

Low Emission Land Use Planning for Madang Province: Options and Opportunities



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Forward by the Governor of Madang

Madang Province is blessed with tremendous biological and cultural diversity, from some of PNG's largest mountains and rivers, to the coasts, and to the many beautiful islands of the province. One hundred and seventy-five languages are spoken by our 600,000 citizens scattered across six districts. "Beautiful Madang", as it's known in Papua New Guinea and internationally, has become a tourist destination for visitors from across the globe hoping to experience our unique and globally significant environment.



As the Governor of Madang, it's the responsibility of my government to ensure that such a blessing of natural resources given by God is managed responsibly, so that it provides for the needs of the current citizens of Madang as well as our future generations. An effective and sustainable land use planning process will allow our valuable natural resources to be sustainably developed for our economic prosperity with positive and long-lasting social and environmental outcomes for all. It is the responsibility of my government to provide infrastructure development and the provision of better education and health services. But in the development process, there are risks and challenges. My government recognizes these and is working in close collaboration with local, provincial and international stakeholders and partners to address these challenges. Climate change will increase the challenges, but we are now exploring low carbon development pathways for a green economy, of which land use planning is a fundamental step. I want to prove that Madang can use our practical experience from the Adelbert Range to achieve this goal.

I am pleased to note that with the collaborative effort from all our partners, especially the USAID Lowering Emissions in Asia's Forests (USAID LEAF) program, The Nature Conservancy (TNC), Almami Local Level Government (LLG), Bogia District, Madang Provincial Administration, Madang Civil Society Forum, and all the local communities and provincial and national stakeholders, Madang has commenced a number of important climate change mitigation efforts. A low emission land use plan can provide a province-wide framework to further build these excellent efforts and help to achieve our development aspirations for the Province. The scenario planning work outlined in this report is the first time this has been considered for the Province and provides an excellent tool to balance economic growth with the management of our unique natural resources and the necessity to keep our natural and social landscapes intact for future generations to enjoy and prosper from.

I am proud to say that Madang Province is the first Province in Papua New Guinea to start implementing Vision 2050's environmental sustainability goals, national level discussions on climate change mitigation efforts, and concepts of green growth, green economy, or low emission development. This important document outlines options and opportunities for our Province. It is my hope that the success of the participatory land use planning work in the Almami LLG is replicated across the entire Province. This is clearly one area that would demonstrate my Government's drive to ensure a low emissions development pathway for Madang. I am proud that Madang Province is leading the climate change discussions with practical, nationally and internationally significant on-ground actions. A special thanks to the people of the Adelbert Range in the Almami LLG for taking on this challenge and showing us what is possible through their participatory land use and management plans.

On behalf of the Madang Provincial Government I would like to thank all those involved in the production of this Options and Opportunities paper, with specific mention of USAID LEAF, TNC, Madang Provincial Administration staff, the Madang Civil Society Forum and all relevant stakeholders.

To the people of Madang and Papua New Guinea, I humbly present this important report.

Thank you all.

A handwritten signature in black ink, appearing to read 'Jim Kas', with a long horizontal stroke extending to the right.

Hon. Jim Kas, MP
Governor for Madang
Madang Provincial Government

Acknowledgments

This report is a product of numerous stakeholder meetings in Madang Province from 2013 to early 2015. A wide range of organizations generously allowed their staff and representatives to attend these meetings and share their valuable knowledge and ideas, including the Madang Provincial Government, the Madang Provincial Administration, Almami Local Level Government, the Madang Civil Society Forum, The Nature Conservancy (TNC), the Wildlife Conservation Society (WCS), FORCERT and a number of community-based organizations including the Almewo, Amarata and Gatik CBO's. The generous participation in these meetings from key National Government institutions included PNG Forest Authority, the Office of Climate Change and Development, Conservation Environment & Protection Authority (formerly known as Department of Environment and Conservation), National Research Institute of PNG and the University of Papua New Guinea is also greatly acknowledged. We extend our appreciation to our development partners, including UN-REDD, with specific mention of Dr. Hitofumi Abe (FAO/UN-REDD PNG) and Mr. Masamichi Haraguchi (PNGFA/JICA) who have shared their knowledge and expertise on remote sensing and GIS for REDD+ in PNG.

We would also like to acknowledge the tremendous efforts of our key collaborative partner, TNC. Without the excellent work of TNC on Participatory Land Use Planning and Management (PLUMP) in the Adelbert Range and in introducing us to the landowners there, our work in the Adelbert Range would not have been possible. As shown in this report, PLUMP could form one of the keystone areas for action to promote economic and sustainable rural development, environmental conservation and reduce greenhouse emissions across Madang. We also acknowledge the excellent work TNC completed in the "Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis" report. This work provided the basis upon which this report is built. Thank you to Francis Hurahura, Clement Kipa, Theresa Kas, Cosmos Apelis, Nate Peterson and all from TNC for your time and support.

The landowners of the Adelbert Range, where we completed our biomass training, ground-truthed our satellite imagery and who we interviewed to understand gardening patterns, provided their valuable time openly. Thank you very much for your support and in allowing us onto your lands. The Ramu Development Foundation, the Port Moresby Chamber of Commerce and other private sector organizations have provided valuable insights into possible partnership arrangements for implementation of key parts of the proposed low emission land use plan for Madang.

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Also, a very special and important thank you to the Madang Governor, Hon. Jim Kas, for his insight and vision in developing a comprehensive policy framework for Madang Province which continues to guide the development of resources across the Province. His tireless efforts to balance economic growth with social and environmental outcomes are acknowledged and truly appreciated. We hope this report provides further information and insight into helping this difficult task. Without the support of Hon. Jim Kas and his staff, this report would not have been possible.

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Acronyms and Definitions

BAL	The Balanced Development Scenario
BAU	Business-As-Usual
CBO	Community-Based Organization
CEPA	Conservation and Environment Protection Authority
CLASLite	Carnegie Landsat Analysis System – Lite
CLRC	Constitutional Law Reform Commission
CO ₂	Carbon Dioxide
CON	The Conservation First Development Scenario
CSO	Civil Society Organization
DAL	Department of Agriculture and Livestock
DEC	Department of Environment and Conservation (now referred to as CEPA)
DDA	District Development Authority
DSIP	District Support Improvement Program
EFF	Eco Forestry Forum
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCPF	The World Bank’s Forest Carbon Partnership Facility
FORCERT	Forests for Certain: Forests for Life
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographical Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit or German International Cooperation Agency
GROW	The Economic Growth First Development Scenario
IKI	The German Government’s International Climate Initiative
JDPBPC	Joint District Planning and Budget Priorities Committee
JICA	Japan International Cooperation Agency
LELUP	Low Emission Land Use Plan
LCC	Land Cover Change
LLG	Local Level Government
MoU	Memorandum of Understanding
MPG	Madang Provincial Government
NGO	Non-Governmental Organization
NMA	National Monitoring Authority
OCCD	Office of Climate Change and Development
PEC	Provincial Executive Council
PLLSMA	Provincial and Local-Level Service Monitoring Authority
PLUMP	Participatory Land Use Management Planning
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PSIP	Provincial Support Improvement Programme
RDF	Ramu Development Foundation
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest

	carbon stocks in developing countries
RIL	Reduced Impact Logging
SGS	Formerly Société Générale de Surveillance
tCO _{2e} y ⁻¹	Tons of Carbon Dioxide Equivalents per Annum
TNC	The Nature Conservancy
UPNG	University of Papua New Guinea
UNDP	United Nations Development Programme
UN-REDD	The United Nations REDD+ Program
USAID LEAF	United States Agency for International Development Lowering Emissions in Asia's Forests
USFS RSAC	United States Forest Service's Remote Sensing Application Centre

Executive Summary

Introduction

The report, “Low Emission Land Use Planning for Madang Province: Options and Opportunities” is the outcome of numerous stakeholder consultation meetings between 2013 and 2015 on how Madang’s forests and land use are changing; possible future greenhouse gas (GHG) emissions under different development scenarios; and recommended policy and mitigation actions the Madang Provincial Government could consider introducing. The work contributes toward achieving the goals and mission outlined in the Kalibobo Vision 2020 and the Madang Province Development Plans. The report also helps the Madang Provincial Government (MPG) prepare for the likely introduction of a Reducing Emissions from Deforestation and Forest Degradation (REDD+) program into the Province and contributes towards the national REDD+ discussions in Papua New Guinea. The report aims to:

- Document historic changes in Madang’s forest and land profile and the reasons for these changes;
- Consider a ‘business-as-usual’ (BAU) development pathway for the Province and estimate GHG emissions from the forest and land use sector expected under this scenario;
- Assess alternative or different low emission development scenarios and likely GHG emission profiles;
- Examine institutional mechanisms and possible financing opportunities both within and abroad for the longevity of any plan that may emerge; and
- Provide guidance on possible emission reduction policies and mitigation actions that the MPG could introduce.

A Low Emission Land Use Plan (LELUP) is a strategic framework that articulates concrete actions, policies, programs and implementation plans to advance economic growth, improve environmental management, consider social issues, and meet development objectives. It provides a foundation for achieving long term, measurable greenhouse gas emissions reductions from the forest and land use sectors as compared to a business-as-usual development pathway. This report is not a plan – it provides the information and data upon which a provincial land use plan may be developed – a fundamental step in achieving ‘sustainable land management’ across the Province.

The report is to encourage debate and discussion on the role of PNG’s Provinces in ‘rolling out’ the national REDD+ program, which Madang has taken a leading role in progressing.

Process

The report was developed by combining REDD+ science and data analysis with a broad, bottom-up consultative approach. Between 2013 and early 2015, the USAID Lowering Emissions in Asia’s Forests (USAID LEAF) project held a number of workshops with stakeholders from the community, districts, provincial and national levels to outline early analysis of GHG emissions from Madang and possible development scenarios, and provide an opportunity for all stakeholders to debate the science, review the analysis and allow their ‘local’ knowledge and expert views to shape the report’s message and recommendations.

The report also builds upon earlier work, including the significant work and recommendations outlined in the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report completed by the Madang Provincial Government, The Nature Conservancy (TNC) and other

stakeholders. It also takes account of the national REDD+ developments to provide a very concrete example of how a Province can develop policies and actions that have real, on-the ground impacts.

Landscape Drivers

Through the consultative forums, drivers of forest and landscape changes in Madang were identified. These important drivers included: logging, both commercially planned logging and small-scale 'walk-about' sawmills; agriculture, both commercial agricultural expansion and small-scale, community agriculture; mining, both commercial and small scale, artisanal mining; and infrastructure expansion, including roads, urban expansion and resettlement. If a provincial land use plan is to be successful it will be essential to understand the multiple drivers of landscape change and the positive and negative impacts of this change (as measured by economic, social and environmental indicators).

Data Sources and Analysis

Deforestation, degradation and resulting greenhouse gas emissions between 2000 and 2014 were estimated using freely available global data and methods, including the 'Hansen' Global Forest Change data, the 'CLASLite' software product and a specially designed multi-date trend analysis. All are based on time-series interpretation of medium resolution Landsat imagery and all have known limitations. These methods were used because the USAID LEAF project did not have the time or resources to complete a validated historical land cover change report for Madang using high resolution imagery, and PNGFA's excellent work on forest and land use change using the CollectEarth software will soon supersede this work making these efforts redundant. The significant advantages of the methods used are in quickly (and freely) illustrating trends and patterns of land use change upon which a policy discussion can start – not in a highly accurate quantification of exact rates.

This preliminary analysis reveals:

- Historical forest loss is moderately high with pressure for future forest conversion likely to remain high;
- Historical degradation rates across Madang appears widespread and again potentially significant;
- USAID LEAF has validated some of the remote sensing analysis and it appears that the global data sets used are relatively reliable. But caution is still needed in interpreting the preliminary results reported and further analysis is required;
- The different drivers will require different policy and mitigation actions to productively manage; and
- Given the relatively high carbon stocks of Madang's forests and historical rates of forest loss, there is potential to establishing a REDD+ program or land use planning process to reduce greenhouse gas emissions.

Institutional Development

The results indicate that a province-wide approach to lower emissions is required and possible. The report recommends that the MPG Planning Division be mandated to develop and implement a cross-sectoral approach to provincial-wide land use planning. The MPG Planning Division would need to be adequately resourced, including remote sensing and GIS capabilities. The Provincial Climate Change Committee and the Madang REDD+/LELUP Working Group Committee should form

a joint steering committee and technical advisory body and promote effective coordination across all sectors as a result of its broad representation.

Scenario Development

In trying to address the drivers of landscape change and to find a balance between economic growth, environmental conservation and social equity, a number of development scenarios were modelled. The aim is to help policy makers and community members understand the implications and impacts of various policy options by estimating future changes on environmental, social and economic indicators and expected greenhouse gas emissions.

For those drivers where policy and mitigation actions could be feasibly introduced, i.e. commercial logging, agriculture and mining; road development; and community agriculture, four scenarios were considered:

- Business-As-Usual (BAU);
- Economic Growth First (GROW);
- Conservation First (CON); and
- A Balanced Approach (BAL)

Development assumptions for each driver are outlined in Table 1 below.

Table 1: Scenario assumptions for each driver of forest and land use change

Scenario	Oil Palm Expansion	Mining	Road Building	Logging	Subsistence Agriculture
Business-as-Usual (BAU)	1,500 ha/year Lax conservation regulations	2 new mines to 2035 Lax conservation regulations	Completion of proposed inter-provincial road network Lax conservation regulations	Extraction continues at historical average in three currently active concessions	Area under subsistence agriculture increases with population (2.7% per year) No community land use planning
Growth First (GROW)	2,250 ha/year Lax conservation regulations	3 new mines to 2035 Lax conservation regulations		Extraction expanded to five concessions	
Conservation First (CON)	1,500 ha/year Strict conservation regulations	2 new mines to 2035 Strict conservation regulations	Completion of proposed inter-provincial road network Increased conservation regulations	Conversion of all logging concessions to protected status	Area under subsistence agriculture increases with population (2.7% per year) 50% of rural
	1,500 ha/year Moderate conservation regulations				

Balanced (BAL)	2,250 ha/year Moderate conservation regulations	3 new mines to 2035 Strict conservation regulations		Extraction continues at historical average but reduced impact logging is implemented	population adopts community land use planning by 2025
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Figure 1 shows that the selection of policies has a large effect on future impacts. A policy that continues ‘business-as-usual’ development in Madang is estimated to result in over 2.5 million tons of carbon dioxide emitted per year ($\text{tCO}_2\text{e y}^{-1}$) (see graph below). A ‘balanced’ approach may reduce emissions by 25%.

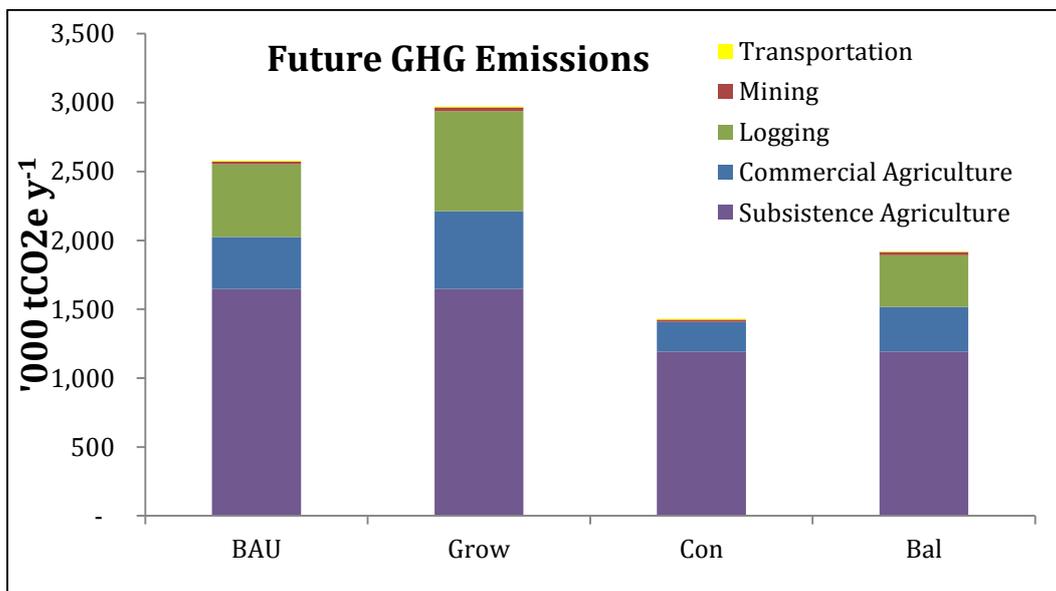


Figure 1: Greenhouse gas emissions for each scenario, across all drivers

This analysis is to help the MPG make better informed policy and development decisions. Remote sensing and GIS capacity is required within the Province to continue this work and aid in spatial planning of on-going resource development across the Province.

Financing

The sustainability of any land use plan is dependent on a committed, long term funding arrangement. Through stakeholder consultations in Madang and Port Moresby, various possible funding sources were identified. The MPG pledge of K1.5 million provides an immediate financial resource to implement a number of recommendations made in this report and in the earlier “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report. Further financial support could also be provided through the Ramu Development Foundation, provided mutual goals were found between the Foundation’s mission and the implementation of actions under any LELUP.

Recommendations

Institutional Development for the Madang Provincial Government:

1. Introduce a time-bound, consultative provincial land use planning process that produces a widely accepted, multi-sector Provincial land use plan.
2. Review and harmonize current policies, laws and regulations to ensure adequate regulatory support for the development of an ambitious LELUP.
3. Mandate the MPG Planning Division as the entity responsible for the development, implementation and monitoring of a LELUP.
4. Task the Provincial Climate Change Committee and Madang REDD+/LELUP Working Group to act as a steering and advisory committee to the MPG Planning Division.
5. Introduce the LELUP concept to key intergovernmental committees, such as the National Monitoring Authority, to ensure national level recognition and support.
6. Assess the operational effectiveness of each District Development Authority (DDA), and if functional mandate the DDA to monitor the implementation of actions at the local level government level.

Implementation:

7. Establish and resource a small remote sensing and GIS unit (preferably within the Planning Division) to measure and monitor forest and land use change and assist in all spatial planning.
8. Scale-up and replicate the successful PLUMP work in the Almami Local Level Government (LLG) to other LLGs, wards and districts throughout Madang Province.
9. Work with PNGFA to further strengthen the implementation, regulation and monitoring of forest codes of practice and the expansion of the current reduced impact logging program.
10. Register and coordinate/regulate “wokabout sawmills” and raise awareness of sustainable forest management and resource use through these ‘wokabout’ mills.
11. Review conservation priority areas and landscapes identified in the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report and consider the establishment of protected areas for high priority landscapes under threat of conversion or persistent degradation.
12. Develop agricultural siting tools to identify the most appropriate locations for development of commercial agricultural developments.

Financing:

13. USAID LEAF to collaborate with other development partners on a funding proposal to the MPG based on recommendations outlined in this report and the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report.
14. USAID LEAF and other development partners to consult with the Ramu Development Foundation on expanding its funding window to support low emissions land use actions and submit a proposal based on recommendations outlined in this report and the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report.
15. USAID LEAF to forge a strong working relationship with the Port Moresby Chamber of Commerce and Industry and present on the advantages to its members of investing in low carbon land use initiatives.

Capacity building and understanding:

16. USAID LEAF to 'hand over' all training material and data and analysis associated with this report to TNC and other development partners and work with all partners to build knowledge and understanding of the potential for a low emission land use plan.
17. The Madang Provincial Government to work with: National Level Government Departments such as PNGFA, OCCD, National Planning, DAL, MRA; international development partners and donors such as FAO/UN-REDD, JICA, USAID, AUSAID and ITTO; NGOs and CBOS; and the private sector to build awareness on the potential of a Madang LELUP.

Conclusion

This report to the Madang Provincial Government outlines historical landscape changes and GHG emissions associated with this change. Building upon this analysis and through a number of stakeholder consultation meetings, four scenarios are considered for the five critical drivers of landscape change. GHG emissions for these scenarios were modeled over the next 20 years. The results suggest that Business-As-Usual (BAU) development will release approximately 2.5 million tons of carbon dioxide per year, but that there are valid and balanced alternatives to significantly reduce this emission load.

The report recommends a number of policy and mitigation actions that may be introduced to reduce future emissions. Introducing a provincial land use planning process is a critical first step in moving toward a 'green economy' and promoting a low emission development pathway for the Province. This will help achieve the Kalibobo 2020 objectives and various national climate change goals.

1 Introduction

The international community has agreed that a “low-carbon development strategy (is) indispensable to sustainable development”¹. The Papua New Guinea 2050 vision embraces this concept by clearly recognizing the threat posed by climate change to PNG’s globally significant ecosystems and cultures and promotes sustainable development through the ‘wise use’ of resources across all sectors. Madang’s Kalibobo 2020 Plan further promotes a ‘peaceful, safe and secure’ Province through the effective planning and implementation of ‘sound, broad-based economic development’ and ‘sustainable land development’ across all sectors and industries that rely on Madang’s unique natural resources.

Given the considerable economic pressures now facing Madang Province, setting out a low emission development pathway will be challenging. The three economic corridors of Madang are to facilitate major infrastructure development, generate positive economic benefits and improve access to education, health facilities, markets and safe, clean drinking water. But as outlined in this report and the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis”², finding the balance between economic development, environmental stewardship and social equity is difficult. Without a clear plan going forward, ‘sound, broad-based economic development’ that is environmentally and socially responsible may not be achieved.

Land use planning is the starting point in the discussion over resource allocation and resource use. As over 95% of greenhouse gas (GHG) emissions in PNG are derived from the forest and land use sector, this report focuses on those sectors and the important role of Reducing Emissions from Deforestation and Forest Degradation (REDD+) in a low emission development pathway for Madang Province.

Combining land use planning with strategies to reduce GHG emissions, a Low Emission Land Use Plan (LELUP) is a strategic framework that articulates concrete actions, policies, programs and implementation plans to advance economic growth, improve environmental management and meet development objectives. It provides a foundation for achieving long term, measurable greenhouse gas emissions reductions from the forest and land use sector as compared to a business-as-usual development pathway.

But this report is not a plan – the report is only intended as a first step. It brings together information and data, outlines options and provides recommendations for the Madang Provincial Government (MPG) to consider. It provides the essential base if the Province considers a land use plan an important tool in helping to achieve the Kalibobo 2020 vision. The aim of this report is to:

- Document historic changes in Madang’s forest and land profile and the reasons for these changes;
- Consider a ‘business-as-usual’ (BAU) development pathway for the Province and estimate GHG emissions from the forest and land use sector expected under this scenario;
- Assess alternative or different low emission development scenarios and likely GHG emissions profiles;

¹ Cancun Agreement, UNFCCC/CP/2010/7/Add.1

² The Nature Conservancy and Madang Provincial Government (2013), Madang Sustainable Development: A Ridges-to-Reef Gap and Priority Analysis, published by The Nature Conservancy. Available from: <http://www.leafasia.org/sites/default/files/public/resources/Madang-Sustainable-Development-R2R-Gaps-and-Priorities-12-February-2014-reduced2.pdf>

- Examine institutional mechanisms and possible financing opportunities for the longevity of any plan that may emerge; and
- Provide guidance on possible emission reduction policies and mitigation actions that the MPG could introduce.

There is now a unique opportunity to capitalize on a growing understanding of the emission profile for Madang and possible mitigation actions and policy choices to maintain the economic growth potential of the province that is balanced with the environmental and social stewardship entrusted with the MPG. Sustainable financing options, while still somewhat ‘cloudy’ also contribute to a growing confidence that a highly ambitious low emission land use plan for Madang Province is possible.

While the MPG can direct such an ambitious plan, it will take a genuine collaborative effort with the National Government, the private sector, civil society, landowners and other stakeholders to really develop specific policy decisions and mitigation actions to reduce GHG emissions within a land use planning framework.

This report is divided into nine major sections:

Section 1: Introduction to set the scene and outline the aims of this report.

Section 2: Defines and explores what a low emission land use plan is and why it is important for Madang Province.

Section 3: Outlines the background and consultative process used in developing this report.

Section 4: Examines the current institutional settings and recommends an appropriate ‘home’ within the MPG for the development and management of a low emission land use plan.

Section 5: Reviews key historical drivers of land use and forest change in the Province since 2000 and provides an estimate of GHG emissions resulting from this change.

Section 6: Examines four possible emission development pathways for the Province (BAU, high growth, high conservation, balance developed), focusing on the logging, agriculture (commercial and subsistence), mining and transportation sectors.

Section 7: Outlines current knowledge on possible public and private funding sources that may facilitate the development of a low emission land use plan or support specific activities within a plan.

Section 8: Recommends policy and mitigation actions that the MPG could introduce to move away from a BAU scenario toward a lower emission development pathway.

Section 9: Concludes the report and recommends short and medium term next steps.

Annexes: Two technical annexes are included that provide further detail and methodology on:

- a. Scenario development and key assumptions used.
- b. Assessment of historical deforestation and degradation rates.

2 Introducing a Low Emission Land Use Plan

A **Low Emission Land Use Plan** is a strategic framework that articulates concrete actions, policies, programs and implementation plans to advance economic growth, improve environmental management and meet development objectives. It provides a foundation for achieving long term, measurable greenhouse gas emissions reductions from the forest and land use sectors as compared to a business-as-usual development pathway.

This report helps build this strategic framework for Madang Province, but does not constitute a 'plan'. The information presented in this report will need to be further debated and discussed by the MPG and other stakeholders before 'concrete actions, policies, programs and implementation plans' can be agreed upon. This document provides the necessary information upon which these decisions can be made.

The development of this report has been part of a **low emission land use planning process**. A systematic and iterative process aimed at creating an enabling environment in which dialogue between stakeholders can define sustainable land based mitigation actions and where trade-offs between economic development, livelihood needs and environmental protection are agreed.

Is this a **REDD+ strategy**? This report provides the basis for the development of comprehensive Madang Provincial REDD+ strategy but does not cover issues of benefit and incentive sharing, safeguards nor is a reference level set in this report. But whether Madang Province pursues a **green growth strategy**, a **REDD+ strategy**, or a **low emission development strategy**, the process and principles are similar³.

Figure 2 provides a simple pathway for the development of a low emission land use plan or even a REDD+ strategy. This simple framework has also been used to develop this options paper.

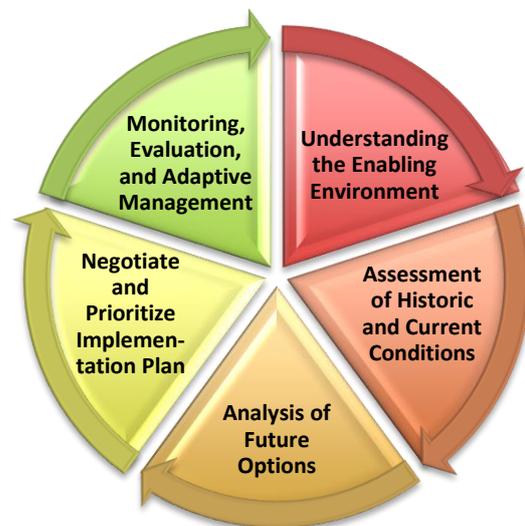


Figure 2: Framework for the development of a low emission land use plan

³ Principals of low emission land use planning include:

- Oriented to local conditions in terms of knowledge, methods, and cultural viewpoints;
- Transparent, where information is shared openly and freely among a diverse group of stakeholders;
- Interdisciplinary and cross-sectorial to ensure a sustainable balance between the social, economic and environmental needs in land use;
- Inclusive and empowering of all stakeholders to improve their capacity to plan and take actions;
- Iterative, so the process is flexible and open for the inclusion of new findings and changing conditions; and
- Outcome based so meaningful and sustainable emission reductions are achieved and reported, yet balanced with social, environmental and economic benefits.

Why pursue a low emission development strategy?

- *The current provincial and national policy environment is supportive:* The PNG Vision 2050, the draft Climate Compatible Development Plan (2013-2015), the draft National REDD+ Policy, the PNGFA Forestry and Climate Change Framework for Action 2009-2015, Kalibobo 2020, the current revisions to the Madang Environment and Forest Policy Bill and the Madang Provincial Forest Management Plan all consistently highlight: 1) the challenges climate change will present to PNG and Madang and 2) the need for action through sustainable land use planning.
- *The Madang Provincial Government is committed to sustainable development:* A substantial commitment to implement recommendations outlined in the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” has been made, including exploring a low emission development pathway for the province.
- *Emissions from deforestation in Madang are high and may increase without action being taken:* Preliminary assessments suggest that GHG emissions from the forest and land use sector may continue to rise without actions to reduce emissions (see section 6). Actions to reduce emissions can be developed and integrated into the Madang Provincial Forest Management plan, the Madang Agricultural Development plan and other land management plans.
- *A strong Provincial framework is needed to support work that has already started on REDD+:* Currently before the Provincial Executive Council is a proposal to establish a REDD+ pilot in the Adelbert Community Forestry Conservation project site. The “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report outlines a number of important actions that can be taken to further protect Madang’s unique landscapes. Without a strong Provincial framework to support these ongoing actions, these efforts may not reach their full potential.
- *On-ground actions are working to reduce emissions:* Preliminary analysis has shown that good, participatory land use planning and management in the Adelbert Range has been successful in reducing deforestation rates, stabilizing agricultural systems and reducing GHG emissions.
- *A solid participatory and collaborative environment has been established:* Strong and capacitated Provincial working groups have been established. Importantly these working groups represent multiple sectors (and not just confined to the forest sector) and link community efforts through to provincial and even national efforts.
- *Interim support is available and sustainable financing mechanisms are emerging:* The Nature Conservancy (TNC), UN-REDD program, the World Bank’s Forest Carbon Partnership Facility and other development partners can provide interim support until the plan is ‘mature’ enough to attract additional longer term funding from both private and public sources (see section 8).

What are the challenges and risks?

While there are tremendous benefits to be gained, there are also challenges and risks:

- There is no national land use plan, although discussions on a national land use plan is under way. As there are no guidelines, frameworks or examples for the Province to follow, developing a provincial low emission land use plan will be difficult and controversial.
- Capacity and knowledge at the Provincial Government level to implement such an ambitious plan are limited. There is little technical understanding of carbon accounting and how GHG emissions can be measured, monitored and reported when there is a change in land use. While considerable capacity and knowledge is now being developed at the national level, this will need to be transferred to the Provincial level where land use decisions are being made. Expertise at the provincial level on Geographical Information Systems (GIS), land use zoning, resource economics, crop/land suitability and stakeholder engagement will also be needed.

- Additional financial resources will be required to implement actions under any plan that is agreed upon. While additional funding opportunities are outlined in this report, the task in securing these resources should not be underestimated.
- The national REDD+ framework has not been confirmed and ongoing delays may mean that political willingness to advance Provincial actions may falter. Long-term political leadership and vision is needed, but must be balanced with short-term political and economic realities.
- Global data sets have been used in this analysis. While these datasets quickly and cost-effectively provide estimates of historical land use change patterns and rates of change, limitations and errors in interpretation are not unknown. It is recognized that this is a significant limitation of this study and more accurate data from the PNGFA/UN-REDD CollectEarth analysis will significantly improve this analysis.
- An effort has been made to engage a wide range of stakeholders in the development of this report. But further engagement, particularly with the private sector, will be essential if the MPG is to move forward on developing any provincial strategy aimed at reducing GHG emissions from the land use and forestry sector.

3 Process

In supporting the MPG, USAID LEAF has taken a bottom-up, consultative approach to building capacity and knowledge on REDD+, including the options and opportunities to develop a broad, inclusive framework for its development. Since early 2013 a number of community, provincial and national consultative meetings have been held to discuss the development of this framework, from which a low emission land use plan has emerged as a broad, multi-sector framework to balance GHG emissions from economic growth with environmental conservation and social equity considerations.

USAID LEAF's collaborative work program was built upon the signing of a Memorandum of Understanding (MoU) between the MPG, TNC and the Madang Civil Society Forum in 2013. The MoU's objectives were to develop a spatial plan to:

“assist MPG to make wise decisions on planning, programming and implementation of sustainable community resource management, promote climate change adaptation and mitigation actions, promote village REDD+ models and ultimately the implementation of the Provincial Sustainable Development Plan for Madang Province for five years.”

The Madang Governor, through his vision to promote sustainable development in the province, committed funding towards achieving this objective.

In 2013, TNC facilitated four stakeholder consultative workshops at the Jais Aben Resort in May, Bogia District in August, Brahman Station in September and again at the Jais Abben Resort in November. These meetings brought together community members from every districts in Madang, along with all representatives of Local Level Government (LLG), Districts, Provincial and National Government departments, NGOS, private sectors, churches and women's groups. These meetings aimed to identify environmentally sensitive sites and landscapes throughout Madang. During these meetings USAID LEAF provided information on climate change, REDD+ and the concept of low emission development as a tool to reduce emissions from forest and land use change and to help balance social, economic and environmental outcomes for the Province.

The outcomes from these consultative meetings were documented by TNC and submitted to the MPG as the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report. This report outlined the conservation priorities for Madang Province, which if implemented, could be expected to reduce GHG emissions.

TNC's work on Participatory Land Use Planning and Management Plans (PLUMP) in the Adelbert Range in the Almami LLG area of Bogia District also provided a significant base upon which to build. Early analysis by USAID LEAF suggested that the PLUMP work was reducing deforestation and possibly stabilizing agricultural systems. Furthermore TNC had proposed to the MPG that the Adelbert Range be considered a REDD+ demonstration site.

From the end of 2013 and to early 2015, USAID LEAF held a number of consultative meetings and trainings that built on the work of TNC and which aimed to strengthen capacity and understanding on GHG emissions from forest and land use change, REDD+ and how improved land use planning (at the community and provincial scale) could reduce emissions yet still allow for sustained and balanced economic growth. Those trainings and consultative meetings included:

- November 2013: A REDD+ introductory training for Madang civil society organizations (CSOs). This training built directly on the TNC consultative meetings and aimed to increase understanding of REDD+ for CSOs representatives and for them to help disseminate accurate knowledge on REDD+ to their communities.
- April 2014: A workshop for Madang stakeholders and the Madang REDD+ Technical Working Group on the drivers of forest and land use change and possible policy actions.
- June 2014: A workshop for the Madang Technical Working Group to map drivers of landscape change, build understanding and knowledge on REDD+ Forest Reference Levels and explore the opportunities and challenges of developing a Madang LELUP.
- July 2014: Forest biomass and carbon calculation training held in the Adelbert Range for both national and provincial stakeholders.
- July 2014: A Madang LELUP concept note developed and circulated with key partners to gain feedback and support for the concept
- October 2014: Consultative workshop with Madang stakeholders on historical emissions from forest and land use change in Madang and to consult on likely development scenarios; the underlying assumptions associated with these scenarios; and policies, laws and mitigation actions that the MPG could introduce in pursuit of low emission development.
- March and May 2015: Ground-truthing of remote sensing analysis and data completed.
- March 2015: The final National and Provincial consultative workshops. One-on-one meetings with PNGFA, OCCD, CEPA, CLRC and representatives from UPNG, UN-REDD, JICA, UPNG, NRI, TNC, EFF and FORCERT were held to present the outcomes of the LELUP work and seek feedback and revisions for the final report. These important consultative meetings were followed up with a final workshop in Madang, where national and provincial stakeholders met to discuss and review final outcomes of the LELUP work and recommend revisions to the report.

Through these trainings and consultative workshops, stakeholders have been able to review, discuss and debate the key findings of the analysis and provide substantial input into the development of the Low Emission Land Use Plan for Madang. The involvement of REDD+ development partners has also been extremely important. PNGFA, OCCD, UN-REDD and JICA have all watched the development of the LELUP with interest and have provided valuable input into the design and structure of the report.

Since March 2015, USAID LEAF has continued to work closely with the Madang Provincial Government through the Planning Division, to build awareness and knowledge on the importance of this work for the future economic, environmental and social development of the Province. It is hoped that this work will be 'mainstreamed' into the sector and land use planning process of Madang, especially the Madang Provincial Medium Term Development Plan.

This final options paper is planned to be submitted to the MPG on 24 June 2015. The hope is that the report will provide guidance to the MPG to achieve its visions and plans for sustainable development and green growth that achieves meaningful economic, social and environmental outcomes for the province. Although this may be seen as the final activity, it is certainly not the end of the process. USAID LEAF will continue to work with the MPG and to assist its officers to implement recommendations made in this report and the earlier "Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis" report.

4 Institutional Settings

If a LELUP for Madang is to be seriously considered, it will require an institutional ‘home’. A review⁴ was completed into the jurisdictional and legal mandates, as well as systems and structures necessary for any institution to design, implement and monitor a province-wide land use plan. Existing government institutions in Madang were reviewed as were institutions within the relevant land use sectors and traditional social frameworks and structures.

Based on this review, this section recommends the most feasible options to pursue in furthering this initiative.

Key findings

The following are key findings from the assessment. These findings are adapted to suit the various revisions and amendments made to relevant Provincial and local level government legislation during 2014⁵.

- If the LELUP is to be effectively implemented, the concept has to be integrated into existing structures and systems at the Provincial level where there is a sufficient degree of financial and legislative power and autonomy required to develop and implement a province-wide plan. Therefore the provincial political head (Governor) and bureaucratic head (Provincial Administrator) will have an extremely important role in determining the institutional structure for a LELUP, due to their mandate and discretion to make decisions concerning budget and resource allocation, approve economic and development projects and provincial plans and their leadership of legislative and executive bodies responsible for passing plans/strategies, policies and laws to be adopted and implemented at the provincial level.
- Local level governments also have certain powers relating to a proposed LELUP, but their discretion in making decisions is more restricted. The mandate of the District Administration and the Administrator (as its head) does not apply to financial/budgetary allocations although their power is exercised through their respective votes as members of the Provincial Executive Committee (PEC) and Provincial Assemblies.
- The position of the District Administration has been enhanced in recent years with the creation of District Development Authorities (DDAs) in 2014. These entities replaced the previous Joint District Planning and Budget Priorities Committees (JDPBPCs)⁶ established in 1996 which administered five-year district development plans and budget priorities at the local level. The DDAs have been given greater power, legal recognition and financial⁷ and administrative autonomy compared to the JDPBPCs, while maintaining the same administrative/management system. The primary difference is that the DDAs now own and manage resources granted yearly under the District Services Improvement Program (DSIP). Due to its very recent creation of the DDA, it is still uncertain as to whether it will also possess the ability to design, manage

⁴The initial assessment was conducted through a desktop review with material provided by both the MPG – Planning Division, The Department of National Planning and Monitoring, online academic papers, news articles and websites related to the topic of National, Provincial and Local-Level Governments in PNG.

⁵The introduction of the District Development Authorities into the Organic Law on Provincial and Local Level Governments.

⁶ s.33A of the OLPLLG.

⁷ The added bonus of situating a LELUP at the District/Local level is that it can receive continuous funding support and resources from the Province as part of the LLG budget allocated each year (K500, 000) and also from the annual District Services Improvement Program (DSIP) grants (K10 million).

and implement initiatives like the LELUP. However it is anticipated that an entity like this would need to work closely with the Provincial Government if a LELUP is developed and implemented.

- Intergovernmental committees at the National level, such as the National Monitoring Authority (NMA), which replaced the Provincial and Local Level Service Monitoring Authority (PLLSMA), coordinate and monitor the implementation of national policies at the provincial and local government levels. The benefits of having national level oversight of initiatives such as the LELUP is that financial and administrative (and possibly political) support is provided at all stages of the initiative. In addition, if the concept is proven to be successful in Madang, the initiative could be rolled out in other provinces as well.
- Potential institutional arrangements also exist within relevant sectors such as forestry, as seen in the PNG Forest Authority (PNGFA) and its Provincial offices. However, despite the obvious benefits of ‘housing’ a LELUP in an independent, multi-tiered, well-regulated, self-sustaining and technically competent entity such as this, the nature of a LELUP focuses on land use management across all land use sectors (e.g., agriculture, mining) and tenure arrangements (e.g., traditional/customary, freehold, leased). These do not fall within PNGFA’s mandate and would therefore limit its ability to effectively implement the LELUP across these other sectors.
- The Madang Provincial Government Planning Division has the traditional role of drafting all Provincial Development Plans (five-year development plans). This vital role provides an opportunity for the LELUP to be integrated into all relevant sectors and avoids limiting it to just one. However, the Madang Provincial Government (MPG), and particularly the Planning Division, are under-resourced, lack adequate technical expertise in the area of designing and monitoring emissions from land use change, and are presently stretched in the face of multiple and competing development interests and priorities.
- The Madang Provincial Climate Change Committee was set up as part of the Office of Climate Change and Development (OCCD) through its designated provincial offices under the Provincial Disaster Office (designated Chair). It consists of members from relevant sectors, civil society and community/landowner groups and is presently functional; however, it lacks the mandate and administrative/political support necessary to effectively monitor a LELUP in Madang.
- Madang REDD+/LELUP Working Group Committee was established at the beginning of 2014. The Working Group comprises representatives from the MPG, the Madang Planning Division, OCCD Climate Change Officer, Almami LLG, Almami Women’s Group, Madang Civil Society, Community Based Organizations, church representatives and officers from the Governor’s office. This committee meets quarterly and gets regular briefs from USAID LEAF program on the progress of the REDD+/LELUP work, especially in the Adelbert Range of the Almami LLG. The Working Group also provides an opportunity for local communities to raise any project-related issues and concerns, and therefore the Working Group provides an important integration and communication role between all stakeholders. The capacity of the Working Group has been considerably strengthened over the last two to three years and they are now involved in disseminating information and knowledge on REDD+ and low emission development to their respective communities. This bottom-up approach will be important in building understanding at the LLG’s, districts and eventually the province level on how a LELUP could be integrated into the current planning process of Madang.

5 Drivers of Land Use Change and Historical Emissions

The success of a LELUP is dependent upon a deep understanding of the multiple drivers of landscape change, in particular deforestation and forest degradation, and both the positive and potentially negative benefits from this change. Therefore understanding historical land use change and what is driving this change is essential in developing a balanced response to these drivers that are locally appropriate, targeted, effective and sustainable.

To determine these drivers, USAID LEAF held a number of consultative meetings with a broad range of stakeholders throughout 2013 and 2014. These meetings culminated in a June 2014 training workshop where Madang stakeholders were asked to map the drivers of landscape change from 2000 to 2014. Figure 4 outlines this analysis and while extremely rough, it provides insight into the reasons for landscape change across Madang, the likely trajectory of these changes and possible policy and mitigation actions that can be implemented to productively manage these changes.

The following section outlines primary or direct reasons for forest and land use change and illustrates broad patterns that have historically occurred across the Province⁸.

5.1 Logging

Planned Logging: The Madang Provincial Forest Plan details gazetted concessions and allowable logging yields within these concessions. Currently there are three active concessions, including Sogeram, Rai Coast and Ramu Block 1 with negotiations still continuing over logging in Ramu Blocks 2 and 3. SGS PNG Ltd. records provide a relatively reliable record of commercially valuable log volumes exported from Madang; however, total log extraction volumes from logging coupes is difficult to obtain. While there has been considerable debate about the economic and environmental impacts of logging in PNG, it is a recognized driver of landscape change in the Province (Figure 3 illustrates log road patterns in Ramu Block 1 and Sogeram concessions) and an action that can degrade forests through the selective logging of highly valuable species (e.g., Kwila).

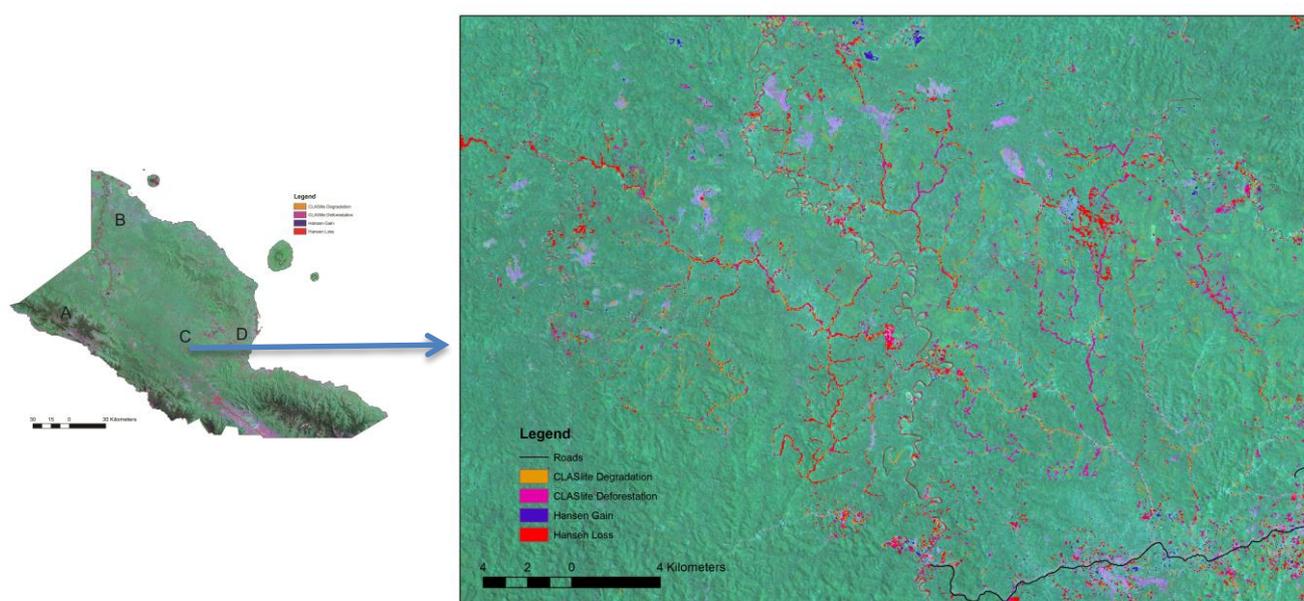


Figure 3: Logging Patterns in the Ramu Block 1 and Sogeram Concessions (Point C)

⁸ Throughout Section 5, deforestation and degradation patterns are highlighted using the 'Hansen' Global Forest Change product and outputs from the CLASLite Analysis. Annex 2 provides details on both methodologies.

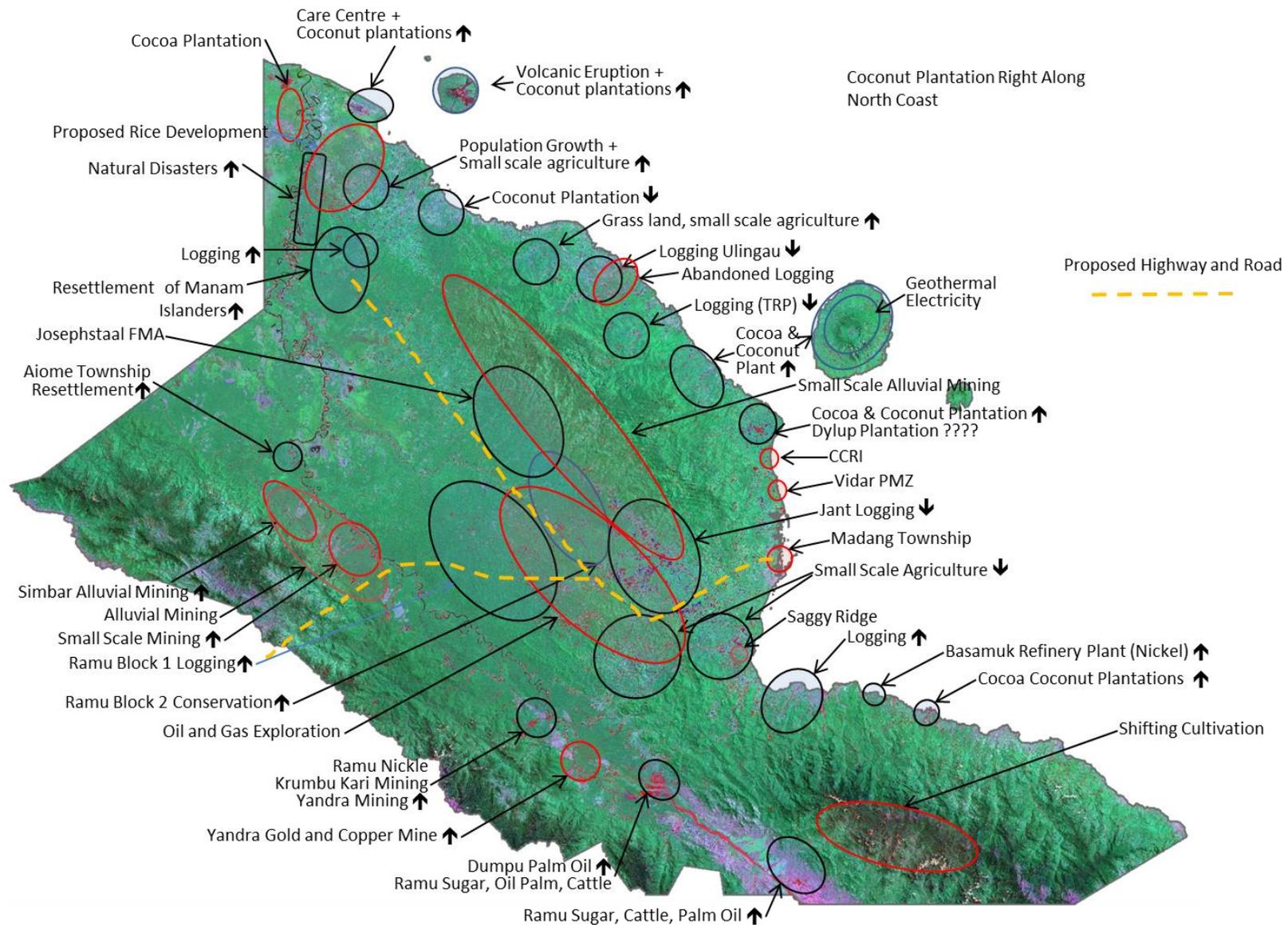


Figure 4: Drivers of landscape change identified by Madang stakeholders in 2014 (↑ indicates increasing trend, ↓ indicates a decreasing trend)

Unplanned Logging: During the stakeholder meetings, there was considerable debate about the impact of unlicensed, unregulated ‘wokabout’ sawmills. While these ‘wokabout’ sawmills provide economic opportunities for owners and an easy source of relatively cheap timber for localized construction, it is believed the poor regulation of these ‘wokabout’ sawmills can lead to localized degradation of forest resources. Current limited knowledge on numbers of ‘wokabout’ mills and extraction rates makes it difficult to quantify the impact on the forest and resulting GHG emissions from this driver.

5.2 Commercial Agriculture Expansion

To date, the expansion of agricultural ‘commercial’ crops such as sugar, palm oil and cattle has been restricted to the already cleared eastern end of the Ramu Valley. However this is likely to change in the immediate future with increased pressure to convert forest lands for commercial agriculture enterprises. For example, there is a proposal for the development of a significant pineapple estate in Madang by the Dole Food Company. While the company has a corporate social responsibility statement that seeks to ‘map and analyze activities in order to locate the sources of carbon emissions and develop alternative practices’ (<http://dolecrs.com/>), a strong enabling environment will be needed to correctly locate any major development away from sensitive forest lands.

Palm oil continues to be highly profitable and an economically resilient food crop. Ramu Agri-Industries (owned by New Britain Palm Oil) has established approximately 5,000 hectares of oil palm at Dumpu in the Ramu Valley (and a similarly large sugar estate and a beef enterprise of approximately 15,000 cattle). While this estate was established on cleared agricultural land, it is expected that oil palm plantations will expand in Madang (Harris, et al., (2013)⁹ has stated approximately 30% of any future palm expansion in PNG is likely to occur in Madang Province). Current expansion plans have been difficult to obtain and while it is expected most companies would operate in accordance with the Roundtable on Sustainable Palm Oil principles and criteria, considerable pressure will be placed upon the MPG to locate new oil palm estates in areas that avoid or minimize forest conversion.

Historically the conversion of coastal forests to coconut plantations for copra has been a significant driver of landscape change. However this conversion process has now finished with some senescent coconut plantations reverting back to forest or other land uses.

5.3 Community Agriculture

The role and impact of community agriculture in the form of gardening and shifting cultivation is a highly debated issue. But it is undoubtedly a driver of landscape change – both in terms of forest loss and forest gain. Figure 5 and Figure 6 illustrate a pattern of subsistence agriculture exerting pressure on the edges of forest in the Middle Ramu and Bogia Districts.

With increasing rural populations, increasing road access (see section 5.5) and more commercial crops being grown by farmers (e.g., coffee and cocoa), it is expected that subsistence gardening will be both more economically important for rural communities and continue to place pressure on existing forest resources.

⁹ Harris, Nancy L; Brown, Kevin R; Netzer, Michael; Gunarso, Petrus; Killeen, Timothy J. (2013) Projections of oil palm expansion in Indonesia, Malaysia and Papua New Guinea from 2010 to 2050. Roundtable on Sustainable Palm Oil

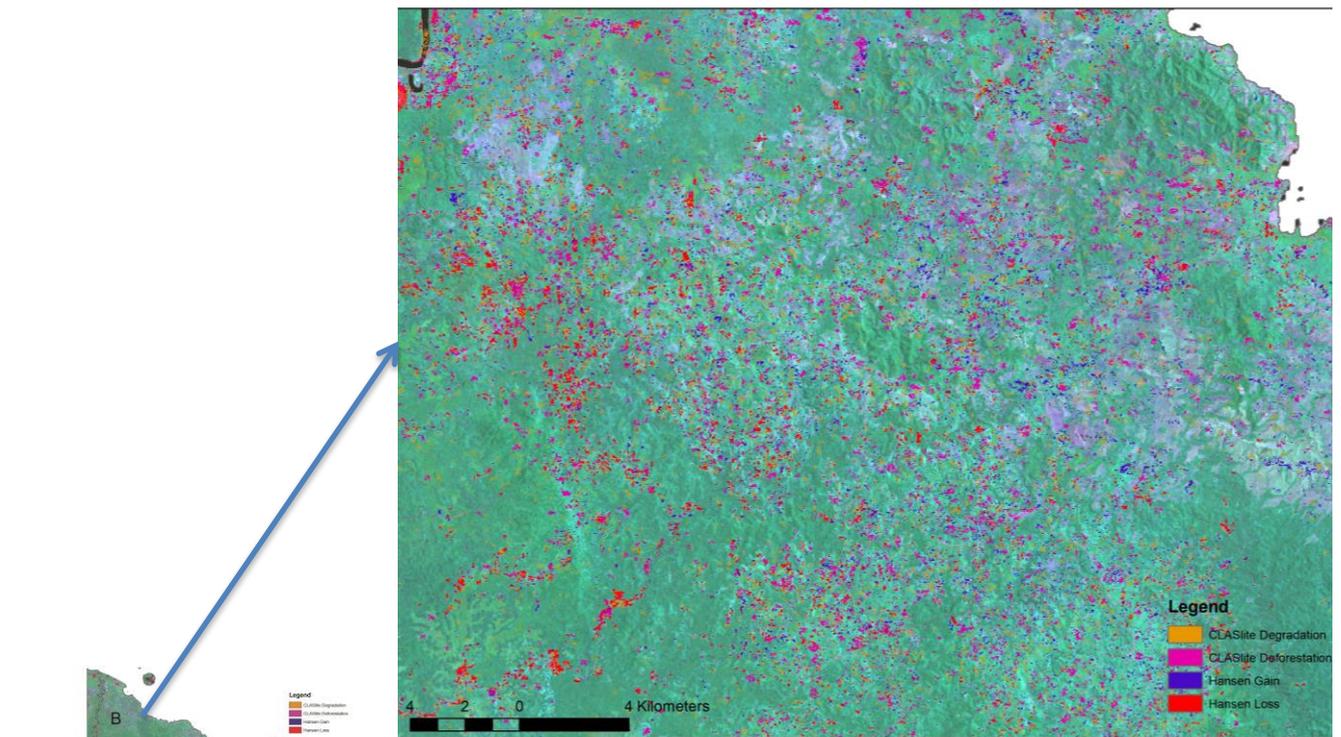


Figure 5: Forest Changes, Bogia District (Point B)

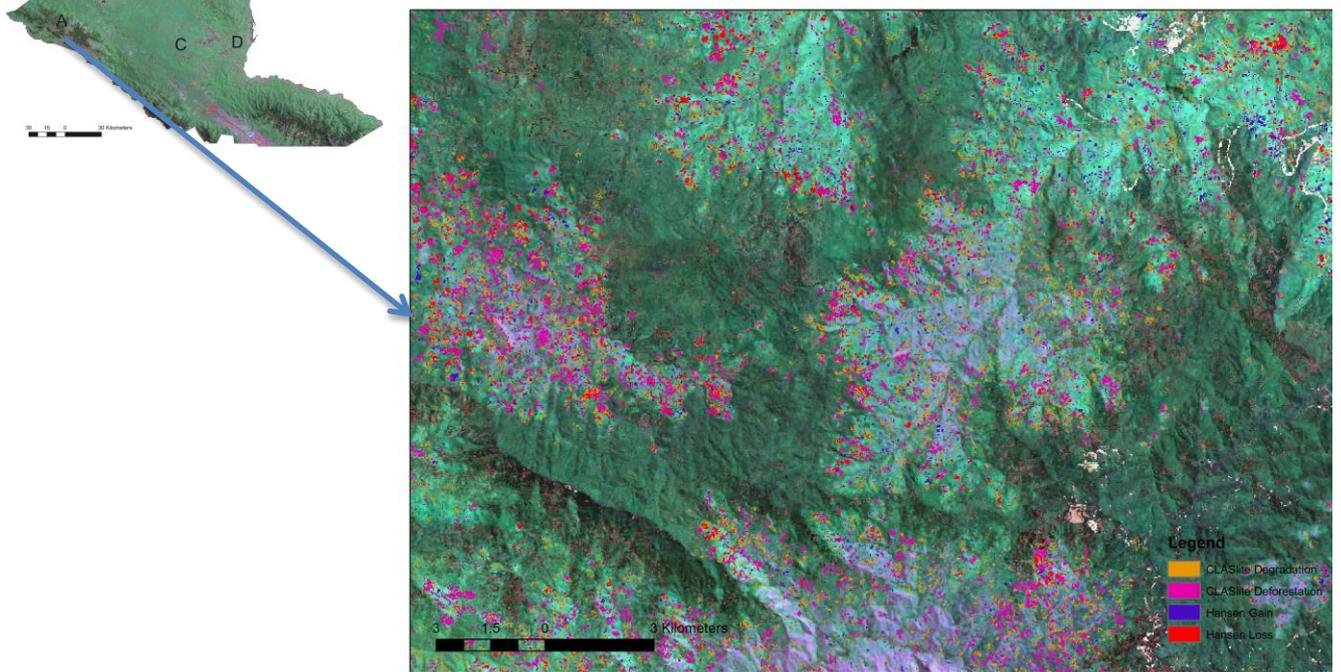


Figure 6: Forest Changes, Middle Ramu District (Point A)

Evidence from the Adelbert Range indicates that PLUMP, initiated by TNC, is having a positive impact on stabilizing agricultural systems. This evidence is only preliminary, but the zoning of lands for agricultural, hunting, forest conservation, village and other land uses by communities does seem to be both reducing deforestation rates and stabilizing agricultural systems.

5.4 Mining

Formal, Large Scale Operations. Currently there is only one operational mine in Madang Province, the Ramu Nickel and Cobalt mine operated by the Chinese Metallurgic Company. If only considering a GHG emissions footprint from forest clearance for this laterite open-pit mine, the impact of the mine is relatively small. However the road infrastructure to the Kurumbukari Mine and the 135km slurry pipeline to the Basamuk Refinery on the Rai coast is a consideration of how land use is planned in the districts of Usino Bundi and the Rai Coast.

Other proposed mining operations currently being explored include:

- The Yandera Mining Exploration lease covering 1,500 square kilometers is currently being explored. The Marengo Mining Limited company has reported a copper deposit estimated at 248 million tons of 0.43% copper with additional deposits of lower copper extraction rates, gold and molybdenum. Current projections are for a large scale open pit mine with a throughput of 25 million tons per annum over a 20-year life. The Madang Provincial Government prefers a land-based disposal system (unlike the deep sea tailings used for the Ramu Nickel and Cobalt mine).
- Heritage Oil, a UK-based company, is currently exploring an active petroleum system over a 5,508 square kilometer area in the Ramu Basin (<http://www.heritageoiltd.com/our-operations.aspx>).

Mining is expected to play an increasingly important role in the Madang economy and therefore presents a significant economic opportunity for the Province¹⁰. But associated infrastructure may also increase pressure on forest resources by opening up access to previously inaccessible forest lands.

Informal, Small Scale, Subsistence Mining Operations. Data on the extent of small scale, subsistence mining is not available. However stakeholders have agreed that the number of informal miners and their impact on natural resources, particularly along stream and rivers systems is likely to increase. Areas identified are along the Ramu River and its tributaries in Sambai LLG of the Middle Ramu District.

5.5 Road Development

There is currently a limited road network across the Province, with plans to extend this network over the next five to 10 years.

- **North Coast Highway:** This road currently connects Madang town with Bogia district ending at the Ramu River. This road is expected to be extended through to Wewak in the East Sepik Province allowing for improved market access and economic opportunities for both provinces.
- **Ramu Highway:** This road connects Madang town to the mining and agricultural-rich districts of Usino Bundi and the financial center of Lae. The Madang Provincial Government plans to re-route this road from Usino Junction through the Gogol Valley to cater to Ramu Sugar for exporting their produce from the Madang Port.
- **National Highlands Highway:** This 300 kilometer road will run from Madang through the Sogeram valley, onto Simbai and eventually the town of Hagen in the Western Highlands Province. It will serve 40,000 to 50,000 people of the Middle Ramu District and 60,000 to 80,000 people of the Bayer River and Hagen District of Western Highland Province.

¹⁰ Current mining leases across Madang can be accessed at the PNG Mining Cadastre Portal, <http://portal.mra.gov.pg/Map/>

- **South Coast Highway:** This highway fell into disrepair and is now closed. But there are plans to revitalize this road to link the Ramu Nickel processing plant at Basamuk Bay to Madang town (to be partially funded by the mine operators). This will also provide an important economic corridor for coastal communities along the Morobe/Madang coast line.
- **Manam-Madang Highway:** To support the Manam resettlement program in the Andarum area of Bogia District, a highway is proposed to connect this settlement to Madang town, via the National Highlands Highway. This resettlement program and the connecting highway provides a significant economic opportunity for the expected 25,000 people involved in this resettlement program and additional communities along this Provincial east-west link.
- **Provincial Trunk Roads:** These roads are designed to serve more than 10,000 people and are extremely important social and economic links. While no further provincial trunk roads are expected, maintenance of this system is extremely important for the development of rural communities lucky enough to have access to this system.

While the expansion of this road network across Madang will have a relatively small GHG footprint, the indirect impact on forest and land resources and potential for deforestation and degradation will need to be carefully considered and balanced against the economic gains from the expansion of the road network (see Figure 7).

5.6 Settlements and Urbanization

The Manam Resettlement Program involves the resettlement of 25,000 people from Manam Island to the Andarum area of Bogia District over the next five to 10 years. To provide economic opportunities to those resettled, a 12 square kilometer oil palm estate is to be established of which six square kilometers is to be allocated to individual family units. A ‘nucleus estate’ is proposed where cluster groupings of oil palm plantations will feed a central processing and distribution point (the ‘nucleus’).

This resettlement program presents a significant challenge in balancing the vital economic needs of the resettled community with the preservation of vital environmental services, such as water and forest in Bogia district. Careful consideration of land zoning and land allocation will be essential for this program to meet its economic, social and environmental goals.

The increasing population of Madang town and growing urbanization of rural areas surrounding the town also provides an ongoing land management and land use planning challenge for provincial planners. Figure 7 illustrates land use change patterns close to Madang town. Developments such as Pacific Marine Industrial Zone (PMIZ) will also continue to advance the urbanization of settlements surrounding Madang town and may continue to see conversion of land and forest to urban settlements.

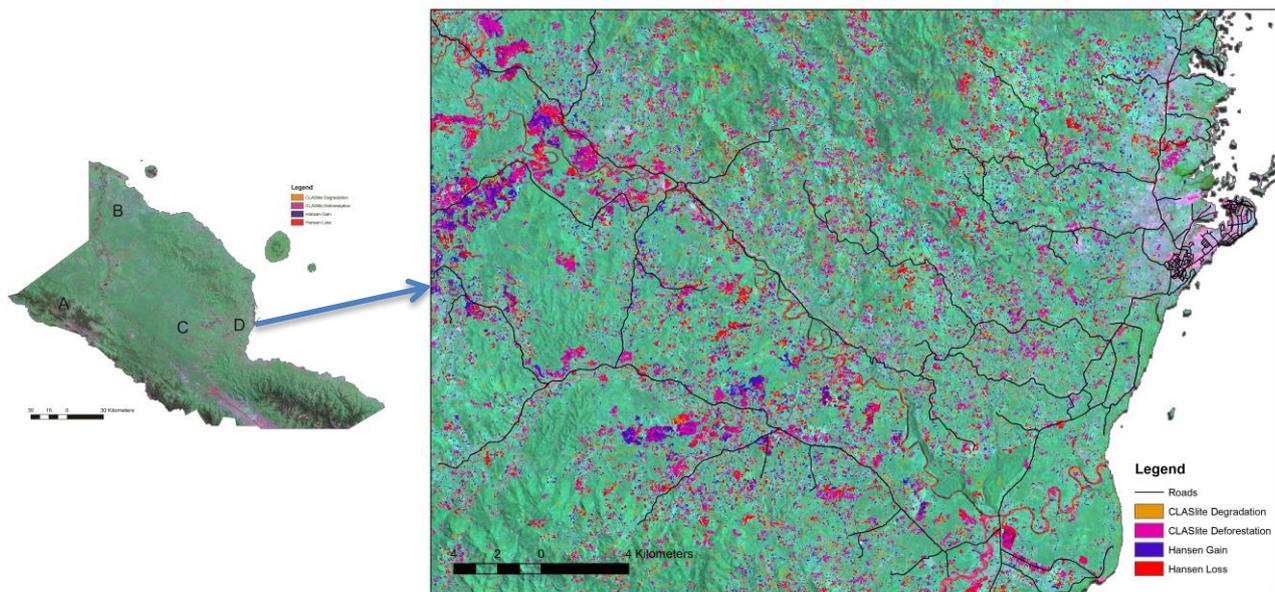


Figure 7: Forest change patterns outside Madang town and along roads (Point D)

5.7 Underlying Drivers

During the consultative meetings conducted in 2013 and 2014, participants were asked what they considered were the underlying forces, or indirect drivers, of forest and land use change. The indirect drivers identified were:

- **External market demand:** While commodity prices for most agricultural products produced in Madang (e.g., copra, coffee, cocoa) are now low, international demand for agricultural commodities will continue to drive the expansion of these crops including palm oil. This will drive larger commercial agricultural enterprises, but also bring an increasing number of rural communities further into a cash economy.
- **Population increase:** The average annual population growth rate for Madang (1980-2000) is 2.7%, leading to an increased demand for energy, food and agricultural land, as well as construction materials for housing and other buildings.
- **Migration:** This further intensifies the population pressures already felt within the Province. The Manam resettlement program is just one example of how migration/resettlement will continue to place pressure on the use of Madang's limited natural resources.
- **Internal market demand:** The increasing population is raising demand for local goods and services. Increasing demand for local food crops will encourage greater economic connections between communities and greater demand for food crops.
- **Provincial and National Policy:** National and Provincial Governments are promoting economic development to increase income levels and livelihood opportunities as well as provide the resources necessary to maintain and build necessary social infrastructure (e.g., schools, roads and hospitals).

While changing the root cause of these indirect drivers may be beyond the immediate scope of a land use plan, they are vitally important to understand these deep, institutional pressures when considering low emission development pathways and designing effective policy and mitigation actions.

5.8 Historical Deforestation and Degradation Rates and GHG Emissions

Three methodologies have been used to estimate forest loss and forest disturbance between 2000 and 2013/14:

1. **The Global Forest Change product**, (commonly known as the ‘Hansen data set’ after the lead author of this work, Hansen et al. 2013¹¹) is a pre-computed global forest change product that depicts forest loss and forest gain between 2000 and 2013. It is updated annually, freely available and based upon Google Earth Engine images.
2. **CLASlite**, (Asner et al. 2009¹²) serves as a method that is easily implemented, freely available, and has been proven effective at identifying deforestation and forest degradation in the tropics. It has a hard-coded change detection decision set that measures in-pixel spectral changes over time allowing for forest disturbance to be mapped. The CLASLite software program has been developed by the Carnegie Institution for Science.
3. **Multit-Date Trend Analysis**, uses a specifically designed algorithm developed by the United States Forest Service’s Remote Sensing Application Centre (USFS RSAC) to detect slow-onset forest change or disturbance. The method builds on the Forest Monitoring for Action (FORMA) work (Hammer et al. 2009¹³) and the USFS Forest Disturbance Monitoring Tool (<http://foresthealth.fs.usda.gov/portal/Flex/FDM?dL=0>). This method measures forest loss and forest disturbance (degradation).

Table 2 summarizes the differences between the three approaches with further detail outlined in Annex 2.

Table 2: Some of the highlights of the differences of each method are below

	Data source	Change Detection	Preliminary change detection method	Final change detection method
Hansen Global Forest Change	Landsat 7	Forest Loss and Forest Gain	Various change co-variates	Statistical classification model
CLASlite	Landsat 5, 7, and 8	Forest Loss and Forest Disturbance	In-pixel spectral change	Multi-year
Multi-date Trend Analysis	Landsat 5, 7, and 8	Forest Loss and Forest Disturbance	In-pixel spectral change and linear trend fit	Multi-date and multi-year

All three methodologies detects vegetation change, regardless of forest/non-forest type (i.e., the methodologies may map changes in plantation or oil palm estates). The Hansen data set, in particular, has been criticized for overestimating historical deforestation rates. While USAID LEAF has assessed accuracy of the Hansen and CLASLite outputs (accuracy for Hansen forest loss was 93%) (see Annex 2), great care is still needed in interpreting the outputs.

¹¹ Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, 342(6160), 850–853.

¹² Asner G P, Knapp D E, Balaji A and Paez-Acosta G 2009 Automated mapping of tropical deforestation and forest degradation: CLASlite *J. Appl. Remote Sens.* 3 033543

¹³ Hammer, D., Kraft, R., Wheeler, D. (2009) FORMA: forest monitoring for action—rapid identification of pan-tropical deforestation using moderate-resolution remotely sensed data. Center for Global Development Working Paper No. 192 (2009) (November)

5.8.1 Historical Deforestation Rates and Emissions

Deforestation Rates

Only the Hansen and Multi-Date Trend Analysis data were used to estimate historical rates of forest loss (noting the broad definition of forest). CLASLite deforestation data was not considered due to an error in the data as a result from persistent ‘banding’ across Sumkar district (see Annex 2 for further details). Historical deforestation rates are presented in Table 3 and Figure 8.

Table 3: Summary of Historical Forest Loss (2000-2013)

	Forest Loss	Forest Gain	Forest Loss % Annual Change
Hansen Global Forest Change Product	71,543 hectares	29,892 hectares	2.62% (Gross) 1.53% (Net)
Multi-Date Trend Analysis	73,150 hectares		2.68%

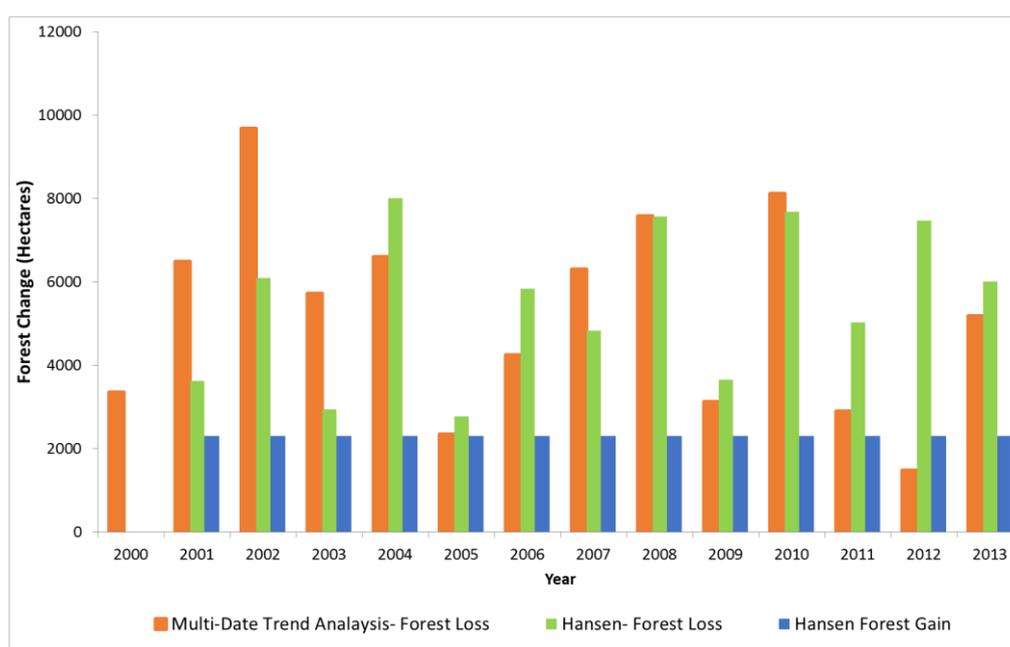


Figure 8: Historical Forest Loss and Forest Gain, 2000-2013

(Note: Hansen ‘Forest Gain’ is only provided as a cumulative figure over the period of assessment and not as a yearly figure. Therefore in Figure 8 a simple yearly average is graphed.)

Deforestation Emissions

Utilizing a pan-tropical forest carbon map of 250m resolution (Saatchi, et al. in preparation¹⁴) and overlaying the Hansen data set, forest carbon stocks by area of ‘forest loss’ were calculated:

$$\text{Live tree carbon stocks in forest (t C ha}^{-1}\text{)} = (\text{AGB} + \text{BGB}) \times 0.47$$

Where,

AGB = area weighted average above -ground biomass (from Saatchi, et al.)

BGB = area weighted average below-ground biomass (from Saatchi, et al.)

0.47 = Conversion factor from biomass to carbon (IPCC default)

¹⁴ For earlier work, see Saatchi et al, 2011, Benchmark map of forest carbon stocks in tropical regions across three continents, Proceedings of the National Academy of Sciences of the United States of America PNAS, Proceedings of the National Academy of Sciences, Vol. 108 No. 24

Between 2000 and 2013, the average forest carbon stocks for areas identified as forest ‘loss’ was 106.9 tons of carbon per hectare.

Multiplying mean forest carbon stocks by area lost and converting to carbon dioxide emissions, it is estimated **27,500,000 million tons of carbon dioxide were released from forest loss between 2000 and 2013**¹⁵.

5.8.2 Historical Degradation Emissions

Degradation Rates

Detecting and measuring forest disturbance from satellite images is difficult given the slow, subtle changes in forest canopy, forest phenology, persistent cloud cover across Madang and data errors in the Landsat 7 satellite imagery¹⁶. This partly explains the difference between the CLASLite and Multi-Date Trend Analysis outcomes (see Table 4 and Figure 9). The Multi-Date Trend Analysis is also likely to be under reporting forest disturbance due to the conservative parameters placed on detecting the slow/subtle change in forest canopy spectral images.

Table 4: Summary of Historical Forest Disturbance (2000-2013)

	Forest Disturbance	Forest Disturbance % Annual Change
CLASLite	43,195 hectares	1.58%
Multi-Date Trend Analysis	13,997 hectares	0.51%

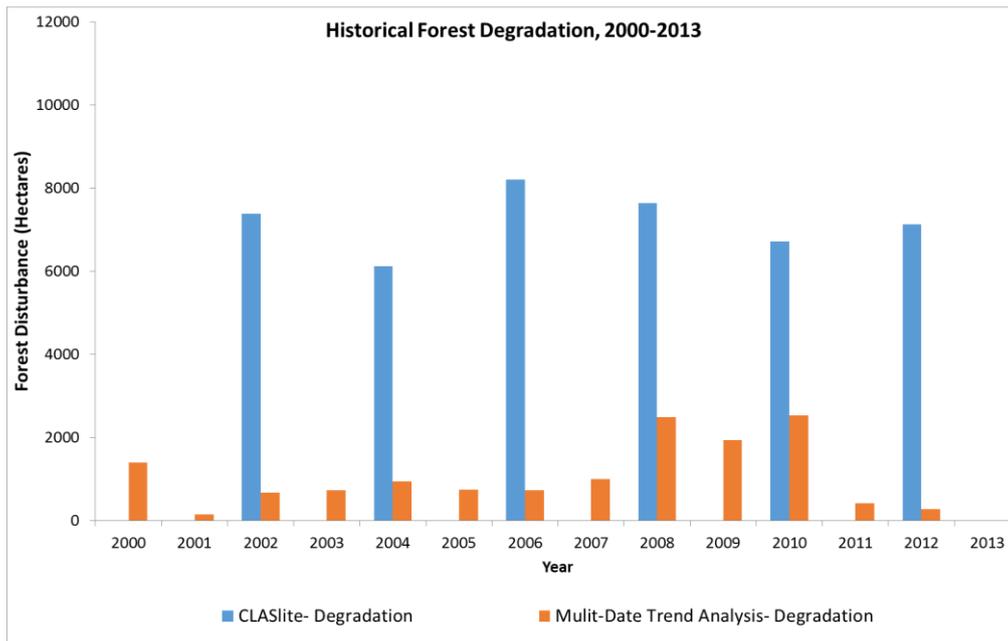


Figure 9: Historical Forest Disturbance, 2000-2013

¹⁵ This is a very simple calculation. Carbon in dead wood, litter and soils are not considered nor post-deforestation carbon stocks.

¹⁶ Due to the difficulty in obtaining historical cloud free imagery and the malfunction of the Landsat 7 satellite, images over a two-year time period had to be merged to form a composite product. The United States Forest Service Remote Sensing Application Centre (USFS RSAC) completed this process by merging images between 28 May and 3 October over this two year period (see Annex 2 for more detail).

Figure 9 should be considered as providing a conservative upper and lower range of historical degradation rates. Further analysis is definitely needed, but these preliminary outcomes do suggest that degradation is a potentially significant issues.

Degradation Emissions

Using the CLASLite data, the same forest carbon stocks calculated for deforestation, and using a highly conservative estimate of only a 10% loss in forest carbon due to disturbance, it is estimated that approximately **1,700,000 tons of carbon dioxide were released through forest degradation between 2000 and 2013.**

Summary

These estimate provided in this section are only preliminary and provide, at best, a ‘first-order’ estimate of both deforestation and degradation rates and associated emissions. The work of PNGFA/UN-REDD to quantify historical forest and land use change through the CollectEarth software will supersede the estimates report here. When this analysis has been completed, this report should be revised and this section updated.

Section Summary

There are a number of very important issues that need to be restated:

- Based on the preliminary analysis completed here, historical forest loss is moderately high with pressure for future forest conversions likely to remain high. Forest degradation is likely to be significant and widespread across the province. The main drivers are subsistence agriculture, commercial agriculture, logging, mining and infrastructure development.
- Policy interventions and mitigation actions can be designed and implemented by the MPG to counter the drivers mentioned above.
- The global data sets used to determine historical rates of forest change are likely to overestimate deforestation, and while their accuracy has been validated (see Annex 2), further validation and scrutiny is required. Great care must be used in interpreting and quoting the final figures presented.
- While there are known limitations in the data sets and methods used, the assessment of historical trends and patterns is still very valuable and extremely important in gaining a deeper understanding of the drivers of forest and land use change in Madang.
- The forests of Madang have relatively high forest carbon stocks and with the estimated historical forest loss rates, there does seem some potential in establishing a REDD+ strategy or land use planning process to reduce emissions and seek outside investment in this program.

6 Low Emission Development Scenarios for Madang Province

6.1 Methodology

The purpose of scenario planning is to help policy makers and community members understand the *plausible* implications and impacts of various policy options. By estimating the future impact of decisions across environmental, social and economic indicators, Madang has a much better chance of achieving provincial development that is agreeable to the widest range of residents and interests. Combining stakeholder consultation on development goals and priorities, and a GIS model (Figure 10), quantitative assessments of development options are outlined in this section of the report. It must be stated that the analysis outlined here and detailed in later sections is highly tentative in that many assumptions had to be made about development targets. For future development of scenario planning, Madang should use official policy and development targets where possible. Much of the value of this analysis is that it provides a framework for GIS-based landscape planning that can be adapted and refined for future use.

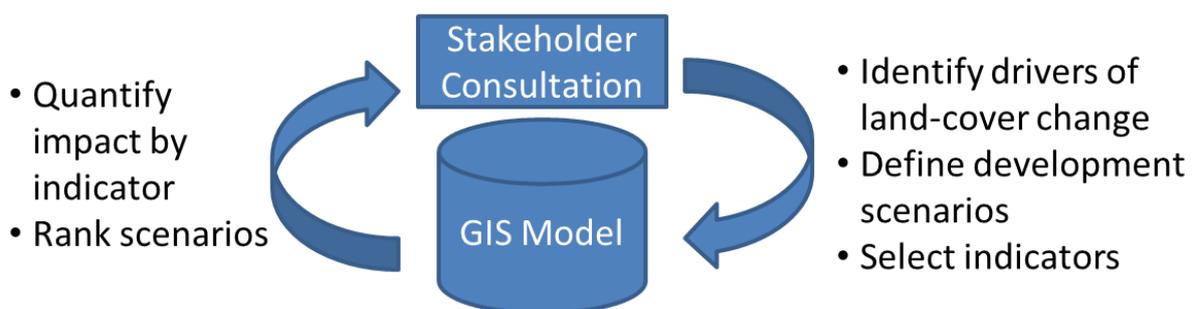


Figure 10: Overview of scenario modeling approach.

USAID LEAF began a stakeholder consultation process in 2013 (see section 4) through a number of workshops and individual meetings in Madang and Port Moresby, and continued this process throughout the entire scenario modeling work. Early consultation focused on the identification of drivers of future land cover change (LCC) as described in Section 6 with the five major drivers of LCC including: logging, commercial agriculture, community agriculture, mining and road development.

USAID LEAF then worked with stakeholders and conducted a literature review to define development scenarios for each of these five main drivers. For each driver, scenarios were defined within four broad development pathways:

- Business-as-Usual (BAU),
- Economic growth first (GROW),
- Conservation first (CON), and
- A balanced approach seeking to optimize economic and conservation outcomes (BAL).

For each driver, these general scenario pathways had to be made into specific policies that could be modeled within a GIS environment. Because the strength of GIS is quantifying geographic patterns, the specific criteria used to define each driver's four scenarios lean towards policies that regulate the location that certain activities may occur (i.e., a policy limiting conversion of high biomass landscapes to commercial agriculture), and are described in more detail in Section 6.2. The scenarios are evaluated based on the selection of indicators by stakeholders and recent statements

by the MPG, and focus on greenhouse gas (GHG) emissions and the total expansion or growth allowed for each driver.

For each driver, a separate GIS model was then constructed that used global and PNG-specific land-cover, population and topographic maps, as well as information on concession areas. While each driver’s relationship with the landscape is different, the general structure, as illustrated in Figure 11 is as follows:

1. A suitability map was created that shows which areas across the Province are more appropriate for the activity, given the climatic, policy and topographic condition of each area.
2. This suitability map is then overlaid with another map that restricts development from some areas (the restriction map). For example, the map of conservation priority areas detailed in the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report was used extensively to plan each scenario.
3. Future areas of expansion of each activity are then mapped in reference to the suitability and regulation maps.
4. Once the future area of each activity is mapped, future expansion is compared to the ecological and conservation value of the landscape at those locations.
5. This comparison is conducted for each affected area (defined by individual map pixels), and when summed across the landscape, provides a quantitative assessment of the scenario’s impact.

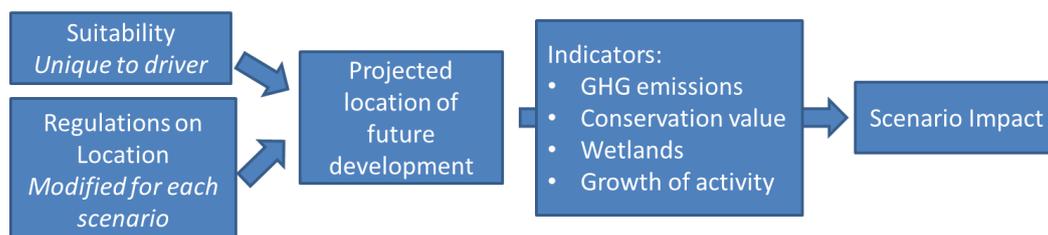


Figure 11. Structure of GIS scenario modeling

The outputs from the GIS model allow actions to regulate one driver to be compared against other drivers. The following sections provide a more detailed description of the individual drivers modeled, an overview of each scenario, and recommendations for continuing to incorporate this work into Madang’s planning processes.

6.2 Sector Introductions and Scenario Definitions

Stakeholders identified five drivers, or sectors, that were likely to result in future land cover change. Based on the four general scenarios detailed in Section 6.1, we devised a series of policies and assumptions that defined the exact parameters used to model future impact. In general, scenarios prioritizing conservation contained more restrictions on the kinds of activities permitted in high priority conservation landscapes, while high growth scenarios had fewer restrictions and an overall higher rate of expansion.

6.2.1 Logging

The selective logging sector has had a large historical importance in Madang, and represents the first global extractive activity to enter native forests. Logging, unlike the other sectors modeled here, does not change land cover, and is therefore difficult to model in a GIS. Scenarios for this

sector were modeled by projecting historical extracted volume into the future based on a series of assumptions:

- Business-as-usual scenario, logging continues at the historical extraction rates;
- Conservation scenario, protected status for forests is expanded; and
- Balanced scenario, Reduced Impact Logging (RIL) practices are expanded.

6.2.2 Agriculture – Commercial

Commercial agriculture refers to the establishment of large-scale plantations and agricultural enterprises primarily for the production of export commodities. For Madang, the most important commodities cited by stakeholders include palm oil, rice and sugar. The scenario modeled here focused on palm oil because of its recent history of contributing to deforestation in the Asia-Pacific region and its high projected growth in PNG. USAID LEAF used a suitability layer for oil palm cultivation to predict the location of future expansion. Under conservation scenarios, expansion was restricted to low biomass landscapes and areas of low conservation priority.

6.2.3 Agriculture – Subsistence

Subsistence agriculture includes a range of gardening, shifting cultivation and swidden systems. The impact from subsistence agriculture increases only slowly over time with rural population growth, and unlike the other sectors modeled here, subsistence agriculture cannot be regulated from a top-down strategy in PNG. This makes it difficult to define scenarios that represent real policy options. The work of TNC and community land use planning in the Adelbert region demonstrates how community-led land-use planning, facilitated by external actors, can result in positive outcomes for livelihoods and conservation. The scenarios used here assess the effect of the projected increase in rural population in PNG assuming either a business-as-usual practice in community land use (no land use planning) or a province-wide effort to extend the activities begun by TNC with communities in the Adelbert Range of Bogia District.

6.2.4 Mining

Mining in Madang has historically been relegated to small scale artisanal operations, and the province has not experienced extensive open-pit operations present elsewhere in PNG. Ramu Nickel currently represents the only significant mining operation, moving beyond pilot operations in 2015. While historically the impact of mining has been small, without a specific strategy to guide development, there is the potential for more large-scale open-pit operations to be established in Madang. The mining scenarios look at policies that would restrict the location of mines to avoid causing unnecessary impact of sensitive landscapes.

6.2.5 Road Development

Stakeholders cited a new highway network under construction in Madang that will connect the province via inland routes to other provinces. Roads cause impacts by clearing forests, but also by encouraging development into previously remote areas. The road development scenarios compare policies that restrict the route of the new highway network to avoid sensitive landscapes.

Table 5 summarizes the scenarios for each of the five drivers and lists key assumptions used to model the scenario impact.

Table 5. Summary of scenario definitions for each driver

Scenario	Oil Palm Expansion	Mining	Road Building	Logging	Subsistence Agriculture
Business-as-Usual (BAU)	1,500 ha/year Lax conservation regulations	2 new mines to 2035 Lax conservation regulations	Completion of proposed inter-provincial road network Lax conservation regulations	Extraction continues at historical average in three currently active concessions	Area under subsistence agriculture increases with population (2.7% per year) No community land use planning
Growth First (GROW)	2,250 ha/year Lax conservation regulations	3 new mines to 2035 Lax conservation regulations		Extraction expanded to five concessions	
Conservation First (CON)	1,500 ha/year Strict conservation regulations	2 new mines to 2035 Strict conservation regulations	Completion of proposed inter-provincial road network Increased conservation regulations	Conversion of all logging concessions to protected status	Area under subsistence agriculture increases with population (2.7% per year) 50% of rural population adopts community land use planning by 2025
	1,500 ha/year Moderate conservation regulations				
Balanced (BAL)	2,250 ha/year Moderate conservation regulations	3 new mines to 2035 Strict conservation regulations		Extraction continues at historical average but reduced impact logging is implemented	

6.2.6 Scenario Outcomes

The results presented here focus on GHG emissions. Full information on other indicators is presented in Annex 2. Results show that the selection of policies has a large effect on future impacts. A policy that continues the business-as-usual development of Madang is estimated by this study to result in almost 2.5 million tons of carbon dioxide (CO₂) equivalent per year (tCO_{2e} y⁻¹) (see Figure 12).

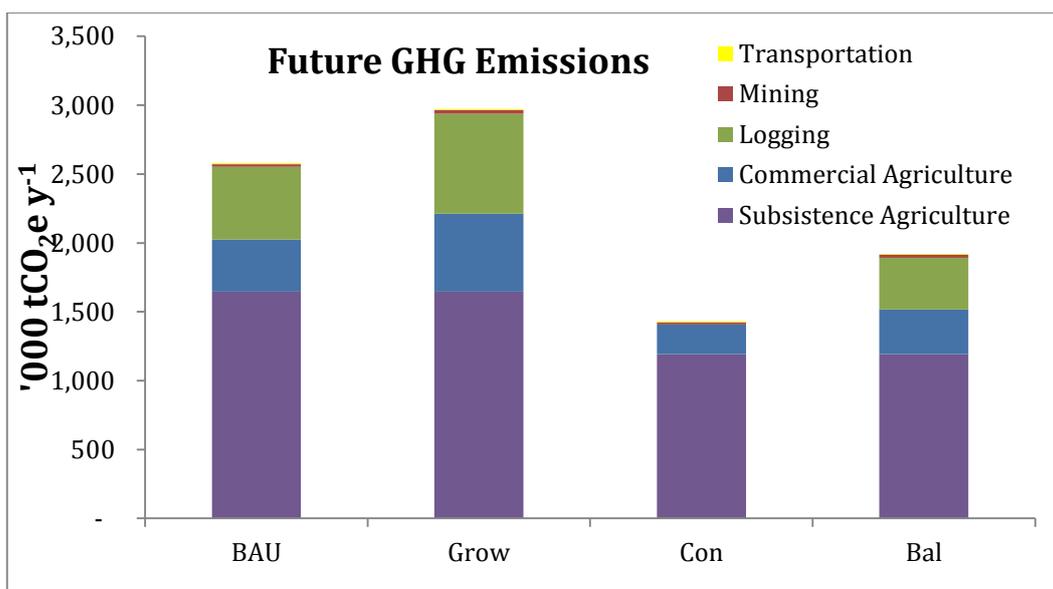


Figure 12. Overview of emission impact estimates from scenarios across all drivers

A policy that seeks to increase development with no additional environmental safeguards would result in a 14% increase in emissions with most of that increase coming from the logging and commercial agriculture sectors. Conversely, a suite of policies adopted to limit the location and type of activities allowed within each sector can reduce GHG emissions to 46-64% from the BAU scenario (see Table 6).

Table 6. Relative impact of scenarios, including all sectors

Scenario	BAU	GROW	CONservation	BALanced
Impact as a % of BAU	100%	114%	46%	64%

There is also a large difference in the total GHG impact that is caused by each activity (see Table 7). For example, the mining sectors and the planned highway system would not cover a large percentage of the land of Madang and therefore the impact is restricted to a small amount of emissions.

Table 7. Annual emissions per scenario ('000 tCO_{2e} y⁻¹)

	Commercial Agriculture	Mining	Logging	Subsistence Agriculture	Transportation	Total
BAU	272,000	19,000	528,000	1,619,000	7,000	2,438,000
GROW	407,000	28,000	725,000	1,647,000	7,000	2,779,000
CONservation	111,000	16,000	-	995,000	6,000	1,122,000
BALanced	169,000	23,000	376,000	995,000	6,000	1,563,000

The conclusions and possible policy implications for each sector area as follows:

- Mining and Road Development** do not represent a large portion of the total emission picture under any scenario. There is the potential that these activities result in higher *indirect* emissions related to attracting development into remote areas, but this process is more speculative. From a strictly GHG perspective, it is not recommended that drafting policies for these sectors should be a priority. There are other forms of impact, from mining in particular such as toxic runoff,

that are highly relevant to Madang for other environmental reasons, but are not necessarily strong drivers of emissions.

- **Subsistence Agriculture** is likely the largest ongoing source of emissions in Madang as a growing rural population must cultivate more gardens to produce adequate food. Because it is a large source, this driver represents a good opportunity to reduce emissions. However, there are significant ethical and legal obstacles to interfering with traditional community agricultural practices. Policies that cooperate with communities and demonstrate the tangible advantages of community land use planning in the style of TNC's work in the Adelbert Range, even if undertaken on less than half of the rural population of Madang, this could equal the impact as stopping the expansion of all commercial agriculture activities.
- **Commercial Agriculture**, including palm oil modeled in this study, represents a profitable source of foreign exchange for Madang, but can result in high impact if high biomass forests are cleared and peat soils are drained for their establishment. The results here show that simply regulating the location of commercial agriculture expansion can have as much or more of an impact on reducing emissions as lowering the amount of allowable expansion by one third. Because commercial agriculture as a sector can be regulated from a central authority, policies that restrict commercial agriculture to non-sensitive lands are highly promising for achieving a low emission development pathway for the Province.
- **Logging** exerts roughly the same range of potential impact as commercial agriculture. In logging, much of the emissions are caused by wasteful and damaging practices that leave trees and wood damaged and decomposing in the field. Simply by adopting reduced impact logging (RIL) practices, it is estimated that the sector could continue to produce at current volumes while decreasing emissions by 29%. Adopting RIL practices should be a high priority as this has a high potential for reducing emissions with minimal economic impact. A more divergent strategy of phasing out of logging and converting forests to protected status is also possible. Granting protected status over high conservation value forests (as identified in the "Madang Sustainable Development: A Ridges-to-Reef Gap and Priority Analysis" report) with allowances for community use could decrease emissions by 530,000 tCO_{2e} y⁻¹.

6.2.7 Options and Opportunities

Based on the assumptions used in these models and guided by stakeholder input, a balanced development policy has significant potential to reduce environmental impact while maintaining or even increasing economic growth. However, even a balanced strategy does allow for more environmental degradation than a policy that favors conservation, so even balanced policies must be carefully drafted with stakeholder input in Madang to ensure no needs are ignored. Based on this assessment, the most promising actions for Madang to ensure low emissions development and maintain economic growth are the following:

- Adopt RIL practices in existing concessions, and plan for conversion of at least some future concession areas into protected status.
- Create regulations that limit conversion of lands to commercial agriculture to avoid high biomass landscapes, areas with high conservation priority, and areas with wetland ecosystems or peat soils.
- Work to extend the successful example of community land use planning in Adelbert communities to wider segment of rural Madang population.

Future work and need for GIS: This analysis focused on modeling a set of sectors and scenarios that were selected by stakeholders over several meetings in 2013 and 2015 in Madang. But priorities for development change over time and new information and data are needed to better assessing new development priorities. This analysis is meant to focus attention in Madang on priority policies, but it is not the final word and the conclusions here must be reevaluated in the future. Land-use planning is highly reliant on geospatial analysis. Regardless of what other policies or action Madang undertakes, it is a strong recommendation that it develop in-province capacity to conduct GIS analysis, even on a basic level. Such capacity will make the process of scenario modeling much more transparent to provincial stakeholders, and ultimately increase the likelihood of well-defined and targeted policy developments with tangible on-ground outcomes.

7 Financing Opportunities

The sustainability of any land use plan is dependent on long term, committed funding. A low emission land use plan has the added potential for attracting investments through performance-based mechanisms where emission reduction units are quantified and traded. This section of the report considers potential sources of finance to support both the implementation of the LELUP, or specific actions within the plan, and possible performance-based payments. These sources could come either from public international, domestic or private spheres and an assessment has been made on the highest potential in terms of accessibility by the MPG (or other designated entity), eligibility for funding, processes for application and capacity to ‘capture’ these funding sources.

The assessment was divided into two tasks: 1) USAID LEAF staff (Regional and PNG based) considered public international finance; and 2) an independent consultant considered private sector finance options¹⁷.

7.1 Public International Finance

From February to April 2015, desk-based research and interviews were conducted with key donor and government representatives to identify international and domestic public funding opportunities that might be available to support LELUP activities in Madang Province. The key findings from this analysis are summarized in Table 8.

Table 8: International Public Financing Opportunities and their Potential for Application in Madang

Funding Opportunity	Description of Funded Activities and Current Status	Current Potential
World Bank's Forest Carbon Partnership Facility (FCPF) – Readiness Fund	FCPF recently signed a grant agreement with the Government of PNG to provide USD 3.8m over the next three years (2015-2018) to support REDD+ readiness activities. This is a continuation of the REDD+ readiness program currently supported by the national government (OCCD) and the UN-REDD National Programme. Due to high relevance of Madang's LELUP activities to national REDD+ readiness objectives, this FCPF grant is likely a key potential funding source. The process to access FCPF funding will need to be channeled through OCCD and UNDP who are recognized fund managers and implementers.	High
Germany's International Climate Initiative (IKI)	IKI currently supports the REDD+ pilot project in Central Suau. The initial phase of funding is ending in 2015 and further support is uncertain. However, IKI issues an annual call for proposal and at least 120 million euros are made available per year (for all countries combined). Additional support will likely depend on the success of the Central Suau project – if this project is successful IKI may fund REDD+ activities in other provinces, including Madang. The process to access IKI funding will need to be channeled through PNGFA and GIZ.	Medium
European Union (EU) Global Climate Change Program	This program currently provides EUR 7.8m (2013-2017) to support PNG's National Forest Inventory. It is unclear how much funding is still available. If certain activities in the Madang's LELUP are designed to directly tie into the National Forest Inventory, the Madang Provincial Government can pursue this option. The process to access funding will need to be channeled through PNGFA and particularly its provincial forestry offices.	Medium
Australia's Direct	This program provides small grants of up to AUD 60,000 each to support small-	Medium

¹⁷ Dargusch, P. 2015, Scoping Study To Identify Emission Reduction Opportunities From the Private Sector in Papua New Guinea, Report prepared for the USAID LEAF program, May 2015 (access at: <http://www.leafasia.org/>)

Aid Program	scale development projects. The application process is relatively easy and TNC's work with the Adelbert communities has been supported through this source. However, it may be difficult for this program to support climate change mitigation actions as there is a stronger focus on funding adaptation actions.	
Japan's Bilateral Support	Japan provided three grants to support forest conservation to address climate change in PNG, including a grant of 700 million yen to support PNGFA's forest monitoring capacity and data management under the Forest Preservation Program (2010-2013); 224 million yen for capacity development on forest resource monitoring (ended in 2013); and 689 million yen for capacity development for operationalization of PNG Forest Resource Information Management System (2014-2018). Since the current program (2014-2018) does not have funding for provincial government in its activities, this is a low potential funding option. Nevertheless, technical outputs from PNGFA's collaboration with JICA (e.g., satellite imageries, forest base maps) can support LELUP activities in Madang Province.	Low
UN-REDD	UN-REDD currently provides USD 6.4m to support REDD+ readiness activities in PNG. However, this program is ending in 2016 and most of the funding has been allocated. The program will be replaced by the FCPF grant after 2016.	Low
FAO-EU Partnership under the 10th European Development Fund	This partnership currently provides EUR 71.5m for the Rural Economic Development program in PNG. However, the program has already selected its target provinces and is focused on improving service delivery mechanisms (e.g., administrative and financial systems). The Madang LELUP would therefore not fit the funding criteria.	Low
Green Climate Fund (GCF)	The GCF is not yet operational in PNG, but likely to be the major source of funding for all development-related climate change mitigation and adaptation activities from 2016. The funding process will need to go through OCCD, who serves as the contact point for the PNG Government in all international climate policy related activities, including the GCF.	Low
Global Environment Facility (GEF) Trust Funds 5 & 6	The GEF Trust Funds 5 and 6 have substantial funding available for projects in PNG in three areas: biodiversity, climate change and land degradation. The Madang LELUP fits into these areas. However, due to co-financing requirements and complex application procedure this is not a high priority funding option for Madang province.	Low
Germany's REDD Early Mover Program	The Program provides results-based payments to REDD+ pioneers that have already taken risks and implemented action to preserve their forests to mitigate climate change. As REDD+ efforts are in early stages in PNG, this is not a high priority funding option.	Low
World Bank's FCPF – Carbon Fund	This Fund provides results-based payments to REDD+ countries that have made significant progress in their readiness activities. As PNG is still in early stages of REDD+, this is not a high priority funding option.	Low

Of the 12 schemes identified, five might be able to fund LELUP activities in Madang in the short to medium term, including: (1) World Bank's FCPF-Readiness Fund; (2) Germany's International Climate Initiative; (3) EU Global Climate Change Program; (4) Japan Fast Start Finance (JICA); and (5) Australia's Direct Aid Program.

7.2 Public Domestic Finance

Of the various options identified from the numerous government agencies and sectors assessed, the most feasible options are listed in Table 9. These options were selected based on accessibility, funding availability and the LELUP's relevance/suitability to the funds criteria.

Table 9: Public Domestic Financing Opportunities and their Potential for Application in Madang

Funding Opportunity	Description of Funded Activities and Current Status	Current Potential
Madang Provincial Government's Budget	K1.5m funding support was confirmed in July 2014 but this has not yet been awarded. This is the most feasible option to pursue in the short term if all the necessary documentation is provided to the MPG by USAID LEAF, TNC and Madang CSOs. This is to assist them in developing detailed activity plans, budgets, and deliverables for endorsement and disbursement before 2017.	High
Public Investment Program (PIP)	This is a local government funding source for which government departments (including provincial governments) can submit applications. The application process is not tedious. The Department of National Planning & Monitoring screens and approves projects on an annual basis. A proposal can be submitted by the OCCD on behalf of the MPG or they can do so directly. Once the MPG has selected the activities to implement, USAID LEAF will provide technical assistance to OCCD or MPG to develop this proposal.	High
PNGFA – National Forest Resource Information System	K4.1m (in 2015) is available for the National Forest Inventory (NFI) as the core activity carried out by PNGFA under this budget line and the LELUP is already, in part, tied into the process, but needs official recognition and approval by PNGFA for part of the LELUP work to be included in NFI. Similar to EU Global Climate Change Program above which funds the NFI. Will need to identify activities in the LELUP Options Paper that can be tied into NFI. This should be considered when MPG selects activities from the option list to implement. Also maintain discussions and strong connections with PNGFA.	Medium

7.3 Private Sector Finance

USAID LEAF commissioned a short assessment of private sector finance options that could be targeted toward supporting implementation of the LELUP, or specific actions within the LELUP. While the original assessment only focused on private sector entities in Madang, the review was expanded to a national level assessment to identify a greater number of possible funding opportunities for the MPG (or designated entity) to access. The assessment was based on an assessment of current private sector financing models in PNG and interviews with private and public sector leaders.

The findings of the study revealed that there have been a small number of REDD+ and low emissions land use policy and project initiatives in PNG over the past five years. Such initiatives include public sector funding opportunities through the Green Climate Fund, the Global Environment Facility, and the World Bank. The April-Salumei REDD+ pilot project also provides an interesting model of how the voluntary carbon market might be used to capture private sector investment in low emissions land use initiatives in Madang.

Based on the interviews conducted at both provincial and national levels, it appears that the private sector in PNG is:

- New to the topic and generally not well informed, yet keen to learn more;
- Broadly aware that investment in 'green' initiatives could benefit their corporate legitimacy and social responsibility obligations; and

- Cautiously interested to contribute funds, but somewhat skeptical of achieving tangible outcomes due to ongoing concerns with misappropriation of funds, especially when engaging with public institutions.

Large scale investments from the private sector are therefore unlikely in the short term (within the next 12 months), other than perhaps support for small-scale (e.g., US\$25,000 to US\$50,000) project specific-based funding.

The main recommendations that came from the study highlighted two short-term, private sector actions that were considered the most promising for the MPG to pursue. These were:

1. To encourage the Ramu Development Foundation¹⁸ (RDF) to include and facilitate low emission land use actions in its funding purview and for those supporting such actions to submit a proposal for the RDF to fund. An example would be a proposal to replicate and scale-up PLUMP in supportive districts of Madang.
2. USAID LEAF to forge a strong working relationship with the Port Moresby Chamber of Commerce and Industry and present on the advantages to its members of investing in low carbon land use initiatives. This would provide a unique opportunity to raise awareness of low emission land use in Madang at the national level and amongst the PNG business community. This could then open up opportunities to identify potential actors that would be interested in investing in low emissions land use initiatives in Madang, as facilitated by the MPG.

Other, longer term business models include registering voluntary carbon market projects based around activities in the Adelbert Range and supporting the establishment of a 'Low Carbon Papua' entity that could create a framework for a voluntary carbon market within PNG¹⁹. However, these options are longer term and are not considered feasible for the MPG to develop under its current operating environment.

¹⁸ RDF is a fund recently established by the Madang Provincial Government to collect mandatory contributions from private sector business developers in the Province.

¹⁹ For further details, please see Dargusch, P. 2015, Scoping Study To Identify Emission Reduction Opportunities From the Private Sector in Papua New Guinea, Report prepared for the USAID LEAF program, May 2015 (access at: <http://www.leafasia.org/>)

8 Recommendations

Deforestation, forest degradation and associated greenhouse gas emissions are high and likely to increase under a 'business-as-usual' scenario. The MPG and stakeholders in the province can take strategic measures to reduce the loss of forests and move away from a business-as-usual scenario towards a low emission development pathway. The work on LELUP has demonstrated that the MPG could adopt such strategies, yet maintain economic growth.

The key recommendation to the MPG is:

- Introduce a time-bound, consultative, province-wide land use planning process that produces a widely accepted, multi-sector provincial low emission land use plan.

However, for this to happen, the MPG will need to introduce land use policies, regulations and actions that balance economic growth, environmental outcomes and social development, plus seek ways to integrate this innovative mechanism into current planning processes.

The Provincial Forest Plan of Madang is currently under review and provides a perfect opportunity for climate change mitigations actions to be incorporated into the Provincial Forest Plan (see specific recommendations below). The Almami Environment and Conservation Law (2003) at the LLG level provides a mechanism for the communities in the Adelbert Range to register a conservation and land use plan based upon community agreement on land zoning and land use. This provides an excellent framework for the MPG to replicate this work in other communities, wards, LLGs, districts and eventually across the whole province. At the provincial level the MPG could also progress the work on LELUP by passing the Madang Environment and Conservation Bill. The MPG Policy and Planning unit is also currently finalizing the Madang Medium Term Development Plan, which has a strong focus on climate change mitigation, adaptation and resilience. This plan outlines strategies to achieve the Kalibobo 2020 vision of "environmental sustainability and wise use of natural resources for the benefit of its future generations". These current regulations provide a framework upon which actions outlined in a LELUP can be implemented.

Key institutional recommendations to the MPG are:

- Review and harmonize current policies, laws and regulations to ensure adequate regulatory support for the development of an ambitious LELUP. The Province does not have the capacity or resources to develop a new or parallel regulatory structure to develop and implement such an ambitious plan. Therefore the development and implementation of a LELUP must be through an existing entity at the provincial level. This review process should be completed in a transparent manner with all stakeholders, including the private sector.
- Mandate the Planning Division as the entity responsible for the development, implementation and monitoring of a LELUP. As the provincial agency responsible for the design and development of provincial and sector plans it is well placed to include mitigation actions in development plans/strategies for all relevant sectors. The MPG will need to provide adequate resources and budgets for the Planning Division to perform this new role.
- The Provincial Climate Change Committee and Madang REDD+ LELUP Working Group to support the Provincial Planning Division as a steering committee/advisory body that provides necessary technical and management support for the division and provide for

effective coordination across sectors as a result of its broad representation. The MPG will need to allocate a budget to support the Provincial Climate Change Committee and REDD+ LELUP Working Group to perform this new role.

- The heads of the MPG to introduce the LELUP concept to key intergovernmental committees, such as the NMA, to ensure national level recognition and support is provided to the provincial and local level governments.
- Assess the operational effectiveness of each DDA, and if functional mandate the DDA to monitor the implementation of the LELUP via a formal endorsement from the relevant tier of government. The DDA should have the capacity to perform this function with assistance from the provincial government as an advisory/oversight body. By basing the management entity at the local level government level the monitoring, implementation and compliance aspects of it are able to be carried out where the target activities are located which should ensure a greater level of success and sustainability of the initiative.

Key implementation recommendations are:

- The MPG to establish and resource a small remote sensing and GIS unit (preferably within the Planning Division) to measure and monitor forest and land use change and assist in all spatial planning work necessary for the appropriate siting of resource developments across the Province.
- Scale-up and replicate the successful PLUMP work in the Almami LLG to other LLGs, wards and districts throughout Madang Province. This will need high level political support from the MPG and adequate resources to train a group of dedicated and capacitated CBOs to scale up the PLUMP work across the province. Funds for this may come through a proposal to the MPG, the Ramu Development Foundation or other sources identified in this report.
- Work with PNGFA to further strengthen the implementation, regulation and monitoring of forest logging code of practice and the expansion of the current reduced impact logging program.
- Register and coordinate/regulate “wokabout sawmills” within Madang, including awareness raising on their activities and methods to promote sustainable forest management and resource use through these ‘wokabout’ mills.
- Review conservation priority areas and landscapes identified in the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report and consider the establishment of protected areas for high priority landscapes under threat of conversion or persistent degradation.
- Develop agricultural siting tools to identify the most appropriate locations for development of palm oil, sugar and other commercial agricultural activities. Based upon this, create regulations that limit the conversion of high biomass landscapes, high conservation priority areas and areas with wetland ecosystems or peat soils. This process must be completed in close consultation with relevant private sector entities and other Madang stakeholders.

Key financing recommendations are:

- USAID LEAF to collaborate with other development partners on a funding proposal to the MPG based on recommendations outlined in this report and the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report.
- USAID LEAF and other development partners to consult with the Ramu Development Foundation on expanding its funding window to support low emission land use actions. Based on these discussions, submit a proposal for the Fund based on recommendations

outlined in this report and the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report.

- USAID LEAF to forge a strong working relationship with the Port Moresby Chamber of Commerce and Industry and present on the advantages to its members of investing in low carbon land use initiatives. This would provide a unique opportunity to raise awareness of low emission land use in Madang amongst the PNG business community. This could then open up opportunities to identify potential actors that would be interested in investing in low emission land use initiatives in Madang, as facilitated by the MPG.

Key recommendations to build capacity and understanding:

- USAID LEAF to ‘hand over’ all training material and data and analysis associated with this report to TNC and other development partners and work with TNC and other partners in the remaining months of the program to build knowledge and understanding of the potential for a low emission land use plan in the province with all relevant stakeholders, including the private sector.
- Work closely with National Level Government Departments such as PNGFA, OCCD, National Planning, DAL, MRA and the private sectors in Madang to create awareness on LELUP and its benefits to achieve economic, social and environmental outcomes.
- Network more effectively with international development partners and donors such as UN-REDD, FAO, JICA, USAID, AUSAID, ITTO, TNC and others, including other NGOs and CBOs.

Key recommendations to improve this report:

- Upon completion of the PNGFA ‘CollectEarth’ historical forest and land use change assessment, update all historical data presented and re-run the scenarios presented in this report.
- Based upon the National Forest Inventory work, update all emission factors that have been used in this report and again re-run the scenarios presented in this report. Also use the National Forest Inventory work to further ground-truth the remote sensing analysis presented in this report.
- Work with PNGFA and other commercial operators in the Province to better define logging extraction rates and infrastructure developments from these operations.

9 Conclusion and Next Steps

USAID LEAF, through a wide stakeholder consultative process, has identified historical and probable future drivers of forest and land use change across Madang Province and estimated likely greenhouse gas emissions associated with these changes. The analysis suggests that greenhouse gas emissions are high and if no action is taken (i.e., 'business-as-usual' continues) greenhouse gas emissions from forest and land use change is likely to remain high, and possibly increase over time. But increasing emissions may not necessarily occur and is dependent on the development path that the Province may take. The scenario planning work presented in this report suggests a 'balanced' pathway may reduce emissions, yet balance economic development needs with other environmental priorities for the Province.

USAID LEAF is aware that there is a lot of information and data presented in this report that will take stakeholders some time to fully appreciate, understand and implement. Hence the submission of this report is not considered a final outcome, but rather a mid-point for discussion and debate about balancing development with other environmental and social indicators. Greenhouse gas emissions are an important metric that can measure impact and possible performance of new policies and mitigation actions aimed at finding this balance.

In order for low emission land use planning to become an integral part of the planning process of Madang Province, this report has outlined several policies and mitigation actions that could be introduced at the local, provincial and national levels. Importantly the report has recommended: scaling up and replicating the successful PLUMP work in the Adelbert Range; introducing and using siting tools to help guide investments and resource allocation for commercial agricultural expansion so as to avoid high conservation value and high carbon stock forests; further promote reduced impact logging in all concession areas; and consider the conversion of at least some future concession areas and high biodiversity sites into protected areas.

With the current national level discussions on REDD+ and land use planning as mechanisms to more sustainably management natural resources, the LELUP work in Madang has demonstrated its usefulness in bringing together a range of stakeholders to discuss these issues and agree on practical implementation actions with the different levels of government. However, these actions will need to be funded and this details possible domestic and international funding sources which the MPG could pursue.

It is hoped that the findings presented in this report will assist the MPG to take advantage of national and international interest in funding ambitious, large-scale climate change mitigation actions as well as developing more resilient and adaptable communities able to meet future climate change challenges. Land use planning that aims for more sustainable, equitable and transparent use and allocation of land and forest resources, as well as reducing greenhouse gas emissions, will become an essential tool for Madang Province.

In the remaining three months of the USAID LEAF program, USAID LEAF will need to work closely with the MPG (especially the Provincial Planning Division) to work through the findings presented in this document and act upon key recommendations made in this report. Awareness of these actions must be rolled out at the district level, including ward council areas, if such work is going to be replicated across the province. USAID LEAF should help facilitate the efforts of the MPG to pursue

funding sources identified in this report and provide the technical detail that might be needed in the development of any concept, proposal or application.

At the same time, the MPG should identify any issues or concerns in this report that needs further clarity or input, so USAID LEAF can address any outstanding issues during the last three months of the project. As much of this report and previous work completed under the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report is based on remote sensing and GIS analysis, USAID LEAF could provide some assistance in this area, particularly in interpreting and analyzing the satellite imagery used in this report.

In summary, USAID LEAF and the MPG Planning Division should:

- Build and strengthen awareness and understanding of the LELUP work in Madang and the benefits that such an approach can bring to the Province;
- Incorporate the LELUP data and analysis into the MPG planning processes, with a specific focus on strengthening the provinces climate change mitigation and adaptation strategies;
- Jointly pursue funding opportunities (both domestic and international sources) identified in this report to ensure sustainability of the LELUP work in Madang Province; and
- Identify capacity limitations within the MPG and put in place strategies to build a solid understanding of low emission land use planning and actions that could be implemented under such a plan.

Low emission land use planning is “a systematic and iterative process aimed at creating an enabling environment in which dialogue between stakeholders can define sustainable land-based mitigation actions and where trade-offs between economic development, livelihood needs and environmental protection are agreed.” It is a process that can ‘ground’ much of the high level discussion REDD+, climate change mitigation and adaptation, low emission development and ‘green growth’ and therefore should become an important, and integrated, part of Madang’s development planning.

ANNEXES

Annex 1: Low Emission Scenario Development and Key Assumptions Used

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1 Scenarios of Development

1.1 Summary

Beginning in 2010, the Madang Provincial Government began drafting a series of guiding principles for medium-term development, and combined them to form the Kalibobo 2020 Vision. These principles cover a wide range of objectives such as spiritual growth, infrastructure, education, law and justice and others. By 2013, The Nature Conservancy (TNC) identified a lack of consideration for environmental and conservation issues within the Kalibobo 2020 Vision. With the support of the governor of Madang, TNC conducted an assessment of conservation gaps and produced policy and technical recommendations for including a greater focus on conservation for future provincial planning. These recommendations are found within the report “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Assessment” (TNC, 2013).

As a follow on to the recommendations in the “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis” report, further recommendations on how to develop a Low Emission Land Use Plan are being created. As a component to this, USAID LEAF has developed a methodological framework to spatially model various development objectives and examine how such development objectives alter future land use change, ecological integrity, biodiversity and greenhouse gas emissions. It is hoped that this type of spatial explicit modeling will be incorporated into all future provincial developmental planning and that providing such a methodological framework will assist in building the capacity at the provincial level for using GIS in planning processes.

To demonstrate how the impact of various development objectives can be modeled, a set of ‘development scenarios’ were developed by USAID LEAF following a four-step strategy:

- 1) Consult with Madang stakeholders to identify the set of economic sectors that have high potential for driving future land-cover change in Madang.
- 2) Develop and define, in conjunction with Madang stakeholders, a series of ‘what-if’ policy scenarios that Madang could potentially choose to implement to regulate each of the identified sectors to meet conservation and economic objectives.
- 3) Develop and demonstrate a GIS modeling framework to project the impact of each policy and sector onto the landscape of Madang.
- 4) Demonstrate impact assessment from scenarios using greenhouse gas emissions as the primary conservation indicator.

This technical report on scenario modeling builds on the results of steps 1 and 2, but is focused on providing detailed description of steps 3 and 4 related to actual GIS modeling and impact assessment. There are two primary outputs of this technical report on scenario modeling. First, it **demonstrates a GIS framework** for integrating development planning of several disparate economic sectors into a single planning exercise. Secondly, a **first-order estimate of impact** in relation to GHG emissions is calculated through 2035 based on assumptions used within various policy scenarios.

It must be stressed very strongly that the impact estimates identified in this report are highly tentative, as the values and assumptions used within the GIS framework relied on a combination of stakeholder-provided estimates, analyst judgement, global datasets, PNG-wide datasets, global default values and literature review. Every attempt has been made to use the best available data and document all assumptions in this report. However, Madang lacks sufficient data on several key

inputs that would have to be resolved before such an analysis could be fully operationalized within a provincial landscape planning process. Key gaps that limit the application of the GHG impact estimates are as follows:

- The policies that define each sectoral scenario were loosely defined by stakeholders throughout workshops in 2014 and 2015, and are not tied to any specific international or local regulation or policy criteria. Therefore, the scenarios presented here are merely indicative of a range of future impacts that could be observed in Madang, rather than a literal modeling of any specific policy initiatives.
- Some sectors, including mining and oil palm, have largely been absent from Madang historically. We estimated the magnitude of future area of change driven by these sectors based on literature review and stakeholder consultation. Therefore, these 'area of change' estimates should not be thought of as literal projections of past trends, but rather as an example of the area of allowable conversion that might be stipulated or targeted in local, provincial or national policy priorities.

The remainder of this technical report on scenarios details the methodological framework developed, including the modeling and calculations completed. From this, indicative examples of the GHG impact of multiple sectors are produced. As more specific potential policies are developed, and additional locally relevant data created, this information can be updated in the framework and analyses updated.

1.1.1 GIS Modeling Approach

The overall framework of this scenario analysis was to first generate maps of where future development would be likely to occur, and to overlay these projection maps with maps showing such features as biomass at the 250m pixel scale and possible peat deposits. We treat the spatial area and location of projected impact as Activity Data (AD) as described by 2006 IPCC Guidelines for National Greenhouse Gas Inventories. It should be noted that this fully-spatial approach was not used for all sectors. Within the logging and smallholder agriculture sectors, USAID LEAF did not have access to sufficient data to implement a fully spatial approach. In spatially explicit models, impact is assessed at a per-pixel scale, while non-spatial sectors only compare total change (AD) to a single emission factor (EF) for the entire activity. The approach for spatially-explicit modeling is provided in Table 10 and Figure 13.

In the absence of any policy restrictions, the future location of an activity is strongly determined by suitability criteria tied to the economic costs of producing in a region, the productivity of the land in the case of agriculture, the presence of key infrastructure and many other possible factors. Policy restrictions are designed to limit negative environmental externalities from land use that are not considered in the economic analyses conducted by the sectors themselves. An example of a policy restriction would be a law to limit conversion of any lands identified as meeting High Carbon Stock (HCS) criteria.

Table 10. Framework used for modeling future impact

Step	Source of information
Determine the total amount of future activity, such as hectares of oil palm or number of mines over a specific time period.	Assumption related to scenario definitions, policy decisions, development goals, literature review and stakeholder estimates
Determine the suitability criteria that will be used to influence where an activity is more likely to occur; create a suitability map from identified criteria	Literature review, analysis of historical spatial patterns using global and local GIS layers
Create a map that restricts where an activity can occur, based on proposed conservation policies	Known or expected policy decisions, industry policy decisions, development goals, assumptions related to scenario definitions, stakeholder input, global and local GIS layers
Produce a map of future location of impact (AD)	Repeated GIS modeling
Overlay AD map with maps of biomass and peat soils and calculate emissions at location	Application of IPCC methods for GHG emissions estimation in AFOLU sector

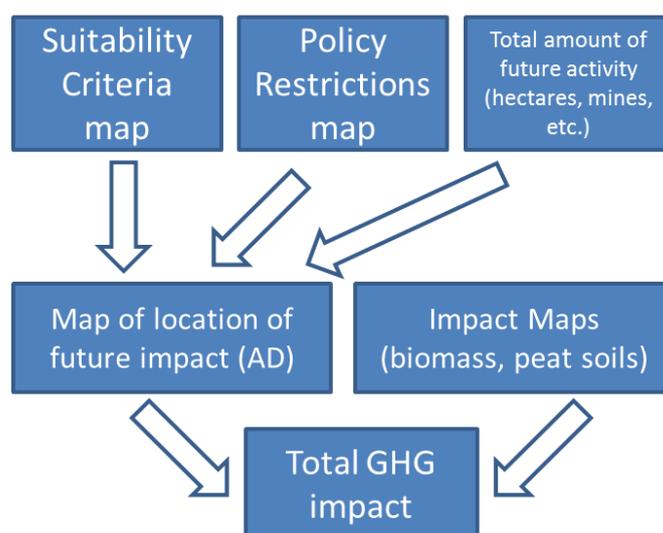


Figure 13. Framework for modeling of spatially-explicit sectors (mining, oil palm, transportation)

The logging and smallholder agriculture sectors were included in this report in order to provide a full picture of the sources of future emissions and to comply with the requests of Madang stakeholders. Both of these sectors occur widely dispersed throughout Madang in small patches, which makes observation of the location of past impact difficult. Furthermore, much of the impact of these sectors could be better characterized as forest degradation that does not result in land cover change. For these reasons, each of these sectors is modeled without respect to location. Logging impact is assessed based on volume of extraction rather than area of operation. We assessed impact of smallholder agriculture on a virtual per-hectare based, but did not identify the actual locations of impact, and used many untested assumptions in arriving at the net area of impact. These two sectors could be modeled using the framework in Figure 14, but this will require additional data collection and may be a long term objective following development of Madang’s GIS facilities.

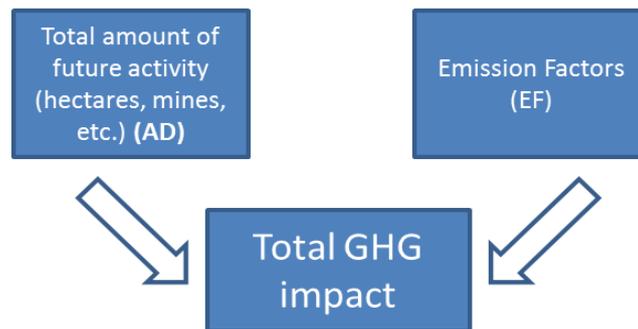


Figure 14. Framework for modeling of non-spatially explicit sectors (logging, smallholder agriculture)

Wherever possible, this study employed an approach to estimate the impact under each scenario through repeating the analysis many times with small variations in the maps used to define suitability. This was done in order to incorporate the impact of projections that may have a lower probability, but a high impact. This process of repeat modeling, a form of sensitivity analysis, is not strictly necessary, but which USAID LEAF recommends as a best practice where GIS resources and capacity allow.

1.1.2 Scenarios

Stakeholders in Madang identified logging, expansion of commercial agriculture focused on oil palm, smallholder agriculture, mining, and new road development as primary drivers of deforestation and related GHG emissions. This analysis models future emissions pathways based on a different set of assumptions regarding the future regulatory and economic environment in Madang. Because the Madang Provincial Government is still in the process of deciding how to implement the recommendations of the Kalibobo 2020 Vision, this analysis did not have access to any specific policy or development plans. USAID LEAF proposed a series of broadly-defined development scenarios that characterize different general priorities Madang could assume within its development strategy. These broad scenarios consider only the intersection of conservation and economic objectives. There are many other potential development objectives and the intent of this report is not to address all of them, but rather demonstrate a quantitative approach to assessing the balance of these two important objectives. The scenarios modeled here were discussed and agreed upon with Madang stakeholders including the Provincial Government through several workshops in 2014. The scenarios agreed upon are:

- **Business-as-Usual (BAU):** Economic development of drivers to continue at historical rate, and environmental regulations to be maintained at current level.
- **High Conservation (CON):** Environmental regulations are strengthened, and development of drivers continues at or below historical trends
- **High Growth (GROW):** Economic development of drivers is given priority over conservation.
- **Balanced (BAL):** Economic growth is maintained at the same level as the “High Growth” scenario, but with the more stringent environmental regulations of the “High Conservation” scenario.

For each driver, the exact parameters defining each of these four scenarios were determined by a combination of stakeholder consultation in Madang, and expert opinion informed by a literature review. Examples of the parameters used include the annual expansion in hectares of commercial agriculture and specific spatial data layers which are used to limit economic activity within environmentally significant lands. While each driver modeled contributes to forest loss and GHG

emissions, the temporal and spatial pattern of that effect varies considerably among drivers. For this reason, the modeling approach contained here is customized to the dynamics of an individual driver. These individual approaches are detailed more thoroughly in Section 0. The output from this analysis is the tons of CO₂ equivalent (tCO₂e) that are projected to be emitted as a result of each driver/scenario combination.

2 Methods

2.1 Scenario Definitions by Sector

Each sector analyzed in this study is divided into a number of scenarios, generally four. The overall logic behind the definition of scenarios within a sector is that two options for total economic growth are compared to two levels of conservation regulations, producing four unique combinations. In the case of oil palm expansion, the High Conservation (CON) scenario was subdivided into two scenarios to highlight the effect of different levels of conservation regulations. There are only two scenarios for Transportation, because Madang is planning a single highway system and therefore the magnitude of the development is fixed. Furthermore, there are only two scenarios for smallholder agriculture, because policy makers can realistically only influence land use decisions in this sector, not the total demand for land which is driven by rural population growth and wider economic trends.

Table 11 presents the factors that were used to define each scenario. These scenario descriptions were the product of stakeholder consultation with representatives of the Madang Provincial Government, relevant land-use sectors and civil society. It should be noted that, unless specifically referenced, the **factors defining each scenario are not based on actual or planned regulations**. Instead, they provide an example of an approach that can be used to project the impact of various development objectives and regulations. If actual regulations or best practice guidance are proposed, this analysis could be updated to incorporate such factors into the scenarios and the modeling repeated.

Since the factors used do not represent actual planned regulatory options, this analysis should be viewed as a potential approach to spatial land use planning. Specific net emission estimates for a given scenario should be viewed in comparison with another scenario but should not be viewed as a precise estimate of projected emissions. In addition, the analysis was done using existing published and unpublished data from both Madang and areas with similar conditions. Therefore, the applicability of such values was not evaluated for Madang and thus should be viewed only as indicative.

Each sector modeled in this study has the potential to result in emissions from the landscape related to loss of forest cover, peat decomposition and loss of below-ground tree biomass. However, the scenarios differ in the way that impact is caused and therefore each demands a unique modeling framework. For this reason, subsequent text on will be divided into each sector, with methods and results presented separately for each.

Table 11. General description of factors defining scenarios for each sector

	Oil Palm Expansion	Mining	Transportation	Logging	Smallholder Agriculture
Business as Usual (BAU)	1,500 ha/year of new lands converted Lax conservation regulations (Table 13)	2 new mines opened by 2035 Lax conservation regulations (Table 14)	Completion of proposed inter-provincial road network Lax conservation regulations (Section 2.2.3)	Extraction continues at historical average in three currently active concessions (Section 2.2.4)	No attempt to extend community land use planning to wider rural population (Section 2.2.5)
High Growth (GROW)	2,250 ha/year of new lands converted Lax conservation regulations (Table 13)	3 new mines opened by 2035 Lax conservation regulations (Table 14)		Extraction expanded to five concessions (Section 2.2.4)	
High Conservation (CON)	1,500 ha/year of new lands converted Strict conservation regulations (Table 13)	2 new mines opened by 2035 Strict conservation regulations (Table 14)	Completion of proposed inter-provincial road network Increased conservation regulations (Section 2.2.3)	Conversion of all logging concessions to protected status (Section 2.2.4)	Community land use planning extended to at least 50% of rural communities in Madang (Section 2.2.5)
	1,500 ha/year of new lands converted Moderate conservation regulations (Table 13)			Extraction continues at historical average but reduced impact logging is implemented (Section 2.2.4)	
Balanced (BAL)	2,250 ha/year Moderate conservation regulations (Table 13)	3 new mines opened by 2035 Strict conservation regulations (Table 14)			

2.2 General Structure of Sectoral Models

2.2.1 Oil Palm Expansion

This oil palm expansion model predicts the future locations of oil palm expansion based on topographic and climatic factors that drive suitability for cultivation. Expansion is modeled by placing 700ha projects in probable locations in Madang, and calculating the impact on lands intersecting each project. Three different policy regimes are incorporated that determine which lands are legally available for conversion: lax, moderate and strict. Lax permits conversion of

virtually any land, while moderate and strict impose progressively greater restrictions on which lands can be converted based on environmental criteria including conservation priority, presence of wetlands, above ground biomass, and protected status. Because exact future plantation locations are unknown, the model simulates the creation of hundreds of plantation locations based on each of the three policy regimes, and calculates the average impact per hectare for each policy regime. Emissions estimates consider both the change in live carbon stocks, as well as from peat drainage. Estimated rates of future expansion are taken from a literature review, as there is no historical trend of widespread oil palm cultivation in Madang. The estimated impact per hectare under each policy regime is multiplied by 'medium' and 'high' projections of annual oil palm expansion to produce total annual estimates of impact.

2.2.2 Mining

The mining model estimates the impact from mine development within the area currently zoned for mineral exploration. The mining model only considers emissions related to the biomass lost in the immediate vicinity of the mine (<1,000m from midpoint) due to construction and clearing. The model simulates the creation of hundreds of potential mine sites, and calculates the direct impact of mine and road due to live biomass removal. Unlike the oil palm model, the mining model does not attempt to predict the location of any future development. Rather, it assumes that there is an equal likelihood that new mines will develop at any location within the mineral exploration zone (Table 14). In the BAU/GROW scenarios, mines are placed anywhere within the exploration zone. In the CON/BAL scenarios, mines may not be placed in areas of high conservation priority, protected status, or high above ground biomass. The average impact of mines is calculated for each of the two conservation regimes: a strict regime for CON/BAL, and lax for BAU/GROW. Total impact is estimated by multiplying the per-mine impact by projections of new mines. There are currently no commercial scale open-pit mining operations in Madang, so there is no determination of historical impact. Future development is understood as the number of new commercial scale mines to be developed to 2035, and was proposed by Madang stakeholders.

2.2.3 Transportation

Madang stakeholders identified a new network of planned inland highways as a potential driver of land-cover change. The transportation model predicts the route of the future road by considering the topography along its intended course, and assuming that rough terrain will be avoided to minimize costs. The only significant direct GHG emission impact we included in the model is the biomass that is cleared prior to construction. The transportation model calculates the amount of biomass that intersects the new road network within a 12meter corridor, and converts it to emissions. Because the exact future location of the road is not known and could be revised before construction is complete, this model incorporates random variation in the calculation of road costs over many simulated roads, which has the effect of modeling the range of likely road locations rather than a single road. The transportation network is modeled under two different environmental policy regimes, a strict and lax version. In the strict version, areas of high conservation priority, wetland ecosystem type, high above ground biomass, and with protected status are avoided, while in the lax version there are no such restrictions.

2.2.4 Logging

The logging scenarios differ from other sectors in this report in that it estimates emissions based on the volume of timber harvested in a non-spatial manner, rather than per hectare in a GIS model. Logging emissions are generated from damaged biomass left in the forest, impact from

construction of infrastructure such as roads and landing areas, and emissions resulting from processing of wood into products. In practical terms, this approach entails multiplying the volume of measured extracted timber by factors to reflect local forest ecology and prevailing logging practices. Scenarios modeled here use historical extracted volumes as a reference point for future extraction, and apply impact factors presented in Pearson, et al. (2014). Scenarios influence total impact in two ways: 1) altering the total extraction rate and 2) reducing the amount of impact per unit of extraction through reduced impact logging practices such as Forest Stewardship Council (FSC) certification.

2.2.5 Smallholder Agriculture

Smallholder agriculture including gardening, shifting cultivation and swidden is not a practice that is regulated beyond the community level in Madang. In these scenarios, we assume that areas that are already under gardening are in a state of long-term carbon equilibrium as lands alternate between fallow and cultivated states. However, as population increases in rural areas, more land must enter into the swidden system. Under business-as-usual scenarios, no attempt is made to extend community land use planning beyond existing areas of the Adelbert Range. In this scenario, the expanded area of gardening is not restricted to any location and can result in deforestation of high carbon forests. In the Conservation scenario, we assumed that community land use planning would be extended to 50% of rural communities, and that communities would set aside a proportion of lands for permanent forest cover similar to the experience in the Adelbert Range, resulting in lower impact on primary forests.

2.3 Historical and Projected Activity Data, Projecting Area of Impact

Activity data refers to the magnitude of an emissions-causing activity over a set time period, such as one year. Activity data can be understood as the number of hectares of expansion for oil palm, the volume of timber removed for logging, or the number of mines to be developed for the mining sector within a specific time period. For activities where impact is assessed on a per-hectare basis, an important factor affecting ultimate impact is where on the landscape that activity happens. Wherever feasible, as in the commercial agriculture, mining and road building sectors, we incorporated an aspect of location in the analysis of impact.

2.3.1 Oil Palm Expansion Activity Data

In our modeling framework, activity data for oil palm is expressed in hectares of conversion. The assumed future area of cultivation is determined by a combination of market demand for palm oil and potential development targets set by Madang. Expansion estimates used here were derived from literature and should be understood only as targets Madang could pursue in a development strategy. Madang leaders will ultimately need to develop their own targets for development of oil palm or other commercial agriculture and use those values in future planning processes.

Historical Impact

There is no record of widespread oil palm cultivation within Madang, and historical impact is therefore not assessed within the province. According to land cover maps by Gunarso, et al. (2013), there are over 130,000ha under oil palm cultivation in PNG as of 2010. The closest major operation to Madang is a new development located within 500m of the border with Madang in the Ramu Valley of far western Morobe province. High resolution Google Earth imagery from 2014 shows over 4,000ha developed to oil palm in this project since 2010. While there has not been any

development into Madang yet, the rapid expansion in nearby Morobe is a demonstration of the economic pressure to expand operations in the region.

Projections of Future Magnitude

The total assumed area of annual expansion is derived from estimates for PNG-wide annual expansion of oil palm under a ‘high’ and ‘medium’ growth scenario proposed by Filer (2009), respectively estimated at 7,500 and 5,000 ha y⁻¹ through at least 2020 for all of PNG. Harris, et al. (2013) projects that approximately 30% of any future palm expansion in PNG is likely to occur in Madang. Combining Filer and Harris, et al. estimates results in ‘medium’ and ‘high’ expansion estimates of 2,250 and 1,500 ha y⁻¹ in Madang. The medium and high projections are used to construct scenarios, with medium projections used in the BAU, CON, and high projection used in GROW and BAL.

Estimate of Area of impact

In the framework used in this assessment, the location of simulated oil palm expansion is influenced by ecological suitability, as well as by policy constraints. In all economic activity that occurs across the landscape, some areas are more desirable than others. A suitability map is a reflection of this varied desirability of a location for an activity. Ideally, a suitability map would be generated by analyzing past expansion trends through a tool such as a logistic regression analysis that considers such criteria such as elevation, distance to roads, etc. Because there is a lack of historical data in Madang, we created a suitability map based on known suitability criteria for oil palm in Kalimantan, adapted from Mantel, et al. (2007) (Table 12). Based on the recommendations of Mantel, et al. and the availability of GIS layers, our approach considers mean annual precipitation, elevation, percent slope and annual flooding pattern. Suitability maps can be easily recreated and refined over time as the activity expands and as more data becomes available. The approach we took is simplistic in that it assigns a value of 0-100 based on Mantel, et al. criteria, with 100 the highest suitability. Individual suitability layers for each factor were combined into a composite suitability map by assigning the *minimum* value among the four factors to a given location. The composite suitability map is presented in Figure 15. Another common option not taken here would be to combine the individual suitability components through an arithmetic mean.

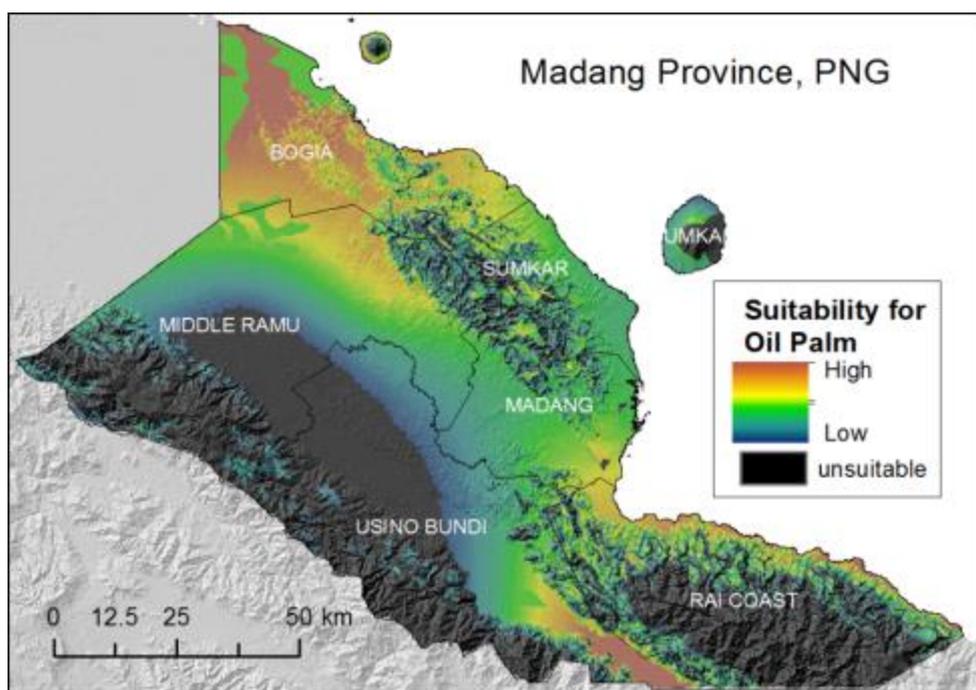


Figure 15. Biophysical suitability for Oil Palm in Madang

Table 12. Criteria used to create suitability surfaces for Oil Palm model. Derived from Mantel, et al. (2007)

Criteria	Effect on Suitability	Data Source
Elevation	<ul style="list-style-type: none"> • Highest at 0-500m • Unsuitable over 1,500m 	SRTM 90m DEM
Slope (%)	<ul style="list-style-type: none"> • Highest below 8% • Unsuitable >40% 	SRTM 90m DEM
Annual Precipitation (cm/year)	<ul style="list-style-type: none"> • Highest at 200cm • Unsuitable < 50cm or >400cm 	Madang Geobook
Flooded days per year (% of year)	<ul style="list-style-type: none"> • 50-70% moderate constraints • >80% high constraints 	PINGRIS

Three conservation policy regimes were defined by stakeholders and were therefore modeled in this study: strict, moderate and lax. From these general regimes, we proposed an example a set of rules that determined where development would be allowed to occur, considering four criteria: aboveground biomass; conservation priority rank; presence of wetlands; and presence of planned or existing protection status. A lax regime as defined in this study places virtually no restrictions on areas that can be developed, while moderate and strict regimes place progressively more restrictions based on pre-existing ecological conditions, and are detailed in Table 13. In all scenarios for oil palm expansion, suitability is used to predict where producers will develop, while conservation regime limits the land that can legally be converted.

Again, it must be emphasized that these conservation policies do not reflect any planned or existing policy in Madang. The values chosen to define each tier of conservation policy were decided through consultation with Madang stakeholders at workshops in 2014. These conservation policies are meant to be indicative of the kinds of measures Madang could implement in a future land use strategy. If the Madang Provincial Government decides to define its own conservation policy related to commercial agriculture expansion, then the definitions of these scenarios should be

updated to reflect that. International frameworks being developed such as the High Carbon Stock, Sustainable Palm Oil Manifesto and High Conservation Value guidelines could serve as a template for a more detailed provincial policy.

Table 13. Criteria used to identify areas eligible for oil palm expansion under three indicative policy regimes

Conservation Regime	Above Ground Biomass	Conservation Priority Rank	Wetland Ecosystems	Protected Areas
Strict	< 40 tCha ⁻¹	<10%	no swamp forest, no swamp shrub/grass	no existing or proposed PAs
Moderate	<100 tCha ⁻¹	<50%	no swamp forest	no existing PAs
Lax	any level	any rank	any ecosystem	no existing PAs

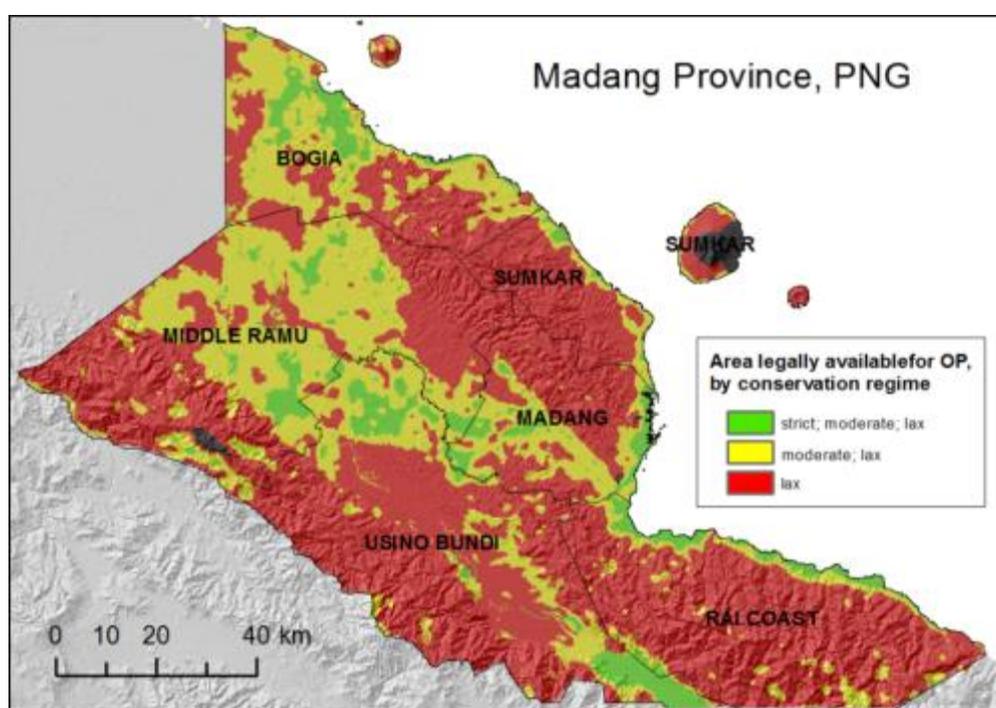


Figure 16. Location of land available for oil palm cultivation, based on conservation policy regime

2.3.2 Mining Activity Data

Historical Impact

There are some existing small scale mining activities in Madang that have generated historical impact. While stakeholders report mining activities throughout the province, it has historically been artisanal and cannot readily be delineated across the landscape. The Kurumbukari nickel mine is the only example of large scale commercial mining this study was able to identify. Construction began in 2008, and is now in the test production phase.²⁰ High resolution Google Earth imagery reveals that approximately 120 hectares of land have been cleared and made bare due to construction, road building and mineral excavation. Based only on biomass loss indicated by Saatchi (2013), this has resulted in a greenhouse gas emission of 60,000 tCO₂e since 2008. We analyzed Google Earth

²⁰ see: <http://www.ramunico.com/plus/list.php?tid=240>

imagery of other mining areas in PNG and found a range of 300 to 1000 hectares defines the area of direct impact from most commercial mines.

Projections of Future Magnitude

This model considers expansion of mining operations in Madang in increments of the number of commercial mines expected to be developed to 2035. Without knowledge of new mines that are under negotiation, it is difficult to project with any precision the number of mines that will ultimately be developed. For this reason, this study simply relies on a number that has been suggested by stakeholders that could plausibly serve as targets for provincial development in the mining sector. This study defines a medium growth scenario to be the development of two new commercial mines from 2015-2035, and high growth to be three mines over this period. It is important to note that business and governmental actors within the mining sector in Madang must critically re-evaluate these estimates in future planning activities and make their own determination whether they are plausible.

Estimate of Area of impact

This study does not presuppose any knowledge about the qualities of the landscape that would attract mine development to any particular area. In reality, production of each mineral entails its own set of restraints on which sites are most attractive for development. For this reason, this study assumes there is an equal likelihood that mines could be developed in any area within the boundaries of the 'mining exploration area' as identified by the UPNG Madang Geobook (Figure 17). As with the oil palm and transportation sectors, the framework we applied to the mining sector limits where expansion can occur in certain scenarios in order to reduce the impact on sensitive landscapes. The conservation rules employed here are not reflective of any specific policy proposal within the Madang government, but are rather indicative of the range of policies that could be developed. These rules, detailed in Table 14, are an example of a set of possible policies, and are limited in this model by the availability of GIS layers.

Table 14. The examples of regulations limiting expansion for mining used in each scenario

Scenario	Allowable Location for Expansion
BAU	Any non-protected lands within mining exploration area
CON	Any non-protected lands within mining exploration area, <i>except</i> : <ul style="list-style-type: none"> • No mines in high biomass landscapes (AGB >150tC/ha)²¹ • No mines in areas of 'high conservation rank'²² (>50%)
GROW	Any non-protected lands within mining exploration area
BAL	Any non-protected lands within mining exploration area, <i>except</i> : <ul style="list-style-type: none"> • No mines in high biomass landscapes (>150tC/ha) • No mines in areas of 'high conservation value' (>50%)

²¹ Saatchi et al. (2013)

²² TNC (2013)

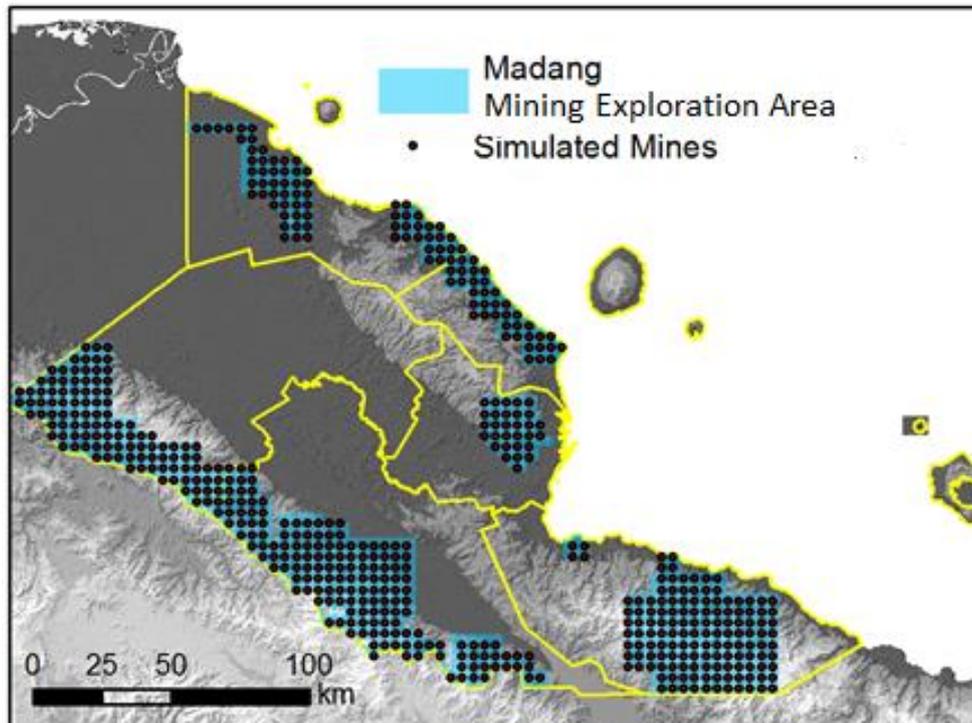


Figure 17. Simulated mines under lax conservation regime (BAU, GROW), placed within mining exploration zones and concessions

In the BAU/GROW scenarios, mines can be placed anywhere within the mining exploration area. However, within the CON/BAL scenarios, mine placement is restricted to avoid high conservation priority lands, areas of high biomass, and protected areas. We chose to assess impact within a 1km radius of the center point of a modeled mine, which equates 314ha of impact. This area of impact is chosen for this study because it is close to the low bound for area of impact based on our visual examination of other mines in PNG through satellite imagery.

2.3.3 Transportation Activity Data

Historical Impact

This study focused on the construction of a single planned transportation project, rather than the entire practice of road building in Madang. For this reason, historical impact was not assessed as this infrastructure project is only in the early stages of implementation.

Projections of Future Magnitude

All scenarios assumed the construction of a single road network that roughly followed the outlines of the project identified by stakeholders in Figure 18. As only one specific project is planned, scenarios do not incorporate any variation on the magnitude of the road building activity.

Estimate of Area of impact

Because the exact location of the planned highway is not known, it is not possible to assess its actual anticipated impact. The framework used in this study estimates the impact of the road network by predicting the range of locations that the road could likely pass through, based on simple landscape and policy considerations. In reality, many demands determine the ultimate location of a road such as minimizing construction costs, connecting key locations, land tenure, and minimizing travel distances. This study did not have access to the actual protocol used for route planning in Madang, and therefore we modeled the route based on the simple assumption that

road building costs increase exponentially with the topographic slope, and that planners would try to minimize these costs by favoring routes with more gradual topography. The actual relationship between slope and cost is in reality much more complex and depends on a host of decisions on construction methods, but this is beyond the scope of this study. Any future assessment conducted for Madang should seek input from local engineers familiar with construction costs in PNG.

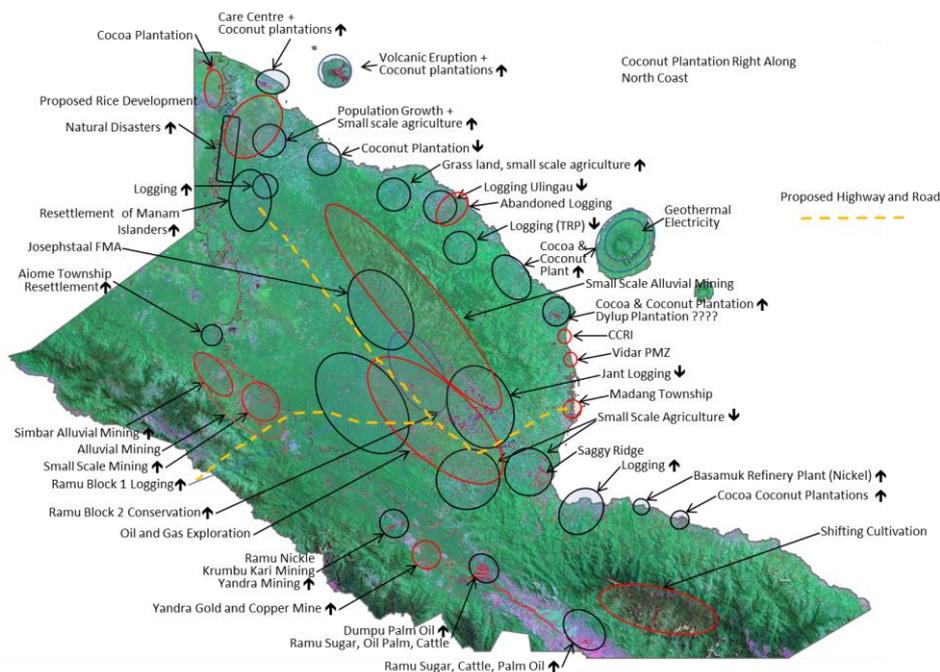


Figure 18. Stakeholder-identified new highway routes

We generated raster cost maps²³ to simulate the relative cost of building a road through a given pixel. We assume a rational designer would seek to choose a road route that minimized costs of passing through high ‘cost’ features such as steep slopes. The exact area of impact is estimated by the common GIS routine of calculating a ‘least cost’ pathway that connects the locations highlighted on Figure 18. The cost surface is the only determinant of route (e.g., area of impact) in our BAU and GROW scenarios. In the CON and BAL scenarios, we developed rules that limit construction on sensitive landscapes in a similar approach to the oil palm and mining sectors. However, in the transportation sector, the presence of conservation criteria does not completely preclude road development, but rather is used in the same manner as the slope-derived cost surface to influence where the ‘least cost’ path would lie. We made this choice because completely precluding road development through any conservation lands resulted in extremely long detours (adding >50% to overall route length) and unrealistic results. For this reason, we developed a simple approach that treats each conservation layer as a ‘cost’. The more conservation criteria that exist in a cell, the higher the apparent ‘cost’ of building through this area. Cost in this sense is not directly associated with any monetary value, but rather is only a site ranking criteria used for planning purposes. The conservation criteria we selected include wetland ecosystems, protected areas and areas with carbon stocks greater than 40 tCha⁻¹. Madang would need to develop its own algorithm for incorporating conservation criteria into its route planning practices. The equations used to produce cost maps are identified below. In the BAU/GROW equation, s^2 is divided by .35² and

²³ Cost maps are conceptually similar to suitability maps, but express the costs (monetized or unit-less) associated with undertaking a specific activity within a pixel, rather than the desirability of that pixel for the activity.

multiplied by 100 only in order to ensure that the vast majority of pixel costs fall between 0-100. A value of 1 is added to all cells to ensure that flat lands have some associated cost to prevent implausible GIS modeling behavior.

BAU/GROW: $Cost = 1 + s^2 / 0.35^2 * 100$

CON/BAL: $Cost = (1 + s^2 / 0.35^2 * 100) + ((c + w + p + agb) * 25) / 2$

Where:

Cost = unit-less cost to construct a road in this cell

s = % slope (as fraction) (see Figure 19)

c = 1 if cell has a conservation priority value > 50, otherwise = 0

w = 1 if cell is a wetland ecosystem type, otherwise = 0

p = 1 if a cell is an existing or proposed protected area, otherwise = 0

agb = 1 if a cell has above ground biomass stocks > 40tCha, otherwise = 0

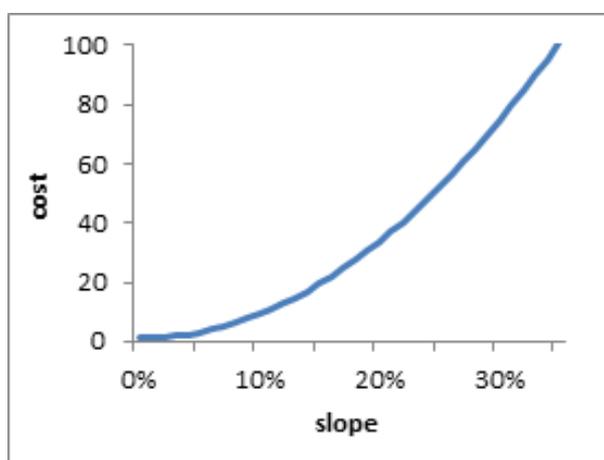


Figure 19: Relationship between % slope and road construction cost developed for this GIS model

The least-cost path is simulated 1000 times for each scenario with slight random variation incorporated in the cost raster (+/-1%) to allow identification various routes with similar costs. The final activity data is an average of the location of the routes simulated from all model runs. Impact is assessed within a 12meter corridor, as we determined through visual inspection of Goolge Earth imagery that existing regional roads in Madang appear to be on average 12meter wide.

2.3.4 Logging Activity Data

Historical Impact

To estimate historical emissions from logging, we used timber volume data (Table 15) from the three active concessions in Madang, Rai Coast, Ramu Block 1 and Sogeram from 2009-2014 based on SGS data. These data represent volume of timber *exported* from these concessions, and therefore likely underestimate true extraction. Actual volume of timber extracted would provide more accurate estimates; however, these data were not made available.

Table 15. SGS timber volume data (m3) for the Rai Coast, Ramu Block 1 and Sogeram concessions from 2009-2014

Concession	2009	2010	2011	2012	2013	2014	Total
Rai Coast	11,019	14,602	142,781	27,629	3,943	24,502	224,476
Ramu Block 1	68,863	25,813	0	0	25,171	26,118	145,965
Sogeram	0	82,621	0	32,464	85,777	8,336	209,198
Total	79,882	123,036	142,781	60,093	114,891	58,956	579,639

Projections of Future Magnitude

Logging development plans for Madang are unknown and thus to project specific logging objectives under each scenario is not possible. For this reason, this study simply relies on the projected estimate suggested by stakeholders for each scenario. In the BAU scenario, it is assumed that emissions continue at historical levels (see Table 16). Because there is no strong trend in historical export volumes versus year ($R^2=0.10$), the historical average is used, or $96,600 \text{ m}^3\text{y}^{-1}$. In the CON scenario, it is assumed regulations prohibit logging and thus all logging concessions are converted to protected areas and commercial logging volumes are reduced to 0. The GROW scenario assumes two new concessions are opened up: Ramu blocks 2 and 3 (Figure 20). We assume that logging exports would increase proportionally with the area of active concessions. By opening two new concessions, the active area of concessions would increase by 37%, resulting in an estimate of future export volumes of $132,700 \text{ m}^3\text{y}^{-1}$. The logging sector is not modeled spatially, and therefore it is not possible to identify which specific areas within a concession are most likely to be impacted.

Table 16. Exported extraction volume estimates by scenario (m^3)

BAU	CON	GROW	BAL
96,600	0	132,700	96,600

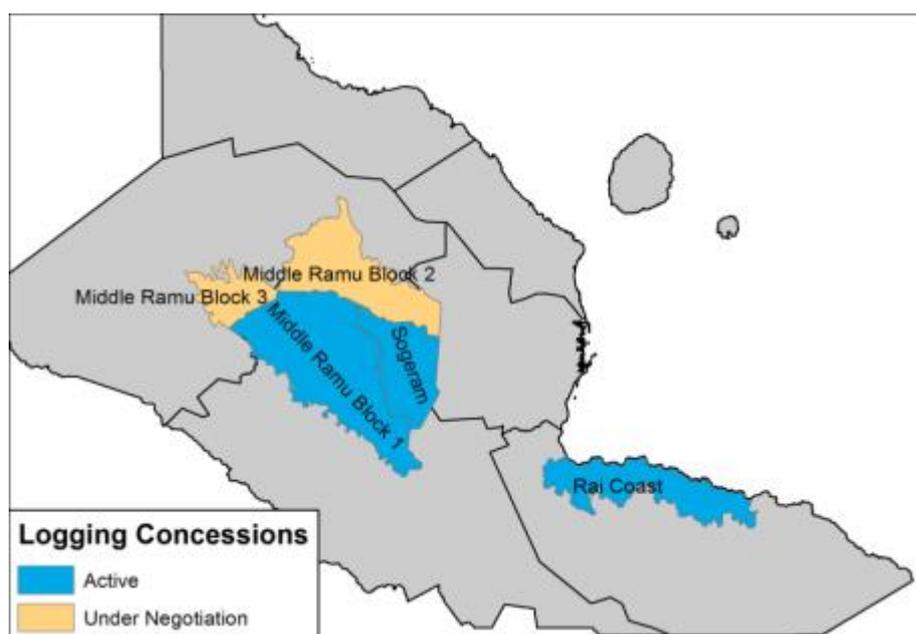


Figure 20. Active and planned logging concessions in Madang Province as of January 2015

2.3.5 Smallholder Agriculture Activity Data

Projections of Future Magnitude

This study assumes that population growth is the main driver of impact from smallholder agriculture. Population data provided by UNPG Madang Geobook for 2008 references an annual 2.7% growth rate in Madang and a total population of 451,270. We defined rural population as all population outside of a 5km radius of Madang city, which results in a rural population of 327,862. The framework used here assumes that this entire 'rural' population is engaged in swidden agriculture, but more accurate assumptions must be developed by Madang. We calculate the increase in future rural population that could lead to expansion of swidden agriculture as:

$$\text{annual growth rate} * \text{rural population} * (1 - \text{urban fraction}) = \text{annual gain in rural population}$$

Urban fraction is an estimate of the proportion of future population that will migrate to urban centers. This study did not have access to reliable estimates of the future rate of urbanization for Madang province, and adopted a placeholder value of 50%. We chose this number to simulate a future where Madang urbanizes more quickly than in the past. However, this assumption is **not** based on any published figures, but rather a place holder to demonstrate a framework for estimating impact. The final emission estimates for this sector are highly sensitive to urbanization, so generating more robust of future rural population should be a priority for improving precision of provincial emission projections. In all scenarios, we calculated gain in rural population as:

$$0.027 * 327,862 * (1 - 0.5) = 8,852 \text{ persons/year}$$

Although gardening lands alternate between fallow and cultivated states, a certain number of total hectares must be made available for eventual rotation to support soil fertility and provide secure food supply for each community member. Spencer (1966) estimates 2ha per person for Papua are needed in a swidden system to produce adequate food supply. The area of new swidden land in the business as usual scenario we therefore calculated as:

$$\begin{aligned} \text{annual gain in rural population} * \text{swidden land per person} &= \text{annual gain in swidden} \\ 8,852 * 2 &= 17,704 \text{ ha/year} \end{aligned}$$

In the business-as-usual scenario, we assumed that communities will expand their areas of gardening by this rate of 17,704 ha y⁻¹. In the Conservation scenario, we assume that communities will choose to set aside 77% of their land for uses that result in permanent forest cover, including conservation, cultural, forestry and hunting. This figure comes from TNC's experience of land use planning in Adelbert communities (Table 17). We assume that in the Conservation scenario, setting aside lands at the community level reduces the expansion of swidden systems by proportional amount to the area preserved. This restriction of agricultural expansion could result in greater intensification of agriculture (e.g., shortening of fallow cycle) in some areas. However, without a fine-resolution map of rural population or longitudinal community studies, it was not possible to assess this phenomenon and we did not address it.

Table 17. Distribution of management designations observed within Adelbert communities engaged in land use planning with The Nature Conservancy

Row Labels	Use	% of area	% of area by use
Conservation	Forest	24%	77%
Cultural	Forest	1%	
Forest Use	Forest	30%	
Hunting	Forest	22%	
Agriculture	Non-forest	9%	23%
Gardening	Non-forest	11%	
General Use	Non-forest	0%	
Village Development	Non-forest	3%	

For the Conservation scenario, we assume that community land use planning is extended to 50% of the rural population. Again, this 50% estimate is not tied to any specific policy planned within PNG or Madang, but is merely selected by us as indicative of a target that Madang could set for extending community planning initiatives. The area of impact under the conservation scenario is thus:

annual gain in rural population * swidden land per person * percent not protected * population targeted + annual gain in rural population * swidden land per person * (1 - population targeted)

This results in: $(8,852 * 2 * 0.23 * 0.5) + (8,852 * 2 * 0.5) = 5,444$ ha

Table 18: Hectares converted to forest through swidden agriculture

Scenario	hectares per year converted to swidden
BAU, GROW	8,852
CON, BAL	5,444

2.4 Emission Factors

2.4.1 Oil Palm Expansion Emission Factors

Emissions from oil palm expansion are calculated from the follow emission sources:

- Conversion of aboveground biomass stocks to oil palm
- Emissions from peat soils due to peat drainage

For GHG accounting purposes in this analysis, all emissions are calculated as occurring at the year of conversion, though in reality much of these emissions occur over the course of 10 years or more. Emission factors are calculated as follows:

$$EF (\text{tCO}_2\text{eha}^{-1}) = \text{soil emissions} + \text{net biomass stock change emissions}$$

Live Biomass emission factors

For each policy regime pre-conversion biomass²⁴ is averaged across all simulated plantations. Each scenario results in a different distribution of possible plantation locations, and therefore the average carbon stock of converted areas is different. Because expansion is simulated many times, highly suitable areas may be converted in more than one model iteration. This process of simulating development many times has the effect of assigning more suitability areas a greater weight in determining what the likely EF will be for that activity. Post Conversion biomass accounts for the carbon stored in palm plantations. This study follows the method of Agus et al. (2013) and uses a time-averaged carbon stock of 36 tCha⁻¹ for typical commercial palm plantations in SE Asia and Pacific. The equation for emissions from live biomass change is:

$$\text{tCO}_2\text{eha}^{-1} = (\text{Pre-oil palm tCha}^{-1} - 36 \text{ tCha}^{-1}) \times (44/12)$$

Table 19. Estimated GHG emissions from biomass stock change

Conservation regime	Pre-conversion Tree Above and below ground Biomass (tCha)	Oil palm long term biomass average (tCha)	Stock Change (Δ tCha)	Emission & Removal Factors (tCO ₂ eha ⁻¹)
Strict	16	36	-20	-73
Moderate	40	36	4	15
Lax	63	36	27	99

Peat emission factors

Peatlands are a major potential source of emissions within palm plantations. This study was not able to identify a definitive map of the distribution of peatlands within Madang. However, reports from Madang partners familiar with local ecology indicate that peatlands do exist along the Ramu River, but they have not been well studied. Minnemeyer, et al. (2009) identifies peat distribution and depth across Indonesia, including Papua province. As the closest Indonesian region to PNG, this study assumes the ecological processes creating peatlands in Papua are likely to be similar in Madang.

To establish peat depth estimates for Madang, the relationship between Minnemeyer, et al. (2009) and the Gunarso, et al. (2012) land cover maps was applied to wetland ecosystem classes in Madang, also from Gunarso, et al (2012). The average peat depths for 'Disturbed Swamp Forests' and 'Swamp Shrub' land-cover classes were calculated for Papua. These average peat depth estimates were applied to the distribution of these wetland types in Madang. Any Disturbed Swamp Forest in Madang is assigned a peat depth of 51cm, while Swamp Shrub and Swamp Grass is assigned 34cm. Emissions are based on the assumption that following RSPO best practices, peat is drained to a maximum depth of 50cm for cultivation. A 4.5cm/year subsidence factor (Wosten, et al., 1997) is applied, which limits accounting for emissions to within the time frame that peat has not yet been exhausted. This defines the 'peat depletion time': a number of years after which no additional emissions are expected because peat resources have been exhausted. An emission factor of 98 tCO₂em⁻¹ha⁻¹ (Hooijer, et al., 2012) is applied to estimate emissions based on the depth of

²⁴ Jet Propulsion Laboratory 250m Biomass Map

drained peat, which is assumed to be a maximum of 50cm in this model. The equation below estimates the total emissions for development on peat, summed overall years.

$$tCO_2e\text{ha}^{-1} = \text{depth}_{\text{drained}} \text{ (m)} \times 98 \text{ (tCO}_2\text{e m}^{-1}\text{ha}^{-1}\text{y}^{-1}) \times \text{depth}_{\text{total}} \text{ (m)} / 0.045$$

The results are that a single hectare of converted Disturbed Swamp Forest are estimated to emit 555 tCO₂e ha⁻¹ until depletion, while Swamp Shrub/Grass would emit 252 tCO₂e ha⁻¹ (Table 20).

Table 20. Estimated lifetime GHG impact from peat emissions per hectare of wetland conversion

Land Cover	Assumed Peat Depth (m)	Estimated Annual emissions tCO ₂ e ha ⁻¹	Estimated Peat Depletion Time (years)	Total emissions until depletion tCO ₂ e ha ⁻¹
Disturbed Swamp Forest	0.51 (0.5 drained)	49	11.3	555
Swamp Shrub + Swamp Grass	0.34	33	7.6	252

The emission factors in Table 20 only apply to wetlands themselves. Because the model used in this study averages impact across all simulated projects within a conservation regime, the actual expected peat emissions per hectare of oil palm expansion is much lower. In addition, the emissions will not occur in one year, but instead will be spread over many years Table 21 provides the area weighted averages of peat emissions, where the expected average area impact on wetlands per conservation regime is taken into account.

Table 21. Estimated peat emissions per hectare of oil palm expansion

Conservation regime	% of impacted oil palm expansion area		Emissions within Wetland class, weighted to % area of expected impact (tCO ₂ e ha ⁻¹)		
	Disturbed Swamp Forest	Swamp Shrub + Swamp Grass	Disturbed Swamp Forest (% × 555 tCO ₂ e ha ⁻¹)	Swamp Shrub/Grass (% × 252 tCO ₂ e ha ⁻¹)	Total Expected Peat Emissions
Strict	0.5%	2.3%	3	6	<u>8</u>
Moderate	1.7%	19.8%	10	50	<u>59</u>
Lax	8.1%	14.7%	45	37	<u>82</u>

Combined emissions factor

The expected GHG impact varies widely among the three conservation regimes modeled here, with a strict regime actually serving as a carbon sink. A lax regime is highly GHG intensive with an estimated 181 tCO₂e ha⁻¹ of impact (Table 22) with projections of total oil palm expansion (Table 11).

Table 22. Final per-hectare Emission Factors for oil palm expansion

Conservation restrictions	Total Emissions per ha. oil palm expansion tCO ₂ eha ⁻¹		
	Peatlands	Tree Above and below ground Biomass	Total
Strict	8	-73	-65
Moderate	59	15	74
Lax	82	99	181

2.4.2 Mining and Transportation Emission Factors

Impact from the mining and transportation sectors assumed that all above and below-ground biomass within the area of impact is emitted, as land is cleared for infrastructure. The biomass located within the area of a simulated road or mine project is identified from a 250m resolution biomass layer (Saatchi 2013). The equation below is used to generate an emissions factor:

$$\text{tCO}_2\text{eha}^{-1} = \text{Pre-conversion Carbon Stock} \times (44/12)$$

Because each project is simulated many times, and because different scenario rules influence the location that projects occur, the carbon density of the landscape that is affected differs. When impact is summed within all simulations for a given scenario, this average expected impact differs across scenarios. The BAL and CON scenarios restrict development on high biomass landscapes, and thus result in a lower average impact per hectare (Table 23).

Table 23. Emission Factors for Mining Scenarios

Scenario	EF tCO ₂ eha ⁻¹
BAU, GROW	602
CON, BAL	498

For the transportation sector (see Table 24), impact is assessed within the entire area of road building rather than per hectare. This is done to accommodate the fact that in the CON and BAL scenario, the road must follow a longer route to avoid sensitive areas, which reduces some of the emissions savings from avoiding high carbon stock forests.

Table 24. Emission Factors for Transportation Scenarios

Scenario	EF tCO ₂ e per project (total over project)
BAU, GROW	7,359
CON, BAL	6,069

2.4.3 Logging Emission Factors

Pearson, et al. (2014) have developed a method that allows GHG emissions to be estimated from logging by knowing the volume of timber extracted and understanding certain factors that cause the emissions of GHGs:

- Extracted log emissions (ELE) are the emissions related to the conversion of the log to wood products and the subsequent emissions from retired wood products (e.g., furniture, housing material etc.)
- Logging damage factor (LDF) relates to the emissions that occur at the logging gap caused by the decomposition of all dead wood produced as a result of felling the tree, including smaller trees and broken branches from trees that are still standing.
- Logging infrastructure factor (LIF) includes the emissions related to the forest cleared to create logging roads, skid trails and logging decks.

Therefore emissions from logging can be expressed as:

$$\text{Emissions from selective logging} = \text{volume of timber extracted} \times (\text{ELE} + \text{LDF} + \text{LIF})$$

Where:

- Emissions from selective logging is expressed in tons of CO₂e for a given time period
- Volume of timber extracted is expressed in m³ for a given time period
- ELE is expressed in tons of CO₂e per m³
- LDF is expressed in tons of CO₂e per m³
- LIF is expressed in tons of CO₂e per m³

Developing country specific or even province specific data for PNG or Madang would require further information such as information on roads, logging decks and skid trail dimensions (LIF) that can be found in logging management plans and remotes sensing, data on saw mill efficiency (ELE) and field work to estimate the average damage associated with tree felling (LIF). The data necessary to develop ELE, LIF and LDF are not available for Madang or PNG as a whole. Therefore, this study employed factors developed by Pearson, et al. (2014) for Indonesia (Table 25) as it is available data that geographically relates the most to PNG. Reduced Impact Logging (RIL) practices can reduce impact from logging, but there are not currently any assessments of the magnitude of the benefit in PNG. For this study, we adopted the assumption that RIL will reduce emissions by 30% across each of the three logging emission factors.

Table 25. Logging emission factors and the total emission factor (TEF), all in units of tons of carbon (C) per m³

Emission Factor	Scenario	ELE	LDF	LIF	TEF
Default (Indonesia)	BAU, GROW	0.25	0.57	0.67	1.49
Reduced Impact (no logging)	BAL	0.18	0.40	0.47	1.04
	CON	n/a			

2.4.4 Smallholder Agriculture Emission Factors

We conservatively assumed that communities are more likely to expand their agricultural practices into areas that are already degraded, as there is significantly less site preparation effort necessary. This is an untested assumption used to demonstrate the modeling framework, and actual robust modeling of stallholder agriculture expansion requires more information on the decision making

process of farmers in Madang. For the pre-deforestation carbon stocks, we assumed a constant 72tCha⁻¹, which is the carbon density obtained by overlaying the Gunarso, et al. land cover map's 'Shrubland' class with the 250m Saatchi (2013) biomass map. The post-deforestation carbon density is assumed to be 22.1 tCha, based on the assumption that the area is maintained in a long-term cycle of 17 years of fallow followed by two years of cultivation based on input from local stakeholders. The value of 22.1 tCha was generated by applying the widely-applied Chapman-Richards model (see Table 26) with coefficients derived from 2006 IPCC AFOLU guidelines for Moist Forest.

Table 26. Coefficients used in Chapman-Richards Model

Type of forest	Max	K	m
Moist Forest	290	0.039	0.55

The emission factor for conversion of forest to shifting cultivation used in this study is therefore:

$$(\text{pre-transition carbon stock} - \text{post deforestation carbon stock}) * 44/12$$

$$\text{This results in: } 72 - 22.1 * 44/12 = 182.9 \text{ tCO}_2\text{eha.}$$

The emission factor applied to each hectare of conversion to smallholder agriculture is therefore assumed to be **182.9 tCO₂eha**.

3 Detailed Results

3.1 Oil Palm Expansion

Total impact of oil palm development in Madang combines the per-hectare estimates of impact (Table 27) with annual expansion estimates. Strict conservation policy that limits all expansion to areas of low biomass and on mineral soils could potentially be a strong carbon sink. In all scenarios, the effect of limiting the location of expansion has a strong effect in impact that can counterbalance a higher rate of expansion (see Figure 21). For example, the Balanced scenario, which allows for more hectares of expansion per year than a BAU scenario, actually results in lower long term net emissions due to policies that limit where that expansion can occur. It must be noted that these results are based on an average of the full range of possible locations development would likely occur under each scenario, and that within each scenario there are outliers where impact may be much higher on a per-hectare basis than the scenario average. It is critical that any proposed conversion project be examined individually and impact be assessed based on the actual features of the proposed site.

Table 27. Total impact from oil palm expansion

Scenario	Annual oil palm Expansion (ha y ⁻¹)	Policy regime	Emissions per ha of oil palm (tCO ₂ eha ⁻¹)			Annual Emission tCO ₂ e
			Peatlands	Tree AGB + BGB	Total	
Strict Conservation	1,500	strict	8	-73	-65	-97,000
Moderate Conservation	1,500	moderate	59	15	74	111,000

BAU	1,500	lax	82	99	181	271,500
Growth	2,250	lax	82	99	181	407,250
Balanced	2,250	moderate	59	15	74	166,500

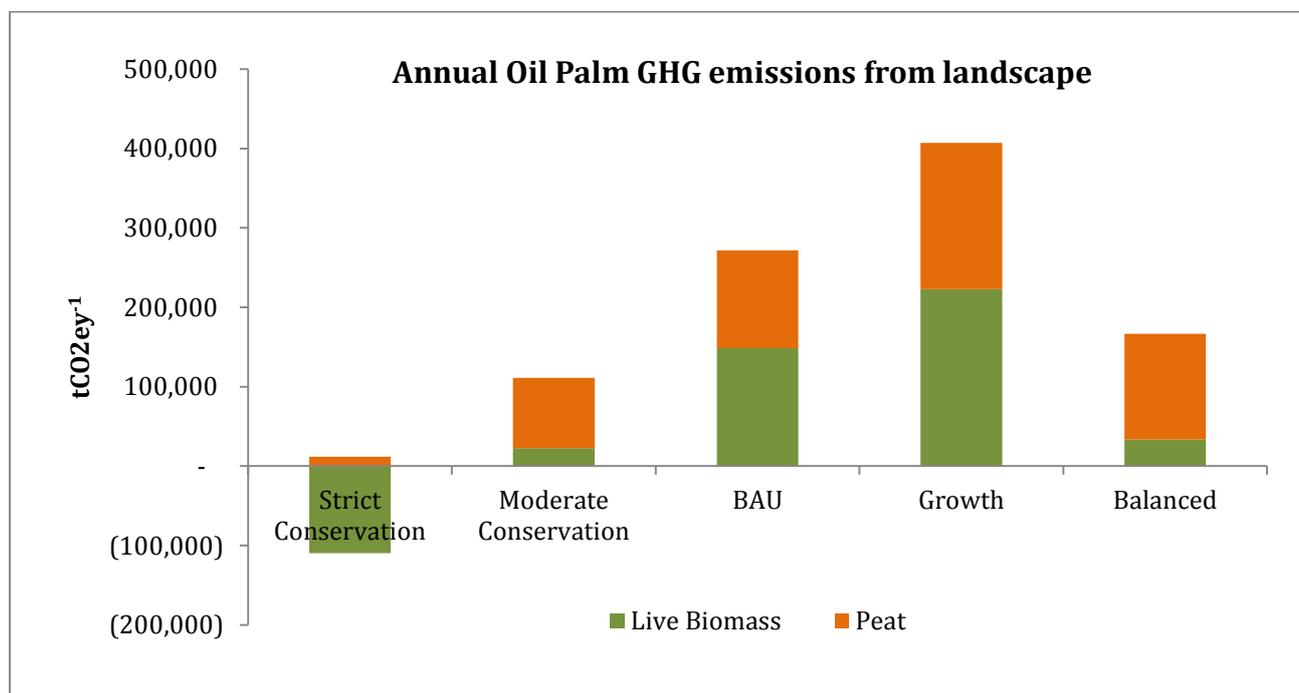


Figure 21. Contribution of peat and tree biomass emission to total impact from oil palm expansion

3.2 Mining

The effect of conservation policies on mine siting is an approximate 13% reduction in the emissions per mine. This is a relatively modest savings especially considering that the overall expectation is that the area of forest cleared for any given mine will be less than 100 hectares (see Table 28).

Table 28. Mining impact per scenario

Scenario	New mining ha developed to 2015-2035	Hectares impacted	EF tCO ₂ e _{ha} ⁻¹	GHG emissions (tCO ₂ e _y ⁻¹)
CON	2	628	498	15,600
BAU	2	628	602	18,900
BAL	3	942	498	23,400
GROW	3	942	602	28,400

3.3 Transportation

Altering the course of the transportation network to avoid sensitive landscapes is estimated to reduce emissions by 18%. However, as with the mining sector, the total magnitude of this savings is small. This scenario only looked at the direct effects of transportation. It is likely that when indirect effects, such as greater access to remote areas, are taken into account, the magnitude of savings would be higher.

Table 29. Impact from transportation network

Scenario	GHG emissions (tCO ₂ e)
CON/BAL	7,359
BAU/GROW	6,069

3.4 Logging

The BAU scenario is simply an extension of historical impact into the future. Under the GROW and CON scenarios, any deviation from BAU is a direct result of lowering or raising extraction estimates, as the impact per volume extracted is calculated to be the same. The BAL scenario reduces emissions from the BAU scenario by lowering the impact expected per volume extracted. While additional field work needs to be done in PNG to quantify the exact magnitude of the savings from reduced impact logging rates, this scenario represents a promising opportunity to reduce emissions while maintaining the forestry sector. However, reduce impact logging is difficult to implement and monitor. The only guaranteed way to lower impact is to convert at least some logging concessions into protected areas and that logging and conversion bans are enforced within such areas.

Table 30. Emissions from future logging scenarios

Scenario	Emissions tCO ₂ e ⁻¹
BAU	528,000
GROW	725,000
CON	0
BAL	376,000

3.5 Smallholder agriculture

Based on the assumptions made in this study, the smallholder agriculture sector is the single largest source of emissions in Madang owing to the large number of residents that are engaged in the practice. The practice of extending community land use planning holds promise in Madang of being a large source of emissions reduction. However, a large amount of additional work must be done to increase the confidence in these estimates. First, there is little understanding how communities will adapt their agricultural systems to accommodate more land placed in preserved status. Secondly, it is not known how community protected forests will be utilized if population pressures increase. While these areas call for additional study in PNG, the large magnitude of potential savings suggests that advocating for extending community land use planning within receptive communities is likely to result in emissions benefits from Madang.

Table 31. Annual impact from smallholder agriculture scenarios

Scenario	ha y ⁻¹	tCO ₂ e ha ⁻¹	tCO ₂ e hay ⁻¹
BAU, GROW	8,852	182.9	1,619,000
CON, BAL	5,444	182.9	995,000

3.6 Combined Results and Discussion

The results in Table 32 and Figure 22 show that there is a wide range in emissions impact between sectors, as well as between scenarios. The largest sources of projected GHG emission, logging, smallholder agriculture and commercial agriculture, are also the sectors where policy actions can have the largest benefit for emissions reduction. The oil palm sector, for example, can be either a net source or a sink for carbon in our model depending on where the conversion it is located.

Within the smallholder agriculture system, the assumptions used in this study suggest that 624,000 tCO₂e⁻¹ could be saved each year by promoting community land use planning. While there is high uncertainty associated with this value, even if only a fraction of this potential is realized, it would be a substantial benefit per year. The logging sector is most closely linked to emissions of any sector – by definition it causes loss of forest carbon. Reduced impact logging can lower the emissions from incidental damage and waste and result in a 30% reduction in emissions per harvested volume. Any other strategy demands limiting the total harvest to reduce emissions.

This study does not project the mining sector to be a large component of future emissions within Madang, and conservation measures only provide a reduction of 5,000 tCO₂e⁻¹ from a business-as-usual scenario. The highway network modeled in this study has a relatively predetermined route and length, and the opportunities for mitigating direct emissions are minimal. For both the mining and transportation sector, it is very possible that significant indirect emissions may be caused by influencing settlement into remote areas. However, this correlation requires much additional research and was not addressed within this framework.

Table 32. Estimated annual emissions by driver (tCO₂e y⁻¹); highway expansion emissions are not included among annual totals

Scenario		Oil Palm Expansion	Mining	Logging	Smallholder Agriculture	Total
Business as Usual		272,000	19,000	528,000	1,619,000	2,438,000
High Growth		407,000	28,000	725,000		2,779,000
High Conservation	Moderate	111,000	16,000	-	995,000,	1,122,000
	Strict	-97,000				914,000
Balanced		169,000	23,000	376,000		1,563,000

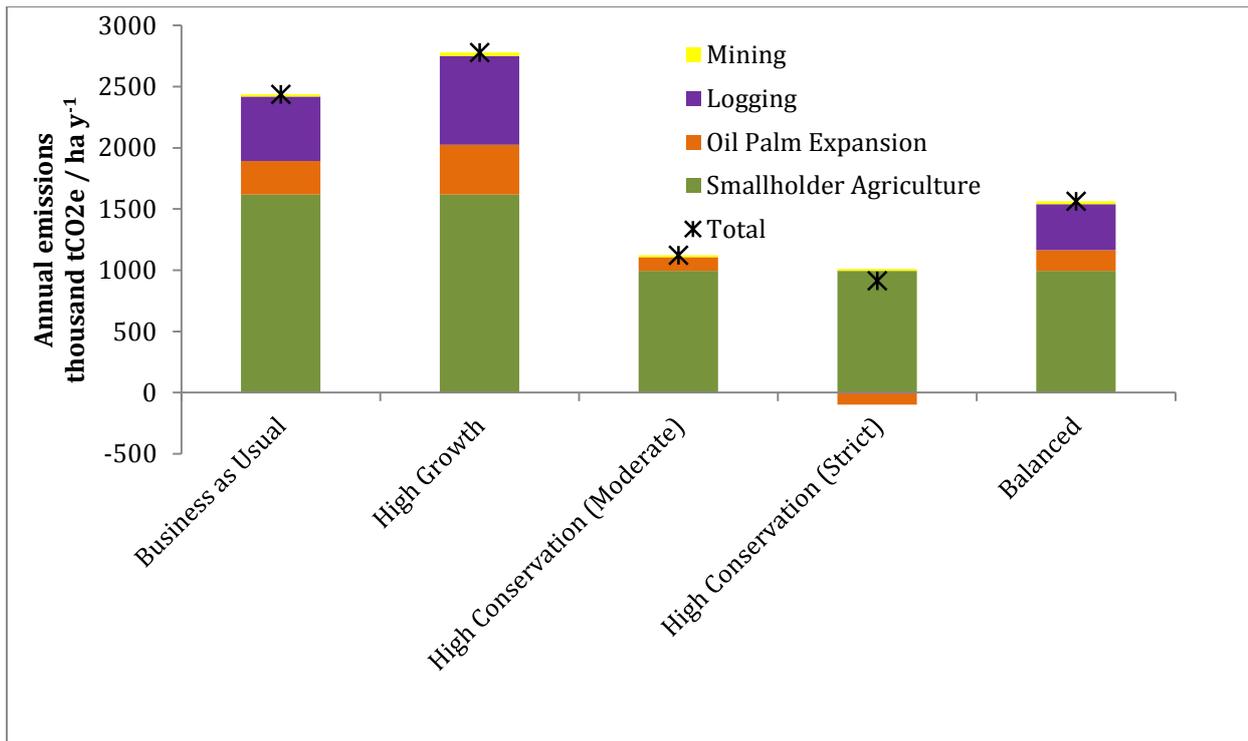


Figure 22. Annual GHG emissions by driver and scenario. Emissions from highway expansion are not annual and are thus excluded here.

Future work on landscape and scenario planning in Madang could be improved by addressing key data gaps:

Peat Soils: We were unable to identify any map detailing the specific location and depth of peat deposits in Madang, and we concluded that such a map does not yet exist. As peat soils comprise a large portion of the emissions profile from agriculture projects, conducting a survey of wetland soils for presence of peat and depth would greatly improve the robustness of conservation criteria for agricultural expansion.

Smallholder Agriculture: There are several areas of high uncertainty around the future impact from smallholder agriculture. Because this is such a large potential emission source, better information of the following factors would improve provincial projections:

- The rate of rural population growth is strongly related to the rate of urbanization. Official estimates of urbanization in Madang, and growth rates specific to rural areas, would allow better understanding of the need for smallholder agricultural land.
- In community land use planning, some areas are set aside for protected status. This could result in an intensification of agriculture in non-protected areas. Long-term studies of land cover change and agricultural practices of areas under community land use planning are needed to estimate the benefit of community land use planning.

Reduced Impact Logging: RIL has the potential to greatly reduce emissions from logging. Based on the expert judgement the authors of Pearson, et al. (2014), a 30% reduction in impact was used in

these scenarios. However, field work should be done in Madang on pilot RIL projects to derive actual locally-calibrated default values for reduction potential.

Indirect Impact: The indirect impact of mining and transportation roads could be higher than direct impact, but the effect of influencing migration and settlement patterns and illegal logging has not been assessed for Madang. A priority should be creating default assumptions for how much secondary impact from resettlement and illegal logging based on either field measurements or reference to other PNG regions.

4 Datasets Used

This study relied on a number of spatial datasets to conduct the analysis. All of these data sets are either publically available or are maintained by PNG institutions.

Elevation	Shuttle Range Topography Mission (SRTM) 1 Arc-Second Global Digital Elevation Model. Accessed from http://earthexplorer.usgs.gov/
Roads	UPNG Geobook Madang. The Remote Sensing Centre, University of Papua New Guinea
Above and Below-ground Biomass, 250m resolution	Saatchi (2013) High resolution spatial patterns of forest carbon stocks in pan tropical regions from fusion of global multi-sensor data fusion. Developed by: Jet Propulsion Laboratory, UCLA Institute of Environment, Winrock International, Applied GeoSolutions. Unpublished dataset.
Land Cover	Gunarso, P.; Hartoyo, M. E.; Agus, F.; Killeen, T. J. (2013) Oil Palm and Land Use Change in Indonesia, Malaysia and Papua New Guinea, Roundtable on Sustainable Palm Oil
Peat Soil Depth (Indonesian Papua)	Minnemeyer, S; Boisrobert, L; Stolle, F; Ketut, Deddy; Muliastira, YI; Hansen, M; Arunarwati, B; Prawijiwuri, G; Purwanto, J; Awaliyan, R (2009) Interactive Atlas of Indonesia's Forests CD-ROM. World Resources Institute, Washington, DC.
Population	<ul style="list-style-type: none"> Center for International Earth Science Information Network (CIESIN), Centro Internacional de Agricultura Tropical (CIAT) (2005) Gridded Population of the World, Version 3 (GPWv3), CIESIN, Columbia University, Palisades, NY. Accessed from: http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/ UPNG Geobook Madang. The Remote Sensing Centre, University of Papua New Guinea
Flooding Risk Areas	PNG Forest Inventory Mapping System (FIMS)
Administrative Boundaries	GADM database of Global Administrative Areas Version 2.0. Accessed from http://gadm.org/
Soil Groups	FAO/IIASA/ISRIC/ISS-CAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.
Mean Annual Precipitation	WorldClim Current Conditions. Accessed from http://www.worldclim.org/current
High Conservation Priority Areas	The Nature Conservancy (2013) Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis, Papua New Guinea (see Figure 23)
Historical Forest Loss	M. C. Hansen, P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, J. R. G. Townshend (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342-6160 pp 850-853 Accessed from http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.1.html

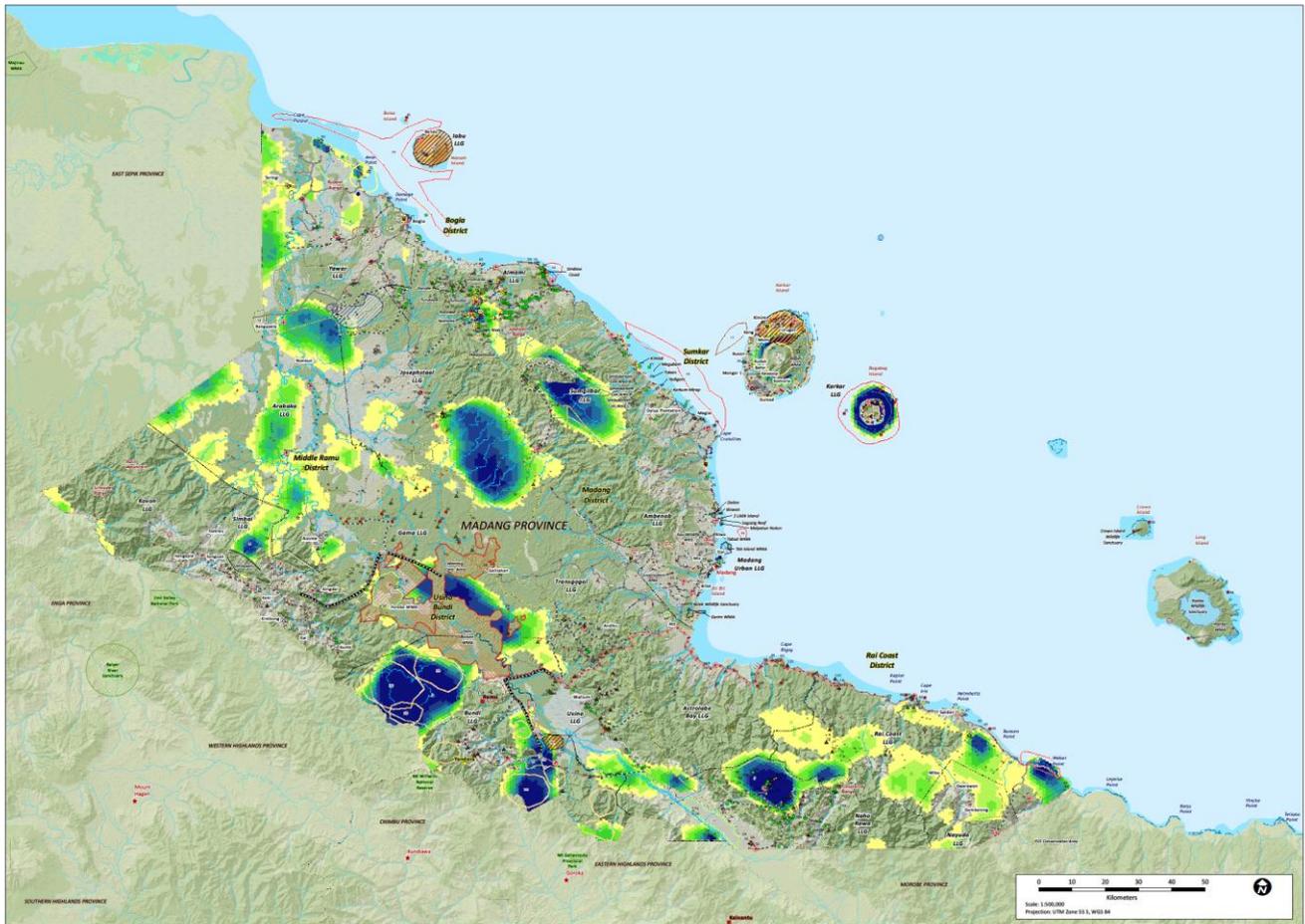


Figure 23. Area of High Conservation Priority identified in “Madang Sustainable Development: A Ridges-to-Reefs Gap and Priority Analysis”

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Annex 2: Assessment of Historical Deforestation and Degradation Rates

The three products and data sets described in this Annex and Section 5.8 provides a rich set of data on historical deforestation and degradation patterns and trends. It is this information on historical patterns and trends that is important for further discussion and debate, and not the relative cumulative rates of forest 'loss', 'gain' and 'disturbance'. The alignment of the data sets in mapping historical patterns of forest change, as illustrated in Figure 5, Figure 6 and Figure 7 further confirms the strength of these data sets.

1. Explaining the 'Hansen' Global Forest Change Data Set

The University of Maryland Global Forest Change²⁵ data provides a globally-consistent map of tree cover loss and gain from 2000-2013. The methods and results are provided in Hansen, et al. (2013). The dataset is produced from the analysis of the entire existing archive of remote sensing imagery from the Landsat mission beginning in 2000, and includes Landsat TM, ETM+ and OLI data. The final data product contains three key data types: 1) areas of tree cover loss and the year loss was detected; 2) areas of tree cover gain since 2000; 3) the percent tree cover of all lands in 2000. Maps are provided with global coverage at 30 meter resolution. It must be stressed that the maps do **not** give any indication of *forest* change, but only physical *tree cover* change.

The data layers are useful for landscape and forestry management due to their spatial and temporal consistency, ease of use and interpretation, and global accessibility.

- **Consistency:** The Landsat imagery used as input is collected consistently worldwide, and the algorithms used by Hansen, et al. are applied to entire data archive allowing results from one year or region to be reasonably compared to other periods or locations.
- **Physical Land Cover:** Many forest maps often include both physical and land-use criteria and changing government definitions of forest can make time series analysis difficult. The Hansen, et al. map provides an assessment of the physical condition of forest land, uninfluenced by various alternate forest definitions.
- **Access:** The project provides convenient and free data access resulting in its wide adoption for forest research and management applications. It is familiar to a wide range of policy makers and scientists and can serve as a common point of reference for collaboration.
- **Continuation of Mission:** It is intended for the data to be annually updated and expanded beyond Landsat to incorporate future satellite sensors allowing confidence in future assessments.

There are certain limitations to the dataset, mostly related to the lack of land-use information and inconsistency between loss and gain layers.

- **Land Use:** Because Hansen, et al. data only reports physical tree cover, loss and gain, it is unable to differentiate between land use classes. An oil palm plantation or acacia plantation will be identified as 'tree cover.' Plantation areas which are cleared as a part of the normal harvest will show up as 'loss' in maps. Small areas temporarily cleared within a swidden agriculture system will also show as loss. Without adjusting for land uses, regional rates of deforestation may appear unusually high based on this data alone.
- **Loss and gain comparisons:** The nature of tree cover loss versus gain is that loss within a 30m cell generally occurs rapidly within 1-2 years and can be readily detected by remote sensing methods, while gain is a slower process. This results in generally underestimating gain in

²⁵ <http://earthenginepartners.appspot.com/science-2013-global-forest>

relation to loss. This difference between loss and gain reporting means that while both gain and loss layers can be used to identify spatial patterns, they cannot yet be compared to one another to estimate net forest change. This may change in future releases as more years are added and confidence in gain estimates increases.

Limitations in Using the ‘Hansen’ Global Forest Change Data Set in Madang.

The detection of physical tree cover is a highly valuable, but in Madang, errors have been noticed. Figure 1 illustrates detection of forest loss, but the change is a result of changes in the river system. Oil Palm growth in the Ramu Valley has also been detected as forest ‘gain’.

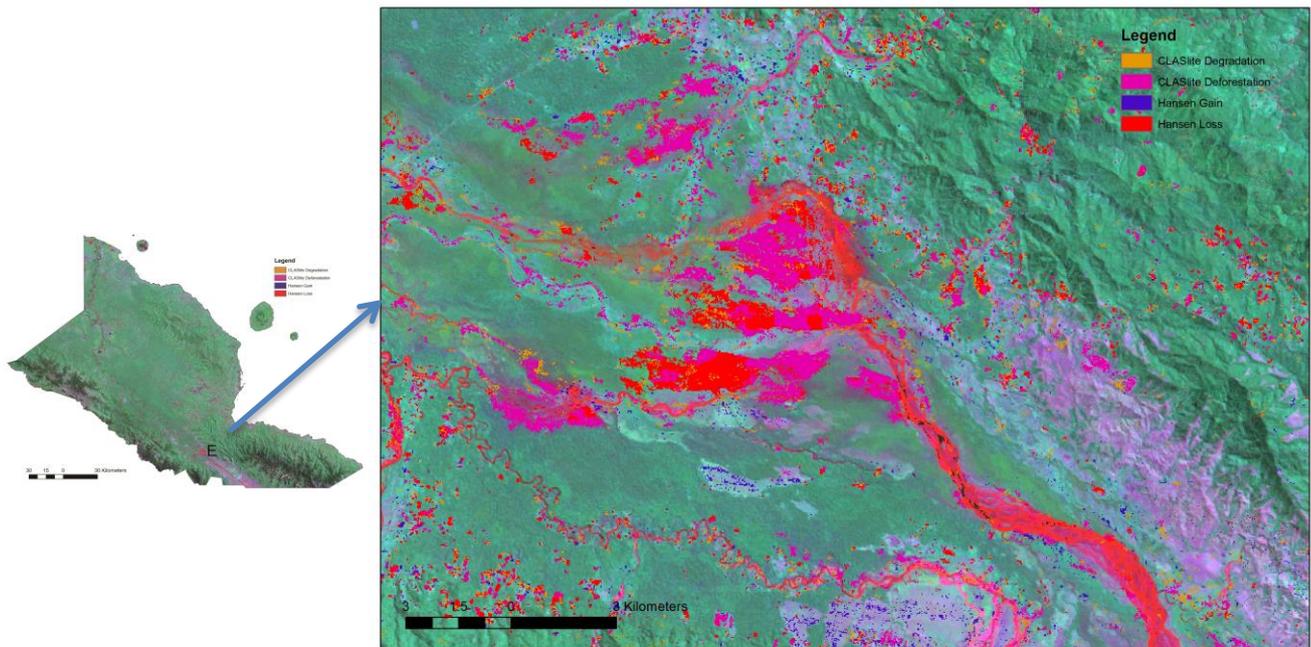


Figure 24: ‘Hansen’ limitation in detecting forest and land use change (Point E)

Hansen’s Outputs and Analysis

Table 33 presents the tabular data for the ‘Hansen’ assessment of forest loss and forest gain in Madang province from 2000-2013.

Table 33: Hansen Outputs for Madang, 2000-2013

Year	Forest Loss (hectares)	Forest Gain (hectares)
2000-2001	3,631	
2001-2002	6,092	
2002-2003	2,939	
2003-2004	8,011	
2004-2005	2,775	
2005-2006	5,844	
2006-2007	4,835	
2007-2008	7,566	
2008-2009	3,654	
2009-2010	7,684	
2010-2011	5,036	

2011-2012	7,472	
2013-2013	6,005	
Total	71,543 hectares	29,892 hectares
Yearly Average	5,503 hectares	2,299 hectares

2. Explaining the 'CLASLite' Dataset

The Carnegie Landsat Analysis System – Lite (CLASlite) developed by the Department of Global Ecology at the Carnegie Institution for Science²⁶, is a semi-automatic software program designed to extract land cover information from raw satellite data and generate images and maps to support forest monitoring efforts. It is a simple, free and easy to use software program that can use remote sensing images from Landsat 4 and 5 Thematic Mapper, Landsat 7 Thematic Mapper Plus, Landsat 8 OLI/TIRS, SPOT 4, SPOT 5, Terra-ASTER and EO-1-Advanced Land Imager (ALI) data.

The program converts satellite imagery and through calibration, pre-processing, atmospheric correction and cloud masking, then performs a *Monte Carlo Spectral Mixture Analysis* to detect deforestation and forest degradation. The outcome is a fractional or percentage cover (0-100%) of live, dead and bare soil. The fractional cover analysis is at the core of the program with a sub-pixel Spectral Mixture Analysis (SMA) method that detects spectral changes within pixels between time sequenced images (see Figure 25). The in-pixel fractional cover analysis allows changes in canopy percentage to be calculated and forest degradation rates estimated. The extensive spectral signature library derived from field databases and satellite imagery make it a very useful program for quickly determining deforestation and forest degradation patterns, trends and rates.

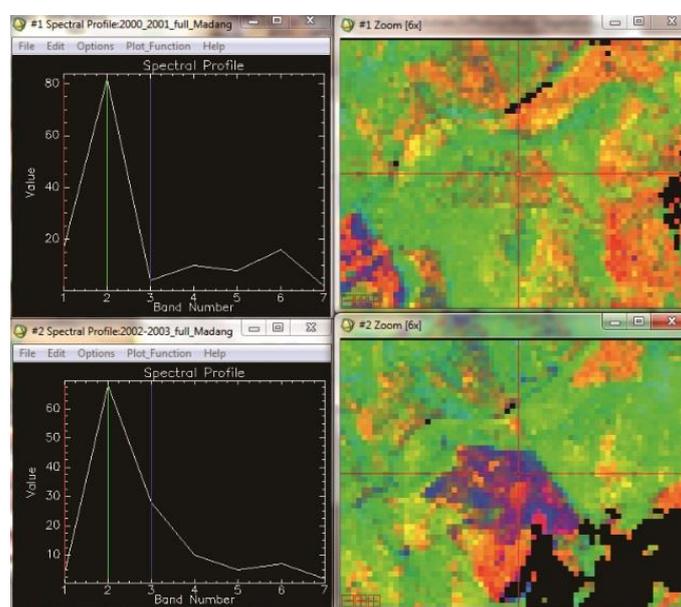


Figure 25: Reflectance Change Detection Between Two Time Sequenced Images

Using CLASLite in Madang

There are two critical problems in obtaining suitable Landsat imageries for Madang between 2000 and 2014:

1. Persistent cloud cover, cloud shadow and haze meaning there are very few imageries across Madang to work with; and

²⁶ (<http://claslite.carnegiescience.edu/en/index.html>)

2. There are relatively few Landsat 5 images available for Madang and malfunction of the Landsat 7 satellite has resulted in significant no-data bands that run through much of the Landsat 7 imagery.

From an analysis of Landsat 7 images between 2000 and 2012, 70% of images were not useable.

To overcome these problems, the United States Forest Service Remote Sensing Application Centre (USFS RSAC) had to composite (or combine) various Landsat 7 images to develop a single image for analysis. Given the difficulty in sourcing enough Landsat 7 images to create a single, 'good' image, all images between 28 May and 3 October and over a two year period were sourced and composited to fill cloud and data gaps. The 'filling' process was based on a median value of each pixel. The composited image was then exported to CLASLite for analysis.

The many advantages outlined for the Hansen data set are also applicable to the use of the CLASLite software. But the limitations of the Hansen data set are also evident in using the CLASLite product in Madang. Figure 24 highlights the limitation of CLASLite detecting natural changes in a river system, but mapping this as forest loss. The other limitation of the CLASLite data set is the 'banding' problem due to the Landsat 7 satellite malfunction (see Figure 26). These 'bands' have been classed as forest loss, disproportionately increasing forest loss for the 2004/2005-2006/2007 analysis period. For this reason the CLASLite data set was not used to quantify historical forest loss.

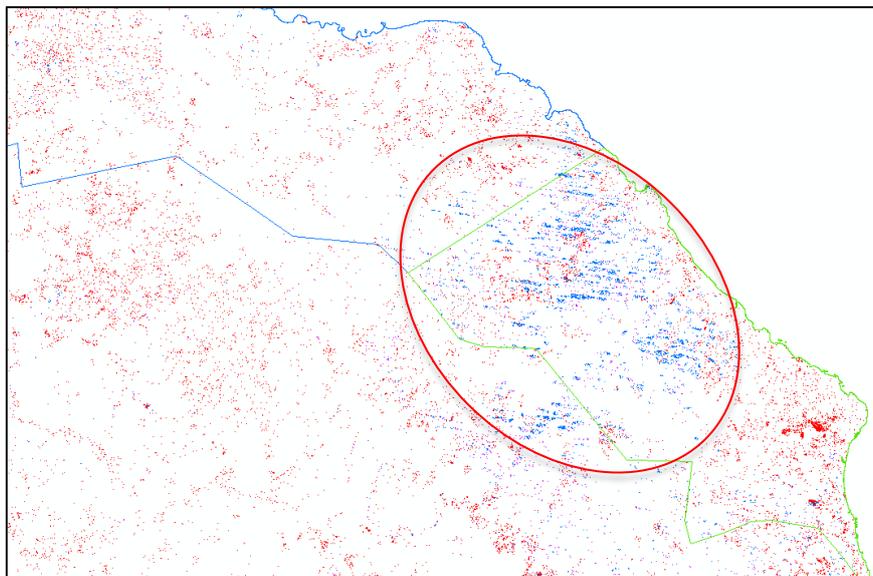


Figure 26: 'Banding' problem due to Landsat 7 Satellite malfunction. The 'banding' is highlighted in the red circle.

CLASLite's Outputs and Analysis

Table 34 details forest disturbance (degradation) and forest loss (deforestation) as detected by CLASLite between 2000 and 2013.

The power of the CLASLite analysis is in its ability to relatively rapidly and easily assess forest degradation. The results for Madang indicate the forest degradation is persistent and widespread across the process.

Table 34: Forest Disturbance (Degradation) and Forest Loss (Deforestation) Detected by CLASLite in Madang Province, 2000-2014

Year	Disturbance (ha)	Forest Loss (ha)
2000/2001-2002/2003	7,383	9,548
2002/2003-2004/2005	6,120	6,964
2004/2005-2006/2007	8,243	12,649
2006/2007-2008/2009	7,730	9,280
2008/2009-2010/2011	6,827	8,741
2010/2011-2012/2013	7,296	4,925
Total	43,600	52,106
<i>Annual</i>	<i>3,354</i>	<i>4,008</i>

3. Explaining the Multi-Date Trend Analysis

In an effort to provide repeatable, statistically valid deforestation and degradation estimates, the US Forest Service International Program (USFS/IP) through the Remote Sensing Applications Center (RSAC) designed and implemented methods to address three key needs:

- Landsat-based annual and biennial image composites;
- Validation of change products depicting deforestation and degradation from 2000-2013; and
- A change detection method designed to be sensitive to slow-onset, long duration change common in LEAF study areas.

Multi-Date Trend Analysis, uses a specifically designed algorithm developed by the USFS RSAC to detect slow-onset forest change or disturbance. The method builds on the Forest Monitoring for Action (FORMA) work (Hammer, et al., 2009²⁷) and the USFS Forest Disturbance Monitoring Tool²⁸. The work is built around the idea that much of the change in the tropics occurs over a period of two years or more. For the purpose of this study, this is considered a slow-onset forest disturbance. Since these changes generally have a low magnitude of change between any single year, many algorithms that depend on changes being abrupt will omit them. The newly developed algorithm loosely defines deforestation as a severe change that occurs over the course of 1-3 years. Forest degradation is loosely defined as a subtle change that occurs over the course of 3-5 years. Since subtle changes that only occur for a short period manifest the same as noise, they are considered undetectable.

With these definitions in mind, the algorithm first gathers all cloud and cloud-shadow-free Landsat observations within the study years (2000-2014 for this project) within a defined set of date periods. The date period is generally between 32 and 64 days, depending on the expected frequency of cloud-free observations in the study area. For each date period, a stack of annual median vegetation index composites are computed. Then, for a specified epoch length, a linear fit is

²⁷ Hammer, D., Kraft, R., Wheeler, D. (2009) FORMA: forest monitoring for action—rapid identification of pan-tropical deforestation using moderate-resolution remotely sensed data. Center for Global Development Working Paper No. 192 (2009) (November)

²⁸ <http://foresthealth.fs.usda.gov/portal/Flex/FDM?dL=0>

performed using the FORMA linear fit algorithm on a moving window. For example, if the study years are 2000-2014 and the epoch length is four years, the first window will be 1997-2000, then 1998-2001, 1999-2002, etc. Each of these epochs will have a slope returned from the FORMA linear fit algorithm (Hammer, et al., 2009), resulting in a stack of trends for each date period.

The next step is to simplify the series of linear slope stacks. Detectability of change is generally a function of the magnitude of change and how many times it is observed. Vogelmann, et al. (2012)²⁹ use a t-test with respect to the slope of the linear fit to filter real change from likely noise. This algorithm adapts this idea of change magnitude and persistence by filtering slopes by the number of date periods the slope is below a certain threshold. If a slope is highly negative in two out of three of the date periods, it is more likely to be real than if it only appears negative in one of the date periods. Additionally, if the slope is only moderately negative, but appears moderately negative in three out of three date periods, it is more likely to be real. Individual change years are identified using this function – the number of date periods a slope is below a certain threshold. This results in a stack of binary change/no-change layers.

The final filter is a moving window majority filter. It is expected that deforestation may occur over a shorter period of time, but have a higher magnitude, while degradation will have a lower magnitude, but be observable over multiple epochs. With this idea, a moving majority filter helps to identify persisting subtle trends associated with degradation. This can yield a depiction of subtle but persistent change, as well as severe, and only moderately persistent change, thus providing a potential alternative method for monitoring deforestation and forest degradation in the LEAF study areas.

Multi-Date Trend Analysis Outputs

Table 345 details forest disturbance (degradation) and forest loss (deforestation) as detected through the Multi-Date Trend Analysis from 2000 and 2013.

Table 35: Multi-Date Trend Analysis Historical Forest Loss and Disturbance

Year	Forest Loss (Hectares)	Forest Disturbance (Hectares)
2000	3,350	1,392
2001	6,488	146
2002	9,686	668
2003	5,721	734
2004	6,607	937
2005	2,344	748
2006	4,255	725
2007	6,304	1,000
2008	7,582	2,492
2009	3,132	1,933
2010	8,117	2,532
2011	2,895	419

²⁹ Vogelmann, J. E., Xian, G., Homer, C., Tolk, B. (2012) Monitoring gradual ecosystem change using Landsat time series analyses: Case studies in selected forest and rangeland ecosystems. *Remote Sensing of Environment*, 122, 92-105.

2012	1,479	271
2013	5,190	-
Total	73,150 hectares	13,998 hectares
Average	5,225 hectares	1,000 hectares

4. Validation and Ground Truthing of Remote Sensing Imagery and Analysis

Two validation exercises have been conducted to assess the accuracy of the Hansen and CLASLite data set (the Multi-Date Trend Analysis output was not completed in time for assessment).

Validation of Hansen Forest Loss Using Worldview-1 Satellite Imagery

The Worldview-1 satellite was launched in 2007, producing panchromatic imagery at a 0.5 meter resolution. The extremely high resolution imagery provides an excellent source to validate data derived from lower resolution imagery, such as the Hansen forest loss data.

Two Worldview-1 strips (2012 imagery) were obtained from the USAID Geocenter from which three scenes were selected to validate the Hansen forest loss data. Three scenes selected coincided with a logging concession, the community conservation zones of the Adelbert Range and an agricultural zone in the north of Bogia District (see Figure 27).

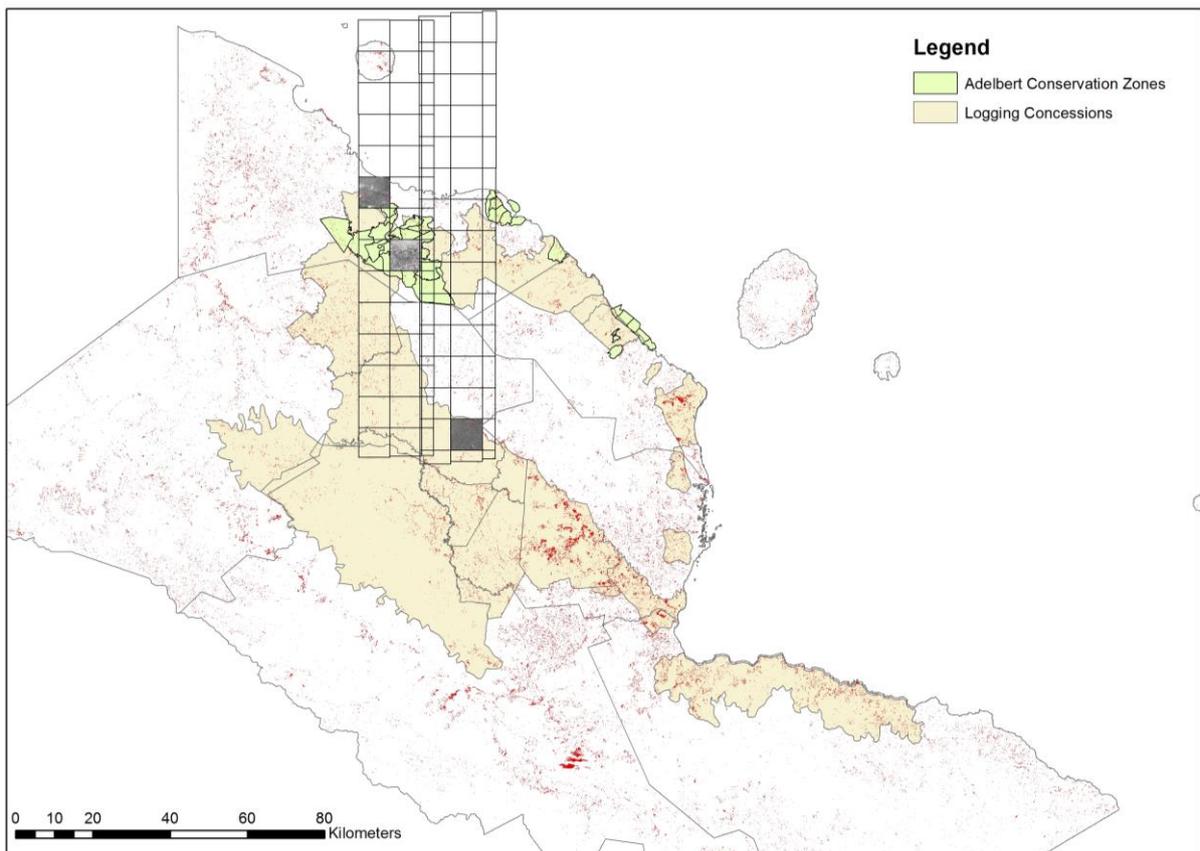


Figure 27: Worldview-1 imagery used to validate the Hansen forest loss data (shown in red)

A visual process was then used to assess, across of each of the three scenes, if the Hansen forest loss data coincided with an area of no forest (scored 1) or forest (scored 0). The red polygons shown in Figure 28 map Hansen forest loss which was then visually assessed against the image.

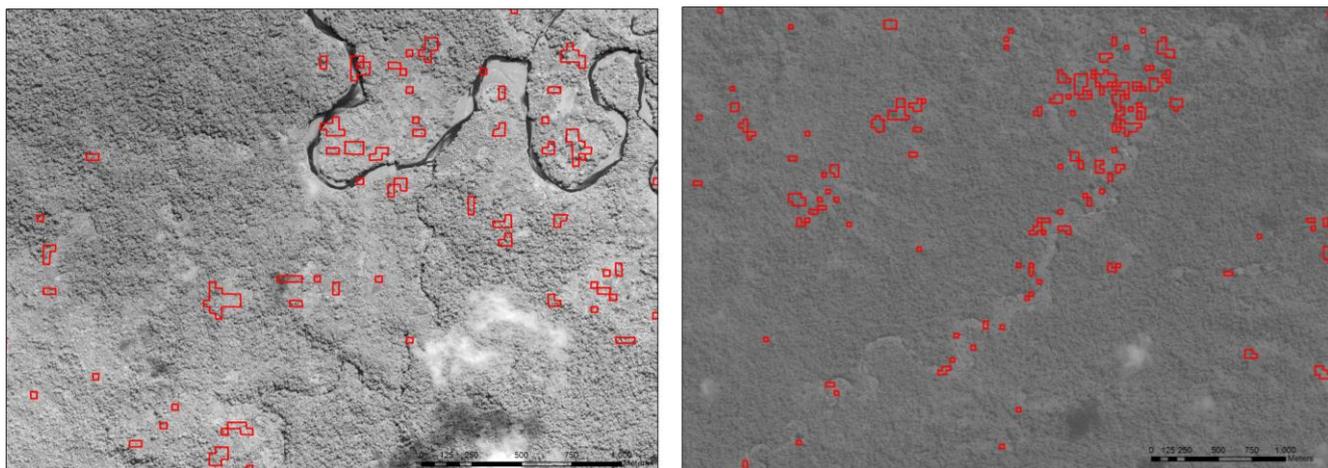


Figure 28: Validation of Hansen Forest Loss Data (Red polygons) using WorldVeiw-1 Satellite Imagery

Of the 699 Hansen forest loss polygons, 368 accurately matched an area of no forest suggesting an **accuracy rate of 53%**.

Ground Truthing of the Hansen and CLASLite Data Sets

To validate and assess the accuracy of the ‘Hansen’ and ‘CLASLite’ data sets, three field validation exercises were completed in November 2014, January 2015 and May 2015 (see Figure 29).

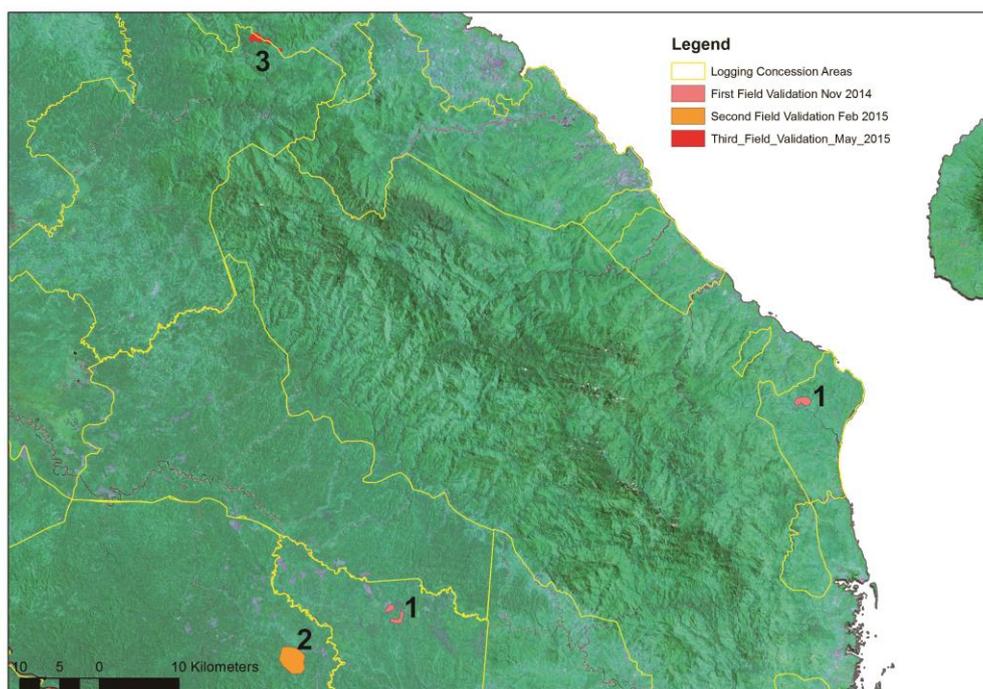


Figure 29: Locations for ground-truthing exercises with logging concession boundaries marked. (Location 1 is the Sogeram and plantation area, Location 2 is Middle Ramu Block 1 logging concession and Location 3 is the Adelbert Range.)

For each exercise, all coordinates for ‘Hansen forest gain’, ‘Hansen forest loss’, ‘CLASLite forest loss’ and ‘CLASLite degradation’ were selected for the location of analysis. Points were then randomly selected for ground-truthing and uploaded into the field crew’s GPS units. Figure 30 provides an

example using ‘Hansen forest loss’ (black squares) and ‘CLASLite forest loss’ (black triangles) as the points of interest with actual locations visited to assess accuracy marked by red circles (location is the Adelbert Range).

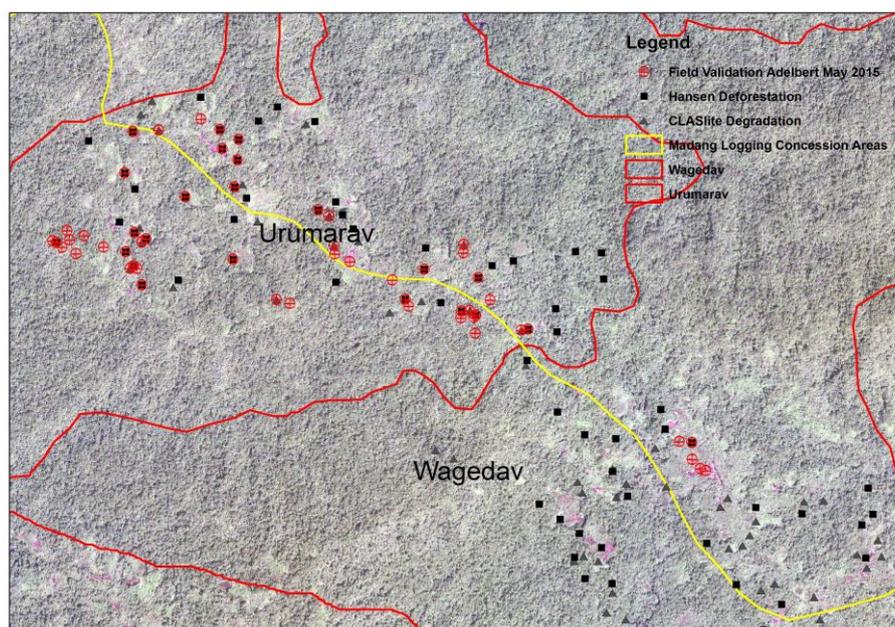


Figure 30: Points of interest and field validation sites for the Adelbert Range sites

Field crews then traveled to the randomly selected coordinates and noted latitude and longitude bearings, current land use, estimated canopy cover (<30%, 30-70% and >70%), signs of forest disturbance and any other interesting features of the site. Photos of the four cardinal points and forest canopy cover were also taken. An assessment was then made on the accuracy of the ‘Hansen forest gain’, ‘Hansen forest loss’, ‘CLASLite forest loss’ or ‘CLASLite degradation’ coordinates as per the field conditions.

Location 1: On 26 and 27 November 2014, two field sites were visited. On 26 November, the Sogeram logging concession was visited (approximately 75km west of Madang town) consisting mainly of second regrowth forest after selective logging. On 27 November 2014, a timber plantation and community gardening area was visited (approximately 30km north of Madang town). This was part of a 2,000ha Acacia plantation managed by PNGFA, but most of the land is now under customary rule and is used for various agricultural activities.

Location 2: The Middle Ramu Block 1 Logging Concession, consisting of secondary re-growth forest, was visited between 27-29 January 2015.

Location 3: The Wagedav and Urumarav communities of the Adelbert Range were visited between 14 and 17 May 2015. The areas selected were of low-mountain forest, interspersed with agriculture plots.

Table 36, Table 37 and Table 38 report the accuracy assessments for each of the three locations.

Table 36: Sogeram and Plantation Accuracy Assessment

Type	# Selected	# Correct	# Wrong	Accuracy %
Hansen's loss	38	36	2	94
Hansen's gain	9	9		100
CLASlite's deforestation	5	5		100
CLASlite's degradation	3	3		100
Total	62	58	4	

Table 37: Middle Ramu Block 1 Accuracy Assessment

Type	# Selected	# Correct	# Wrong	Accuracy %
Hansen's loss	2	1	1	50
Hansen's gain	8	8	0	100
CLASlite's deforestation	14	11	3	79
CLASlite's degradation	9	5	4	55
Total	88	75	13	

Table 38: Adelbert Range Accuracy Assessment

Type	# Selected	# Correct	# Wrong	Accuracy %
Hansen's loss	20	19	1	95
Hansen's gain	10	9	1	90
CLASlite's deforestation	10	6	4	60
CLASlite's degradation	15	11	4	73
Total	55	45	10	

The combined accuracy assessments are:

- Hansen Forest Loss: 93.3% accurate
- Hansen Forest Gain: 96.3% accurate
- CLASlite Forest Loss: 75.7% accurate
- CLASlite Degradation: 70.4% accurate.

The results indicate a very high level of accuracy for all remote sensing data sets.