PRODUCTIVE LANDSCAPES (PROLAND)

PRIORITIZING INVESTMENTS IN LAND-BASED CLIMATE MITIGATION IN PAPUA NEW GUINEA

PHOTO: TETRA TECH

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AFOLU	Agriculture, Forestry, and Other Land Use
BAU	Business as Usual
B-LEADERS	Building Low Emission Alternatives to Develop Economic Resilience and Sustainability
BUR	Biennial Update Report (to the United Nations Framework Convention on Climate Change)
CO_2e	Carbon Dioxide Equivalent
FAO	Food and Agriculture Organization of the United Nations
FOLU	Forestry and Other Land Use
FRL	Forest Reference Level
GFW	Global Forest Watch
GHG	Greenhouse Gas
GoPNG	Government of Papua New Guinea
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
JICA	Japanese International Cooperation Agency
LULCC	Land Use and Land Cover Change
LULUCF	Land Use, Land Use Change, and Forestry
MRV	Monitoring, Reporting, and Verification
Mt	Million Tons (metric)
$MtCO_2e$	Million Tons (metric) of Carbon Dioxide Equivalent
NDC	Nationally Determined Contributions
NRS	National REDD+ Strategy
PNG	Papua New Guinea
ProLand	Productive Landscapes Project
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RIL	Reduced Impact Logging
SABL	Special Agricultural and Business Lease
SL	Sustainable Landscapes
SLOA	Sustainable Landscapes Opportunities Assessment

SWAMP	Sustainable Wetlands Adaptation and Mitigation Program
tC/ha	Tons (metric) of Carbon per Hectare
tCO_2e	Tons (metric) of Carbon Dioxide Equivalent
UNFCCC	United Nations Framework Convention on Climate Change
UPNG	University of Papua New Guinea
USAID	United States Agency for International Development
WRI	World Resources Institute

EXECUTIVE SUMMARY

- Papua New Guinea (PNG) is a lower middle-income country with a resource-dependent economy, a large remaining forest estate, and significant carbon stocks in tropical rainforest, globally significant peatlands, and high carbon-density mangroves.
- Forest cover in 2014 was estimated to be 32.6 million hectares (ha), of which 27.9 million ha was closed-canopy rainforest and 24.2 million ha was primary rainforest.
- The Agriculture, Forestry, and Other Land Use (AFOLU) sector constitutes a large majority of PNG's greenhouse gas (GHG) emissions, representing 74% in 2016 according to data from the World Resources Institute (WRI).
- To date, ecosystems in PNG have remained in relatively good condition, particularly when compared to neighboring Indonesia or many Southeast Asian countries.
- The three most significant processes resulting in loss of ecosystem carbon and, therefore, GHG emissions in PNG are as follows:
  - Degradation of tropical rainforest via logging;
  - Conversion of tropical rainforest; and
  - Peat conversion and drainage.
- Historically, the islands in the Bismarck Archipelago have had the highest rates of deforestation and forest degradation; however, increasingly, forest conversion and logging has been moving into the lowland rainforest in the coastal mainland provinces of West Sepik and Western Province. Generally, logging impacts in PNG are determined by access constraints; thus, sub-montane and montane forests have experienced limited logging impacts to date.
- Mangrove forests are carbon rich and important for long-term carbon burial and as of yet have not seen substantial change in extent in PNG. Shrimp mariculture, the largest threat to mangroves globally, including in Indonesia, has not yet become established as a significant industry in PNG. As such, historical emissions from mangroves have been low. However, because of their disproportionate role per area as a carbon stock and in carbon burial, mangrove conservation may become a very important opportunity if mariculture or other threats to mangroves become more established in PNG.
- According to the national Forest Reference Level (FRL) and the National Reducing Emissions from Deforestation and Forest Degradation (REDD+) Strategy (NRS), forest degradation affects an area more than ten times larger than the area deforested annually, and in the years from 2001 to 2013, it was on average a larger source of emissions than deforestation by a factor of five.
- The largest driver of that degradation (98%) is commercial logging. Commercial logging in PNG is generally focused on raw logs for the export market and has very low local economic benefit.
- Forest conversion in PNG has a mixed set of drivers. According to the FRL, more than half results from conversion to small-scale agriculture, frequently as part of a shifting cultivation system. However, as population density increases in rural areas, shifting cultivation systems are becoming less sustainable.
- The next most important driver of forest conversion is oil palm. Oil palm is also the most important driver of peatland conversion and drainage, meaning that as a driver of change, oil palm expansion ranks with commercial logging as one of the two most important drivers of land-based carbon emissions.
- Oil palm plantations and commercial logging both represent large vested interests in the country and, as such, it is challenging to address the emissions from these industries. They are also linked to each other, particularly through the system of special agricultural and business leases (SABLs). These large leases together cover 2.2 million ha of PNG. They were written for the expansion

of oil palm, but analysis suggests they have effectively been a legal loophole to enable logging expansion.

- An important underlying driver of ecosystem change in PNG, and one that is poised to accelerate rapidly in the coming years, is an expansion of the road network. There is presently a plan for a large-scale expansion of the road network—partly with Asian Development Bank (ADB) funding—that would link many rural areas to the highway network but would also cut through many high-carbon and high-biodiversity landscapes.
- Emissions from the agriculture and livestock sectors are quite limited when compared to emissions from forestry and other land use (FOLU), and opportunities for emissions abatement in the agriculture and livestock sectors are similarly limited. The greatest potential for agricultural emissions abatement may be through biodigester-based management of pig manure. This intervention can be cost effective and has benefits for health and for rural electrification; however, its total potential contribution from an emissions perspective is a small fraction of the potential from the larger ecosystem-based abatement opportunities.
- Cost estimates for emissions abatement in PNG are limited to activities linked to Reducing Emissions from Deforestation and Forest Degradation (REDD+), and the most recent estimates are several years old (2010). The cost estimates that do exist suggest that activities focusing on reduced impact logging, sustainable forest management, limiting forest clearing for agriculture, shifting oil palm onto non-forest land, fire management, and afforestation/reforestation can all result in emissions abatement at costs ranging from $2.9 to $7.4 per metric ton carbon dioxide equivalent (tCO_2e; average $5.6). These estimates, however, have been critiqued for being overly optimistic, especially with respect to the cost of shifting oil palm onto non-forest land.
- Regarding co-benefits and alignment with other priorities, the largest opportunities for sustainable landscapes (SL) investment in PNG will almost certainly be well-aligned with biodiversity priorities. PNG has very high levels of biodiversity and is a globally significant hotspot for species endemism. Reducing impacts on high-carbon ecosystems will safeguard that biodiversity.
- There will be more difficult trade-offs when it comes to economic development. With regard to the transportation network in particular, the lack of safe and regularly accessible road transport in the majority of the country is part of the reason why there exist such large disparities in economic development—and in particular in access to health and education—between urban and rural areas in PNG. However, planned expansions of the road network may drive large increases in emissions, particularly from peatlands, and can fragment important biodiversity hotspots. While advocating for general limitations on road development is not likely to be a viable option, improved planning of the road network offers opportunities for both emissions abatement and biodiversity conservation.
- The United States Agency for International Development (USAID), via the Pacific-American Climate Fund, has previously invested in fire management in New Britain province, partly for climate mitigation. This work included monitoring, investments in fire risk reduction, and training in harm reduction. Fire management has the advantage of achieving carbon and biodiversity benefits as well as livelihood improvements. Fires in PNG are irregular, with incidence during El Niño events many times higher than in other years. While in most years, fires are only responsible for a small percentage of disturbance in PNG's forests, in El Niño years, such as 2015, fire becomes an important driver of deforestation.
- Donor funding for climate change in PNG is focused to a large degree on adaptation, including mangrove planting, and on REDD+ and the monitoring, reporting, and verification (MRV) systems that support REDD+ and the Nationally Determined Contribution (NDC). Given the importance of peatlands to the national carbon budget, they are under-represented in terms of dedicated donor funding as well as in terms of the national-level planned activities under the NDC.

1.0 INTRODUCTION

The United States Agency for International Development's (USAID's) sustainable landscapes (SL) programs promote and enable activities that lead to reductions in land-based greenhouse gas (GHG) emissions. To support those efforts, the Productive Landscapes (ProLand) project is developing a series of Sustainable Landscapes Opportunities Analyses (SLOAs) for several countries, including PNG. This PNG SLOA follows three phases: first, it characterizes emissions and sequestration in the Agriculture, Forestry, and Other Land Use (AFOLU) sector in Papua New Guinea (PNG) in order to understand which subsectors are most dominant in total contribution and in rate of change; second, it identifies a comprehensive suite of options for reducing those emissions; and lastly, it prioritizes among those actions and identifies areas of synergy among them.

Our approach to prioritization of opportunities was to evaluate a given activity with respect to four fundamental components:

1. Magnitude of potential emissions reduction or sequestration enhancement;
2. Likelihood of success;
3. Cost per unit of emissions reduction/sequestration; and
4. Non-GHG effects of the activity.

Estimates for the cost of emissions abatement in PNG are relatively limited. The national Reducing Emissions from Deforestation and Forest Degradation (REDD+) technical working group estimated costs per ton of abatement for those mitigation opportunities that were identified in the National REDD+ Strategy NRS. However, these estimates only cover REDD+-related opportunities and as such do not provide insight into the estimated costs for improvements in agricultural technology or in the livestock sector. Opportunities for abatement in the agriculture and livestock sector are likely to be small, meaning that this limitation is less of a concern than it otherwise might be.

There is no single best way to prioritize SL investments. Prioritization exercises will differ depending on the specific goals of the decision-makers undertaking the exercise. Some questions that may help frame how best to approach prioritization are:

- Is the goal of the program to maximize climate mitigation for a given level of investment? Should the program also prioritize other goals, such as livelihood benefits or biodiversity conservation?
- Are there specific geographies that a program should target or avoid, for reasons of feasibility or for reasons of compatibility with other programs?
- Are there other existing or planned investments that an SL program should be designed to complement?

The goals of the present report are to familiarize the reader with possible SL interventions in PNG; to evaluate each of those potential interventions according to criteria that include cost, co-benefits, and practical feasibility; identify areas of geographic focus; and identify gaps and limitations in the existing data.

PNG has 20 provinces, plus the National Capital District and the Autonomous Region of Bougainville (Map 1; Note that maps are included in a separate section at the end of this assessment). These provinces are further divided into 87 districts, each of which has one or more local-level government (LLG) areas. The country is also divided into four broad regions: the Southern Region, Islands Region, Momase Region, and Highlands Region (Map 2). This report refers both to provinces (Map 1) and to regions (Map 2) when discussing geographic prioritization.

2.0 OVERVIEW OF EMISSIONS SECTORS AND ABATEMENT STRATEGIES

PNG is a lower middle-income country. PNG had relatively strong economic growth starting in the mid 2000's, but growth has slowed in the last four years with lower oil and commodity prices. PNG has a large rural population (over 80%) that in many areas has poor access to health and education facilities. About 80% of population relies on agriculture for income, and agriculture accounts for about 25% of gross domestic product. Primary agricultural exports include cocoa, coffee, copra, palm oil, rubber, and tea, while other key exports include oil, gold, and copper (CIA, 2020).

Most of the country has a humid tropical climate with two exceptions: the high elevation areas of the Highlands Region that have a humid subtropical climate and the Trans Fly area in Western Province that has a tropical savanna climate (Beck et al., 2018). The Trans Fly Savanna and Grasslands resemble northern Australia in climate and ecosystem more than they do the rest of PNG; the ecoregion has both a dry season and a monsoon season and is characterized primarily by grasslands with some areas of dry evergreen forest (WWF, 2001).

Land use represents the greatest source of emissions in PNG, although data sources differ on the estimates of the total emissions as well as the estimated net emissions once CO_2 removals from land use are included. According to the Government of PNG's (GoPNG) 1st Biennial Update Report (BUR) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2018, emissions from land use, land use change, and forestry (LULUCF) was PNG's second highest source of emissions behind energy in 2015 (the most recent reported year in the BUR) followed closely by agricultural emissions. The importance of net emissions from LULUCF shifted significantly during the five-year period from 2010 to 2015. Prior to 2010, LULUCF provided a significant net source of removals, changing from -18.0 $MtCO_2e$ of removals in 2005 to a net source of 1.8 $MtCO_2e$ in 2015. The BUR reported LULUCF data for all years from 2000–2015; LULUCF sector was a net sink in the years 2000–2010 and 2012 and a net source of emissions in 2011 and 2013–2015.

The emissions and removals from LULUCF reported in PNG's BUR differ significantly from estimated national emissions from other sources including the estimates reported to the Food and Agriculture Organization (FAO) and estimates from the World Resources Institute (WRI) Global Climate Watch. Both of these sources show significant emissions from LULUCF (Figures 1 and 2, respectively). Differences in these estimates may be due to several factors, but the principal reason is variation in methodologies for forest change accounting. Significant estimated removals from natural forest growth and plantations are included in the estimates in the BUR GHG reporting but are not included in the FAO or WRI estimates. The data presented in Figures 1 and 2 shows gross emissions as opposed to the BUR which reports net emissions (gross emissions minus removals due to sequestration). The inclusion of sequestration from plantations is particularly significant. These differences between FAO and GHG inventory reported to UNFCCC are not uncommon, although the differences here are particularly large.[1] When looking at gross emissions rather than net emissions, forest sector (forestry and other land use [FOLU]) emissions are the largest category of emissions in the country—not the energy sector as is reported in BUR.

The forest reference level (FRL; GoPNG, 2017b) submitted by PNG in support of its NRS (GoPNG, 2017a) estimates that emissions from deforestation and forest degradation averaged 31.9 $MtCO_2e$ annually from 2001 to 2013 (see Table 10.1 in FRL) excluding sequestration estimates from plantations.

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1 See Ambiguity in the Land Use Component of Mitigation Contributions Toward the Paris Agreement goals https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019EF001190

This is slightly lower than the estimate used by Global Forest Watch (GFW) and WRI of 50.7 $MtCO_2e$ annually in the same 2001–2013 timeframe (WRI, 2018). The greatest source of emissions in the FRL is forest degradation primarily driven by logging, according to the BUR and associated FRL report. The majority of deforestation is reported to be driven by conversion to small scale agriculture and oil palm. From the PNG 1st BUR:

> *"Logging was the major driver of forest degradation responsible to 90% of the degradation occurred during the reporting period. Almost the entire (99.3%) of deforestation was due to land use conversion from forest land to cropland. Subsistence agriculture is the most significant (69.8%) driver of deforestation during the reporting period followed by oil palm plantation development (24.4%)."* (GoPNG, 2018a, page 35).

It is worth noting that subsistence agriculture, especially in the case of shifting cultivation as is frequently the practice in PNG, does not necessarily lead to permanent conversion because farmers allow garden plots to regenerate after some years of cultivation. There is some indication that increasing population density in PNG is leading to a larger proportion of forest clearings for smallholder agriculture staying in cultivation for longer periods. However, it should be assumed that more of the land cleared for subsistence agriculture will eventually return to a more natural state than would land cleared for oil palm (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015).

The majority of these emissions appear to be captured in the PNG BUR report as burning biomass and croplands—which includes conversion of forests to cropland. A significant gap in the GHG emissions reported by PNG to the UNFCCC is the lack of estimated emissions from peatlands due to lack of data. Within the agriculture sector, the majority of emissions are associated with managed soils, and enteric fermentation and manure management from livestock (see Figure 2).

Figure 1: Trends in emissions in PNG; all sectors included (WRI, 2019).

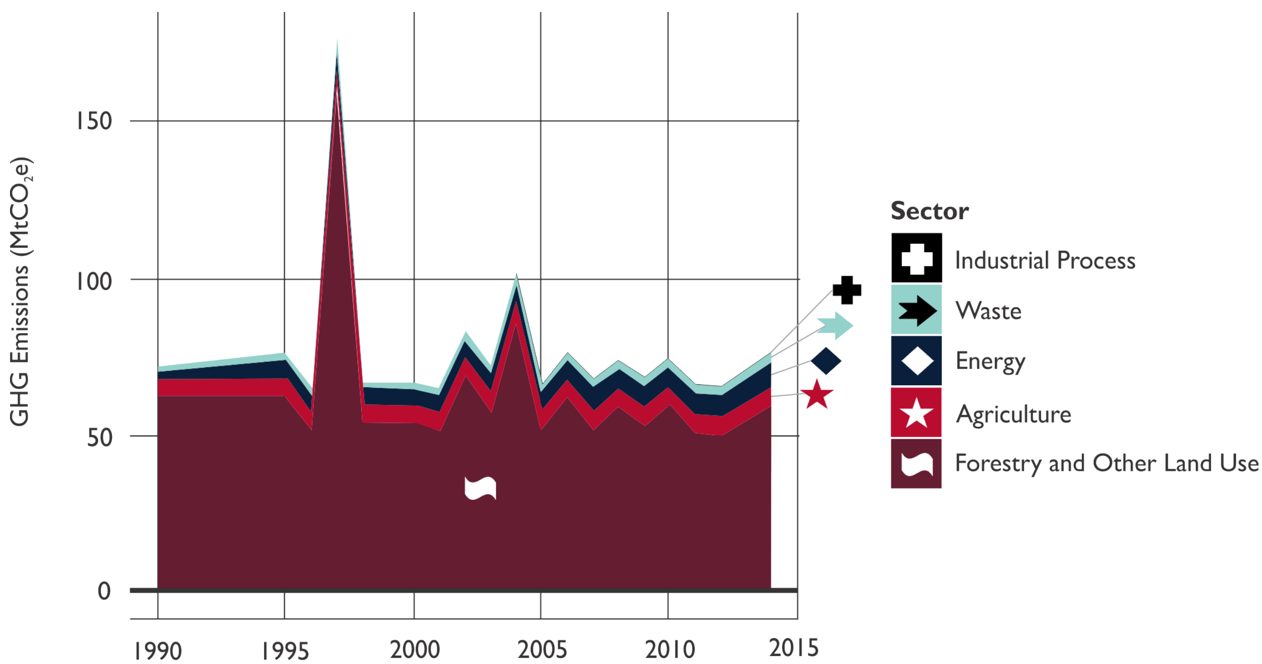
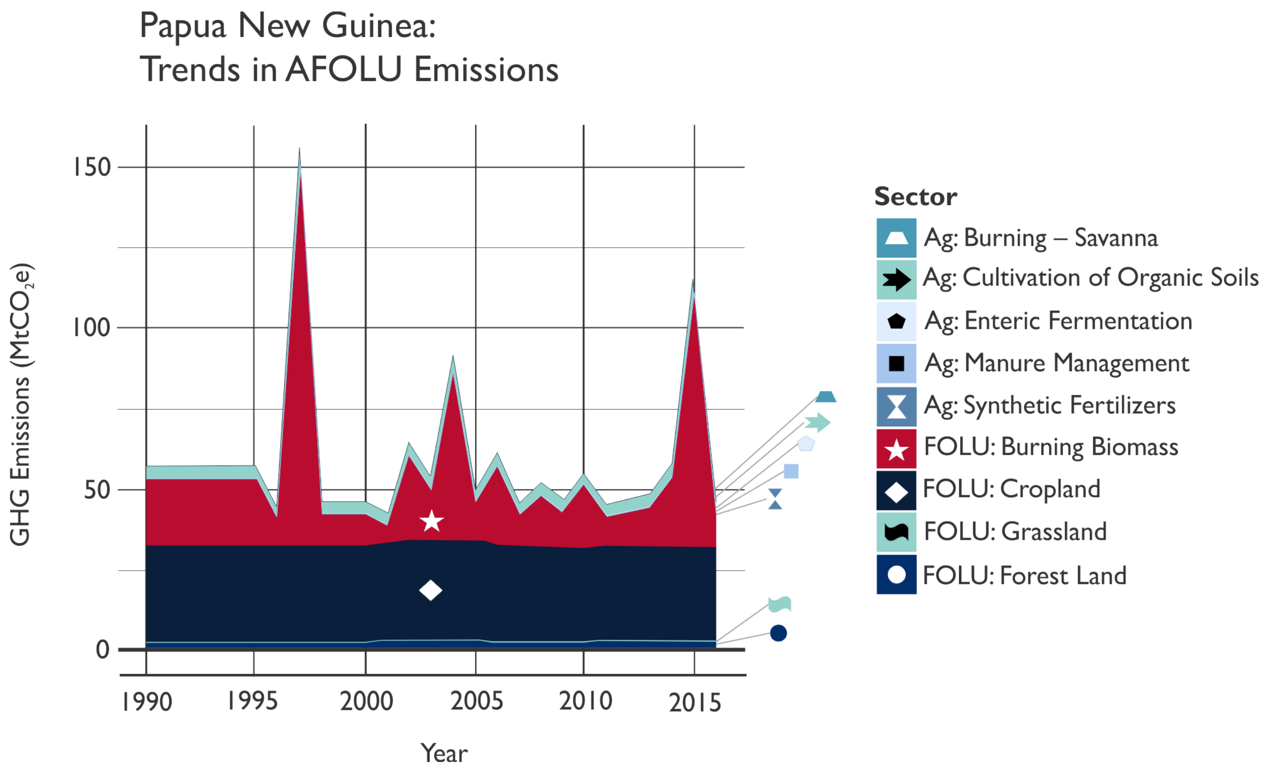


Figure 2: Trends in AFOLU emissions in PNG (FAO, 2020). Categories under "FOLU" are based on the land cover at the end of the accounting period. As such, forest loss that results from conversion of forests to crops is counted under "FOLU: Cropland." "FOLU: Forestland" represents emissions on forest land that stayed forest land.

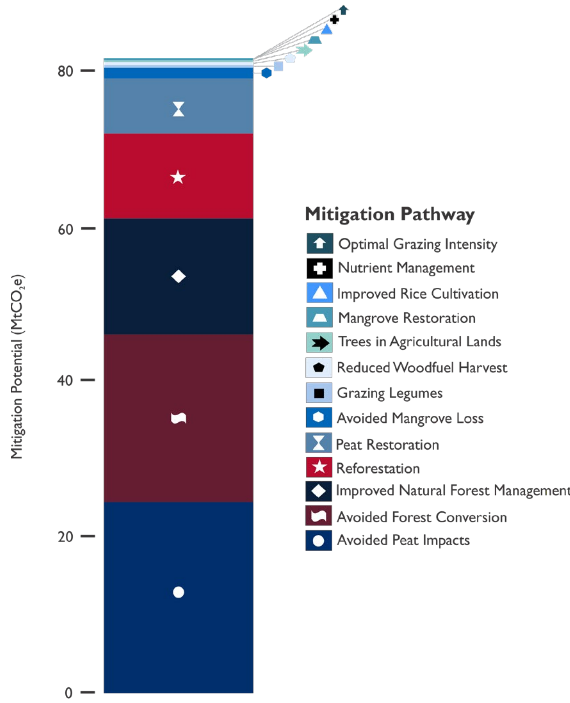


2.1. ABATEMENT STRATEGIES

In order to identify a suite of options to evaluate, we began with a global scale analysis (Griscom et al., 2017; 2020), and a range of reports and studies that include at least some part of the AFOLU sector in PNG. We also reviewed the NRS and nationally determined contributions (NDC), which state PNG's plans for climate mitigation options in the FOLU sector. Although comprehensive information on mitigation in the AFOLU sector is limited in PNG, we evaluated the identified options based on mitigation potential and available information on cost effectiveness and feasibility.

Opportunities identified by Griscom et al. 2020 are dominated by peatlands, inland forests, and mangroves. Direct emissions from agriculture are not identified as a significant opportunity for mitigation by Griscom et al. 2020. The six highest-potential pathways of intervention, in descending order, are avoided peat impacts; avoided forest conversion; improved natural forest management; reforestation; peat restoration; and avoided mangrove loss (Figure 3).

Figure 3: Griscom maximum cost-effective with safeguards



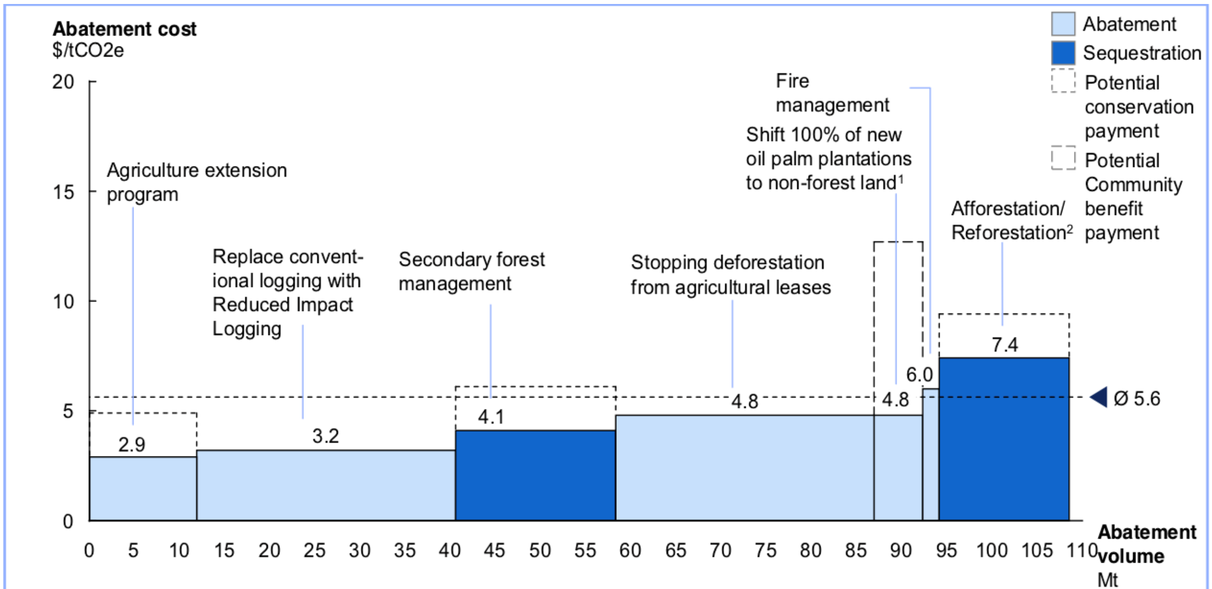
The significant potential for reducing emissions from deforestation identified by Griscom et al. is in agreement with information reported in PNG's 2nd National Communication to the UNFCCC (GoPNG, 2014) and NRS (GoPNG, 2017a), as well as other studies. Likewise, PNG also identified opportunities for reforestation and reducing forest degradation as priority opportunites for mitigation.

The most important difference between the Griscom et al. assessments and the national documentation is the absence of a consideration of emissions from peat in the latter. Two significant pathways for mitigation identified by Griscom, avoided peat impacts and peat restoration have not been included in PNG's reports or plans. This is at least partially because of a lack of data availability on peatlands in PNG and by association on the mitigation potential of avoiding impacts on peatlands or of restoring them. PNG has not included carbon fluxes for belowground peat organic soils or other soils in their GHG inventories due to a lack of national data according to their BUR, and have therefore also excluded analysis of peatlands in their mitigation options (GoPNG, 2018a). Regionally-specific studies on the island of New Guinea and in PNG specifically support the Griscom et al. assessment of peatlands being an important area of investment (e.g. Hope, 2015; Sasmito et al., 2020b).

2.2. ABATEMENT COSTS

The initial abatement cost curve developed for the PNG NRS suggested that major opportunities include forest conservation, management, and restoration. That analysis projected emissions reductions in the AFOLU sector relative to business as usual (BAU) of 107 $MtCO_2e$ which would mean a reduction of 60–80% compared to BAU. The average costs for those measures were estimated to be \$5.6/tCO_2e (Figure 4). Cost estimates were based on an analysis carried out by McKinsey & Company (2010) that took two general approaches to cost estimation: an opportunity cost method where costs were assessed based on foregone profit of activities that were no longer undertaken, and a program cost method that assessed the costs of the investments that would be required to alter the practice of an activity.

Figure 4: Marginal abatement cost curve from PNG National REDD+ Strategy (Source: McKinsey & Company, 2010)[2]



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below USD 90/ tCO_2e if each measure was pursued aggressively, starting with the most affordable measures. It is not a forecast of what role different abatement measures and technologies will play. Assumes a 4% societal discount rate. These are preliminary numbers, more precise figures can be determined once pilot projects are completed.

Estimates by McKinsey & Company (2010) were generalized at national scale but nonetheless provide useful insights into potential costs of REDD+ mitigation opportunities. They identify an agricultural extension program as the lowest-cost abatement option at $2.9 USD per ton CO_2e. That estimate is based on the assumption that a large-scale extension program could reduce forest clearing by improving yields and long-term soil fertility which would allow less clearing for new gardens. The estimated cost is based on reductions in forest clearing by subsistance agriculturalists, relative to a 2010 baseline, of 25% by 2020 and 50% by 2030. Costs are estimated in terms of operating costs and upfront investments for an extension program—it is assumed that there would be no opportunity costs because yields are maintained at a constant or improved level.

The impact of improving yields on agricultural expansion is complex and continues to be debated. Although increasing production per unit area would intuitively suggest that the pressure to bring new land into production (and thus clear additional forests) would reduce, this is not always the case. By increasing profitbaility of agriculture, yield improvements may in some cases lead to increasing deforestation (Angelsen & Kaimowitz, 2001). This relationship depends on where the yield increases are taking place and what is driving the change. In agricultural systems dedicated primarily to subsistence food production as is the case with home gardens in PNG, yield increases are not likely to increase the pressure to clear forests; however, in the case of commodity production for external markets, there is a risk that yield improvements would increase rates of deforestation (Byerlee, Stevenson, & Villoria, 2014).

The cost estimate for reduced impact logging (RIL) is based on shifting practices from conventional logging to sustainable forest management (McKinsey & Company, 2010). It is assumed that reduced impact logging (RIL) is 50% more expensive than conventional logging and, as such, results in foregone

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2 For more information on the GHG abatement cost curve, please see https://www.mckinsey.com/business-functions/sustainability/our-insights/greenhouse-gas-abatement-cost-curves.

profit. The costs of RIL are estimated as the sum of that foregone profit plus the cost of monitoring timber concessions for compliance. The emissions reductions result from both the reduction in forest degradation—an emissions abatement of approximately 80 tCO_2e per hectare (ha)—as well as a reduction in deforestation (approximately 460 tCO_2e/ha) that results from road construction and poor logging practices. The projected cost of $3.2 per tCO_2e is based on the weighted average of reduction in both degradation and deforestation and assumes abatement over time (relative to 2010 baseline) of 40% by 2020 and 50% by 2030. Given that logging pressure has only increased since the time of the McKinsey report in 2010, it is a safe assumption that projected costs for RIL have since increased.

Estimates for secondary forest management are based on the upfront and operating costs involved in enrichment of secondary forests through planting, treatment, and protection. Assumptions are that improving carbon stocks in secondary forests would require $77/ha in one-time costs and $41/ha annually in monitoring and continued treatment (McKinsey & Company, 2010). The analysis estimated that these practices could increase carbon stock by about 8 tCO_2e/ha per year which resulted in a cost per ton of abatement of about $4.1/$tCO_2e$.

At present, the majority of oil palm in PNG is being planted in areas of lowland forest. Shifting commercial plantations—primarily oil palm—onto grasslands or other non-forest land potentially avoids carbon losses of approximately 470 tCO_2e/ha from the conversion of that forest. The costs associated with the change in practice result from the foregone profit from a one-time timber harvest ($4,400/ha) and increased use of fertilizer. We do not have clear data on the cost of the required increase in fertilizer that would result from the shift onto non-forest land. There are also some monitoring costs associated with this change that are expected to be $11/ha per year. There is a relatively large range of uncertainty on the cost of this option—partly due to the limited data on changes in fertilizer use—but the estimate is that this intervention could cost between $4.8 and $10 per tCO_2e (McKinsey & Company, 2010).

It is important to note that no cost estimates outlined above include carbon stored in peat or soils in their estimates: all emissions estimates are based on tree biomass only (aboveground biomass multiplied by a fixed factor to obtain an estimate that also includes belowground). As such, they underestimate the carbon abatement benfit, and by extension, overestimate the cost per unit of abatement. Because peat stocks in PNG are so large (Hope, 2015; Gumbricht et al., 2017b), this omission may prove to be quite significant. Of the options presented above, reduced impact logging and shifting commercial plantations onto non-forest land are the two which—because of their geographical concentration in coastal lowland forests—are most likely to have additional positive effects on carbon stored in peat that are not captured in the cost estimates above. The emissions potential of those options should be thus considered to be somewhat higher, and the cost of abatement somewhat lower, than what is presented in the McKinsey (2010) results.

3.0 FORESTS ON MINERAL SOILS

The forests of PNG are diverse (Map 3) and forest cover remains extensive, with much of the remaining cover still being primary (Map 4). In this report, we follow Bryan, Shearman, Aoro, Wavine, & Zerry (2015) in their definition of primary forest as forest that is closed canopy. The definition excludes woody scrub, household gardens, secondary forest on abandoned household gardens, and plantations. Forest degradation is defined as any conversion of primary forest into a lower-quality forest—either through logging or low intensity burning—that leaves the canopy cover intact.

An assessment completed by the University of Papua New Guinea (UPNG) estimated 71% forest cover nationally in 2014 (Table 1; Bryan, Shearman, Aoro, Wavine, & Zerry, 2015), while our analysis of GFW data suggests forest cover of 90% in 2018. This discrepancy likely results mostly from a difference in the definition of forest: GFW data by default uses a canopy cover of 30% as the threshold for forest and will have counted some areas as forest that in the UPNG analysis were likely included in a woodland (non-forest) category.

PNG has extensive tropical rainforests that are rich in biodiversity. However, the carbon density of PNG's forests is generally lower than the density of forests of the same type in other countries in the region—Indonesia, for example. The estimates used in the FRL and the BUR are based on a combination of a field-based PNG-specific source (Fox et al., 2010) for lowland humid forests and Intergovernmental Panel on Climate Change (IPCC) default values for montane forests and for dry forests because of a lack of robust data on carbon density in those forest types in PNG. Fox et al., 2010 estimate 111.4 tC/ha in primary lowland rainforest and 73 tC/ha in that same system following disturbance. These estimates are based on a system of fixed field plots maintained by the PNG Forest Authority (PNGFA). The IPCC-based estimates used by the FRL are 70 tC/ha in primary montane forests and 46 tC/ha in disturbed montane forests. The estimate for dry forests is 130 tC/ha for primary and 42.5 tC/ha for disturbed.

The values used are generally consistent with a more recent study (Peck et al., 2017) that reports carbon densities of 137.3 tC/ha in lowland PNG rainforest. Those authors acknowledge that their estimates are higher than most for PNG but are still lower than mean global estimates for average density in moist tropical forests. There is no certain explanation for why PNG's forests tend to have lower biomass and carbon densities than other forests in similar climate regimes. One explanation is the particular vulnerability of PNG forests to El Nino Southern Oscillation events and associated drought and high fire years. Another is the long history of shifting cultivation in the country that may mean higher levels of historical human disturbance took place even in areas that are apparent primary forest.

The PNG export economy has changed significantly in recent decades. Particularly, while agricultural and forestry exports have grown in absolute terms, their relative contribution to total national exports has declined as extractive industries have grown much more quickly (UNDP, 2018). In 2016, revenue from mining and hydrocarbon extraction together constituted 80% of national exports, while the agriculture and forestry sectors together constituted 11.7% of national exports. The two largest exports in the sectors are round logs ($375M) and palm oil ($360M); together those two commodities represent 69% of agriculture and forestry exports. The next two largest exports are coffee ($180M) and cocoa ($86M); together, those four commodities represent 94% of agriculture and forestry exports (UNDP, 2018).

The rate of deforestation in PNG was slower in the 2002–2014 period (Table 2) than it was in the 1972–2002 period (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015). Part of this deceleration was due to a reduction in forest clearing for subsistence agriculture. Bryan, Shearman, Aoro, Wavine, & Zerry (2015) speculate that some of the reduction in clearing for subsistence agriculture may in part have resulted in the rapid increase in mineral exports and the increased percentage of the population integrated into the cash economy.

3.1. AVOIDED FOREST CONVERSION

PNG has identified agriculture as the principle driver of deforestation, responsible for 99.3% of all forest conversion by area according to the FRL.[3] 66.3% of this deforestation is from small scale agriculture and 29.9% is from comercial agriculture—mostly oil palm. These estimates are based on image-based (Landsat) assessments by analysts supporting the FRL. Estimates are based to a large degree on hand-classification of Landsat images by analysts with exptertise in the region. As such, while we have no reason to distrust the relative split between small scale agriculture and commercial, we also have no way to independently verify it.

Reform of land concession policy is identified in the NRS as a potential mechanism for reducing deforestation from agriculture. A significant portion of forest converson in the last 15 years took place on land leased under the SABL program, which allowed a form of land concession of customary lands for agricultural clearing. Government officials including the Prime Minister have acknowledged that the program was frequently abused, allowing illegal timber extraction by both national and foreign entities without subsequent development (Babon & Gowae, 2013; Global Witness, 2017). Several court cases against individual SABLs have been decided in favor of communities; however, there are not yet any examples of leaseholders being compelled to let go of their lease (Global Witness 2017; 2018).

[3] The Forest Reference Level underwent revisions between versions dated January 15, 2017 and July 10, 2017. As of August 2020, both versions were still present on the UNFCCC website. The National REDD+ Strategy uses values from the earlier version which differ from the final version's values that we present here.

Table 1: Area of forest in 2014 by province and by forest type (based on Bryan, Shearman, Aoro, Wavine, & Zerry 2015)

Province	Area by forest type in 2014 (km2)							
	Total area	All rainforest	Primary rainforest*	Secondary rainforest	Dry evergreen forest	Swamp forest	Mangrove	Total forest*
Western	98,115	45,167	38,161	7,006	7,507	10,860	1,175	64,709
Gulf	34,550	23,311	18,465	4,846	0	5,013	2,605	30,929
Central	29,802	19,541	17,332	2,209	0	639	586	20,766
Milne Bay	14,196	9,125	8,079	1,046	0	124	446	9,695
Oro	22,608	15,369	14,423	946	0	1,939	161	17,469
Morobe	33,762	20,783	19,643	1,140	0	543	36	21,362
Madang	28,970	19,573	18,380	1,193	0	921	8	20,502
East Sepik	43,671	20,196	19,222	974	0	10,554	197	30,947
West Sepik	35,908	26,955	23,159	3,796	0	2,044	8	29,007
Mainland coastal region	**341,581**	**200,021**	**176,865**	**23,156**	**7,507**	**32,637**	**5,221**	**245,386**
Southern Highlands and Hela	25,598	18,574	18,500	74	0	179	0	18,753
Enga	11,730	7,989	7,989	0	0	2	0	7,991
Western Highlands and Jiwaka	9,123	4,941	4,941	0	0	0	0	4,941
Chimbu	6,134	3,596	3,596	0	0	1	0	3,597
Eastern Highlands	11,147	5,687	5,617	70	0	0	0	5,687
Highlands region	**63,731**	**40,787**	**40,643**	**144**	**0**	**183**	**0**	**40,970**
Manus	1,913	1,213	910	303	0	178	74	1,465
New Ireland	9,581	6,363	3,384	2,979	0	123	188	6,674
East New Britain	15,280	11,126	8,018	3,108	0	35	28	11,189
West New Britain	20,296	14,661	7,449	7,212	0	337	144	15,142
Bougainville	9,357	4,597	4,597	0	0	375	80	5,052
Islands region	**56,427**	**37,961**	**24,358**	**13,603**	**0**	**1,047**	**513**	**39,521**
TOTAL PNG	**461,739**	**278,767**	**241,865**	**36,902**	**7,507**	**33,866**	**5,734**	**325,874**

** Variable calculated from other data in the table; not included in original report.*

3.2. DRIVERS OF DEFORESTATION

As stated above, most forest clearing in PNG results in forest land being converted to agricultural uses, with the majority being subsistence agriculture. Subsistence agriculture in PNG generally takes the form of shifting cultivation where garden plots will be brought into cultivation for a number of years before being left to fallow for a longer time period. In PNG's emissions accounting, it is assumed that clearing of existing fallow land does not cause any emissions because there is a balance between what is cleared and what regrows (McKinsey & Company, 2010). There are two mechanisms where subsistence cropping does result in emissions. First, expansion of agriculture into natural forest instead of into previous fallows. McKinsey (2010) estimate that this results in emissions of 613 tons CO_2e/ha in the lowlands and 701 tons CO_2e/ha in the highlands, although we were not able to independently confirm that estimate. Second, the increasing population pressure in rural areas, particularly in the highlands, is leading to shorter rotation lengths in shifting cultivation systems, which in turn leads to lower time-averaged carbon stock on the landscape. A McKinsey (2010) analysis assumed that rotations in the lowlands were decreasing from 15 years on average to nine years on average and that this shortening would reduce the time-averaged carbon stock from 43 tC/ha to 20 tC/ha, representing an overall loss of 23 tC/ha or 84 tCO_2e/ha. In the highlands, the same analysis projected rotations shortening from 10 years to seven years and time-averaged carbon stocks declining from 24 tC/ha to 14 tC/ha—a reduction of 10 tC/ha or 37 tCO_2e/ha.

Although estimates vary among sources, there is a consistent conclusion that the area of forest clearing in PNG is much smaller than the area of forest degradation. The PNG FRL (GoPNG, 2017b) reports that 0.7% of forest was cleared between 2001 and 2015, while 6% was degraded in the same period. Bryan, Shearman, Aoro, Wavine, & Zerry (2015), using a different methodology, report that between 2002 and 2014, 1.3% of PNG's rainforests were cleared, while 2.7% were logged.

Forestry in PNG is overseen by the PNGFA under a system of logging concessions. These concessions are mostly leased and operated by foreign companies, primarily from Malaysia. As of 2014, 298 current or proposed concessions collectively covered 14.9 million ha of rainforest. Between the years 1972 and 2014, logging activities occurred on 228 (77%) of these concessions. By 2014, 72 of the logging concessions (24%) had already been logged at least once on at least 80% of their accessible forests. Of those concessions that had been at least 80% logged, 38% are in West New Britain province (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015). One estimate predicts that at current rates of logging, 83% of the commercially accessible forests in PNG will be depleted by 2021 (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015). Harvesting for fuelwood is a further contributing factor to forest damage, with annual fuelwood use in PNG estimated at 3.4 million cubic meters (m^3).

Forests in PNG generally have lower canopies and generally produce lower volumes of timber than other tropical nations. However, rotation lengths can be shorter than in some other countries, and re-entry logging 35 years after first harvest generally provides sufficient volume to be profitable (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015).

Logging in PNG operates under the PNG Logging Code of Practice which lays out a set of principles of RIL. The principles of the logging code include minimum diameter limits for trees harvested, buffer zones along waterways, recording and planning of skid trail locations, and vine cutting to reduce damage to non-target trees. The logging code also includes a provision that allows the customary landowners of the land under the concession to set aside 10% of the concession as a protected area; however, this provision is rarely used (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015).

Table 2: Deforestation and logging-linked degradation in PNG rainforests 2002-2014 (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015)

Province	Rainforest area 2014			Rainforest change 2002 2014				Total change (%)
	Total (km^2)	Unlogged (km^2)	Logged (km^2)	Deforested (km2)	Logged (km^2)	Deforested (%)	Logged (%)	
Western	45,167	38,161	7,006	583	1,476	1.3	3.2	4.5
Gulf	23,311	18,465	4,846	360	1,474	1.5	6.2	7.7
Central	19,541	17,332	2,209	89	409	0.5	2.1	2.5
Milne Bay	9,125	8,079	1,046	135	40	1.5	0.4	1.9
Oro	15,369	14,423	946	226	45	1.4	0.3	1.7
Morobe	20,783	19,644	1,140	182	38	0.9	0.2	1.1
Madang	19,573	18,380	1,193	376	455	1.9	2.3	4.2
East Sepik	20,196	19,223	974	273	532	1.3	2.6	3.9
West Sepik	26,955	23,159	3,796	329	1,394	1.2	5.1	6.3
Mainland coastal region	200,021	176,865	23,156	2,553	5,864	1.3	2.9	4.2
Southern Highlands and Helaa	18,574	18,501	74	196	1	1.0	0.0	1.0
Enga	7,989	7,989	0	90	0	1.1	0.0	1.1
Western Highlands and Jiwaka	4,941	4,941	0	39	0	0.8	0.0	0.8
Chimbu	3,596	3,596	0	42	0	1.1	0.0	1.1
Eastern Highlands	5,687	5,617	70	39	0	0.7	0.0	0.7
Highlands region	40,787	40,643	144	406	0	1.0	0.0	1.0
Mainland total	240,809	217,508	23,301	2,960	5,864	1.2	2.4	3.6
Manus	1,213	911	303	27	86	2.1	7.0	9.1
New Ireland	6,363	3,384	2,979	105	385	1.6	5.9	7.6
East New Britain	11,126	8,018	3,108	259	577	2.3	5.1	7.3
West New Britain	14,661	7,449	7,212	330	793	2.2	5.3	7.5
Bougainville	4,597	4,597	0	70	0	1.5	0.0	1.5
Islands region	37,961	24,359	13,603	790	1,842	2.0	4.8	6.8
TOTAL PNG	278,767	241,866	36,902	3,752	7,705	1.3	2.7	4.1

3.3. FOREST CONCESSIONS

The 2012 National Forest Plan (PNGFA, 2012) provided a complete list of PNG forest concessions as of 2012 and indicated whether they were current or expired. This included 92 concessions that were current, 220 that were expired, and two that were disputed. Current concessions were generally larger than expired ones; although there were more than twice as many concessions expired as there were current concessions, the current concessions had a total area of 72,284 km^2, while the expired concessions only covered an area of 28,013 km^2. Between 1972 and 2014, logging occurred in 228 different concessions, the majority of which were in West New Britain, West Sepik, and Western provinces (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015). The PNGFA, with technical support from the Japanese International Cooperation Agency (JICA), maintains a web map[4] that displays data on current forest concessions (Figure 5). We were not able to gain access to the data itself; however, a visual inspection that included using GIS to estimate areas of large concessions and counting visible concessions suggested that the patterns described in the 2012 concession data are broadly consistent with current patterns.

Figure 5: PNG REDD+ and Forest Monitoring Web-Portal displaying current data on forest concessions.

The 92 concessions that were current in 2012 ranged in size from 16.8 km^2 (16,800 ha) to 5,394 km^2 (539,400 ha) in gross area and from 12.8 km^2 to 3,204 km^2 in net area. Here, the term "gross area" is used to refer to the total area within the boundaries of the concession, while "net area" is the area that is available for harvest. The difference between the two represents land within the total concession area that is not harvestable either because of a lack of forest, steep inclines, or for other reasons. The median net area for concessions was 400 km^2; however, the 50 concessions where net area was less than or equal to 400 km^2 only represented 22.5% of the total net concession area, while the 42 concessions that were larger than 400 km^2 represented the remaining 77.5% of net area. The 16 current

[4] http://www.png-nfms.org/portal/

concessions that were larger than 1,000 km^2 in 2012 represented 48.6% of the concession area available for harvest, while the five concessions that were larger than 2000 km^2 represented 21.2% of the total national net area.

Average concession sizes vary among provinces. The three provinces with the largest concession net area in 2012 were West New Britain (13,015 km^2), Gulf Province (12,625 km^2), and Western Province (9,071 km^2). Of those three, West New Britain had more and smaller concessions—27 concessions with an average net area of 482 km^2—while the other two had fewer larger concessions. Gulf Province had nine concessions with an average net area of 1,403 km^2, while Western Province had six concessions with an average area of 1,512 km^2.

Forest productivity in PNG is relatively low. Typical volumes extracted on first harvest generally range from 10 m^3 to 20 m^3. Bryan, Shearman, Aoro, Wavine, & Zerry (2014) used an intermediate value of 15 m^3 to estimate the probable level of sustainable harvest in PNG. Using the 15 m^3 value and an assumption (consistent with PNGFA) that forests can be sustainably re-harvested 35 years after first entry, Bryan, Shearman, Aoro, Wavine, & Zerry calculated that the sustainable level of harvest in PNG in 2014 was 2.8 million m^3. Communication with a PNGFA representative confirmed that at present, the official sustainable harvest level is 3.5 million m^3. Export tables from the Bank of Papua New Guinea state that PNG exported 4.04 million m^3 and 3.68 million m^3 in 2018 and 2019, respectively. PNG has not exported less than 2.8 million m^3 in any year since 2010.

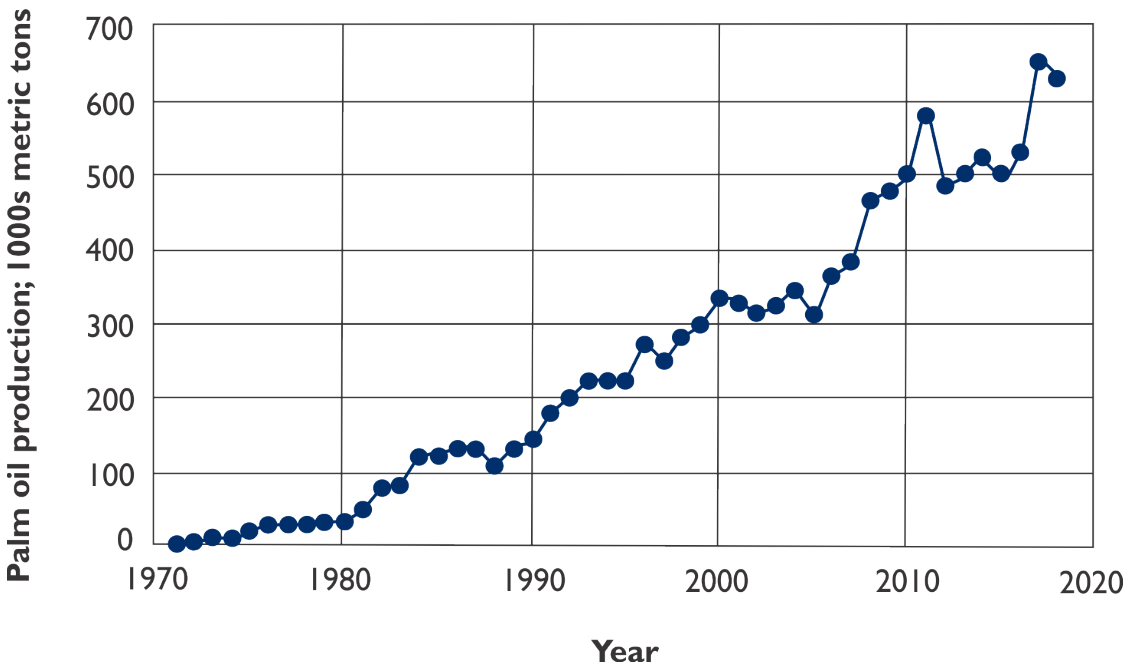
There is no publicly available data on harvest levels for individual concessions; however, comparing the 2019 export volume with the 2012 net area of current concessions yields a volume per area value of 0.62 m^3/ha. That is about 44% higher than would be sustainable assuming a 15 m^3 harvest every 35 years.

3.4. OIL PALM EXPANSION

The expansion of oil palm is the largest driver of peatland loss globally (Mudiyarso et al., 2010). As regional neighbors Indonesia and Malaysia have become saturated with oil palm plantations, investors have begun looking to PNG as an area of further expansion. This pressure may increase further based on a recent Indonesian government announcement of a moratorium on further palm oil expansion in Papua and West Papua (Jong, 2020). Palm oil production in PNG doubled from its 2001-2005 average of 325,000 metric tons to 650,000 tons in 2017 (Figure 6; FAO, 2020).

The values underpinning the NRS assume that conversion from lowland forest to oil palm represent a loss of carbon of 128 tons/ha (470 tCO_2e/ha) based on a difference between an average stock of 167 tons/ha in lowland forests of PNG and 39 tons/ha in oil palm plantations.

Figure 6: Palm oil production in PNG from 1970 to present (FAO, 2020).



As of 2013, the government of PNG had issued 36 SABLs that together covered 2.2 million ha of land and that included plans for 947,814 ha of oil palm plantation (Nelson et al., 2013). Were these plantations to be established, they would represent a seven-fold increase in the national area of oil palm (144,183 ha in 2012) and a dramatic increase in the rate of plantation establishment that historically has proceeded at about 3,000 ha per year. However, an analysis by Nelson et al. (2013) suggests that the likelihood of these plantations being established is in many cases very low as a result of factors relating to company capacity, socio-legal constraints, or land suitability. The companies holding those SABLs generally have low capacity in the sector (only one of the companies was involved in palm oil production in PNG); in most cases (19 of 36), the legal status of the land is in dispute, and the lands in question in many cases had low suitability for oil palm. What these SABLs more likely represent is a strategy to engage in logging and raw log exports that would otherwise be either illegal or at least subject to higher levels of scrutiny and environmental safeguards. For example, the 2009 National Forestry Development Guidelines prohibit raw log exports from areas under new timber permits (permits that are issued by the PNGFA on land governed by forest management agreements entered into between communities and PNGFA) but has no such limitation on logs from areas covered by SABLs and associated Forest Clearing Authorities. As such, these areas of forest are at risk of loss with even less prospect for longer-term economic returns in the area. If this analysis is correct, logging should be seen as the true driver of forest loss in this case even if the SABLs themselves would suggest that the driver is oil palm expansion.

It is important to note that SABLs were granted with little or no respect paid to customary tenure. As discussed above, several of the SABLs have been challenged in PNG's courts, and in some cases, the courts have ruled in favor of customary landowners. Although no new SABLs are presently being granted, none of the existing SABLs have been canceled, and extraction taking place on them has not been meaningfully curtailed.

Oil palm expansion and shifting cultivation overlap in some parts of PNG but are to a large degree spatially segregated. Oil palm is cultivated almost exclusively on land at elevations lower than 200m with particularly large existing areas in West New Britain and Oro Provinces and areas of projected future expansion in East New Britain, and Sandaun Province (formerly West Sepik).

Oil palm, logging, and smallholder agriculture are to some degree stratified by elevation. Oil palm in particular is only cultivated below 200m, while logging has also been concentrated in the lowlands where access is easier. Other forms of agriculture, however, are more common at higher elevations (>1000m) where human population densities are higher than on the coast (Gamoga, 2016). Even in areas where subsistence agriculture and oil palm overlap in generally the same area, oil palm plantations have the incentive of timber revenue to establish in areas with highest density of timber (Nelson et al., 2013). Smallholder agriculturalists, by contrast, tend to favor areas where timber clearing is easier. In many of the large SABL areas, both shifting cultivation and oil palm plantations are present (Bryan, Shearman, Aoro, Wavine, & Zerry, 2015).

3.5. POLICY REFORM AND LOG EXPORT BANS

Since 1990, PNG has banned log exports of fifteen specific timber species for reasons of conservation. Additionally, round log exports from concessions granted since 2010 are not permitted (Schaap & Canby, 2018). Despite these restrictions, the flow of logs out of PNG—primarily to China—remains large. Global Witness (2017) estimates that 90% of PNG's log exports are to China, while a third of China's imports of tropical logs are from PNG. Global Witness estimates that about 10% of tropical logs entering China come specifically from SABL areas in PNG.

Export data from PNG to China suggests that the partial log export ban that was enacted in 2010 had little effect on net exports of logs to China. Following the partial ban in 2010, log exports to China increased to a historic high in 2014 before declining somewhat in 2015 and 2016, but to levels that were still higher than they had been before the ban (Schaap & Canby, 2018). A Forest Trends analysis (Schaap & Canby, 2018) found that log export bans were successful in reducing log exports—Gabon and Myanmar were two countries where volumes fell off immediately following bans—but this was not the case in PNG. This is at least in part because the ban is only partial: concessions from prior to 2010 and logs from SABLs were still legal to export. The existence of raw logs legally in the supply chain, coupled with poor monitoring of timber chain of custody and of logging operations themselves, makes it difficult to prevent raw logs from entering supply chains illegally.

As the destination for most of PNG's log exports, China and Chinese manufacturers have the greatest potential leverage to effect change in the PNG forest sector. As China and its export destinations in the U.S., E.U., and Australia increasingly demand higher standards for timber legality assurance, importers may follow suit by requiring higher sustainability standards and improved verification systems for the timber they import (Global Witness, 2018). As recent Global Witness investigations have shown (2017; 2018), there remain many gaps in the timber legality assurance systems. Products made from illegal timber sourced from PNG continue to enter markets in the West despite legal prohibitions (Global Witness, 2017). Chatham House estimates that in 2014, of the 87%–88% of PNG's timber exports destined for China, 90% represented illegal trade. This value is somewhat lower for other export destinations. Legality varies by product: trade in logs is estimated to be 86% illegal, while trade in sawn wood is only 15% illegal (Chatham House, 2020). Logs, however, represent 98% of PNG's timber trade and sawn wood only 1%.

In 2018, the GoPNG stated that it would impose a ban on round log exports by 2020. The new government, having been elected in 2019, announced in June of 2020 that the 2020 timeline for a round log ban would not be feasible. The GoPNG has now committed to putting in place a ban on round log exports by 2025.

4.0 MANGROVES

Mangroves are carbon-dense ecosystems, and as such their conservation and restoration generally has a large carbon benefit per unit area. PNG has relatively extensive mangroves—representing slightly more than one percent of total national area—with the three provinces of the southern coast containing 75% of the country's mangroves in 2016 (Table 3): Gulf (48.5% of 2016 national mangrove area), Western (16.2%), and Central (10.7%). Two districts alone contain 57.2% of PNG's mangroves: Kikori in Gulf Province (2,047km^2; 43.7%) and South Fly in Western Province (630km^2; 13.4%).

More than two-thirds of total carbon stocks in mangrove ecosystems is in the soil (Sasmito et al., 2020b). This contrasts to upland forests, where in most cases the majority of carbon is in aboveground woody biomass (Spawn & Gibbs, 2019). Mangrove forests globally accumulate organic carbon at rates of 10.7 ± 9.4 tons/ha/year which is similar to rates of accumulation in tropical upland forests (Alongi, 2014). An overview of Indo-Pacific mangroves found ecosystem carbon stocks as high as 1,023 tCO_2/ha—about three to five times greater than that found in tropical rainforest (Donato et al., 2011).

In Indonesia, mangroves were found to store up to five times as much total carbon as did upland forests in the area (Mudiyarso et al., 2015). That research by Mudiyarso et al. (2015) studied eight sites in Indonesia, three of which were on the island of New Guinea: two in West Papua Province, Indonesia, and one in Papua Province, Indonesia. Those sites had total ecosystem carbon densities of 911 tC/ha, 1,083 tC/ha, and 1397 tC/ha; the latter, in Bintuni Bay, West Papua, was the highest ecosystem carbon density observed in any of the Indonesian sites. In those three sites, between 20% and 22% of carbon was found in the aboveground biomass of the trees, while 72–76% was found in the soil (Mudiyarso et al., 2015: Supplementary Information).

Estimates from West Papua suggest that logging in mangrove forests eliminates nearly all of the carbon stored in live biomass. However, logging had very little effect on the soil carbon stock where most of the carbon is mangrove ecosystems is found (Sasmito et al., 2020b). Aquaculture, however—generally shrimp ponds—caused average declines of 60% in the soil carbon pool while reducing the live biomass carbon pool by 85% (Sasmito et al., 2020b). Twenty-five years after replanting, mangrove tree biomass had generally recovered to levels similar to prior to disturbance. However, soil carbon remained lower than its initial levels even after 25 years; the deepest soil pool measured (200–300cm) experienced the least recovery and after 25 years was observed to be less than 10% of the levels seen in undisturbed plots (Sasmito et al., 2020b).

Mangroves also play a role in re-capturing carbon stocks that are lost from upland forests through erosion. This is particularly the case in estuarine mangroves–those found at the mouths of rivers–that are the primary type of mangrove found in PNG. A recent study by the USAID-funded Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) found that in West Papua, Indonesia, the carbon content of soil in the outer fringe of mangroves contained more carbon from upstream forests–carbon that had flowed downstream and been captured and buried among the mangroves–than it contained carbon that had been sequestered by the mangroves themselves (Sasmito et al., 2020a). By burying this upstream carbon that would otherwise have been flushed into near-shore waters, mangroves and coastal mudflats play a role in mitigating carbon losses from upstream forests.

Globally, rates of mangrove loss have been faster than rates of tropical forest loss generally (Valiela, Bowen, & York, 2001). However, rates of mangrove loss in PNG have to date been very low. Shearman (2010) used aerial photography to analyse change in mangroves in the Gulf of PNG—the largest area of mangroves in PNG and one of the largest and most pristine in the Asia-Pacific region (Map 9)—between 1973 and 2007. He found shifts in mangrove areas resulting from sea-level rise as well as from natural processes of sedimentation and subsistence; however, he found little change resulting from human pressure. Shearman (2010) points to the lack of shrimp farming and of land reclamation in the area as the main reasons for the limited loss until 2007.

For a more recent picture, we analyzed data from Global Mangrove Watch (GMW; Bunting et al., 2018). Although this is a global data product based on 30m resolution satellite imagery rather than aerial photography, it provides data up to 2016. Generally, it is consistent with Shearman's (2010) finding of limited loss of mangroves. Our analysis of GMW data found that between 1996 and 2016, only 61km^2 of mangrove was lost (about 1.3% of the original area over 20 years): a rate of loss of only about three square kilometers (300 ha) per year. More than half of that loss was in Gulf and Western Provinces (Table 3), and 41% was in the two districts mentioned above as together having more than half of PNG's mangroves—Kikori in Gulf Province and South Fly in Western Province. Each of those two districts had more than double the total mangrove loss of any other single district.

Table 3: Mangrove extent and mangrove loss by province in PNG; 1996-2016 (Bunting et al., 2018).

Province	Mangrove area 2016 (km2)	Mangrove area 1996 (km2)	Mangrove loss 1996 2016 (km2)	Mangrove loss (% of 1996 area)
Gulf	2,272.0	2,287.6	15.6	0.68
Western	757.7	775.8	18.1	2.33
Central	500.9	509.0	8.1	1.60
Milne Bay	332.6	338.2	5.6	1.65
New Ireland	172.2	172.1	-0.1	-0.04
Oro	159.2	165.9	6.7	4.04
East Sepik	155.1	158.5	3.4	2.13
West New Britain	128.6	129.7	1.1	0.83
Manus	93.3	93.9	0.6	0.64
Bougainville	43.9	42.6	-1.3	-2.93
Morobe	27.3	28.1	0.8	2.89
East New Britain	18.8	18.9	0.1	0.59
Madang	10.4	11.0	0.6	5.80
Sandaun	8.4	8.7	0.3	3.58
National Capital District	0.6	0.6	0.0	-0.73

4.1. AVOIDING MANGROVE LOSS AND MANGROVE RESTORATION

The Wildlife Conservation Society (WCS) has been investing in mangrove replanting in PNG both as a climate mitigation approach and as an approach to reduce vulnerability to coastal flooding. Their focus has been on Manus Island and in Kavieng District in New Ireland. These are districts that have seen relatively little mangrove loss in absolute terms (Bunting et al., 2018); however, as outer islands in the Bismarck Archipelago, coastal vulnerability is likely a key concern.

WCS worked with communities on Manus Island to plant mangroves. Although WCS recommendations were that planting only take place in areas that previously had mangrove cover, some communities planted in areas with no previous history of mangrove cover (Arihafa, 2016). The success rates of these plantings—measured as the number of mangrove seedlings that survived—varied greatly among sites and among mangrove species. Out of three sites where mangrove seedlings were planted into areas that had never had mangroves previously ("novel" sites), two sites of the three had zero survivorship after 22 months. In the third novel site, the two species planted–*Rhizophora apiculate* and *Rhizophora mucronate*– had 39% and 25% survivorship, respectively, after 22 months (Arihafa, 2016).

In each of six mangrove restoration sites on Manus Island, there was at least one species that survived in some numbers through 22 months. An assessment of the factors influencing survivorship found that species selection was particularly important. In the context of Manus Island, *Rhizophora* sp. fared better than other species. This was the dominant species prior to mangrove loss in the area, so this should not necessarily be taken to mean that species in that genus are more likely to have higher survivorship but rather to mean that species that were previously well-established in a given area are likely to be the best choices for restoration efforts (Arihafa, 2016). The study by Arihafa (2016) also found, perhaps unsurprisingly, that survivorship of mangrove seedlings was better in areas that were more protected from wind and wave action.

Sasmito et al. (2019) completed a meta-analysis of existing studies on the effect of land use and land cover change (LULCC) on mangrove carbon stocks. They found that LULCC, on average, led to an 82% reduction in biomass in mangrove ecosystems and a 54% reduction in soil carbon stocks. Following mangrove regeneration, biomass stocks generally recovered after 40 years. However, the trajectory of soil carbon stocks following ecosystem regeneration showed no clear patterns. This highlights that although restoration efforts may be able to reverse some of the ecological and social harms of mangrove clearing, the climate impacts of clearing are likely to be long-lasting or permanent.

5.0 PEATLANDS AND PEAT FORESTS

Global analysis of the extent of peatland in PNG differ, but all suggest that peatland make up a significant area of PNG, and due to their very high carbon content, peat soils are a major potential source of emissions if disturbed. Griscom et al. 2020 used data from Joosten (2010) which estimates that 12.9% of PNG's land area is peat (59,922 km^2). Recent USAID-funded estimates of peat area by Gumbricht et al., (2017a; 2017b) were based on a combination of remote sensing and of modeling based on geomorphology, soil characteristics, and hydrology. That analysis reported slightly lower areas of peat in PNG: 45,018 km^2 (9.6% of national area; Gumbricht et al., 2017a) In our analysis of an updated version of the publicly-available data (Gumbricht et al., 2017b) we calculated a national total for PNG of 42,296 km^2 (9.0%; Map 10). We analyzed the Gumbricht et al. (2017b) by province in PNG; Table 4 shows the areas of peat in each of the 13 provinces that have more than 500 km^2 total. Western Province has nearly 30% of PNG's total peat area, while the three provinces of Western, East Sepik, and Gulf together have 67.9% of total peat area.

Table 4: Area of peat in the 13 provinces in PNG that have at least 500 km^2 of peat.

Province	Peatland Area (km2)	Peatland Area (% of Province)	Percent of National Peat Area
Western	12,573	12.72	29.73
East Sepik	8,477	19.40	20.04
Gulf	7,656	21.91	18.10
Sandaun	2,658	7.45	6.29
Oro	2,112	9.16	4.99
Madang	1,478	5.08	3.50
Central	1,302	4.37	3.08
Milne Bay	1,056	7.15	2.50
West New Britain	1,034	4.96	2.45
Morobe	799	2.33	1.89
Southern Highlands	656	4.11	1.55
New Ireland	570	5.69	1.35
Bougainville	526	5.25	1.24

The Gumbricht et al. (2017a; 2017b) data may be underestimating montane peat. Hope (2015) estimates 5,965 km^2 of montane peatland in PNG that is almost entirely in the Highlands Region. This contrasts with Gumbricht et al. (2017b) who found a total of only 1,342 km^2 of peat in the seven Highlands provinces. The Hope (2015) study, like others that it cites, is based on direct field work in PNG and, as such, has more detail on specific sites and wetland types in PNG. That study notes that "no comprehensive account of wetland vegetation exists for the entire island of New Guinea, as only scattered ecological survey work has been carried out" (Hope, 2015, p. 3) which is why we will continue relying in part on the Gumbricht et al. data that does provide spatially-explicit estimates of peat. However, while using the Gumbricht et al. data, it is important to consider that it may insufficiently account for opportunities in the highlands. The Hope (2015) source is useful for identifying particular sites of key importance for carbon storage—for example, the Tari basin in the Western Highlands that has an extensive complex of montane swamps with deep peats or the upper Wahgi River near Mount Hagen where peats up to 5m in depth have been measured.

Gumbricht et al. (2017b) show large areas of deep peat in PNG, including extensive areas greater than 9m in depth (note: an interactive web map displays these data—both peat area and peat depth—at https://www.cifor.org/global-wetlands/). In describing montane wetlands, Hope (2015) estimates area and peat depth for three general categories of wetland. He estimates montane swamp forests, found between 500–3,000m elevation, have thickness ranging from 1.5–8.5m and cover 1,419km^2 in PNG. Sedge-grass fens occur between 500–2,900m elevation have peat thickness between 2.0–9.0m and cover 836km^2 in PNG. Subalpine moorlands and fens, occurring between 2900m–4500m elevation, represent most of the area of montane wetlands in PNG and cover 3,707km^2. Peat in subalpine moorlands and fens is not as deep as in the two lower montane systems: it ranges in depth from 0.4–3.0m. Overall, peat volume in montane peatlands in PNG is estimated by Hope (2015) to be 12.5 billion cubic meters with 3.5 billion m^3 in montane swamp forest, 3.4 billion m^3 in sedge-grass fens, and 5.6 billion m^3 in subalpine moorlands and fens.

5.1. OPPORTUNITIES FOR REDUCING EMISSIONS FROM PEATLANDS

Peatlands have to date been largely excluded from PNG's national GHG accounting and climate change policy. The Second National Communication to the UNFCCC (GoPNG, 2014), the NRS (GoPNG, 2017a), and the PNG FRL (GoPNG, 2017b) all make no reference to peat. The BUR (GoPNG, 2018a) is the first major GoPNG submission within either REDD+ frameworks or UNFCCC reporting to reference peat. The BUR identifies peatlands as a contributor to GHG emissions in PNG and identifies a lack of data as the reason for their non-inclusion in national accounting to date.

National data on the extent of degraded peatland, outside of the data from Joosten 2010, does not apear to be available, making it difficult to further assess the mitigation potential of peatland restoration in PNG. Leifeld and Menichetti (2018) estimate that across the tropics, degrading peatlands emit 61.1 tCO_2e/ha/year; those authors suggest that peat rewetting and revegetation can be effective to mitigate those emissions from degrading peat. There are examples of peatland restoration success from tropical and temperate Asia: experience from Sumatra has shown that canal blocking can effectively raise water tables in degrading peatlands (Sutikno et al., 2019), while rewetting and revegetation have succeeded in restoring more than 1,500 ha of peatland in the upper Yellow River basin (Cris et al., 2014). In addition to the mitigation benefits of arresting peat degradation, soil carbon has been shown to recover in restored peatlands in temperate systems (Bobul'ska et al., 2019). However, we have not been able to find estimates of carbon recovery post restoration in tropical upland peatlands. Given the high carbon content of peat soils and the significant potential for restoration, obtaining improved data on peatlands should be a priority for improving PNG's land use monitoring system.

Two of the largest areas of peat extent in PNG (Map 10) coincide with areas of swamp forest (Map 3)—that is, the northern part of the Gulf of PNG in Gulf Province and to a lesser extent in Western Province, and along the Sepik River valley in East Sepik. Along the Gulf, the peat area also coincides with mangrove forests in the areas closer to the coast. In the Gulf peat area, rates of forest loss have been low to date (Maps 6 and 7). However, forest clearing is increasing in important peat areas in East Sepik (Map 7).

5.2. ROAD CONSTRUCTION IMPACTS

An analysis of PNG's road development plans found that construction of planned roads could directly impact 68,000 ha of peatlands, of which approximately 50% are deep (4m–8m), and 15% are very deep (9m or greater) (Alamgir et al., 2019). These planned roads include "missing link" roads that connect existing parts of the presently fragmented national road network as well as other roads that expand the network (Map 12). Road construction on peatlands would almost certainly result in significant GHG emissions; however, the rate and total extent of emissions would depend on multiple factors. The extent of the of the water table that resulted from road construction would greatly affect the rate of peat oxidation and therefore GHG emissions. Additionally, the frequency of fire—linked both to peat drying and to the presence of mechanized activity on the surface—is an important driver of the rate of loss of peat carbon stocks (Jaenicke et al., 2010). In addition to their impact on GHG emissions, these roads would fragment key biodiversity habitats and would create new hotspots of deforestation via expansion of logging, mining, and oil palm establishment (Alamgir et al., 2019).

The issue of roads is challenging in PNG. A large proportion of the rural population in PNG is completely disconnected from the national road network. This limits access to healthcare and markets and is an important contributor to significant economic disparities between urban and rural areas in PNG. Road expansion may well bring benefits to many local communities. The Government of Australia—the largest donor of ODA in PNG—has in the past focused on improving the existing road network and not invested significantly in new road construction. The new road expansions planned are described in the Medium Term Development Plan created by the Department of National Planning and Monitoring and are funded by the Asian Development Bank (ADB).

6.0 AGRICULTURE AND LIVESTOCK SECTORS

There is some potential for emissions reductions in PNG in the agriculture and livestock sectors; however, the scale of potential in these sectors is likely small relative to potential reductions in emissions resulting from land cover change. Note that in this section we are referring to emissions that result from agriculture itself and potential reductions resulting from improvements in agricultural technology. Emissions from forest or peatland conversion that result from agricultural expansion are included in the discussion above in the sections on land cover change emissions and opportunities.

PNG has relatively few cattle for a nation of its land area and population: the FAO estimates there were just over 93,000 head of cattle in the country in 2018 (FAO, 2020). The livestock pathways described by Griscom et al. (2017; 2020) are estimated using the data on area of pasture used for grazing cattle and on number of head of cattle. Given the limited number of cattle and area of pastureland in PNG, estimates are very small. When we combine estimates published by Griscom et al. (2017; 2020) with additional estimates we created for improved livestock feed and livestock management using similar methods, the total annual potential of cattle-based interventions (including pasture management) is only 365,000 tCO_2e per year. This is less than 0.5% of the total national cost-effective mitigation potential after safeguards.

PNG has 2.15 million swine, which may offer larger mitigation potential than do cattle in the country, potentially through biodigesters and associated improvement in manure management. The two Griscom et al. (2017; 2020) studies do not assess emissions related to swine at national levels. They justify this omission by pointing to studies that show relatively low total global mitigation potential in manure management and high overall costs. The study that showed low global potential for manure management, however, only focused on ruminants, and therefore will not have captured potential with pigs. Regarding cost, other estimates exist that are much more promising. There is some dispute around these estimates, however. Work in the Philippines funded by the Building Low Emission Alternatives to Develop Economic Resilience and Sustainability (B-LEADERS) project (IRG, 2015) suggested a price of $1.58/ton for emissions abatement resulting from investing in biodigesters that would be fueled by swine manure. We do not know how the costs in PNG would compare, but the estimated Philippines cost is less than a third of the average price for emissions abatement for REDD+ abatement measures in PNG. In terms of total abatement potential, this opportunity has limited potential relative to the ecosystem-based options discussed in the sections above. However, for individual households or businesses, it can be cost effective and could play a role in a rural electrification strategy. As such, there may be opportunities where this intervention would be attractive.

7.0 EXISTING INVESTMENTS AND SECTORS OF OPPORTUNITY

Climate-related donor investment in PNG is summarized in the BUR (GoPNG, 2018a). Of $123.7M USD in funding described, $47.9M is directly or indirectly linked to land-based climate mitigation. These investments primarily fall into one of two categories: ones related to REDD+ and ones related to improving coastal adaptations that include a mangrove restoration component. Table A1 in Appendix A shows all investments described in the BUR.

The geographic focus on REDD+ activities is not yet fully apparent. Although PNG was one of the countries that in 2005 first requested a discussion of REDD+ (at that time, simply "RED") by the UNFCCC, the country has made limited progress with on-the-ground piloting activities. The NRS (GoPNG, 2017a) and other national REDD+ documentation makes little reference to specific geographies. The NRS does not reference any specific pilot activities, although it does mention voluntary carbon standard projects on Manus Island and in New Ireland Province.

In addition to REDD+, adaptation has been an important focus of donor funding on climate change in PNG. Several projects—including the USAID-funded MARSH project while it was running—comprise mangrove planting or restoration as an adaptation component. This has benefits for mitigation, but as discussed, restoring mangroves may have limited success in restoring the large soil carbon stocks that are found in primary mangrove ecosystems.

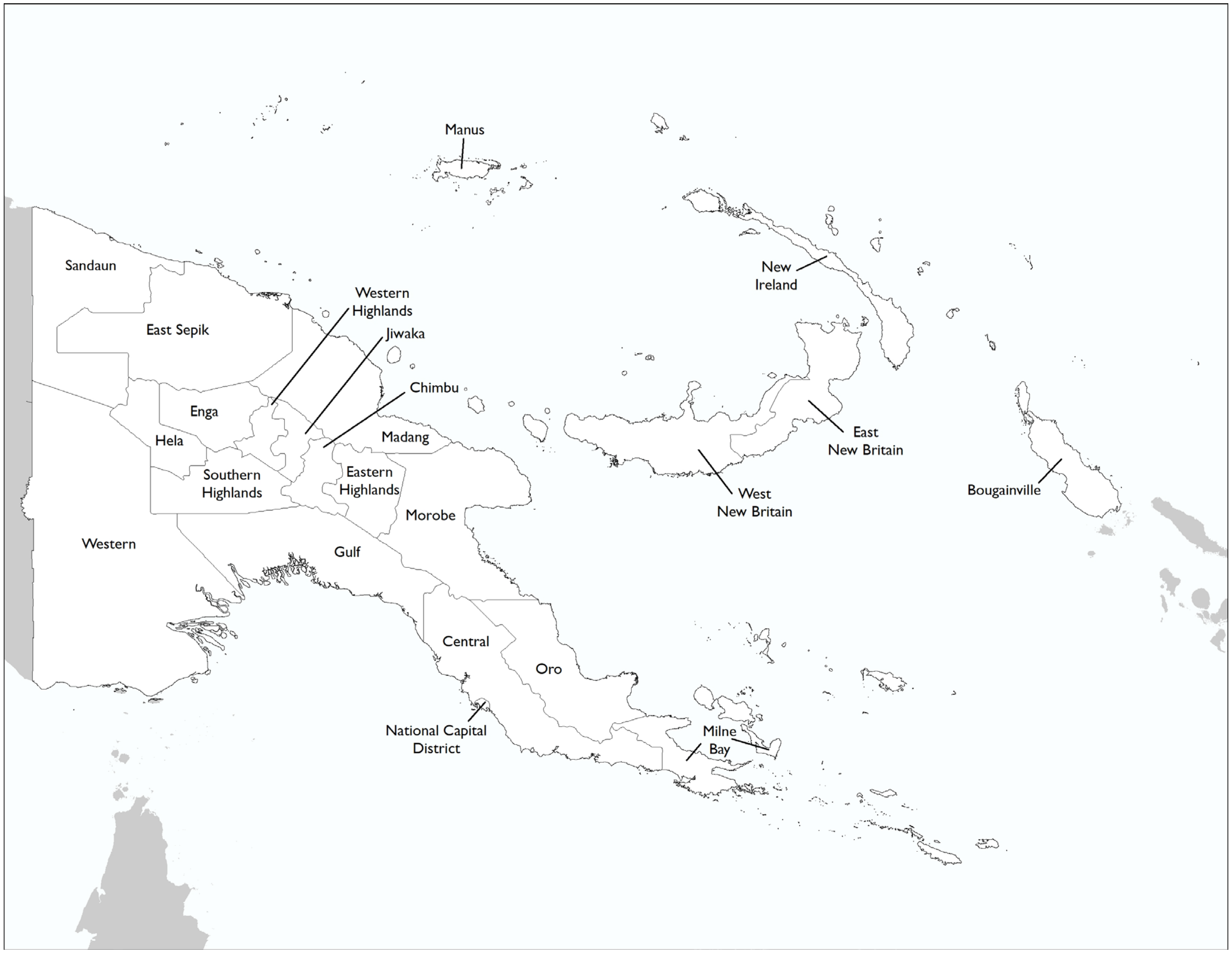
Given the importance of peatlands to the national carbon budget, they are underrepresented in terms of dedicated donor funding (Table A1) and in terms of the national-level planned activities under the NDC. There are important data gaps in understanding peatlands in PNG and the potential impact of conservation efforts; however, given the rapid expansion of oil palm and the projected rapid expansion of the road network, peat conservation has the potential to play a particularly important role in climate mitigation in PNG. Data on peat and peat impacts is limited, and there is no nationally specific assessment of peat in PNG. As discussed above, we have reason to believe that global peat estimates may be underestimating peat in the highlands, so this lack of data may be masking important opportunities.

The expense of working in PNG has been identified as a major constraint for conservation work in the country. This highlights the challenging issue of road development and its impacts on forests, peat, and biodiversity. Regarding the national transportation network, the lack of safe and regularly accessible road transport in the majority of the country is part of the reason why there exist such large disparities in access to markets and to services between urban and rural areas in PNG. However, the planned road expansion is likely to result in a large increase in emissions. While advocating for general limitations on road development is not likely to be a viable option, improved planning of the road network may result in emissions reductions relative to development as planned.

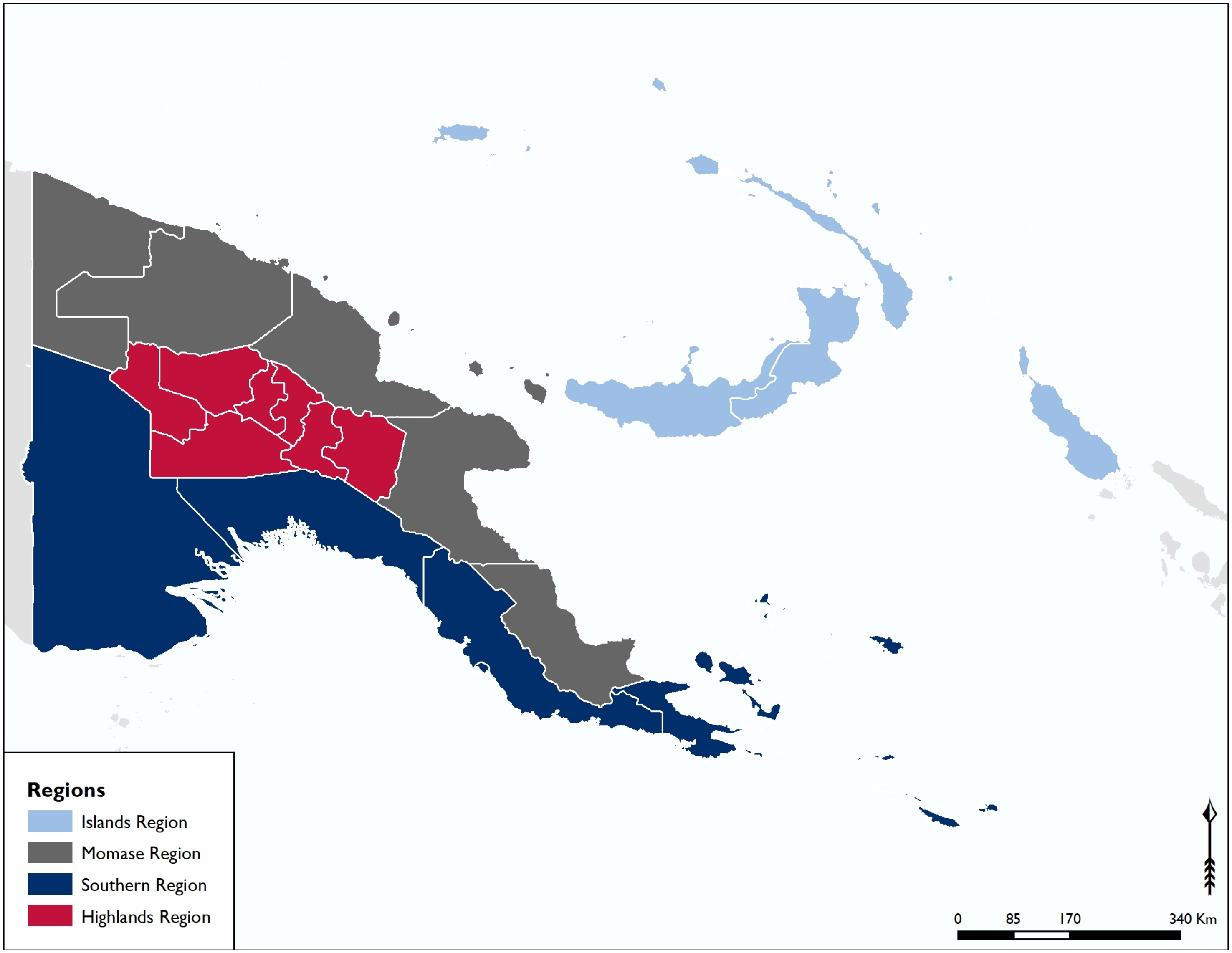
Existing bans on log exports in PNG have not had significant effects on reducing either log exports or illegal practices in the logging sector. However, the logging sector in PNG is likely to face increasing market pressure via China and its western buyers to improve timber legality and chain of custody systems particularly. This may offer important opportunities to improve compliance with the existing logging code and reduce the climate impact of the logging sector.

8.0 MAPS

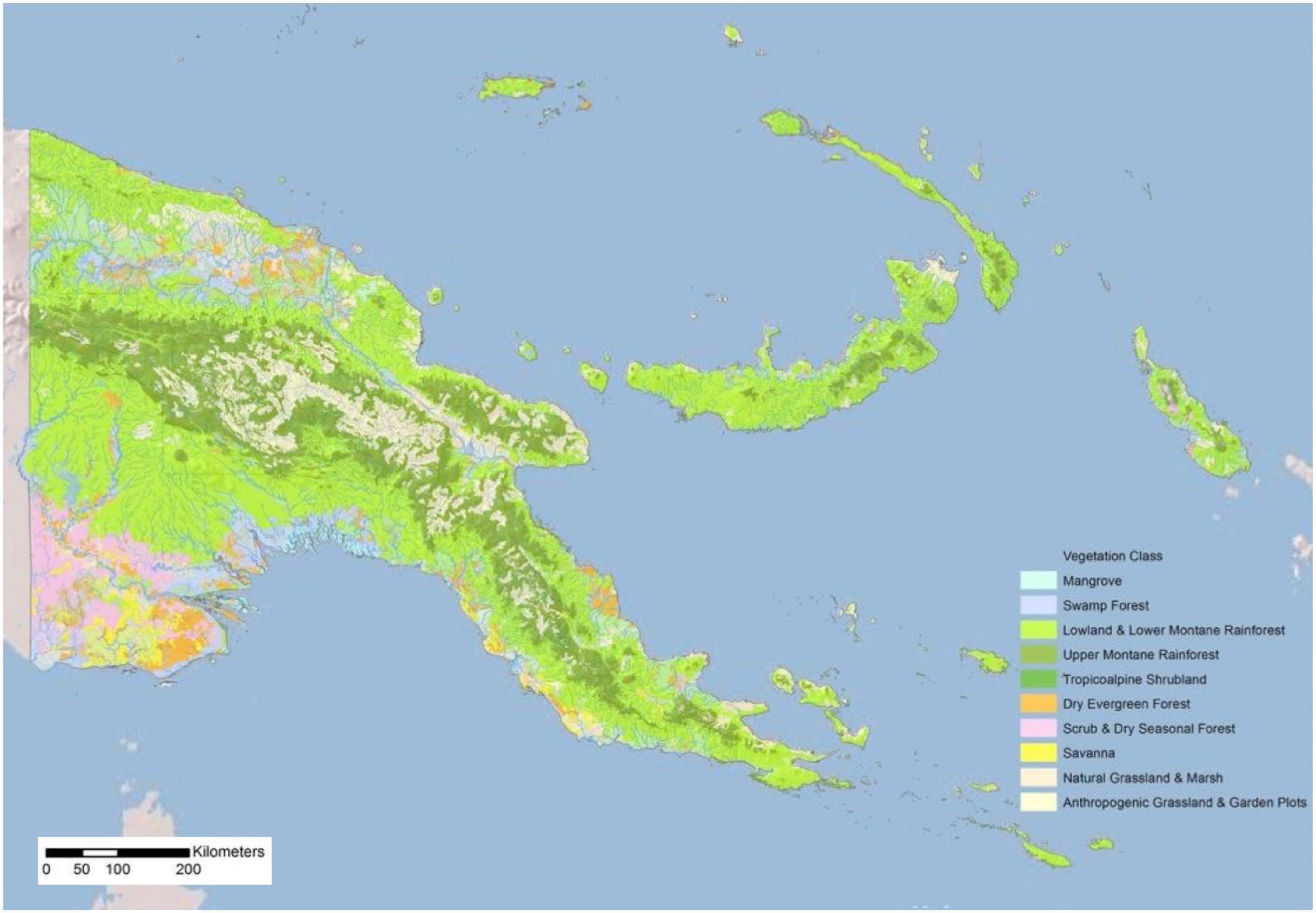
Map 1: Provinces of Papua New Guinea



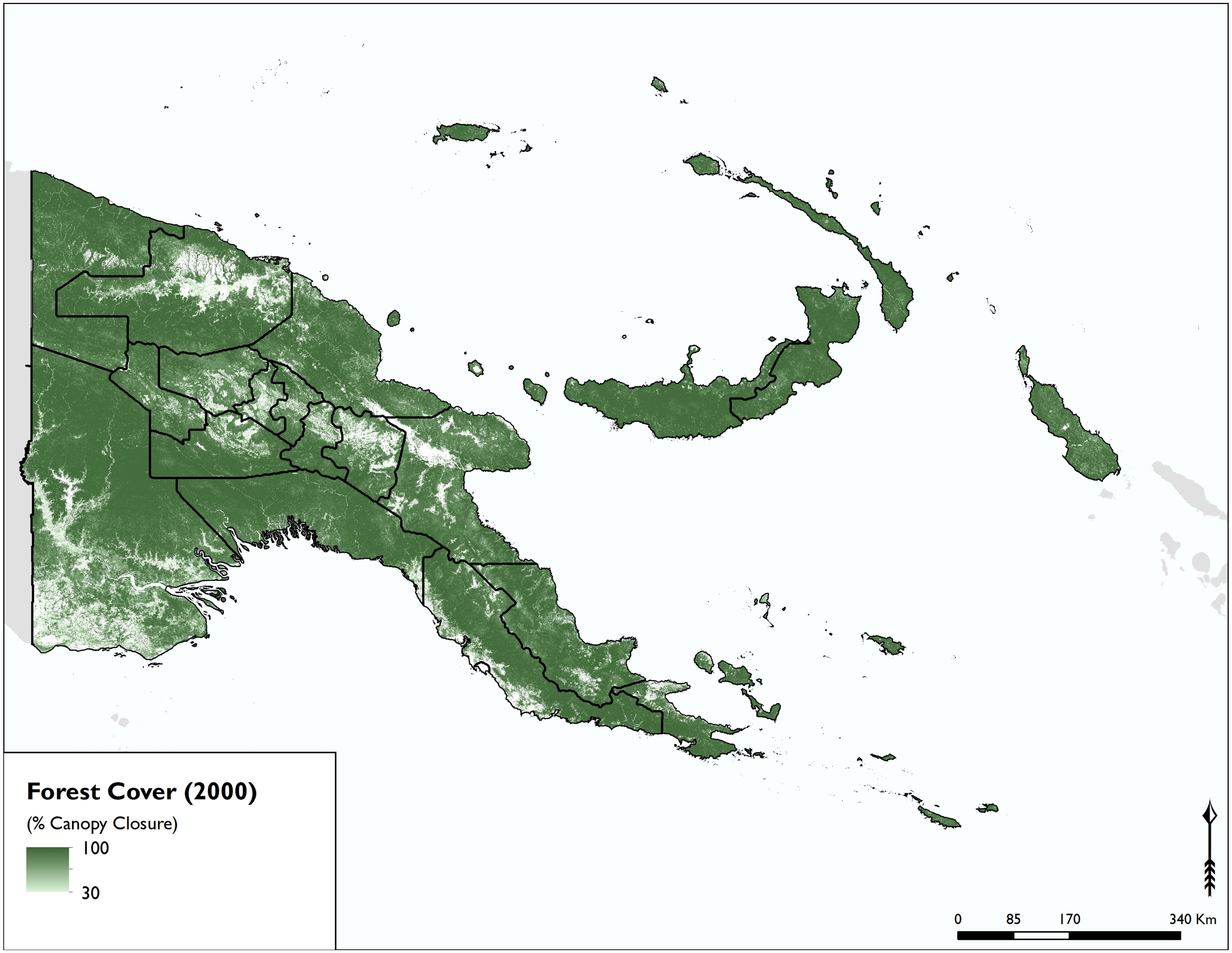
Map 2: Regions of Papua New Guinea



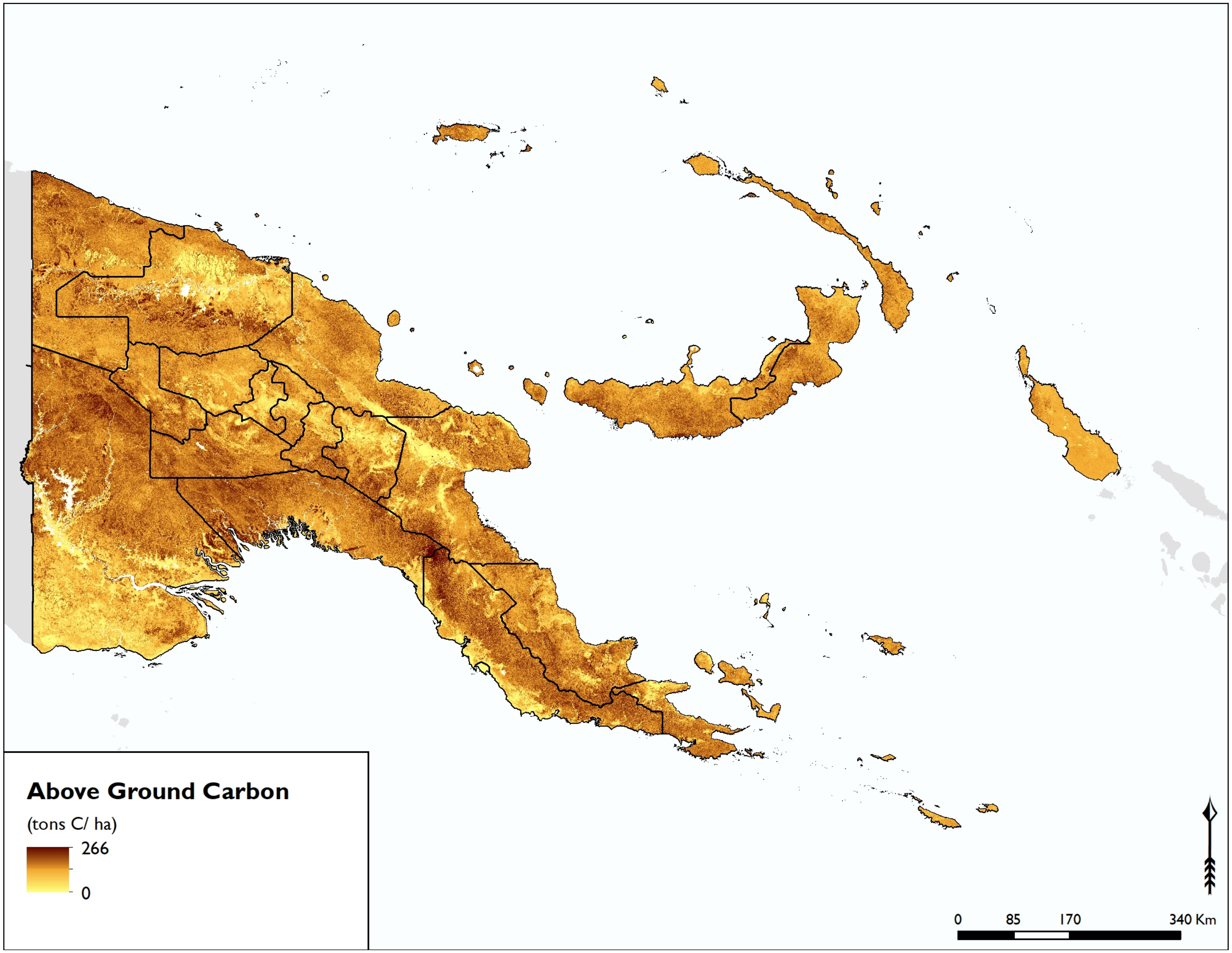
Map 3: Forest types in PNG. Map source is PNG Biodiversity Assessment (DOI-ITAP, 2017) that had originally used data from the Forest Inventory Mapping (FMI) System of 1998 (McAlpine and Quilley, 1998).



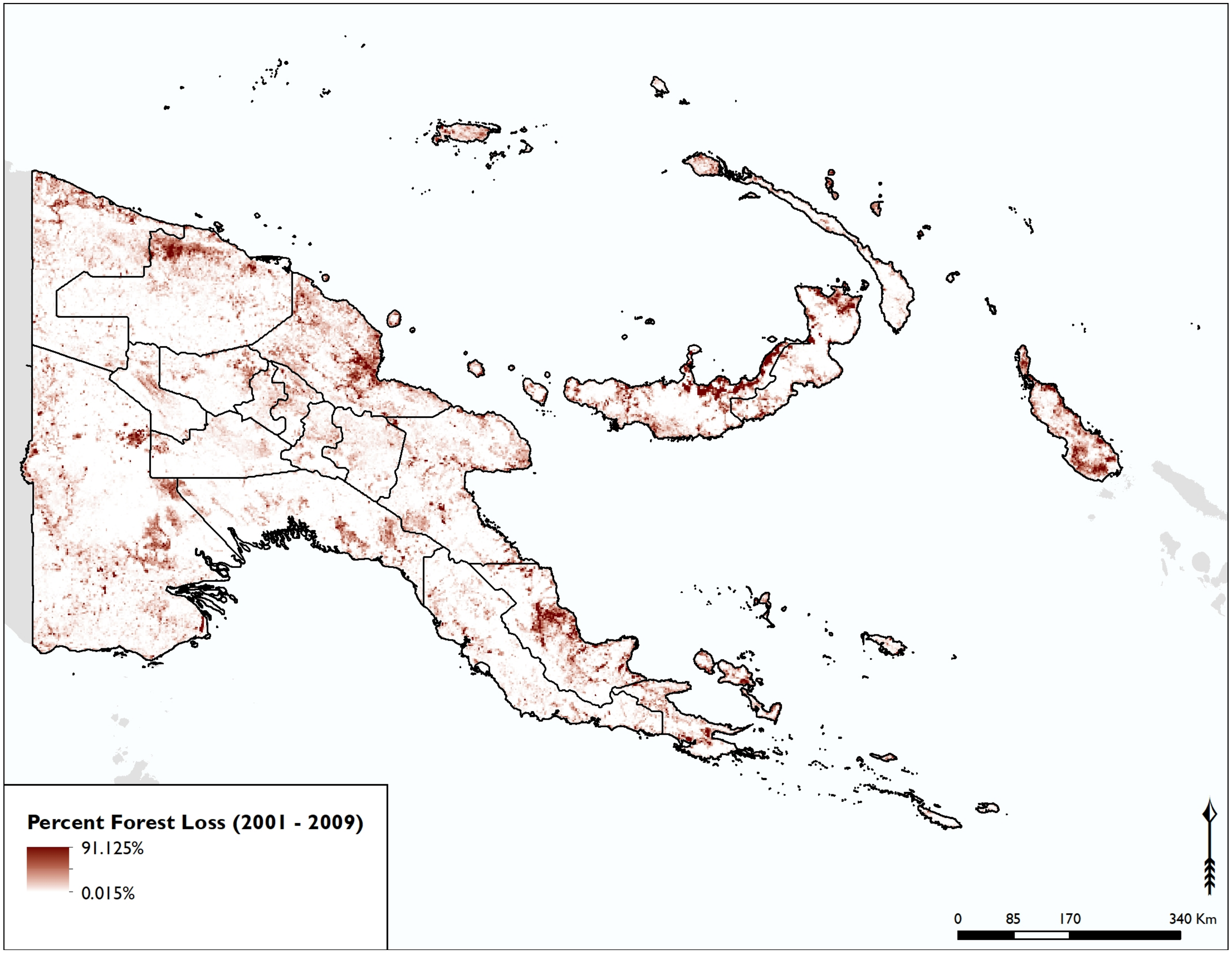
Map 4: Forest cover in PNG in 2000 based on data from Hansen et al. (2013; updated 2019). Can be compared to maps 6 and 7 that show forest loss 2000-2018, although these maps cannot be directly combined because of data limitations.



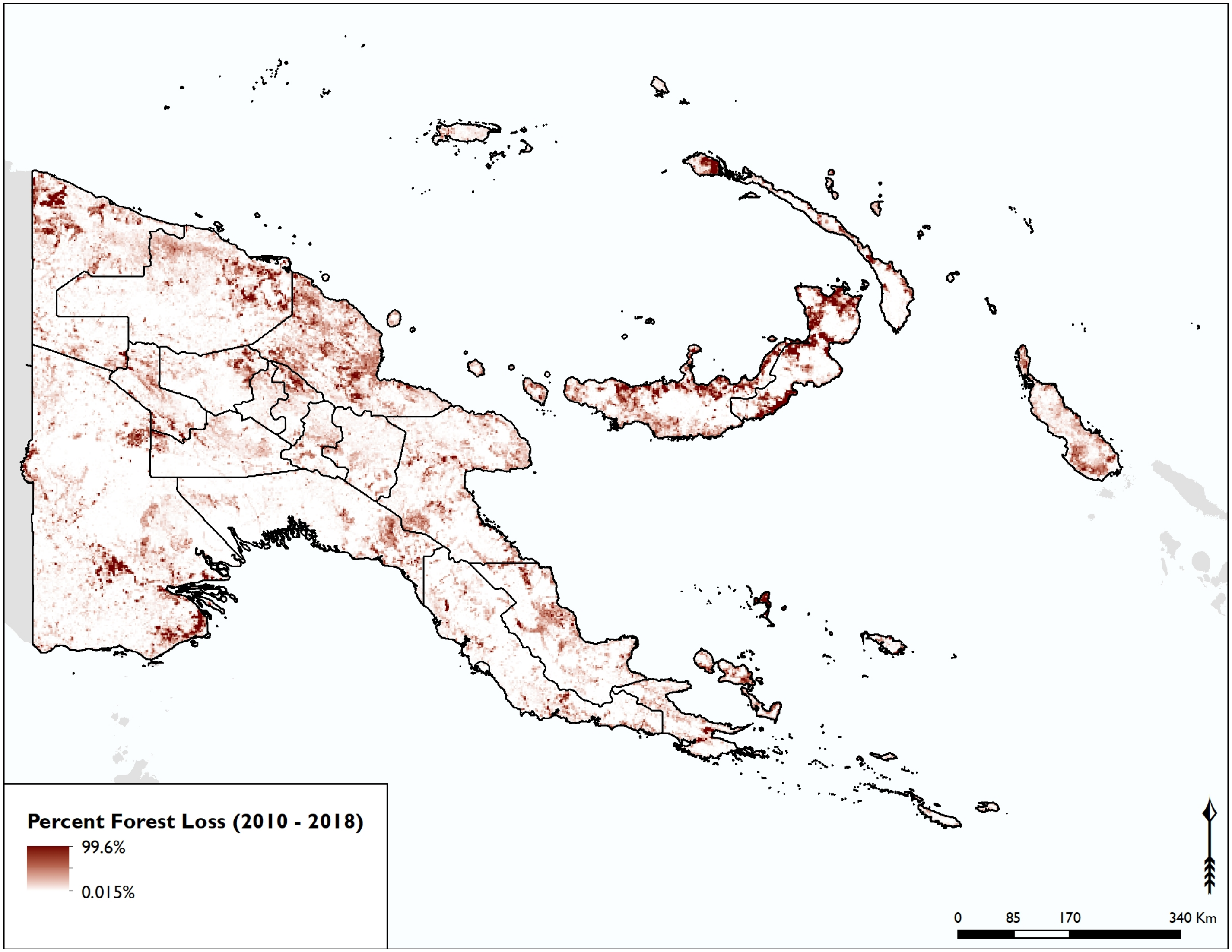
Map 5: Aboveground carbon in 2010 stored by trees, crops, and grasslands in tons of carbon per hectare at 300m spatial resolution. Map is based on a global dataset developed by Spawn and Gibbs (2020).



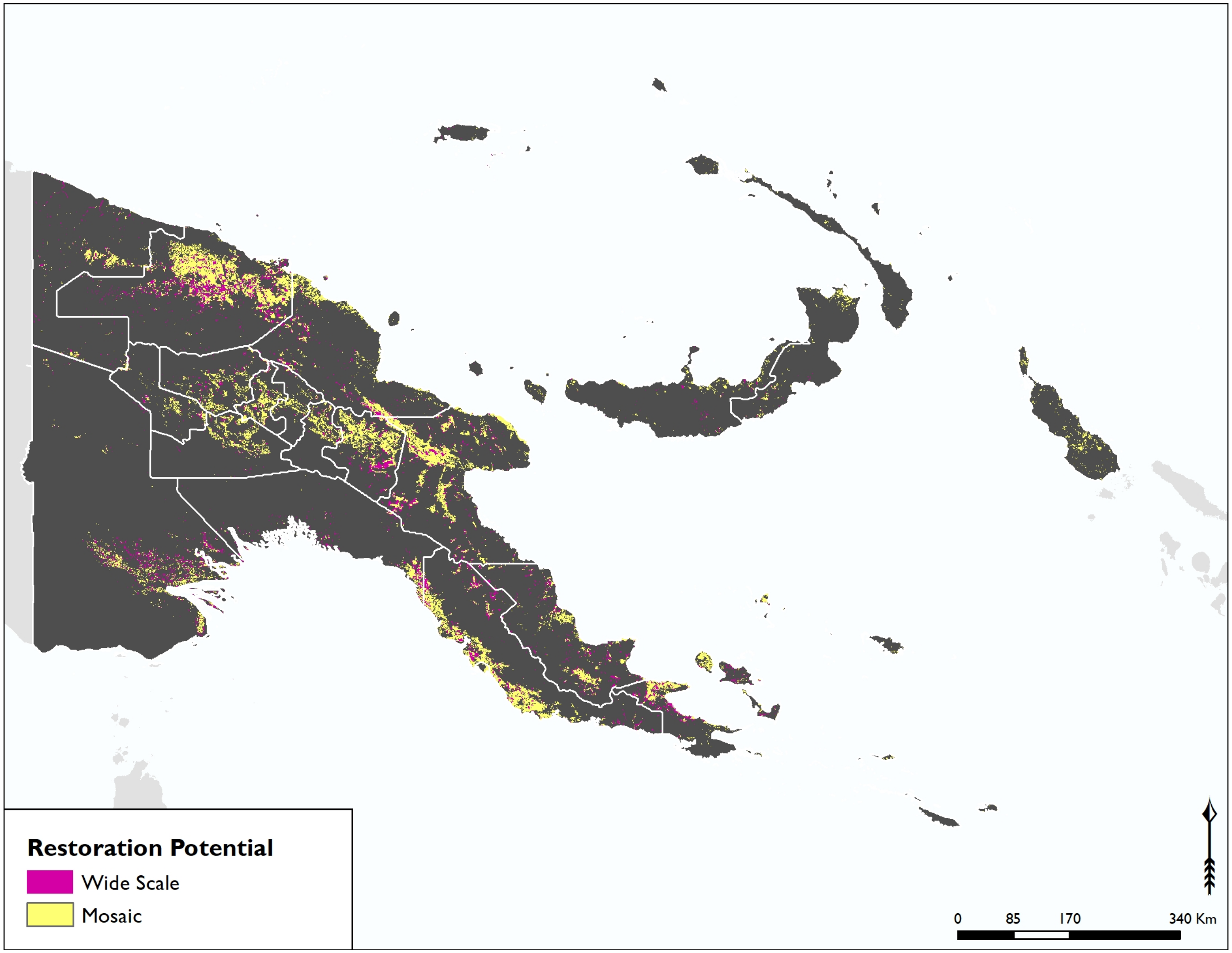
Map 6: Forest loss from 2001-2009 based on data from Hansen et al. (2013; updated 2019). Original data has 30m spatial resolution that we have aggregated in this map to 2400m. Pixels here represent the percentage of pixels in the 30m data that showed forest loss.



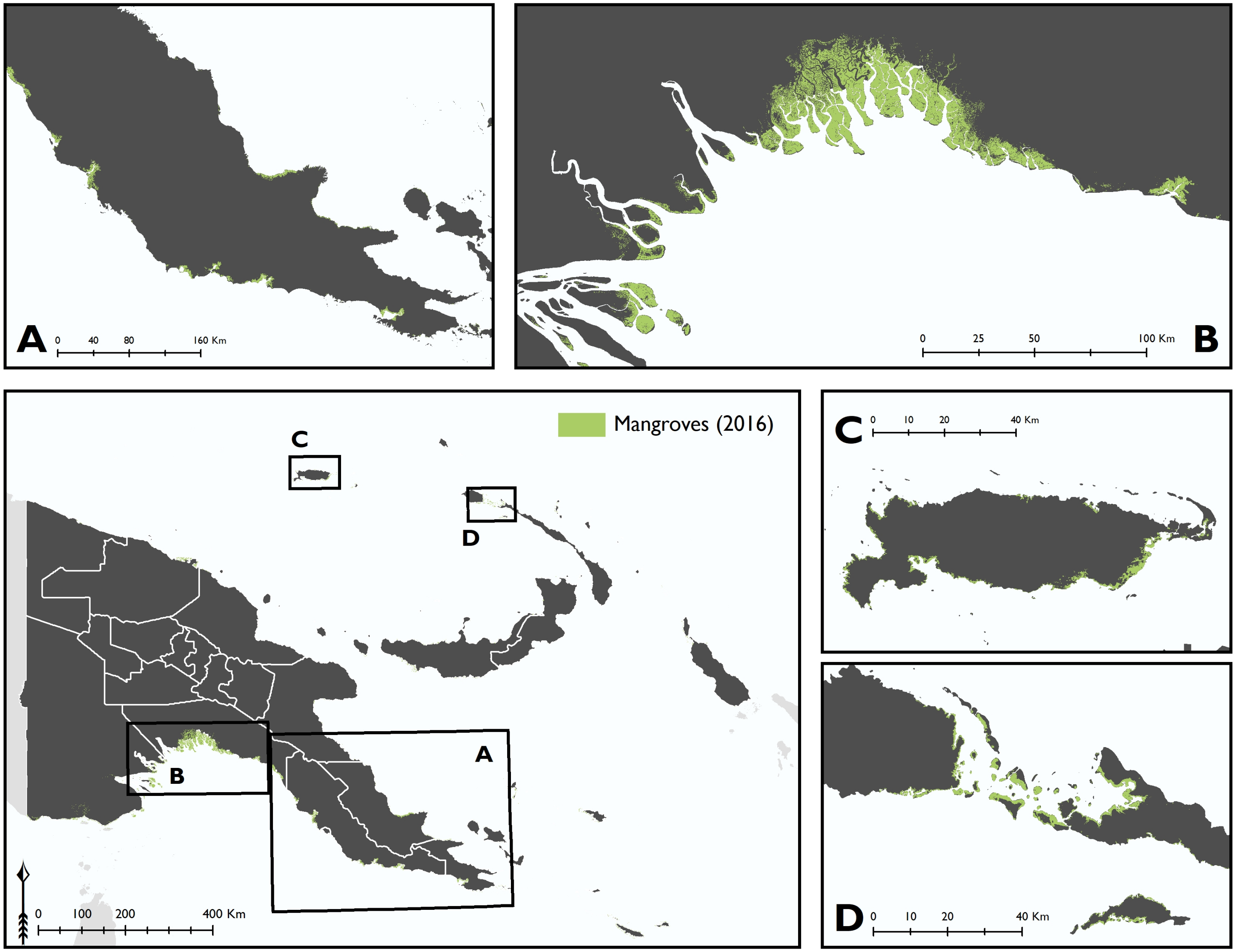
Map 7: Forest loss from 2010-2018 based on data from Hansen et al. (2013; updated 2019). Original data has 30m spatial resolution that we have aggregated in this map to 2400m. Pixels here represent the percentage of pixels in the 30m data that showed forest loss.



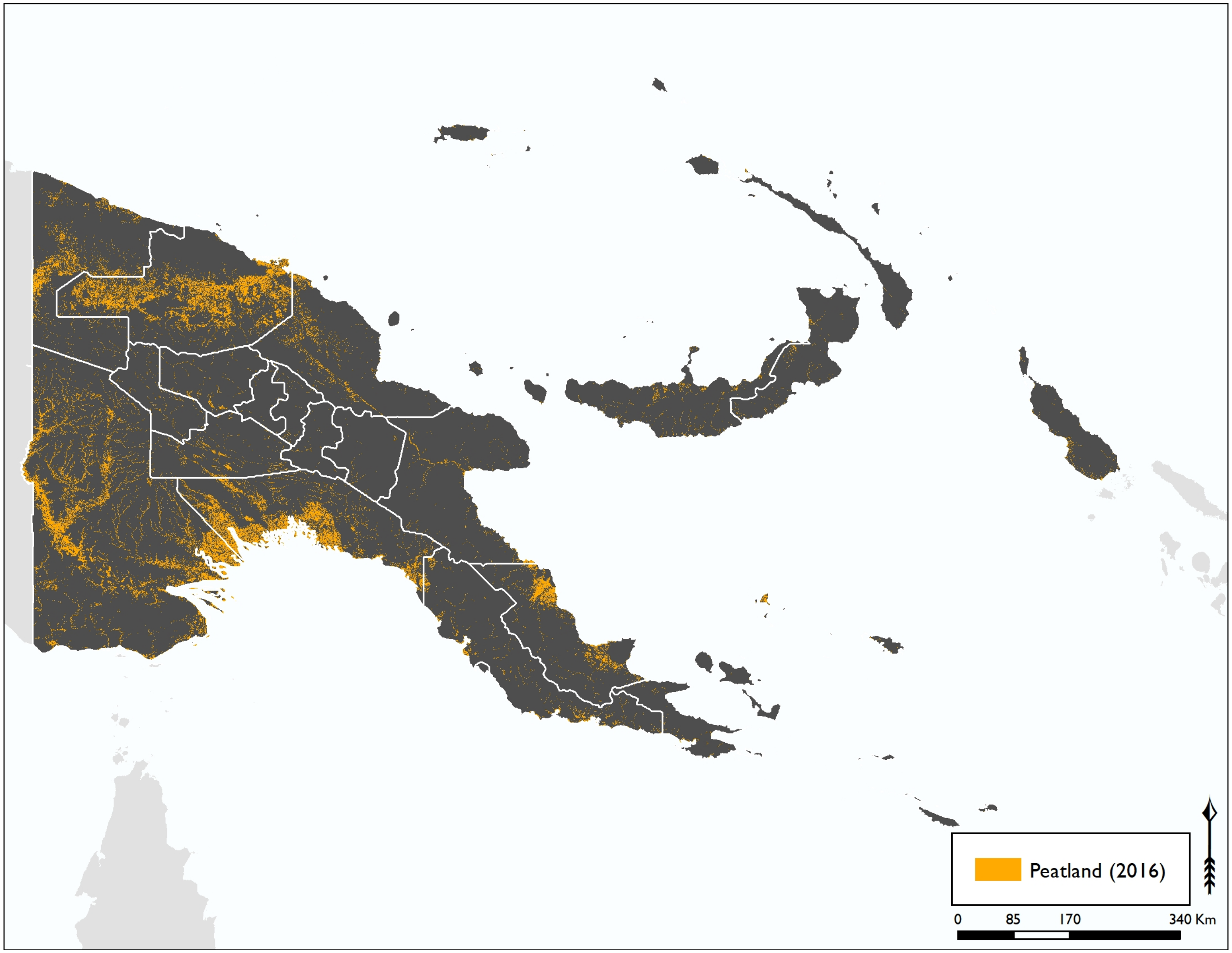
Map 8: Potential for two types of forest restoration in 2010. Wide scale restoration refers to restoring forest at relatively large scale in areas of low (<10 people per km²) population density. Mosaic restoration refers to restoring scattered forest parcels in areas where population density is moderate (10-100 people per km²). Data from Laestadius et al., 2011.



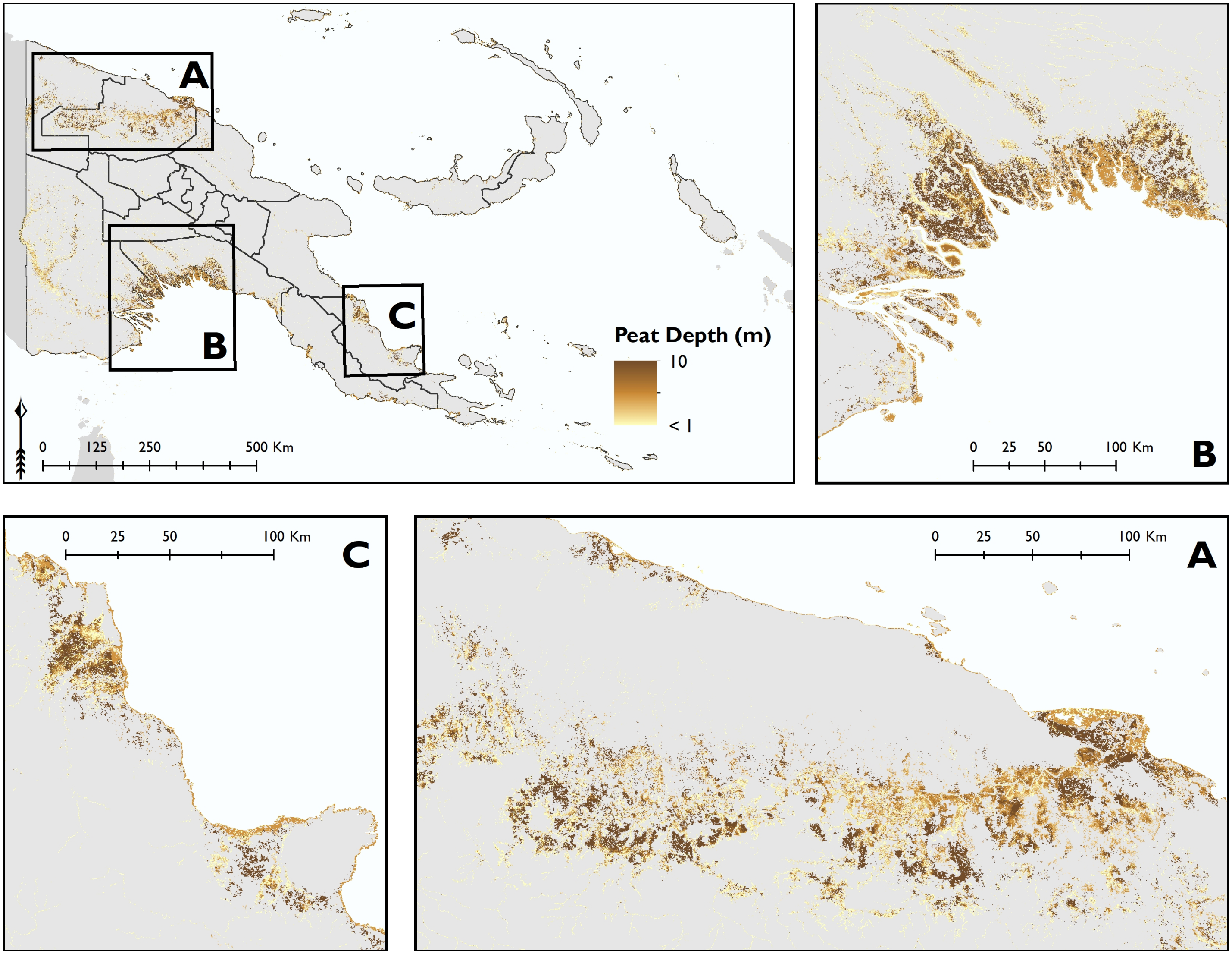
Map 9: Mangrove area in 2016. Data from Bunting et al. (2018).



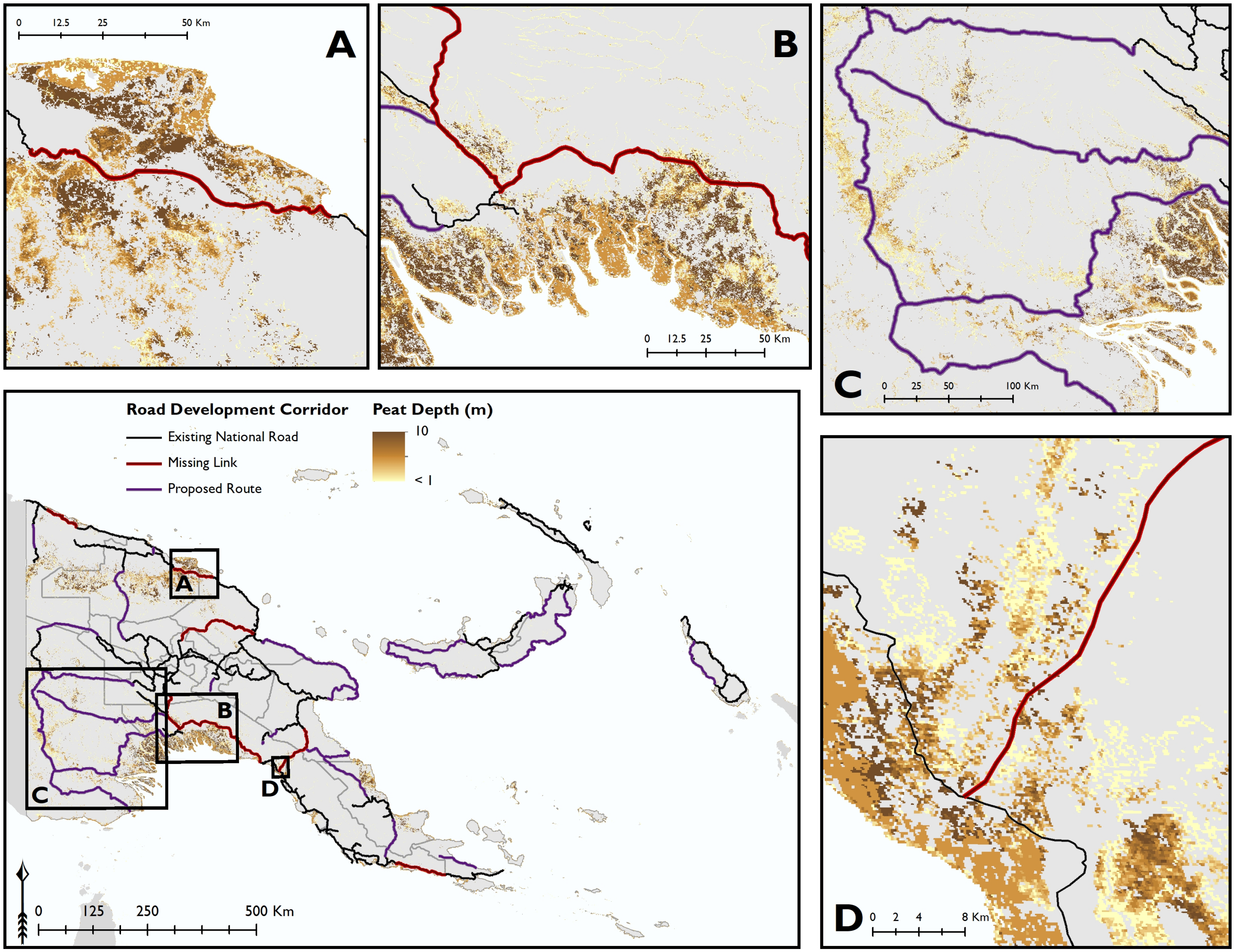
Map 10: Area of peatland in 2016 based on global dataset (Gumbricht et al., 2017b). Note: Hope (2015), in a study focused specifically on the island of New Guinea, suggests that there are larger areas of montane peat in the highlands of the island than this global dataset suggests.



Map 11: Peat depth estimated by Gumbricht et al. (2017b) highlighting areas of greatest peat extent.



Map 12: Planned expansion of roads as described in Medium Term Development Plan III 2018-2022 (GoPNG, 2018b) overlain on peat depth (Gumbricht et al., 2017b). Alamgir et al. (2019) provided spatial data for roads and initial map concept.



APPENDIX A

Table A1: Existing donor investments in climate change in PNG

Climate Change Activity	Funding Source	Project Title	Duration	Cost	Cost in Millions USD (2020 exchange)	Years	USD Annually	Development Partner(s)
REDD+ & Mitigation	GEF, GoPNG, Australia, ExxonMobil, Barricks Gold	Sustainable Financing of Papua New Guinea's Protected Area Network	2019–2024	US $61.2M (11.3m GEF grant; 49.5m co-financing)	61.200	5	12.24	UNDP
Adaptation	ADB	Strategic Program for Climate Resilience (SPCR) – Building Resilience to Climate Change in PNG	2015–2021	US $25M	25.000	6	4.17	ADB
REDD+ & Mitigation	JICA	Promotion of Regional Initiative on Solid Waste Management in Pacific Island Countries	2015–2020	PGK 47.2M	13.688	5	2.74	JICA
Adaptation	USAID, AusAID, GEF	Coral Triangle Initiative	2010–2015	US $11M	11.000	5	2.20	USAID
Adaptation	USAID	Mangrove Rehabilitation for Sustainably Managed, Healthy Forests	2012–2015 (5-year project but early phase-out)	US $7M	7.000	3	2.33	USAID

Climate Change Activity	Funding Source	Project Title	Duration	Cost	Cost in Millions USD (2020 exchange)	Years	USD Annually	Development Partner(s)
Adaptation	Adaptation Fund	Enhancing adaptive capacity of communities to climate change related floods in the North Coast and Islands Region of Papua New Guinea	2012–2017	US $6.5M	6.500	5	1.30	UNDP
REDD+ & Mitigation	UN-REDD	PNG UN-REDD Programme	2011–2017	US $6,388,884	6.389	6	1.06	UNDP/UNEP/FAO
MRV	EU	Technical support to the Papua New Guinea Forest Authority to implement a multipurpose National Forest Inventory	2014–2019	EUR 5.8M	6.380	5	1.28	FAO
MRV	JICA	Capacity Development for Operationalization of PNG National Forest Resource Information Management System (FRIMS) for Addressing Climate Change	2014–2019	PGK 20.3M	5.887	5	1.18	JICA
REDD+ & Mitigation	World Bank	Forest Carbon Partnership Facility Project 2	2018–2020	US $5M	5.000	2	2.50	FCPF/UNDP
Adaptation	GIZ German Government	Coping with Climate Change in the Pacific Islands Region	2009–2013	EUR 4.2m	4.620	4	1.16	GIZ/SPC
REDD+ & Mitigation	JICA	Biodiversity Conservation through implementation of the PNG Policy on Protected Areas	2015–2020	PGK 15.3M	4.437	5	0.89	JICA
REDD+ & Mitigation	World Bank	Forest Carbon Partnership Facility Project	2015–2017	US $3.5M	3.500	2	1.75	FCPF/UNDP

Climate Change Activity	Funding Source	Project Title	Duration	Cost	Cost in Millions USD (2020 exchange)	Years	USD Annually	Development Partner(s)
REDD+ & Mitigation	GEF	Facilitating Renewable Energy & Energy Efficiency Applications for Greenhouse Gas Emission Reduction (FREAGER)	2017–2021	US $3,140,640	3.141	4	0.79	UNDP
REDD+ & Mitigation	JICA	Capacity Development on Mine Waste Management	2015–2020	PGK10.2M	2.958	5	0.59	JICA
Adaptation	EU	Migration, Environment and for Policy Climate Change: Evidence	2014–2016	EUR 2.4M	2.640	2	1.32	IOM
Adaptation	WB and Japanese Government	Global Fund for Disaster Risk Reduction (GFDRR).	2012–2015	US $2.6M	2.600	3	0.87	WB
REDD+ & Mitigation	JICA	Port Moresby Wastewater Management Improvement	2017–2020	PGK 8.9M	2.581	3	0.86	JICA
MRV	JICA	Project for enhancing capacity to develop a sustainable GHG inventory system for PNG	2017–2021	PGK 8.7M	2.523	3	0.84	JICA
Adaptation	USAID/Pacific American Climate Fund (PACAM)	CBO/CSO Climate Change adaptation projects	Ongoing	US $1,908,478	1.908			PGRD
Adaptation	USAID	Coastal Community Adaptation Program	2013–2017	US $1.4M	1.400	4	0.35	USAID, DAI, University of the South Pacific (USP) & Kramer Ausenco PNG Ltd.
Adaptation	German Government, EU	Solar Farm and Integrated Water Supply for Rural Communities in PNG	2016–2018	EUR 1M	1.100	2	0.55	EU-GIZ
MRV	GEF	Strengthening capacity in the agriculture and land-use sectors for enhanced transparency in implementation of monitoring NDC under the	2018–2021	US $1M	1.000	3	0.33	FAO

Climate Change Activity	Funding Source	Project Title	Duration	Cost	Cost in Millions USD (2020 exchange)	Years	USD Annually	Development Partner(s)
		Paris Agreement in Papua New Guinea						
Adaptation	UN Habitat	Cities and Climate Change Initiative	2012–2014	US $1M	1.000	2	0.50	UN Habitat
MRV	GEF	Preparation of the First BUR and Third National Communication under UN Framework Convention on Climate Change (UNFCCC)	2014–2020	US $832,000	0.832	6	0.14	UNEP
REDD+ & Mitigation	Italy Government (Italy-PNG MoU)	REDD+ Programme	2017–2019	EUR 400,000	0.440	2	0.22	CfRN
MRV	GEF	Papua New Guinea: Preparation of Intended Nationally Determined Contribution to the UNFCCC	2017–2021	US $210,000	0.210	3	0.07	UNEP
Adaptation	Australian Government	Pacific-Australia Climate Change Science and Adaptation Planning Program	Ended June 2013	Regional Program (Total funding unspecified)				AusAID, CSIRO, BoM
REDD+ & Mitigation	Australian Government	Pacific Appliance Labelling and Standards	2017–2018	Technical Assistance		1		SPC
Adaptation	EU-GCCA (Global Climate Change Alliance)	Community Climate Change Adaptation Projects	2012–2015			3		PACE-SD USP & CCCSD UPNG

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