resolution of the input digital elevation model (DEM). Analysis of the results show that the DEM excluded some areas of potential mangrove cover by averaging elevation and/or vertical accuracy. This step of the analysis could be improved by using a higher resolution DEM for coastal regions (available) or mangrove cover data for the period 1990-2015 (not currently available).

### Combined degradation (D4)
All three degradation layers (D1-D3) were combined into a single layer representing forest canopy cover loss of any type for 1990-2015. Unique values were retained for each type of forest loss, however, so that the contributing input can be identified if desired.

## 3.3. Prioritization

This analysis considered seven input data sets to help identify areas of higher priority for FLR. This is important because it helps better make use of limited resources and maximize benefits to people and the environment. The input data included (1) basins with high forest canopy cover loss, (2) watersheds important for water quality and water provision, (3) river corridors, (4) high biodiversity areas, (5) high slope (mountainous areas), (6) watersheds with at least one city/village, and (7) areas generally accessible to a city/village or a road. Each prioritization data input is described below.

### Basins with high forest canopy cover loss (P1)
Areas with high rates of recent forest canopy cover loss are priorities for FLR. These areas, since more recently deforested, may be more likely to retain land use that would allow FLR. The analysis identified basins with at least 10% forest canopy cover in 1990 (Leimgruber et al., 2005) and forest canopy cover loss of at least 15% between 1990 and 2015 (Hansen et al., 2013). The entire area of these basins was assigned a value of "1", not just areas of forest canopy cover loss. This helps identify select basins as priorities but does not select the areas within the basin that are most suitable for FLR; such activity should be done as part of a more focused, local analysis.

### Watersheds important for water quality and water provision (P2)
Watersheds were selected upstream of waterbodies as a rough proxy for the importance of water provision, hydropower production, and erosion avoidance. Watershed boundaries were obtained from the highest resolution level (Level 12) of the global HydroBASINS data set (Lehner, 2014). Basins were selected if they were upstream of or adjacent to a waterbody of at least (1) 1,000 hectares, (2) at least 250 hectares and adjacent to a waterbody of at least 1,000 hectares, and/or (3) any waterbody with a hydropower or irrigation dam (Ayeyarwady or Salween basins only, due to data availability). This selection was manually refined by adding or removing select basins, for example narrow, downstream watersheds that had a single point touching the edge of a lake.

### River corridors (P3)
River corridors (also referred to as riparian corridors, depending on proximity to a river) are important for reducing erosion and flood risk. In regions with high seasonality, such corridors can also help maintain higher biodiversity and serve as refugia as the climate changes. River corridor areas were selected from a subset of past Key

Biodiversity Areas (KBAs). This data from 2012 was provided by Conservation International and was used because the river corridors are not included in more recent KBA boundaries for Myanmar. For this 2012 data, only the river corridors were selected.

### Biodiversity areas (P4)

KBAs were used as a proxy for high biodiversity. KBAs are "sites contributing significantly to the global persistence of biodiversity", as identified and agreed upon by experts.[4] For this study, IUCN obtained national-level KBA data from the Key Biodiversity Area Partnership for 2016. This data was analysed separately from the river corridors data (P3), because although the river corridors were considered KBAs in 2012, they had been removed from the data for 2016, and because for this project they are analysed for different values.

### High slope (P5)

Areas with high erosivity can contribute higher sediment loads to downstream areas. This in turn can reduce soil fertility, negatively impact water quality, and decrease reservoir storage capacity. Erosivity is a function of several factors, notably land cover, slope, and precipitation. However, for this analysis only slope was considered as part of the prioritization for erosivity.

Slope, the change in elevation over a change in horizontal distance, was calculated using a 90 m resolution DEM. Slope was selected as a prioritization factor because areas of higher slope are generally more susceptible to erosion. The DEM was projected to a conformal projection and initially reclassified to areas at or above 10, 15, or 20 degrees slope. A threshold of 15 degrees and above was selected for high slope, based on work that established this as the lower end of "high slope" areas (Dry Zone Greening Department, *In*: (Asia-Pacific Network on Integrated Plant Nutrient Management, 1997).

### Watersheds with population centres (P6)

An additional prioritization layer was based on whether a city, town, or village was present in a watershed. An assumption was made that if a watershed had no permanent population, it would be more difficult to feasibly implement forest landscape restoration due to the difficulty in transportation to the site and monitoring and protection of resources, when required. This does not account for the fact that in some cases a watershed could be accessible from a population centre in an adjacent watershed. However, given the location of many of the watersheds identified without towns (in far northern Myanmar, for example), this assumption is reasonable. In addition, since it is a single prioritization factor, it will not preclude an area from being identified as a potential FLR opportunity area if there are other factors in an area.

### Accessibility (P7)

A final prioritization layer was based on potential accessibility. Like P6 (above), this layer considered the location of population centres but adds transportation networks (roads) as an additional factor. The assumption is that if an area is more accessible it provides a more feasible opportunity for FLR. This layer includes two factors: (1) areas within 10 km of a population centre, and (2) areas within 500 m of a roadway (all types). However, it excludes the built-up areas of towns and the road itself as these areas are not available for FLR. For further discussion of exclusion areas see Section 3.4: Exclusion.

It should be noted that the accessibility layer does not include estimated travel times, only straight-line distance. This was done because of the greater simplicity in calculating straight-line distance and because many roads did not have a surface type attribute or average travel speed, making it difficult to calculate travel times.

### Combined prioritization (P8)

A final step in the prioritization analysis was to combine all input prioritization layers (P1-P7). Each layer was assigned a binary value of "1" if the criteria of interest (for example P1) was present, and "0" if not present. Areas with more overlapping criteria therefore obtain a higher value. However, the analysis does not assign a higher importance to any single layer. Due to the distribution of layers across Myanmar, not all overlap, and four was the maximum value possible. **This layer was used for visualization and easy communication of where multiple layers overlap but was not otherwise used in identifying opportunity areas.**

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[4] http://www.keybiodiversityareas.org/what-are-kbas

## 3.4. Exclusion
Four layers were used to exclude areas assumed to be unsuitable for FLR. These include roads, areas of open water, urban areas, and areas of irrigated agriculture land.

### Roads (E1)
Roads were obtained from OpenStreetMap (OSM). The vector line road layer was converted to a raster with 90 m resolution. This will overestimate the width of roads but matches the resolution of the analysis.

### Open water (E2)
Areas of fresh water were excluded. Freshwater areas were identified by reclassifying 2014 land cover to only include areas of water (Bhagwat et al., 2017). This includes rivers, natural lakes, reservoirs, and other areas of water within Myanmar's boundaries. Marine areas such as the oceans and estuaries were automatically excluded since all layers were clipped to Myanmar's national terrestrial boundaries.

### Urban and built-up areas (E3)
Urban or built-up areas were identified based on population density data from WorldPop estimated for 2015.[5] WorldPop provides a 100 m resolution data set of UN-adjusted population estimates for Myanmar. This data was resampled to match the 90 m resolution of all other data. Population density was used as a proxy for developed area because no suitable land cover/land use layer identified rural towns (which often have a relatively smaller proportion covered by mand-made surfaces) and because the WorldPop data is also partially based on the developed land cover of an area.

A threshold of at least 5 persons/hectare (pph) was selected after experimenting and adjusting to match the visual extent of both urban and rural towns as well as possible using high resolution satellite imagery for comparison. Once the threshold was set, a binary value was given for urban (1) or not urban (2). This threshold is a compromise: In more rural areas, 4 pph more accurately matched satellite imagery of built-up areas. However, in some regions this greatly overestimated built-up area by including expansive areas of rice cultivation.

### Irrigated cropland (E4)
Areas of irrigated cropland are assumed to be of high enough economic value so that they are unlikely to be converted back to forest in the near term. An irrigated agriculture layer was obtained from the U.S. Geological Survey (USGS) based on imagery for 2007-2012.[6] As of late 2017, only 1 km resolution data was available. A visual comparison of the data with satellite imagery shows some significant differences between the data set and actual land cover/land use. Due to data resolution and accuracy, the irrigated cropland layer misses some areas with active cultivation, while incorrectly classifying some non-agricultural areas as irrigated agriculture. Nevertheless, the layer was used because it was the best available at time of analysis and does appear to correctly capture large areas of rice paddy cultivation in the Ayeyarwady Delta and other regions in Myanmar.

### Combined exclusion (E5)
Exclusions areas E1-E4 were combined into a single layer and reclassified as a binary value for areas to exclude or to not exclude. This was layer was used later to exclude outputs from the final analysis.

## 3.5. Analysis and outputs
The analysis of input degradation, prioritization, and exclusion data took two approaches. First, a multi-criteria analysis (MCA) was conducted to see what areas emerged as potential priorities for FLR. The MCA was used for visually identifying areas of potential opportunity, but did not inform quantitative, final outputs. Second, a weighted overlay analysis ('weighted MCA') was conducted that assigned higher priority to individual inputs, such as areas of recent forest loss.

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[5]WorldPop uses a variety of factors in estimating population. This data set incorporates data from Myanmar's 2014 census but also considers other factors. It is not an official government estimate of population:
http://www.worldpop.org.uk/data/WorldPop_data/AllContinents/107_metadata.html
[6]https://lpdaac.usgs.gov/sites/default/files/public/product_documentation/gfsad1k_user_guide.pdf

## Multi-criteria analysis

The MCA was carried out to visually identify areas where multiple criteria overlap. First, input data was reclassified to give each a value of "1" where the criteria was present. Each input layer was then combined into a single thematic layer (degradation, prioritization). These thematic layers were then overlaid, with areas of higher values representing more overlapping layers. For example, an area with forest canopy cover loss, a river corridor, and a watershed important for water quality and water provision would have a value of three, because there are three overlapping layers. This layer helped to visualize potential opportunity areas based solely on the number of overlaps (see Map 19).

## Weighted multi-criteria analysis

When assessing FLR opportunities, not all criteria have equal importance. To account for this, the analysis also applied a weighted MCA to identify areas for potential FLR by assigning higher importance ("weights") to some criteria relative to others. In a weighted MCA, the input criteria are multiplied by their assigned weights and then added together (see table, below). In this approach, input criteria with higher weights are considered to be more important.

| Input | Weight (%) |
|---|---|
| Degradation (D4) | 30 |
| Watershed above waterbodies (P2) | 20 |
| River Corridors (P3) | 15 |
| Biodiversity (P4) | 15 |
| Slope (P5) | 15 |
| Accessibility (P7) | 5 |
| **Total** | **100** |

*Table 1: Weighted MCA criteria.*

Watersheds with high forest loss (P1) were not included in the weighted MCA assuming that D4 more accurately captures the *actual area* of degradation, rather than the entire watershed, which could still have areas with high quality forest. Similarly, watersheds with towns were not directly considered in the prioritization analysis, since they include large areas that are captured by the accessibility criterion (also known as a data "layer") (P7). These criteria were used in the MCA, but not for the weighted MCA or when reporting the total opportunity area identified by this analysis.

For the weighted MCA, each input layer had a base value of 1. This is important because weighted values are scaled and equivalent. For example, on a scale of 1-2, "2" is twice (100% more) than a value of "1". The analysis therefore gives a special weighting to areas of dry deciduous forest loss and mangrove forest loss since they were given a value of "2" (their own value of 1, added to the overlap with the input of all canopy cover loss, from which they were partially derived). These layers therefore have a relative weighting of 0.6 (30% assigned overlay weight * 2), higher than any other layer.

The exclusion areas (E5) were removed from the output of the weighted MCA. The output of the weighted MCA, with exclusion areas removed, was then reclassified to only include areas with values above 0.25. This was done to narrow and better prioritize the output, because at least one or two prioritization layers can be found across most of the country. Using the 0.25 threshold limits this to a much smaller area of higher opportunities, and further excludes areas where only a subset of lower-weighted inputs may be found.

As an additional step, the proportion of the overlying FLR priority areas was calculated for each of Myanmar's 5,353 sub-watersheds as defined by the Hydro BASINS level 12 watersheds data set (Lehner, 2014). This was further narrowed to identify watersheds with at least 10% of their area covered by the output of the weighted MCA (with values above 0.25). These areas represent 1.9 million hectares. These potential priority basins are useful in visually demonstrating the distribution of opportunity watersheds across the country. This is relevant becauseprojects can be designed at the basin scale and achieve results such as water quality enhancement that benefit local communities. However, due to the scale of the analysis, these areas may require further refinement before an on-ground project is implemented. These priority basins are identified in yellow on the final poster maps (see Final Poster Maps in Appendix B).

# 4 - Results

The results on the Myanmar ROAM study are the output of an analysis that overlays the degradation and prioritization layers and removes the exclusion areas using the methods and steps described in Section 3.

The analysis identified up to 2.5 million hectares as FLR opportunity areas before the exclusion layer was applied. After excluding areas where FLR is impractical (built-up areas, water bodies, etc.) or low priority (if they only deliver one rather than multiple benefits), 713,000 hectares were identified as priority FLR areas.

## Regional results

Priority FLR areas include the dry deciduous forest of central Sagaing Region, the mangroves of northern Rakhine State and the Ayeyarwady Delta, the lowland evergreen forest of southern Tanintharyi Region, and the mixed deciduous forest of the Bago Yoma. The map is indicative only. These areas are especially relevant to achieving the MRRP objectives, which include not only restoring degraded and deforested land, but also improving economic and environmental outcomes for local communities.

The results of this study identify potential FLR opportunities across the country. However, the largest areas are found in the following states/regions (see Table 2 below and Map 1).

**Regional results of Restoration Opportunity Area (ROA) and Prioritized Forest Landscape Restoration Watershed (PFLRW), dominant or prioritized forest type(s), and brief deforestation history (Unit: Hectare)**

| State/Region | ROA | PFLRW | Forest Type | Deforestation |
|---|---|---|---|---|
| Sagaing | 206,947 | 582,478 | DDF | DDF historically cleared across areas of the CDZ and more recently in some remaining areas, lowland subtropical, evergreen forests cleared in the late 2000s through present |
| Kachin | 117,897 | 214,810 | DDF | |
| Rakhine | 68,886 | 306,437 | Mangrove | Mangrove cleared in the 2000s |
| Shan | 55,313 | 119,621 | Rainforest | Rainforest cleared in the 2010s |
| Tanintharyi | 52,752 | 138,445 | Lowland rainforest | Rainforest cleared in the 2010s |
| Mandalay | 46,752 | 160,974 | DDF/mixed deciduous | Areas along the eastern border of the region cleared in recent years for timber, mining, and infrastructure |
| Ayeyarwady | 42,992 | 137,959 | Mangrove | Mangrove cleared in the 1990s |
| Bago | 42,923 | 100,546 | Mangrove | Mangrove cleared in the 2000s |
| Magway | 33,618 | 14,238 | DDF | DDF cleared prior to 2000, areas in the west of Magway more recently cleared |
| Naypyitaw | 25,532 | 105,265 | DDF | Cleared prior to 2000 for agriculture |
| **National*** | **713,000** | **1,901,000** | | |

*Table 2: National figures rounded to nearest one-thousand*

**ROA in Select States/Regions (hectares)**

| State/Region | ROA (hectares) |
|---|---|
| Sagaing | 206,947 |
| Kachin | 117,897 |
| Rakhine | 68,886 |
| Shan | 55,313 |
| Tanintharyi | 52,752 |
| Mandalay | 46,752 |
| Ayeyarwady | 42,992 |
| Bago | 42,923 |
| Magway | 33,618 |
| Naypyitaw | 25,532 |
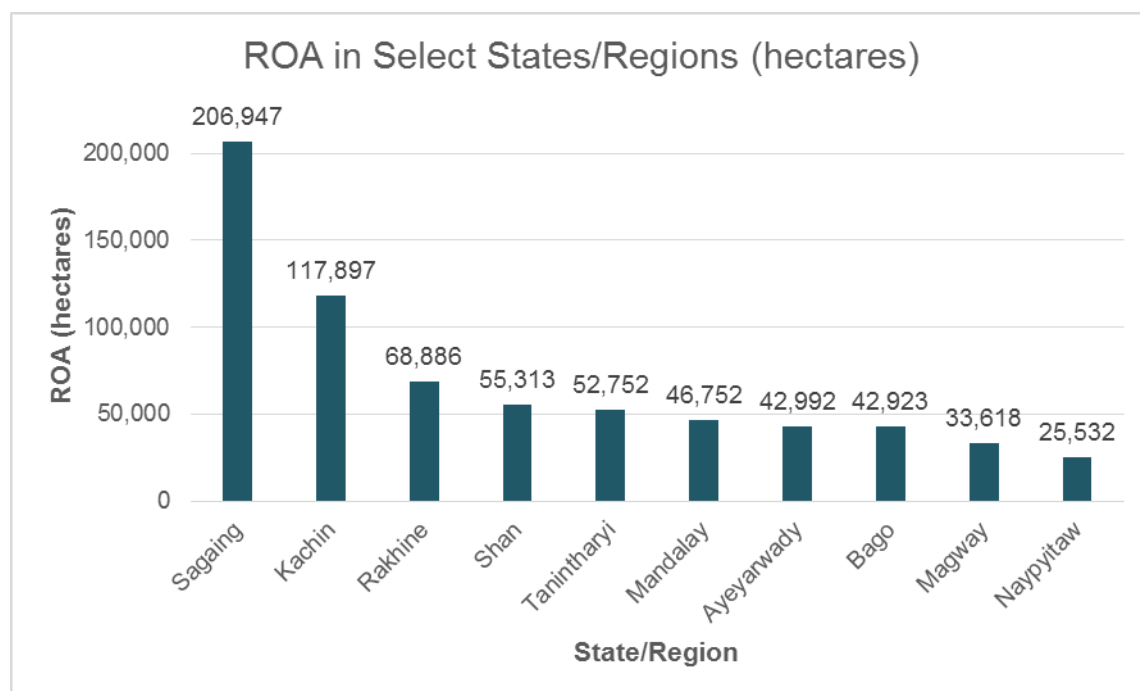
*Figure 1: Restoration opportunity areas: Top ten state/regions*

*Below illustrate briefly the landscape contexts and opportunities in Sagaing Region and Kachin State (northern Myanmar), Rakhine State (west), Shan State (east), Tanintharyi Region (southern Myanmar), Mandalay Region (central), Ayeyarwady Region (Ayeyarwady Delta), Bago Region (Gulf of Mottama to central), and Naypyitaw and Magway (central) (Map 1).*

### Sagaing region
The largest contiguous areas of forest loss in recent years have been in the southern half of the region and to a lesser extent along the Chindwin River. Across the Sagaing-Kachin border near Hpakant, Kachin, large areas have been cleared in recent years for jade mining.

### Kachin state
Kachin State has experienced deforestation throughout the far north of the state, including near the border with China, south of Hukaung and the town of Danai, and to the north of Putao. In central Kachin surrounding the city of Myitkyina, much of recent forest loss has been driven by conversion to plantations.

### Rakhine state
Rakhine State represents some of the highest mangrove forest loss in recent years for rice, shrimp, and fuelwood. Large-scale mangrove restoration would contribute to disaster risk reduction and would be part of a major economic recovery program for the region.

### Shan state
Deforestation exhibits a more distributed pattern, with patches of logging occurring across the state. The largest contiguous areas of deforestation occur near the border with China, with select areas also deforested near the Thai border. Although the total area of deforestation is large, accessibility to some areas may make FLR more difficult here.

### Tanintharyi region
Tanintharyi Region has experienced large areas of forest loss during the 2010s, especially in the southern half of the region and along the route from Mawdaung on the border with Thailand to the west. The largest FLR

opportunity areas were identified north of Kawthaung where large areas of forest have been cleared in recent years for, or in anticipation of, oil palm plantations.

### Mandalay region
Forest loss in Mandalay has been concentrated in recent years in the southeast, where it has been driven by logging, along the eastern edge of the region (logging and industrial development), and the north (mining activity).

### Ayeyarwady region
The Ayeyarwady Delta has suffered very large-scale mangrove clearing driven by production of charcoal and conversion to rice paddy, and to a much smaller extent aquaculture. The importance of mangroves for protecting coastal and inland regions of the delta make it a FLR priority.

### Bago region
Bago is an import region for water supply to Yangon and as Myanmar's main rice producing area. Areas in the Bago Yoma have been deforested from conversion to reservoirs, with additional large contiguous areas along or close to the Bago-Kayin border.

### Magway region
Magway has been deforested in areas close to the Naypyitaw-Magway border, and along its western edge toward the Chin Hills. Much of this loss occurred prior to 2000.

### Naypyitaw
Areas in southern Naypyitaw were cleared before 2000. Although some relatively large areas were identified here as potential FLR opportunity areas, this analysis did not take into account future planned land uses. Outside of built up areas in Naypyitaw, deforestation has been driven by agricultural expansion, particularly along existing natural riparian corridors.

# 5 - Conclusion

This report summarized the methodology and findings of a ROAM analysis of Myanmar. It focused on identifying potential FLR opportunities throughout the country. The analysis used a variety of input data sets, with an emphasis on recent forest canopy cover loss. Due to data availability, demographic and socio-economic data was not used. Given the data inputs, the study should be considered as a broad or first cut analysis to inform MRRP implementation.

The analysis employed a weighted MCA that input degradation data (forest loss), prioritization data (including high slope areas, areas upstream of reservoirs and lakes, and others), and excluded land cover and land uses that may preclude FLR (such as built-up/urban areas and land being used for irrigated agriculture).

At the national level, this study identified 713,000 hectares as potential priority FLR areas. These areas are primarily distributed across 10 states and regions, but the most accessible and largest contiguous areas are found within just six: Sagaing, Kachin, Rakhine, Tanintharyi, Ayeyarwady, and Bago.

## Application of results

The 10-year MRRP aims to restore over 1.2 million hectares of degraded and deforested land by 2026. This plan is to be achieved through a combination of plantations, community forestry, agroforestry, natural forest regeneration, and enrichment planting projects (MOECAF, 2016). If MRRP can invest strategically in priority areas, it will generate multiple benefits for people and biodiversity.

A number of key messages can be concluded from the ROAM mapping exercises:

1. ROAM mapping identified national FLR priorities based on consideration of both degradation drivers and restoration priorities.
2. The stakeholder-driven FLR design and priority-setting is the corner-stone of this ROAM analysis. The same approach is recommended for future ROAM analyses.
3. While forest loss has been weighted significantly in the analysis, it is the inclusion of human factors such as watershed protection and consideration given to settlement/population and accessibility that make the ROAM analysis more holistic and relevant.

We hope this study will provide useful references for the implementation of MRRP and other FLR initiatives in Myanmar.
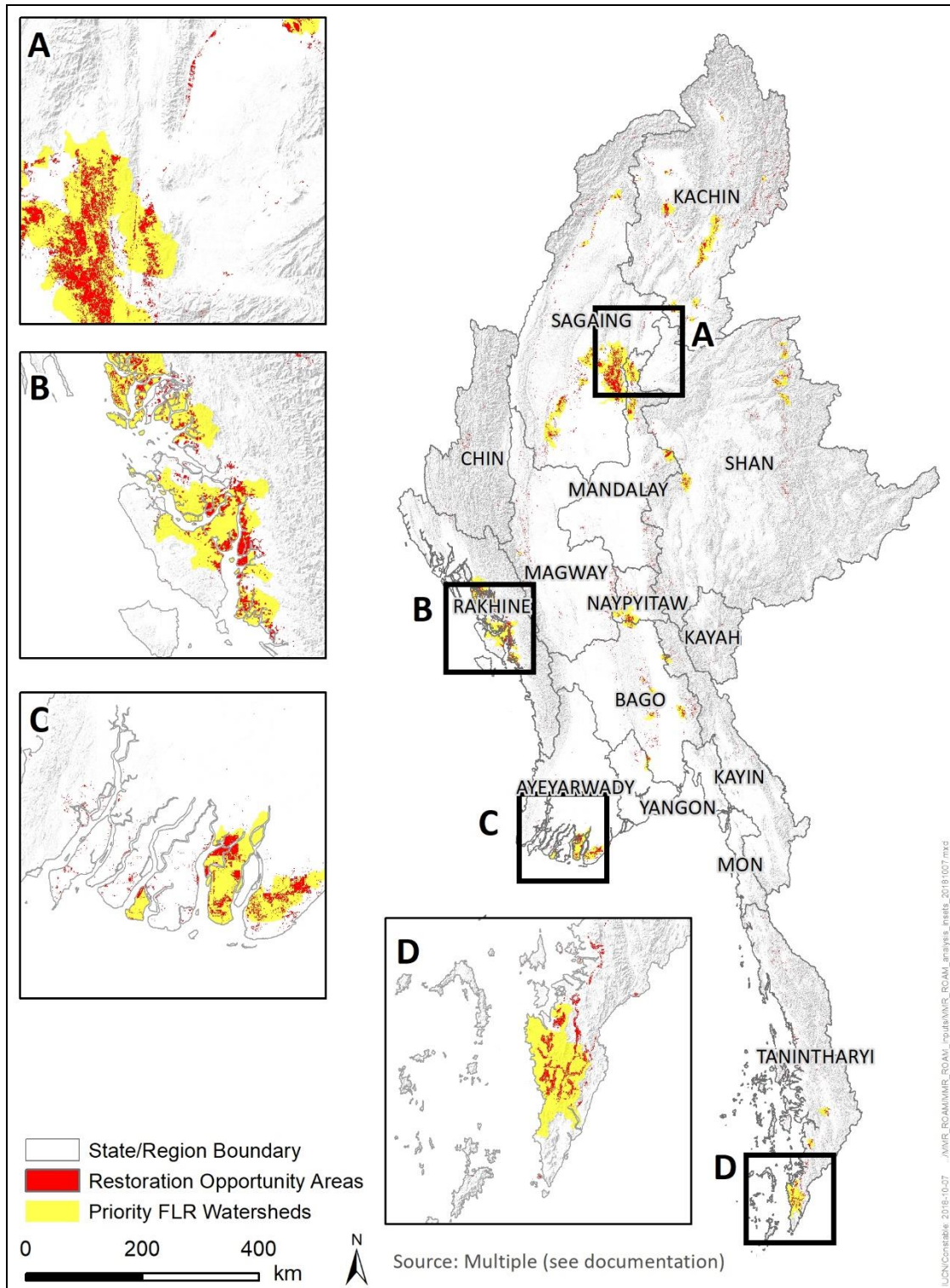
*Map 1: Priority restoration areas.*

Box A in Sagaing/Kachin Mandalay includes areas previously including DDF and mixed deciduous. Boxes B and C in Rakhine and Ayeyarwady include areas of previous mangrove forest that could be restored once again. Box D in Tanintharyi includes areas of lowland rainforest that have primarily been cleared in anticipation of oil palm plantations.

# References

The following references provide background on spatial methods and forest cover and landscape restoration in Myanmar. Not all sources below are cited in inline text in this report. When available, an open-access URL has been included to the original source.

Asia-Pacific Network on Integrated Plant Nutrient Management (1997). *Gateway to Land and Water Information: Myanmar.* Text 6.1.1 Case study on Land Degradation of Dry Zone of Myanmar. Available at: http://www.apipnm.org/swlwpnr/reports/y_ta/z_mm/mmtx611.htm#s07 (Accessed: 28 April 2018)

Bhagwat, T., Hess, A., Horning, N., Khaing, T., Thein, Z. M., Aung, K. M., Phyo, P., Tun, Y.L., Oo, A.H., Neil, A., Thu, W.M., Songer, M., LaJeunesse Connette, K., Bernd, A., Huang, Q., Connette, Grant, Leimgruber, P. (2017). 'Losing a jewel—Rapid declines in Myanmar's intact forests from 2002-2014'. *PLOS ONE*, *12*(5), e0176364. Available at: https://doi.org/10.1371/journal.pone.0176364

Brunner, J. (2017). Personal Communication [Phone].

Emerton, L., and Aung, Y. M. (2013). 'The Economic Value of Forest Ecosystem Services in Myanmar and Options for Sustainable Financing'. *IMG, Yangon and Ministry of Environmental Conservation and Forests, Nay Pyi Daw*. Available at http://www.researchgate.net/profile/Lucy_Emerton/publication/269099141_The_Economic_Value_of_Forest_Ecosystem_Services_in_Myanmar_and_Options_for_Sustainable_Financing/links/548023da0cf25b80dd704005.pdf

Food and Agriculture Organization of the United Nations (FAO) (2015). *Global forest resources assessment 2015.* Available at: http://www.fao.org/3/a-i4808e.pdf

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J. R. G. (2013). 'High-Resolution Global Maps of 21st-Century Forest Cover Change'. *Science*, *342*(6160), 850–853. Available at: https://doi.org/10.1126/science.1244693

Lehner, B. (2014). *HydroBASINS: Technical Documentation Version 1.c* (p. 9). Available at: http://hydrosheds.org/images/inpages/HydroBASINS_TechDoc_v1c.pdf

Leimgruber, P., Kelly, D. S., Steininger, M. K., Brunner, J., Müller, T., and Songer, M. (2005). 'Forest cover change patterns in Myanmar (Burma) 1990–2000'. *Environmental Conservation*, (04), 356–364. Available at: https://doi.org/10.1017/S0376892905002493

Sexton, J. O., Song, X.-P., Feng, M., Noojipady, P., Anand, A., Huang, C., Kim, D-H., Collins, K.M., Channan, S., DiMiceli, C., Townshend, J. R. (2013). 'Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS vegetation continuous fields with lidar-based estimates of error'. *International Journal of Digital Earth*, *6*(5), 427–448. Available at: https://doi.org/10.1080/17538947.2013.786146

Snyder, J. P. (1987). *Map Projections--A Working Manual* (U.S. Geological Survey (USGS) Professional Paper No. 1395) (p. 397). Available at: https://pubs.usgs.gov/pp/1395/report.pdf

Teluguntla, P., Thenkabail, P. S., Xiong, J., Gumma, M. K., Giri, C., Milesi, C.Yadav, K. (2014). 'Global Cropland Area Database (GCAD) derived from Remote Sensing in Support of Food Security in the Twenty-first Century: Current Achievements and Future Possibilities'. In: Prasad S. Thenkabail (ed.) *Land Resources: Monitoring, Modelling, and Mapping, Remote Sensing Handbook.* Volume 2, chapter 7. Available at: https://geography.wr.usgs.gov/science/croplands/docs/Teluguntla-thenkabail-xiong-etal-global-croplands-mask.pdf

Webb, E. L., Jachowski, N. R. A., 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. Available at: https://doi.org/10.1016/j.gloenvcha.2013.10.007

Weber, S. J., Keddell, L., and Kemal, M. (2014). *Myanmar Ecological Forecasting: Utilizing NASA Earth Observations to Monitor, Map, and Analyze Mangrove Forests in Myanmar for Enhanced Conservation* (p. 20). NASA. Available at: https://ntrs.nasa.gov/search.jsp?R=20140006912

Wohlfart, C., Wegmann, M., and Leimgruber, P. (2014). 'Mapping threatened dry deciduous dipterocarp forest in South-east Asia for conservation management'. *Trop. Conserv. Sci*, *7*, 597–613. Available at: http://tropicalconservationscience.mongabay.com/content/v7/TCS-2014-Vol7(4)_597-613_Wohlfart.pdf

# Appendix A: Data sources

The following table lists relevant spatial datasets which have been compiled and used in this analysis. Data used for the underlying basemap is not listed here but is primarily from Natural Earth (https://www.naturalearthdata.com/) and the Myanmar Information Management Unit (MIMU; http://themimu.info/). All data is available at no cost. However, some data sets require a license agreement or do not allow redistribution and must be acquired from the original data provider. When possible, the direct URL for the data source is included. Derived data is generally available from IUCN (Asia Regional Office). If underlying data is restricted this may not be available for redistribution.

*Classified value refers to the assigned value in the data used in the analysis. It can be used to disaggregate data after it has been combined. However, some values are duplicates, and have to be analysed separately to identify their original source.
**All data resampled to 90 m resolution before analysis.

| Cate-gory | Dataset | Class. Value* | Year/ Period | Original Spatial Resolution** | Source/ Citation | Data URL | Access | Notes |
|---|---|---|---|---|---|---|---|---|
| Degradation | D1: Canopy Cover Loss | 1,000 | 1990-2015 | 30 m | Hansen et al. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850-53. | https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.4.html | Public | Data is available starting for the year 2001 |
| | D2: Dry Deciduous Forest Loss | 3,000 | 1990-2015 | 250 m | IUCN 2017. Derived from: Hansen et al. 2013 (see D1) with consideration of Wohlfhart et al. 2014. | Available from IUCN | Public (derived) | 90 m resolution elevation data set |
| | D3: Mangrove Loss | 4,000 | 1990-2015 | 30 m | IUCN 2017. Derived from Hansen et al. 2013 (see D1), MIMU administrative boundaries (coastline) and elevation CGIAR-CSI (see Jarvis et al. 2008) Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database (http://srtm.csi.cgiar.org). | Available from IUCN | Public (derived) | Based on 30 m data from Hansen et al. 2013 |
| | D4: Combined degradation | Multiple | 1990-2015 | 30 m and 250 m | *See individual layers* | Available from IUCN | Public (derived) | --- |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Prioritization** | P1: Basin/forest loss | 10 | 1990-2015 | N/A | Derived from HydroBASINS and degradation layers | Available from IUCN | Public (derived) | Not used in weighted MCA |
| | P2: Key watersheds | 150 | N/A | N/A | Derived from HydroBASINS, CGIAR-WLE, and Bhagwat et al. 2017.<br><br>WLE (2017), Dataset on the Dams of the Irrawaddy, Mekong, Red and Salween River Basins. Vientiane, Lao PDR: CGIAR Research Program on Water, Land and Ecosystems - Greater Mekong. https://wle-mekong.cgiar.org/maps/ | Available from IUCN | Public (derived) | --- |
| | P3: River corridors | 150 | 2012 | N/A | Conservation International (2012). | https://www.conservation.org/ | Restricted | --- |
| | P4: Biodiversity areas | 15 | 2016 | N/A | Key Biodiversity Area Partnership (2016). | http://www.keybiodiversityareas.org/ | Restricted | --- |
| | P5: High slope | 20 | N/A | 90 m | Derived from Jarvis et al. 2008. | http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1 | Public | --- |
| | P6: Watershed with town | 1 | N/A | N/A | Identified from MIMU village database (2014) and HydroBASINS data. | Available from IUCN | Public (derived) | Not used in weighted MCA |
| | P7: Accessibility | 1 | N/A | N/A | Derived from OpenStreetMap (2017) and MIMU village database (2014). | Available from IUCN | Public (derived) | --- |
| | P8: Combined Prioritization | Multiple | N/A | Multiple/ N/A | Multiple, see individual inputs | Available from IUCN | Public (derived) | --- |
| **Exclusion** | E1: Roads | 1 | 2017 | N/A | OpenStreetMap Contributors (2017). | https://www.openstreetmap.org/ | Public (derived) | --- |
| | E2: Open Water | 1 | 2014 | 30 m | Derived from Bhagwat et al. 2017. | See references | Public (derived) | --- |
| | E3: Urban | 1 | 2014 | 250 m | Pesaresi, Martino; Ehrilch, Daniele; Florczyk, Aneta J.; Freire, Sergio; Julea, Andreea; Kemper, Thomas; Soille, Pierre; Syrris, Vasileios (2015): GHS built-up grid, derived from Landsat, multitemporal (1975, 1990, 2000, 2014). European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-ghsl-ghs_built_ldsmt_globe_r2015b | http://cidportal.jrc.ec.europa.eu/ftp/jrc-opendata/GHSL/GHS_BUILT_LDSMT_GLOBE_R2015B/GHS_BUILT_LDS2014_GLOBE_R2016A_54009_250/V1-0/ | Open | Data reclassified at 5 persons per hectare threshold to identify built-up areas based on visual analysis |
| | E4: Irrigated cropland | 1 | 2007-2012 | 1 km | Thenkabail et al. 2012 and Teluguntla et al. 2014. | https://croplands.org/ | Open | Higher resolution data now available. |
| | E5: Combined exclusion | 1 | Multiple | Multiple | Multiple | Available from IUCN | Public/ Open | --- |
| **Outputs** | Restoration opportunity areas | Multiple | 2017 | 90 m | IUCN 2018 | Available from IUCN | Public (derived) | Combination of degradation, prioritization, and exclusion layers. |

*Table 3: Data sources.*

# Appendix B: Maps

This appendix includes maps generated as part of the analysis, as well as the final output maps. In order, it lists degradation layers, prioritization layers, exclusion layers, output layers, and two final poster maps created for the project. On these maps four areas (or "boxes") are included to show select areas in more detail. These areas were selected due to the relatively large and contiguous nature of FLR priority areas in these regions, and include:

- **Box A:** Areas potentially suitable for DDF and mixed deciduous FLR in Sagaing, Kachin, and Mandalay.
- **Box B:** Areas of mangrove loss in Rakhine that could be restored to mangrove forest.
- **Box C:** Areas of mangrove loss in the Ayeyarwady Delta that could be restored to mangrove forest.
- **Box D:** Areas potentially suitable for lowland rainforest FLR.

# Degradation maps
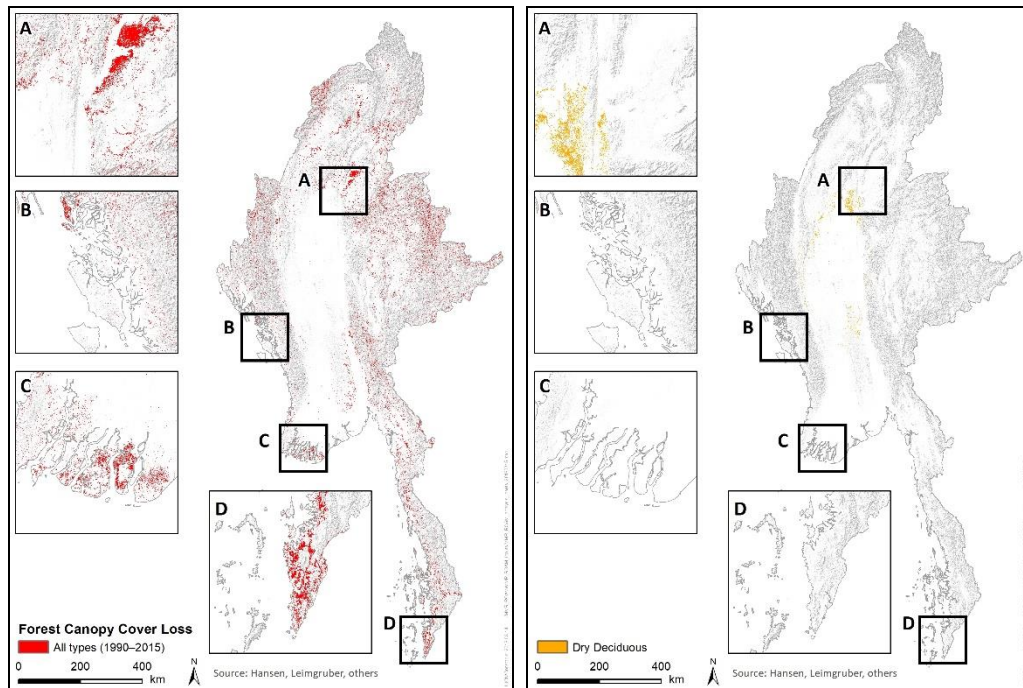


*Map 2: Forest canopy cover loss (D1).*



*Map 3: Dry deciduous forest loss (D2).*
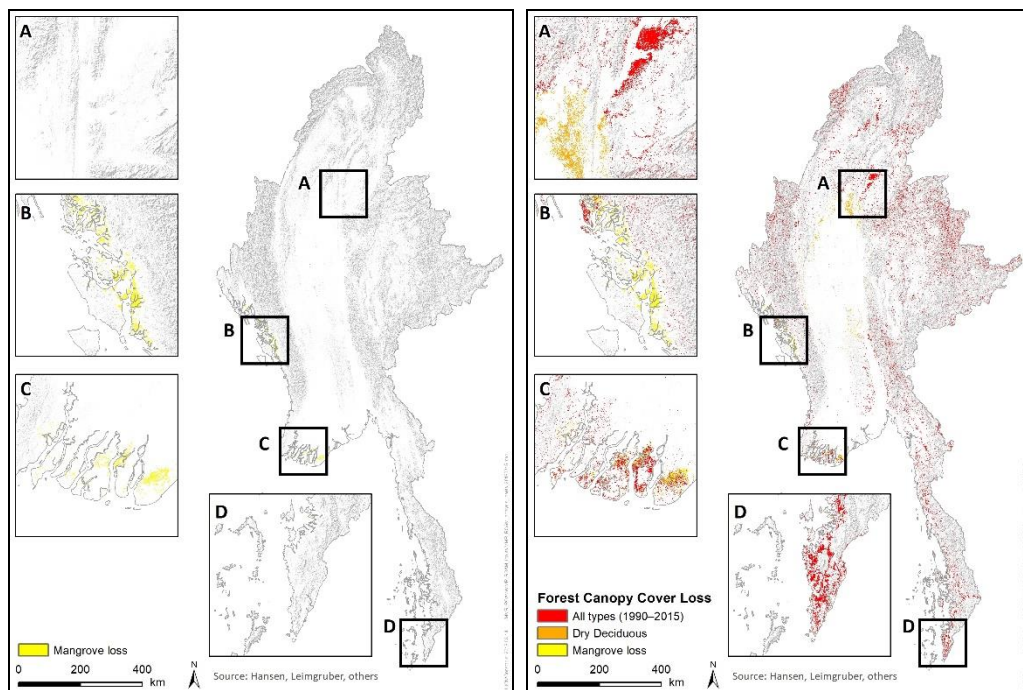


*Map 4: Mangrove forest loss (D3).*



*Map 5: Combined forest loss (D4).*

# Prioritization maps (1 of 2)
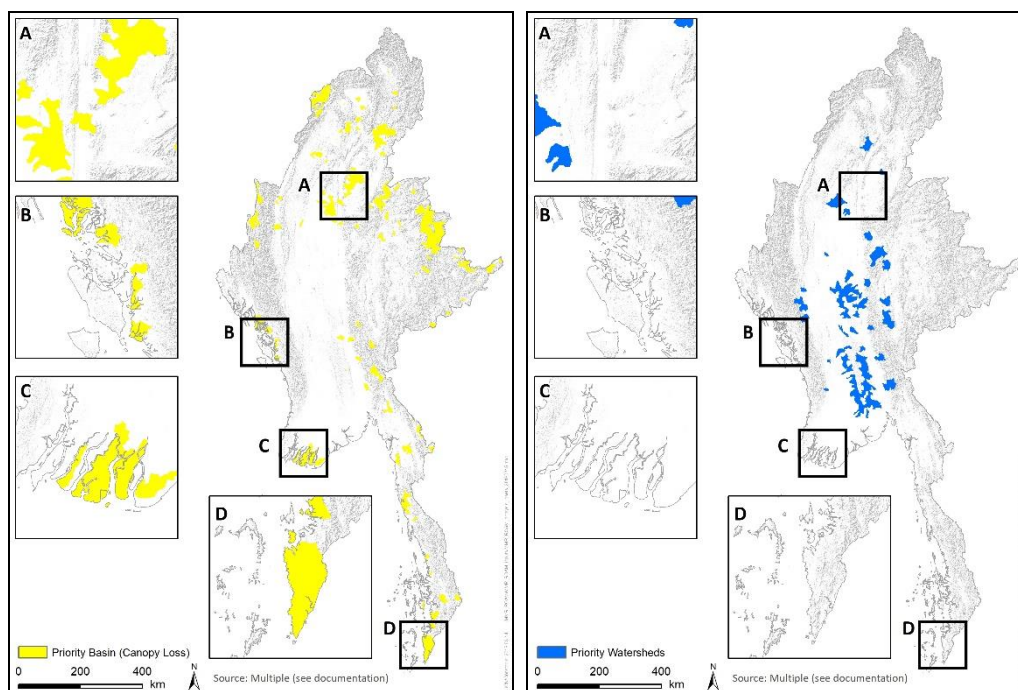


*Map 6: Basin and forest loss (P1).*



*Map 7: Priority watersheds above waterbodies (P2).*
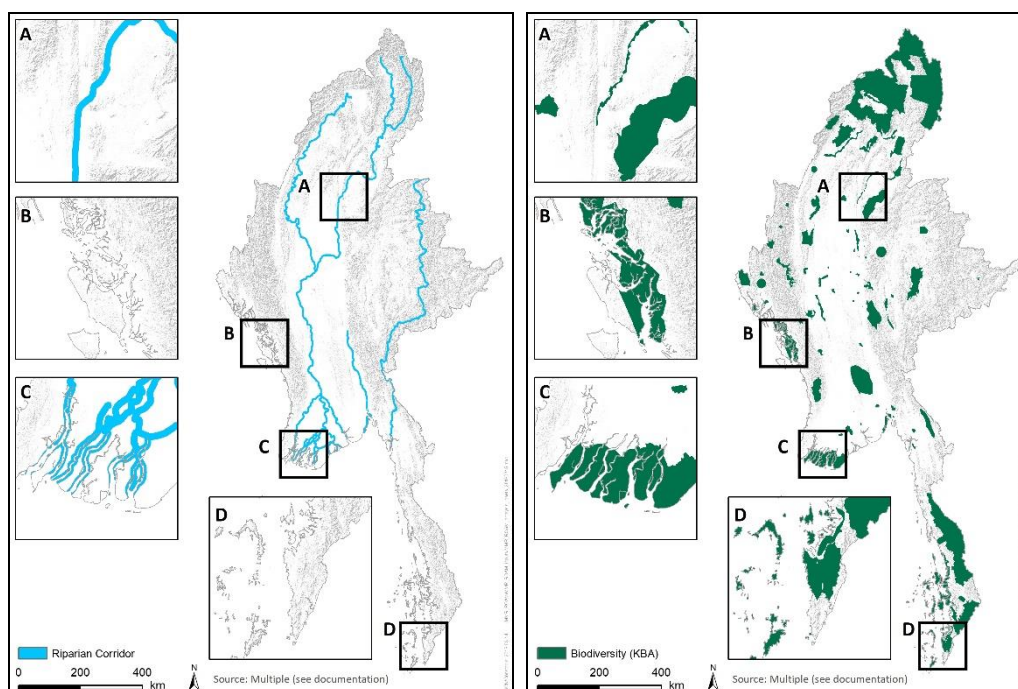


*Map 8: River corridors (P3).*



*Map 9: Key Biodiversity Areas (P4).*

# Prioritization maps (2 of 2)
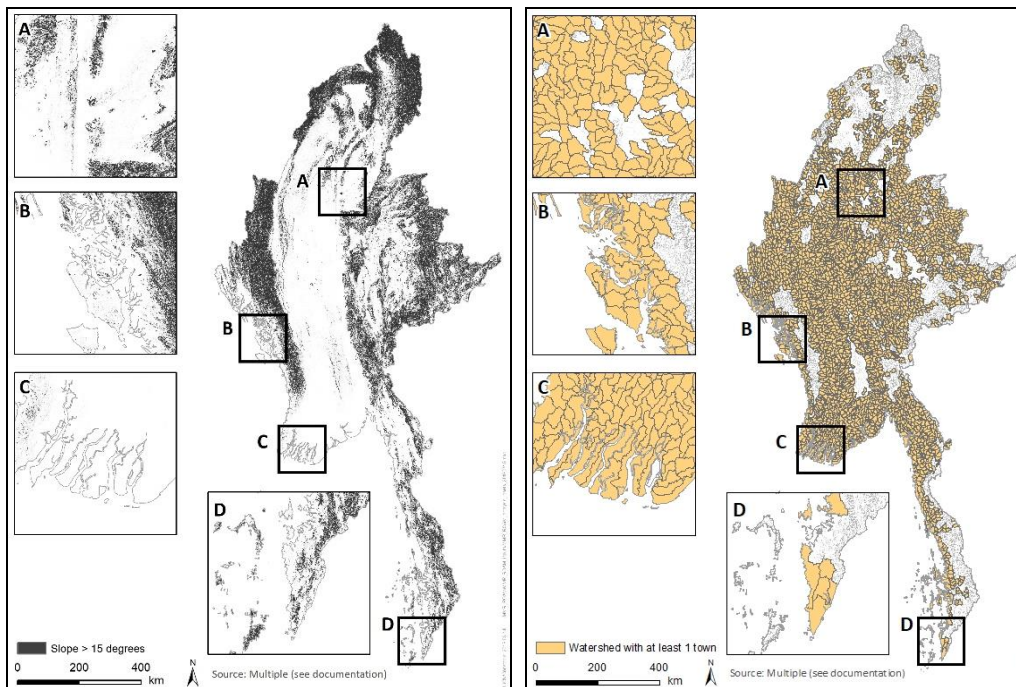


*Map 10: High slope areas (P5).*



*Map 11: Watersheds with towns (P6).*
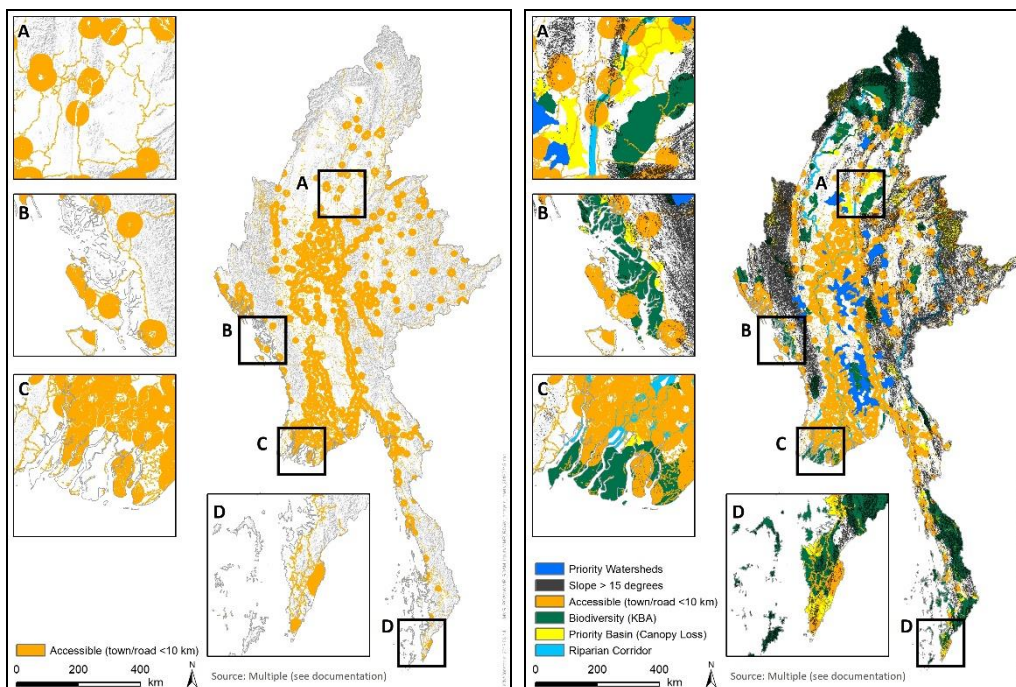


*Map 12: Accessibility (P7).*



*Map 13: Combined prioritization areas (not showing basins with/without towns on this map) (P8).*

# Exclusion maps (1 of 2)
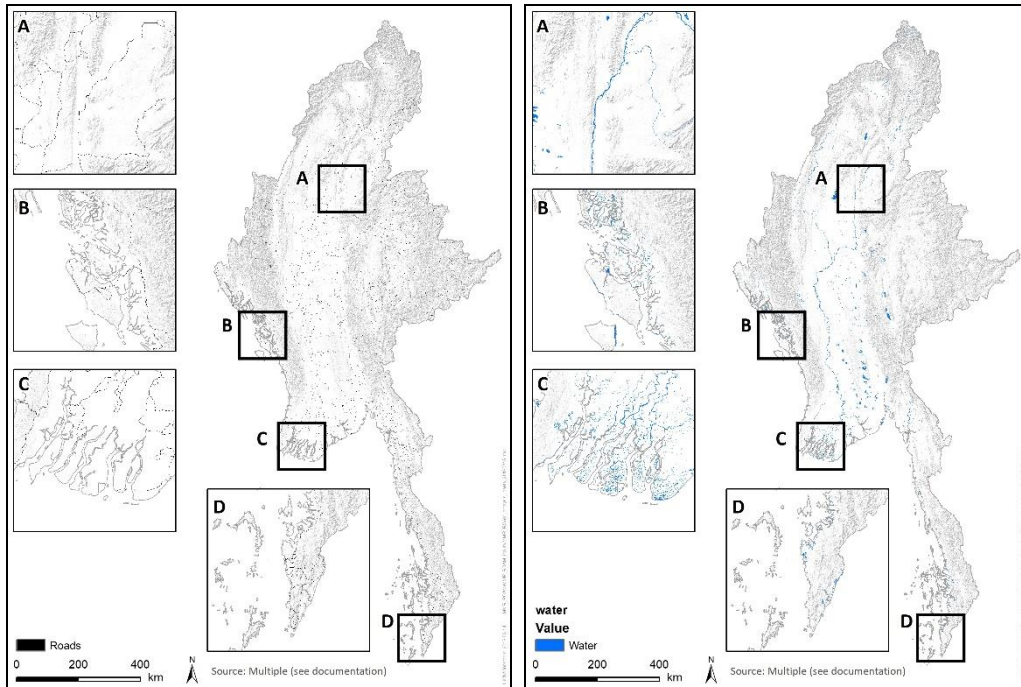


*Map 14: Roads (E1)7.*



*Map 15: Open water (fresh water only) (E2).*
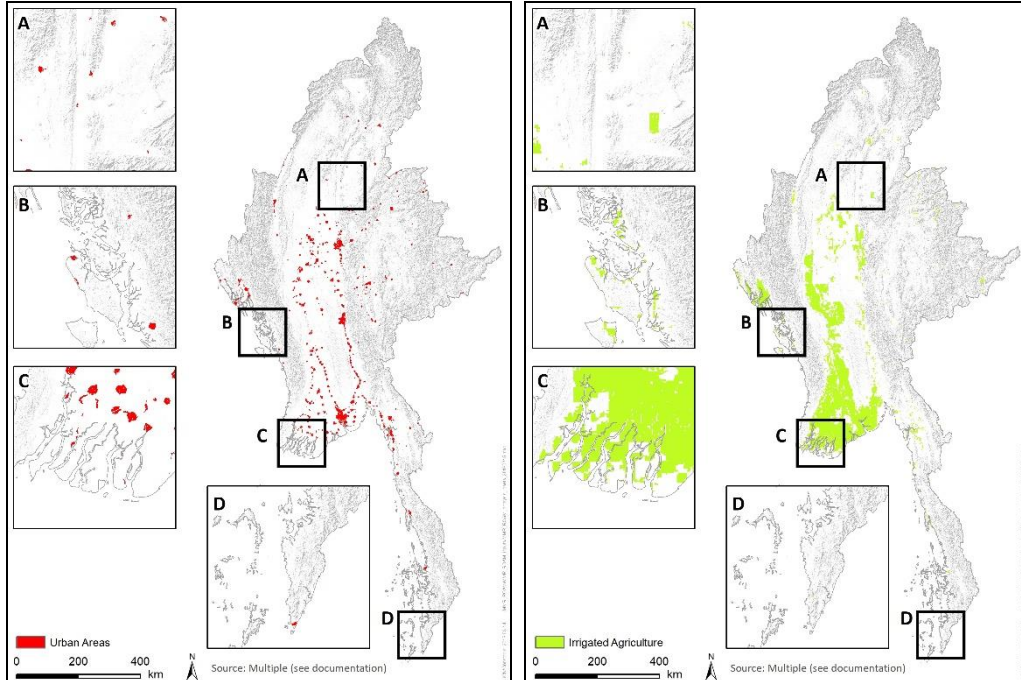


*Map 16: Urban/built-up areas (E3).*



*Map 17: Irrigated cropland (E4).*

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[7]Although features may not be visible on many maps in this report at this scale, this is especially true for roads, which are herein defined as 90 m wide). Please see original data for a more accurate depiction of the roadway network.
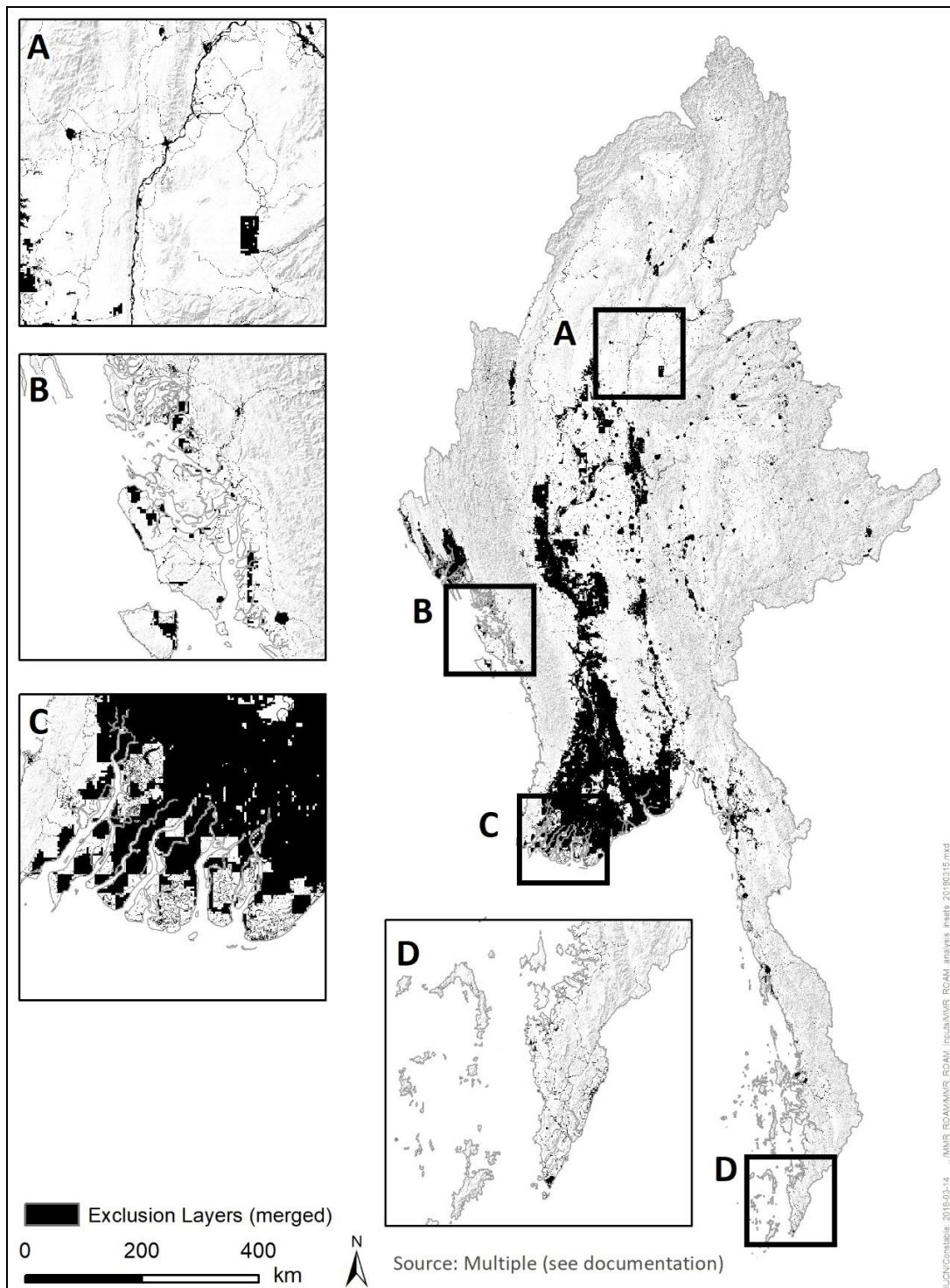
*Map 18: Combined exclusion areas (E5).*

# Output maps
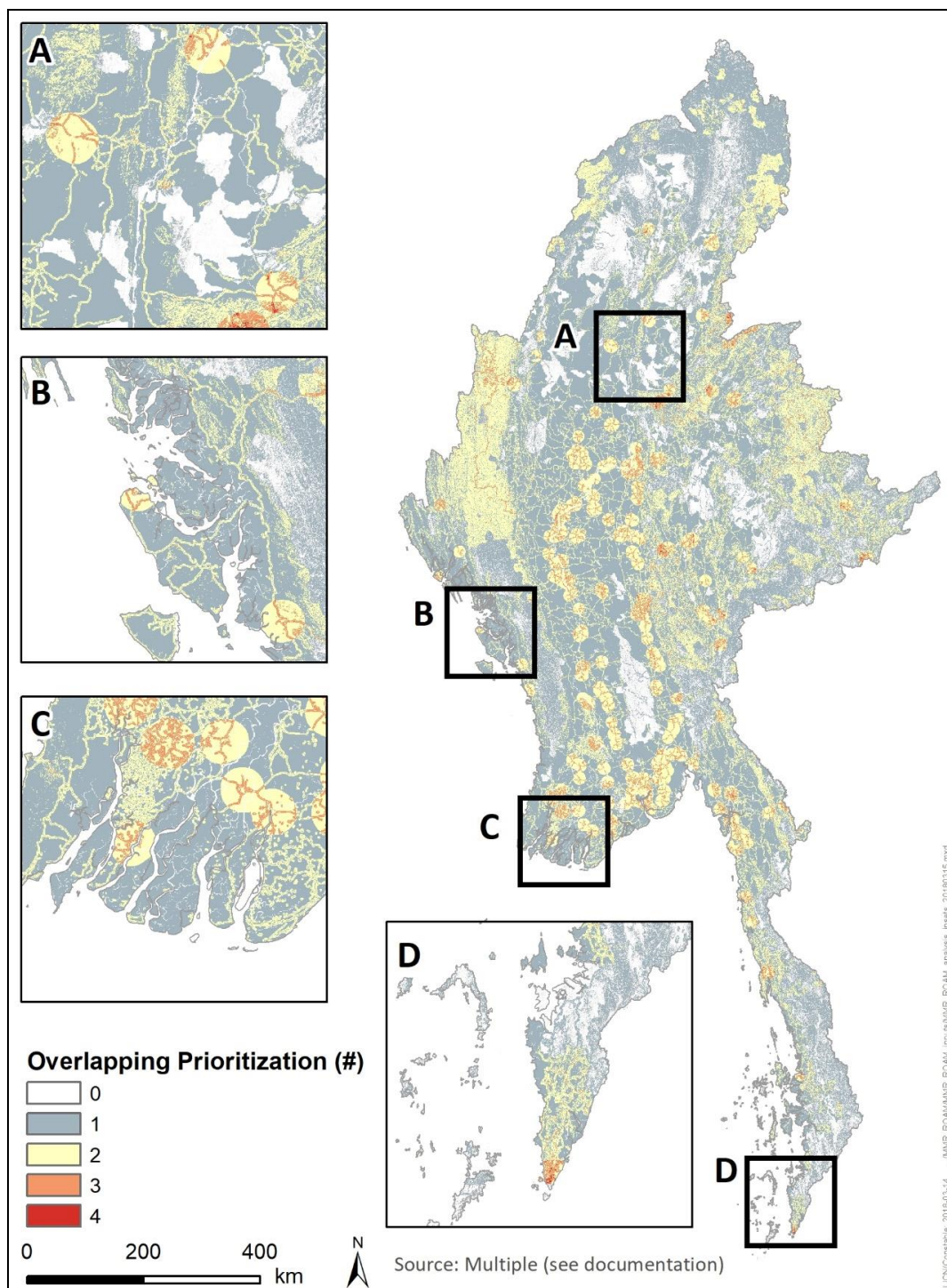


*Map 19: Multi-criteria Analysis (MCA) map.*

## Final poster maps
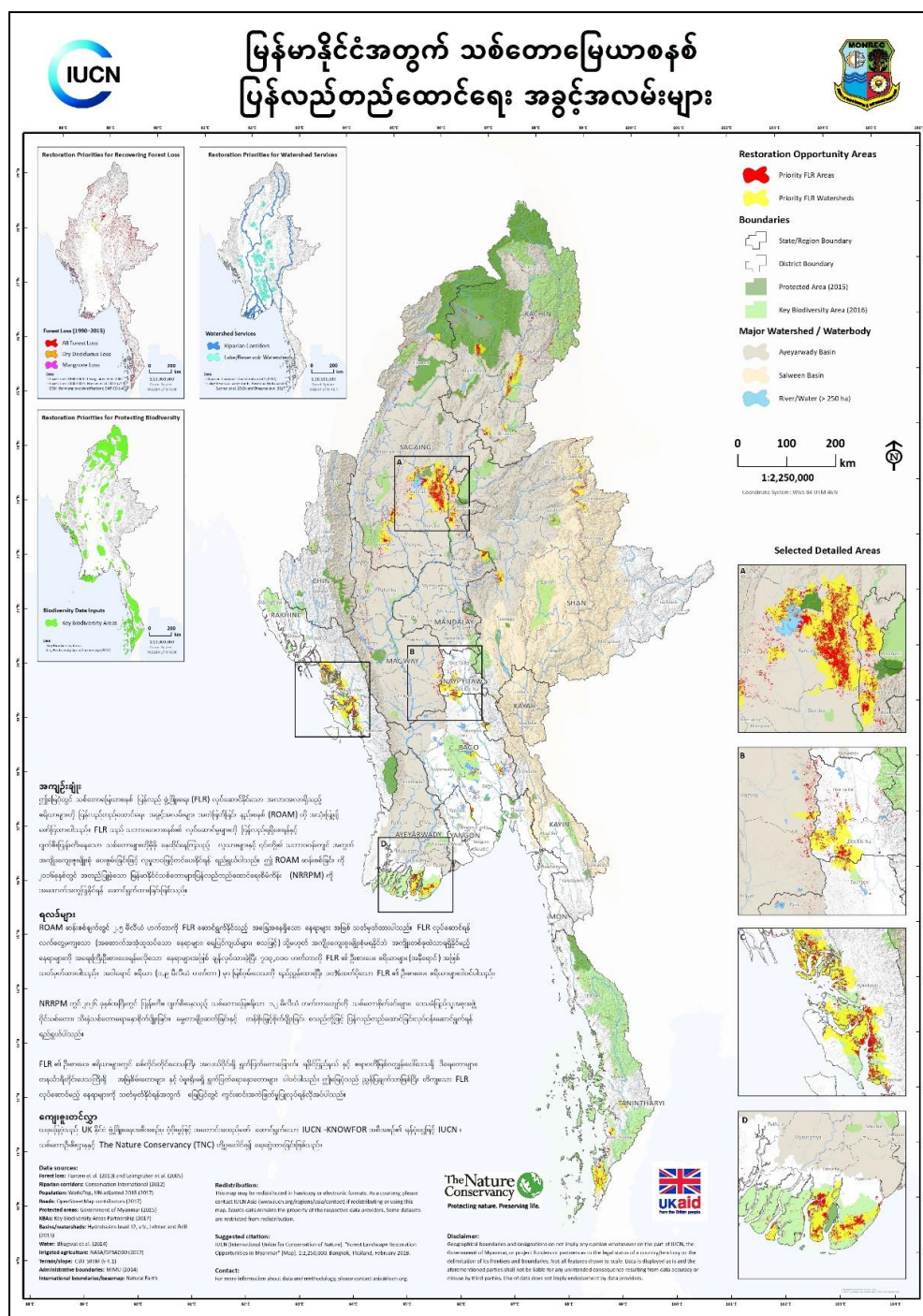


*Map 20: Final output map (Myanmar language).*

In this view the map has been simplified to only show areas with significant areas overlapping. Although there are areas with more overlapping criteria, they generally cover small areas. At the extreme end, only a single pixel (90x90 m) had nine overlapping criteria. This map shows the MCA prior to a full exclusion being applied.

# Forest Landscape Restoration Opportunities in Myanmar

**IUCN**

**MONREC**

**Restoration Priorities for Recovering Forest Loss**

**Restoration Priorities for Watershed Services**

**Forest Loss (1990–2015)**
- All Forest Loss
- Dry Deciduous Loss
- Mangrove Loss

**Watershed Services**
- Riparian Corridors
- Lake/Reservoir Watersheds

**Restoration Priorities for Protecting Biodiversity**

**Biodiversity Data Inputs**
- Key Biodiversity Areas

**Restoration Opportunity Areas**
- Priority FLR Areas
- Priority FLR Watersheds

**Boundaries**
- State/Region Boundary
- District Boundary
- Protected Area (2015)
- Key Biodiversity Area (2016)

**Major Watershed / Waterbody**
- Ayeyarwady Basin
- Salween Basin
- River/Water (> 250 ha)

0    100    200 km

1:2,250,000

Coordinate System: WGS 84 UTM 46N

**Selected Detailed Areas**

A

B

C

D

### Overview:
This map shows potential forest landscape restoration (FLR) areas in Myanmar, identified using the Restoration Opportunities Assessment Methodology (ROAM). FLR aims to regain ecological function and enhance human well-being across deforested and degraded forest landscapes, allowing multiple benefits for people and nature. The ROAM analysis was produced in support of the National Reforestation and Rehabilitation Program in Myanmar (NRRPM), which was approved in 2016.

### Results:
The ROAM analysis identified **2.5 million hectares** as FLR opportunity areas. After excluding areas where FLR is impractical (built-up areas, water bodies, etc.) or low priority if they only deliver one rather than multiple benefits, **713,000 hectares** were identified as priority FLR areas (in red). Yellow areas **(1.9 million hectares)** indicate river basins with more than 10% of their area covered by FLR priority areas.

The NRRPM aims to restore over **1.2 million hectares** of degraded and deforested land by 2026, through plantations, community forestry, agroforestry, assisted natural regeneration, and enrichment planting.

FLR priority areas include the dry deciduous forest of central Sagaing Region, the mangroves of northern Rakhine State and the Ayeyarwady Delta, the lowland evergreen forest of southern Tanintharyi Region, and the mixed deciduous forest of the Bago Yoma. The map is indicative only; the identification of specific FLR sites requires on-the-ground assessments.

### Acknowledgements:
The map is a joint product of IUCN, the Myanmar Forest Department, and The Nature Conservancy (TNC), by IUCN through the KNOWFOR programme, funded by U.K. aid from the UK. Government.

**Data sources:**
Forest loss: Hansen et al. (2013) and Leimgruber et al. (2005)
Riparian corridors: Conservation International (2012)
Population: WorldPop, UN-adjusted 2015 (2017)
Roads: OpenStreetMap contributors (2017)
Protected areas: Government of Myanmar (2015)
KBAs: Key Biodiversity Areas Partnership (2017)
Basins/watersheds: Hydrobasins level 12, etc.; Lehner and Grill (2013)
Water: Dhaprot et al. (2004)
Irrigated agriculture: NASA/GFSAD30 (2017)
Terrain/slope: CGIAR SRTM (v 4.1)
Administrative boundaries: MIMU (2014)
International boundaries/basemap: Natural Earth

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**Suggested citation:**
IUCN (International Union for Conservation of Nature). "Forest Landscape Restoration Opportunities in Myanmar" [Map]. 1:2,250,000. Bangkok, Thailand, January 2018.

**Contact:**
For more information about data and methodology, please contact asia@iucn.org.

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*Map 21: Final output map (English language).*

# Appendix C: Custom projection parameters

For this study a custom equal area projection was created that is centred on Myanmar. The projection parameters are listed below and an ESRI projection file (".prj" extension) is included with the data.

Myanmar_Albers_Equal_Area_Conic
Authority: Custom

Projection: Albers
False_Easting: 0.0
False_Northing: 0.0
Central_Meridian: 96.0
Standard_Parallel_1: 14.5
Standard_Parallel_2: 25.0
Latitude_Of_Origin: 20.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563

# Appendix D: Additional notes

Some analysis steps could have been improved through inclusion of alternative data or alternative analysis methods. Most of these have been mentioned throughout relevant sections of this report. These issues are also summarized here as areas where a subsequent analysis could improve upon.

1. **Elevation and Mangroves:** Mangroves were identified using a proxy of elevation and coastal adjacency. Late in the project it was found that some areas of likely mangrove cover – as identified visually – were excluded because of distance from the coast or exclusion by the elevation thresholds. This could be improved by using a yet-to-be-developed mangrove data set from satellite imagery and averaging a 30 m DEM by a 9 by 9 cell window for a more accurate elevation threshold (Weber et al., 2014).
2. **Irrigated Cropland:** At time of analysis no suitably accurate irrigated rice layer was identified. If such a layer is developed in the future this would improve the applicability of the results by more accurately developing areas that are likely unsuitable for FLR. A 90 m or better resolution data set would improve this.
3. **Socio-economic Data:** Georeferenced census data – for example gender and socio-economic data – would improve the analysis by making a strong connection to vulnerable communities. At time of analysis census analysis units were not available in electronic format, so it was not possible to integrate this data at a township level.
4. **Weighted MCA Analysis:** The weighted analysis incorporated assumptions as to the relative importance of different criteria, and which criteria should be included in the analysis. Further review by stakeholders and provision of multiple different iterations using different weights would help validate the outcome.

Additional data – and reasons they were not utilized – are listed below. The primary limiting factor was that census reporting unit boundaries were not available in electronic format and available boundaries did not match State/Region or District boundaries.

| Thematic Area | Data | Source | Notes |
|---|---|---|---|
| Socio-economic | Fuelwood use | Myanmar Census (2015) | Reporting areas did not match MIMU administrative areas; all areas outside of major urban areas have high fuelwood use so this does not help prioritize regions for FLR. |
| | Income, employment, GDP | Myanmar Census (2015) | Reporting areas did not match MIMU administrative areas; reporting areas would have been too low resolution for any use besides identifying general areas for further study |
| | Gender | Myanmar Census (2015) | Reporting areas did not match MIMU administrative areas; reporting areas would have been too low resolution for any use besides identifying general areas for further study |
| | Population density and settlements | WorldPop, NASA | Population was initially considered as a filter to exclude areas with very high or very low population. In the end, only WorldPop was used to exclude areas of the highest density, assuming that the built environment and local pressures on forests would preclude effective FLR. |
| Biophysical | Bare Ground | UMD/NASA | Bare ground was considered to help identify areas for FLR. However, areas classified as 0-40% 'bare' often included rice and other agricultural crops, while areas of >90% barren area were in-river sand islands. |
| | Climate and meteorology | WorldClim | Average and seasonal precipitation was used to help identify areas of potential dry deciduous forests. However, it could have also improved analysis of sedimentation risk, water supply, and suitability for FLR without irrigation. |
| | Fire recurrence | NASA | Frequent burn areas could be considered as a proxy for degradation. |
| Biodiversity | Biodiversity | Conservation International KBAs | No spatially-explicit biodiversity data identified. This could be estimated through a proxy of select land cover types known to support higher biodiversity. Instead, Key Biodiversity Areas (KBAs) were used. |
| | Land cover | Multiple | Attempted to identify select land cover for their importance to biodiversity: mangrove, coastal rainforest, rainforests, dry deciduous forest. The data (WWF) Is low resolution and selects large areas of the country, so ultimately was not used. |

*Table 4: Additional data considered.*

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