DEFORESTATION AND FOREST DEGRADATION ANALYSIS OF SOUTHERN SIERRA MADRE, PHILIPPINES USING GOOGLE EARTH ENGINE AND COMMUNITY MAPPING

Kyle Pierre R. Israel*[1], Marie Jessica C. Gabriel[2], Wencelito P. Hintural[3] and Michael Maoi M. Baldonado[3]

[1]Department of Community and Environmental Resource Planning, College of Human Ecology, University of the Philippines Los Baños, Los Baños, Laguna
[2]Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of the Philippines Los Baños, Los Baños, Laguna
[3]Ecosystems Research and Development Bureau, Department of Environment and Natural Resources, Los Baños, Laguna

KEY WORDS: remote sensing, google earth engine, deforestation, forest degradation, community mapping

ABSTRACT:

Google Earth Engine (GEE) has empowered researchers to map and monitor vegetation cover through the utilization of satellite imagery and cloud-computing resources. This study employed such platform to evaluate deforestation and forest degradation (DFD) in the Southern Sierra Madre Mountain range, where historical and current evidence underscores ongoing degradation. This research endeavors to capitalize on GEE to generate land cover maps for the Southern Sierra Madre region, specifically in General Nakar, Quezon, and in Rodriguez, Rizal and to present the changes that occurred during three specific years: 2016, 2019, and 2022. Community mapping activities were also conducted in these municipalities to further validate the results from GEE. The findings indicate that forested lands predominantly encompassed both municipalities, albeit exhibiting a declining pattern for successive years. Analysis of land cover maps revealed that in General Nakar, most of the forest areas converted to shrublands are found in the barangays of Umiray and Pagsangahan while for Rodiguez, most of the forest areas converted to shrublands were found to be in Marikina Watershed Forest Reserve and in Puray. Community mapping unveiled that DFD factors such as kaingin, infrastructure extension, timber poaching, small-scale mining, charcoal making, and natural hazards are also present in these areas. With the availability of these openly available cloud-computing platforms, aided by inputs from members of the communities, efficient monitoring and implementation of interventions may be realized.

1. INTRODUCTION

Research on the rate of deforestation in the Philippines has been a persistent area of interest due to the country's heavy reliance on its natural resources. The earliest recorded forest cover in 1565 stood at 92%, but this figure steadily declined to 50% by 1950, as reported by Lahmayer (2003) and cited by Bankoff (2007).

According to data from the Department of Environment and Natural Resources (DENR), forest reserves only covered 11% of the total land area in the Philippines in 1990, 2000, and 2010 (FMB-DENR, 2010). Factors contributing to this substantial forest loss include a rapid increase in population and the conversion of land for agriculture (Kummer, 2006). Recent research conducted by Carandang et al. (2013) identified practices like kaingin, mining, logging, as well as the impacts of climate change and natural disasters as drivers of deforestation and forest degradation (DFD)

The persistent deforestation within the nation is a significant concern, primarily because it has led to various adverse outcomes, including soil erosion, landslides, flooding, the decline in biodiversity, and the degradation of watersheds. These consequences become even more critical when considering the crucial functions that forests perform, such as capturing atmospheric carbon dioxide, safeguarding existing biodiversity, and enhancing ecosystem resilience in the face of climate change (Perez et al., 2020).

Innovations, such as cloud computing, have been helpful in various applications, such as in vegetation mapping and monitoring, land cover mapping, agricultural application, disaster management, and earth sciences. With the rise of cloud computing platforms (such as Google Earth Engine) for analysis and decision making (Kumar and Mutanga, 2018), the visualization of the land cover dynamics within regions of interest done much easier. Following the release of the Landsat series for free in 2008, Google archived all data sets and linked them to its cloud computing engine for open-source use in research and other purposes (Mutanga and Kumar, 2019).

2. OBJECTIVES

The goal of this study is to observe changes in the vegetation cover of the Southern Sierra Madre, specifically in the regions covered by the municipalities of General Nakar in Quezon and Rodriguez in Rizal. With the mobility restrictions during the pandemic, monitoring of forest and implementation of conservation projects were halted. It is hypothesized that forest cover will exhibit a decreasing trend. These changes in vegetation shall be calculated with the use of cloud-computing platform and supported by results from community mapping.

Specifically, the study aims for the following:

1. Observe vegetation coverage in the region for the years 2016, 2019, and 2022

2. Calculate land cover changes that occurred before (2016-2019) and after (2019-2022) the pandemic.

3. Visualize drivers of deforestation and forest degradation identified by the communities.

* Corresponding author

https://doi.org/10.5194/isprs-archives-XLVIII-4-W8-2023-313-2024 | © Author(s) 2024. CC BY 4.0 License.

3. MATERIALS AND METHODS

3.1 Site Description

3.1.1 General Nakar, Quezon

Salva, et al. (2012) stated that General Nakar was once a barrio of Infanta, Quezon and was legally declared as a separate municipality in 1949. Currently, the municipality is comprised of 20 barangays and 82 sitios. The municipality is located at the northern part of the province of Quezon with approximately 1134.86 km^2 land area. Statistical data indicate that approximately 80% of the municipality's land area is classified as forest land, while only 20% is designated as agricultural or alienable and disposable land. Furthermore, 40% of the total land area is situated at elevations exceeding 500 meters above sea level (masl), with the remaining 60% lying below 500 masl. Additionally, the local government unit has documented a consistent annual decline of 5.6% in forest conversion to other land uses, such as cultivation or plantation areas, as noted by MENRO General Nakar in 2015.

According to the Modified Corona classification system, the municipality falls under the Type IV climate, characterized by relatively uniform rainfall throughout the year. Additionally, the area is marked by the presence of seven distinct soil series: Annam Clay Loam, Antipolo Sandy Clay, Antipolo Soils (undifferentiated), Hydrosol, Mountain Soil (undifferentiated), Quiangua Silt Loam, and Umingan Loam (as reported by NAMRIA and cited by Sazon et al., 2018).

Based on the 2020 census of population, the coastal municipality of General Nakar is home to 34,225 individuals and indigenous peoples (IPs), such as the Agta-Dumagat tribe (Future of Forest Work and Communities, 2023). The primary livelihood activities identified are agriculture, fishing, upland cultivation, and harvesting of non-timber forest products. The indigenous tribal group typically rely on upland farming, charcoal making, weaving, and copra-making (Salva et. al, 2012).

3.1.2 Rodriguez, Rizal

The municipality of Rodriguez, formerly known as Montalban, is situated at the northern region of the Rizal province, nestled at the base of the Southern Sierra Madre Mountains. It is the largest municipality of Rizal, covering a total land area of 363.07 km^2. Portions of the Upper Marikina River Basin Protected Landscape (UMRBPL) are also found within the boundaries of the municipality, as indicated in CDP's 2016 report. Furthermore, the Pamitinan Protected Landscape (PPL) was designated within the municipality in 1996 under Proc. No. 901, encompassing the cave and its surrounding cave ecosystems.

The municipality is generally comprised of rugged and mountainous terrain, along with volcanic, metamorphic, and dioritic hills. The highest recorded peak is Mt. Irid, standing at an elevation of 1,469 (masl). As per the Modified Corona Classification System, Rodriguez experiences a Type I climate, which is characterized by a pronounced dry season from December to April. Seasonal changes in rainfall patterns are observed due to monsoon circulations, with minimal rainfall of 15 to 23 mm in January and February, while excessive moisture occurs from June to October. Also, the municipality receives an annual average of 2,471 mm of rainfall, with the rainiest months being July, August, and September, and the coolest months spanning from October to March (CDP, 2016).

In terms of population, the municipality has experienced consistent growth, as reported by the Philippine Statistics Authority (PSA), with an average growth rate that is more than twice that of the whole province. The records indicate a sudden surge in population, primarily ascribed to the national government's relocation project, which started in the 1990s.

This population spike was particularly notable between 1995 and 2000, specifically in Barangay San Jose, and between 2004 and 2007 in Barangay San Isidro. The ongoing increase in the population has led to the municipality's transition from a rural to an urban classification (CDP, 2016). The figure shows the location map of the study site.

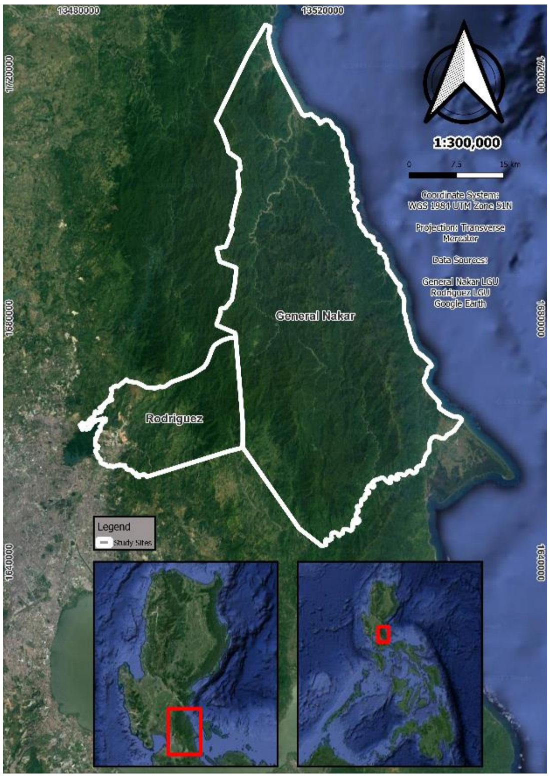

Figure 1. Location map of the study site

3.2 Land Cover Mapping using Google Earth Engine

The analysis of land cover change was performed within the Google Earth Engine interface. Google Earth Engine (GEE) is a cloud-based platform developed which provides easy access to powerful computing resources for processing large geospatial datasets. Through the Earth Engine API and its operator library, users can analyze both public catalog information and their own private data (Google Earth Engine, n.d.).

In this study, Landsat imagery for years 2016, 2019, and 2022 were utilized. Cloud-free mosaics for the municipalities were generated within the GEE platform. Administrative boundaries provided by the Local Government Units (LGUs) were used to confine the data processing within the bounds of the sites.

Training points for the identified land cover classes (Forest, Water, Shrubs/Grassland, Open/Barren, Agriculture, and Built-up) were created for each of the mosaics created for the sites for each of the years of interest (2016, 2019, and 2022). These points were then used as input for the image classification within the GEE interface.

The Classifier package within the GEE interface was used in the image classification. In GEE, Classification and Regression Trees (CART) are crucial machine learning algorithms that aid in the comprehension and analysis of satellite imagery. When classifying data, the algorithm uses satellite images with labelled information, which lets us know what each pixel in the image stands for—forests, water bodies, or metropolitan areas, for example. After that, it constructs a tree of queries to categorize the pixels. The method begins by asking queries regarding the pixels' attributes, such as color, texture, or reflectance.

It determines how to split the pixels into two groups based on the responses. If the response to the question "Is this pixel's color green?" is yes, it belongs to one category (such as vegetation), and if the answer is no, it does not. As the process continues, the algorithm asks more questions to further divide the groups it formed in the previous stage into even smaller sub-groups. This process is repeated until the groups can no longer be divided further or until it reaches a certain level of accuracy. "Leaf nodes," the last set of groups, stand in the image for various classes.

Eventually, the overall accuracy and Kappa statistics of the image classifications were also computed for each site for each year. A higher overall accuracy denotes a more accurate classification outcome, demonstrating that the algorithm did a better job of giving the pixels the appropriate class labels. Meanwhile, the Kappa statistics or coefficient (Viera & Garrett, 2005) is a numerical way to measure how much agreement there is between different observers or methods when categorizing things into different groups. It is used to assess the consistency of classifications for nominal scales, where objects are sorted into non-numeric categories. The Kappa coefficient helps determine the level of agreement in classifying objects into exclusive categories. The formula for this follows

$$\kappa = \frac{p_o - p_e}{1 - p_e},$$

Where:

p_o = proportion of agreements and

p_e = is the expected proportion of agreements by chance

3.3 Community Mapping

Mapping the occurrences of activities causing deforestation and forest degradation was also performed for the study. Information used for mapping were obtained from the inputs provided by different stakeholder groups, such as local implementers and regulators, forest users, private sector, and civic society organizations (CSOs) and non-government organizations (NGOs).

3.4 Comparison with Secondary Data

Secondary data were also collected for support and validate the results of the study. The land cover maps from the National Mapping and Resource Information Authority (for years 2015 and 2020) and the field data from the LAWIN Forest and Biodiversity Protection System (from 2016 to 2022) were acquired and utilized

4. RESULTS AND DISCUSSION

4.1 Land Cover Mapping

Accuracy assessments for the land cover maps yielded for the study sites revealed that the rasters generated are highly accurate and the observations are in almost perfect agreement, with overall accuracy values at least 80% and Cohen’s Kappa coefficient values at least 90%.

Year	General Nakar		Rodriguez	
	OA	κ	OA	κ
2016	0.90	0.90	0.95	0.94
2019	0.88	0.85	0.96	0.93
2022	0.84	0.83	0.93	0.91

Table 1. Overall accuracy and Cohen's Kappa Coefficient values for General Nakar and Rodriguez

4.1.1 General Nakar, Quezon

Land cover analysis conducted in General Nakar indicated that, during the specified study years (2016, 2019, and 2022), forested areas predominated in the municipality, accounting for 72.18%, 69.73%, and 57.52% of the total area for each respective year. Notably, there was a discernible decline in forest cover throughout the study period. Following forested areas, brush and shrubland emerged as the next prominent land cover type within the area, covering 11.74%, 18.48%, and 32.04% of the municipality's total area for each corresponding period. Unlike the forests, brush and shrubland areas exhibited an increase over the study duration.

This decline in forest cover from 2016 to 2022 may be attributed to heightened kaingin activities, particularly during the pandemic. Kaingin areas in Landsat images may not be classified as agricultural areas due to the presence of understory vegetation and a mix of shrubs and trees, unlike conventional rice or corn fields. Additionally, the decrease in canopy cover could also be associated with the impact of typhoons within the period, such as Typhoon Karding (September 2022), Typhoon Ulysses (November 2020), and Typhoon Lando (October 2015).

The majority of forested areas within General Nakar are primarily located in barangays Umiray and Pagsangahan. In 2022, it was determined that Umiray accounted for 38.65% of the municipality's forests, while Pagsangahan had 21.97%. Together, these two areas comprised over 60% of the municipality's total forested area for that year. The remaining forested areas are spread across the other barangays. It's worth noting that a significant portion of the forests within these barangays has been observed to be diminishing.

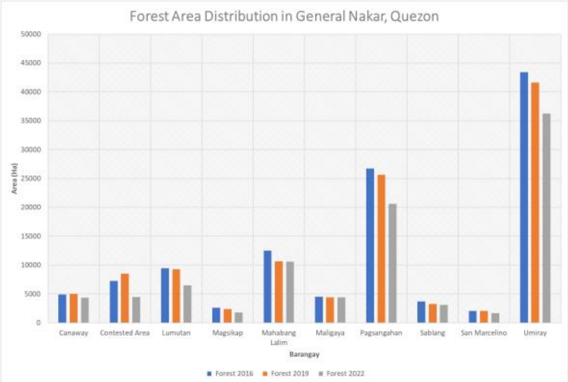

Figure 2. Forest cover distribution in General Nakar, Quezon

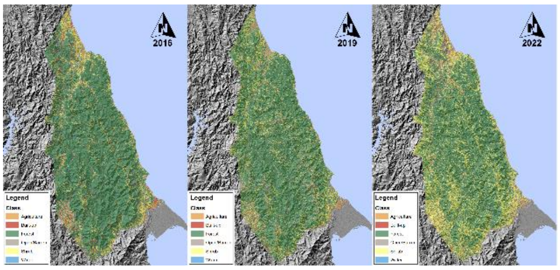

Figure 3. Land Cover Map for General Nakar in years 2016, 2019, and 2022

4.1.2 Rodriguez, Rizal

Land cover analysis in Rodriguez during the specified time periods revealed that more than half of the municipality was consistently occupied by forested areas. In 2016, these forested regions covered 22,254.88 hectares, accounting for 55.24% of the total area. In 2019, the forested area expanded to 27,160.43 hectares, encompassing 67.42% of the total area. By 2022, forested areas still dominated, occupying 22,561.21 hectares or 56.00% of the total land area. Simultaneously, shrub-covered areas also held a notable portion of the municipality's land. In 2016, shrub areas spanned 10,729.48 hectares, making up 26.63% of the total area. In 2019, this decreased to 8,765.02 hectares, representing 21.76% of the total area. However, by 2022, shrub-covered regions expanded to 12,305.25 hectares, accounting for 30.54% of the total land area.

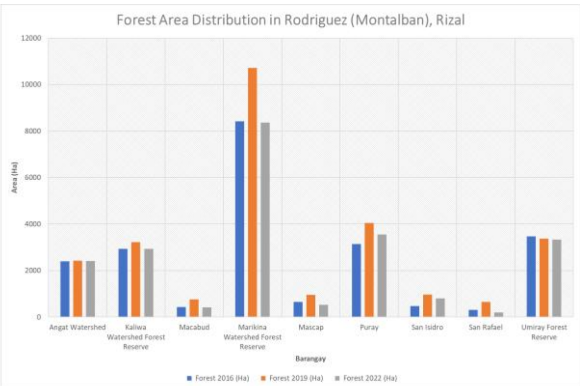

Figure 4. Forest cover distribution in Rodriguez, Rizal

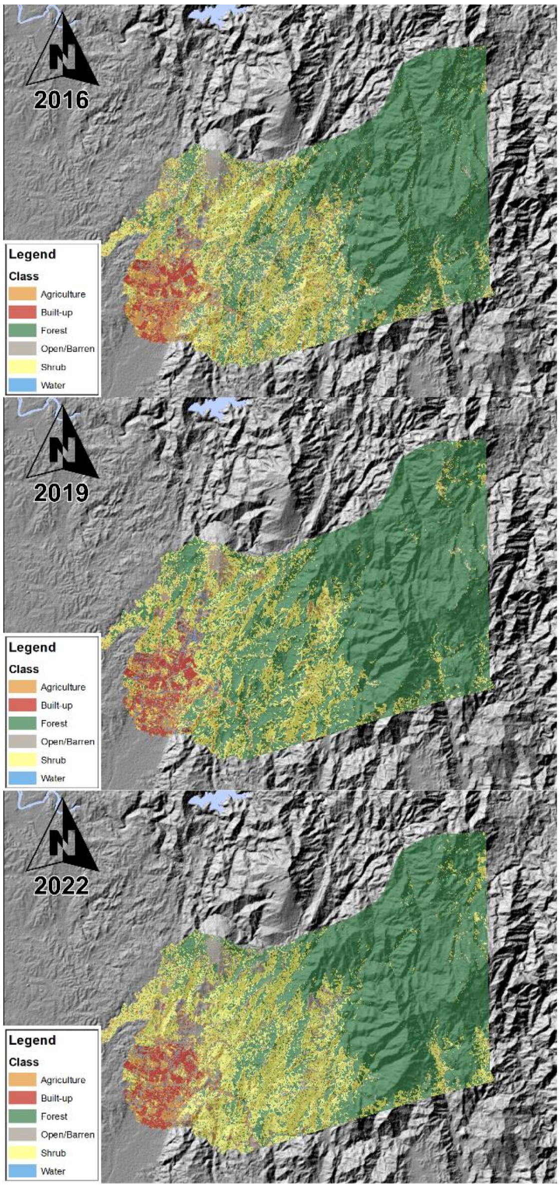

Figure 5. Land Cover Map for Rodriguez in years 2016, 2019, and 2022

The local government unit (LGU) provided data for administrative boundaries that delineate watersheds and forest reserves separately from the barangays. An analysis of these boundaries revealed that the majority of the municipality's forested areas are concentrated within the Marikina Watershed Forest Reserve, Umiray Forest Reserve, and Barangay Puray.

In 2022, these areas collectively comprised a total forested area of approximately 15,259.82 hectares. Specifically, the Marikina Watershed Forest Reserve accounted for 8,371.61 hectares, representing 37.13% of the total forest area in 2022, while the Umiray Forest Reserve covered 3,329.82 hectares or 14.77%, and Barangay Puray encompassed 3,558.38 hectares, equivalent to 15.78% of the total forested area

4.2 Change Detection

4.2.1 General Nakar, Quezon

The transformation of forested areas both before the onset of the pandemic (2016-2019) and during the pandemic (2019-2022) predominantly led to the emergence of brush/shrub-covered regions. Before the pandemic, approximately 8,170.99 hectares of forest areas transformed into shrubland, and this figure increased to 10,142.57 hectares after the pandemic. Moreover, portions of forested areas were also lost to open/barren areas, with 2,586.11 hectares converted before the pandemic and 3,348.91 hectares during the pandemic. Furthermore, it's worth noting that the conversion of forested areas into built-up and agricultural areas was more pronounced before the pandemic compared to the transformation that occurred after the pandemic. Further data analysis revealed that the majority of forested areas that were lost to brush/shrublands were primarily located in barangays Umiray and Pagsangahan. Specifically, before the pandemic, 5,736.30 hectares in Umiray and 3,127.16 hectares in Pagsangahan were transformed into brush/shrublands.

After the pandemic, these conversions increased to 9,486.08 hectares in Umiray and 7,306.96 hectares in Pagsangahan. Additionally, transformations from forest areas to brush/shrublands were also observed in the barangays of Lumutan, Mahabang Lalim, and the Contested area in the northernmost part of the municipality.

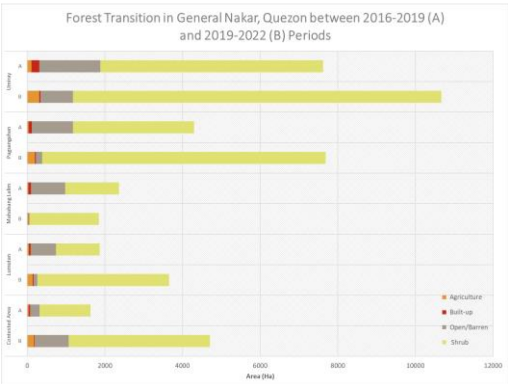

Figure 6. Forest Transition in General Nakar, Quezon in 2016-2019 (A) and 2019-2022 (B) Periods

4.2.2 Rodriguez, Rizal

Like in the case of General Nakar, majority of the forested areas lost both before the pandemic (2016-2019) and after the pandemic (2019-2022) transformed into brush/shrub areas. Specifically, there were 1,065.40 hectares lost before the pandemic, and this increased to 5,621.48 hectares lost after the pandemic. Furthermore, other forested areas in the municipality that were lost also changed into agricultural areas, with 53.94 hectares lost before the pandemic and 189.55 hectares lost after.

Upon closer examination, it was observed that the majority of forested areas that changed into shrublands were primarily found within the Marikina Watershed Forest Reserve. Before the pandemic, 373.75 hectares of forest in this reserve had transformed into shrubs, and this figure increased to 2,647.38 hectares after the pandemic. Significant forested areas were also lost to shrubs in barangay Puray, with 161.86 hectares lost before the pandemic and 674.47 hectares lost after. Additionally, in barangay San Rafael, significant forested lands changed into shrublands, with 43.88 hectares lost before the pandemic and 452.21 hectares lost after the pandemic.

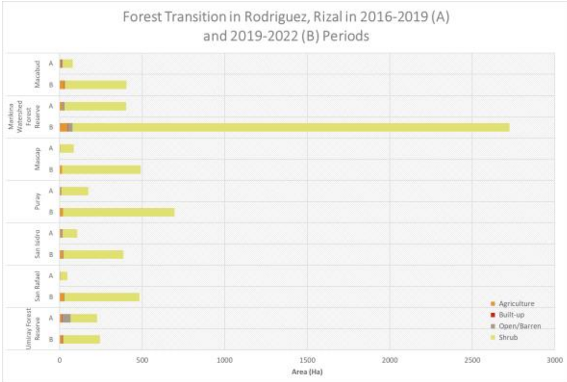

Figure 7. Forest Transition in Rodriguez, Rizal in 2016-2019 (A) and 2019-2022 (B) Periods

4.3 Comparison of Land Cover Dynamics with the NAMRIA Data

The National Mapping and Resource Information Authority (NAMRIA), an agency part of the Philippine government, under the Department of Environment and Natural Resources, is mandated to provide the public services in line with mapmaking. The agency serves as the central authority for collecting, storing, and disseminating natural resource data in various formats, including maps, charts, written documents, and statistical information.

The agency releases updated land cover maps for the country. Since 2015, they began using 12 land cover categories, such as: (1) Closed Forest, (2) Open Forest, (3) Mangrove Forest, (4) Annual Crop, (5) Perennial Crop, (6) Brush/Shrubs, (7) Grassland, (8) Open/Barren, (9) Built-up, (10) Fishpond, (11) Marshald/Swamp, (12) and Inland Waters.

To facilitate comparison of statistics with the dataset generated for the study, the NAMRIA land cover data for 2015 and 2020 were reclassified into 6 major land cover categories: (1) Forest, (2) Cropland, (3) Other Wooded Land , (4) Built-up, (5) Wetlands, (6) Other Land. This reclassification is similar to the land categories employed by the International Governmental Panel for Climate Change in their greenhouse gas inventory reporting (Intergovernmental Panel on Climate Change, 2003). The table shows how the land cover classes were harmonized to facilitate comparison.

NAMRIA Land Cover Class	Reclass (From IPCC)	Study Land Cover Classes
Closed Forest	Forest	Forest
Open Forest		
Mangrove Forest		
Brush/Shrubs	Other Wooded Land	Shrubs/Grassland
Grassland		
Annual Crop	Cropland	Agriculture
Perennial Crop		

NAMRIA Land Cover Class	Reclass (From IPCC)	Study Land Cover Classes
Marshland/Swamp	Wetlands	Water
Fishpond		
Inland Water		
Built-up	Built-up	Built-up
Open/Barren	Other Land	Open/Barren

Table 2. Harmonized land cover classes

Data analysis revealed that the Forest class for the NAMRIA data for General Nakar from year 2015 to 2020. This also aligns with the results of the land cover mapping generated for the municipalities using the remotely sensed data.

For Rodriguez, the Forest class for the NAMRIA data was observed to have a slight decrease, but the data generated for this study, an increase was observed between 2016 to 2019. This difference may be attributed to the activities reported in the municipality that are main drivers of forest degradation which have been exacerbated by the COVID-19 pandemic in 2020.

4.4 Community Mapping compared with LAWIN Data

The LAWIN Forest and Biodiversity Protection System incorporates a science-driven evaluation, user-friendly features, and the utilization of cutting-edge technology for monitoring forest conditions. This aids in environmental monitoring, particularly in areas with significant biodiversity conservation value. It enables both local communities and environmental authorities to improve the state of natural forests and effectively manage ecosystems to prevent degradation and deforestation.

The system was introduced by the Department of Environment and Natural Resources (DENR) in collaboration with the United States Agency for International Development (USAID) as part of the Biodiversity and Watersheds Improved for Stronger Economy and Ecosystem Resilience Program (DENR, n,d).

4.4.1 General Nakar

Looking at the LAWIN Data for General Nakar, it was found that apprehended forest products, conveyances, tools, and equipment in 2016 to 2022 were found in barangays, with varying frequency, with most frequent occurrences in barangay Pagsangahan.

BARANGAY	2016	2017	2018	2019	2020	2022	Total
Anoling		3	1	1	1		6
Banglos							0
Batangan				1			1
Canaway	3	1	1		1	1	7
Catablingan	5		1				6
Contested Area							0
Lumutan							0
Magsikap	1		2	1	1		5
Mahabang Lalim		1		1			2
Maigang		3		1	1		5
Maligaya			2	1	3		6
Minahan Norte		3	1	2	1		7
Minahan Sur		3	1	1	1	1	7
Pagsangahan	4	2	1	1			8
Pamplona							0
Pesa				1			1
Poblacion							0
Sablang	1			1	1	1	4
San Marcelino			2	1		1	4
Umiray	4		1				5

Table 3. Frequency of apprehended forest products, conveyances, tools, and equipment in General Nakar

Drivers of deforestation and forest degradation in General Nakar include infrastructure development, timber extraction, small-scale mining, charcoal making, upland farming, and wildlife poaching. It was found that barangay Umiray had the most drivers, with Infrastructure, timber extraction, small-scale mining, and wildlife poaching. Other barangays found with high frequencies include Lumutan, Maligaya, and San Marcelino.

Several barangays that had high frequencies of incidences in the LAWIN data had low frequencies in the drivers found in the community mapping. This may be because of the lack of representation from the barangays in the conduct of the community mapping activities.

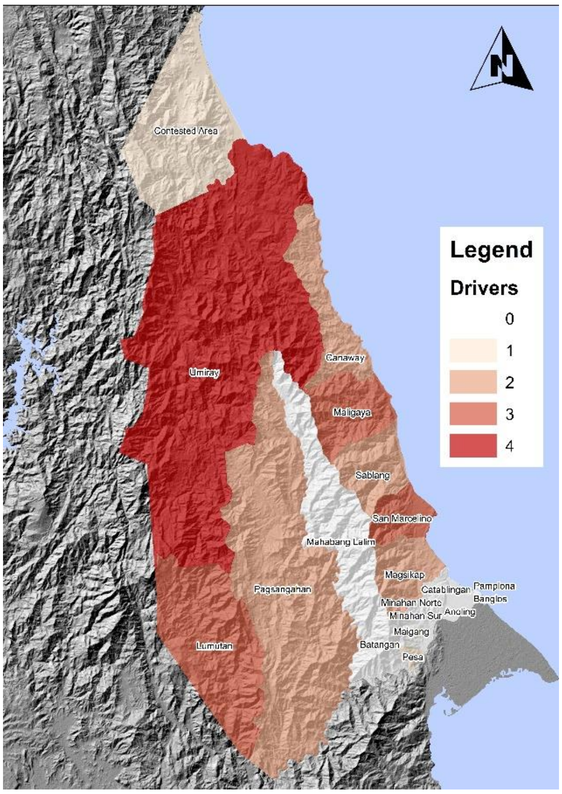

Figure 8. Frequency of drivers of deforestation and forest degradation in General Nakar

https://doi.org/10.5194/isprs-archives-XLVIII-4-W8-2023-313-2024 | © Author(s) 2024. CC BY 4.0 License.

4.4.2 Rodriguez

LAWIN data for Rodriguez were not as comprehensive as the ones from General Nakar, only showing relative locations of observed threats. Threats identified include cutting of trees, garbage, hunting, landslides, hunting, charcoal making, mining, and kaingin. Meanwhile, community mapping found that most barangay San Rafael was found to have the highest occurrence of the drivers for deforestation and forest degradation, namely: upland farming, infrastructure development, timber extraction, quarrying, and charcoal making.

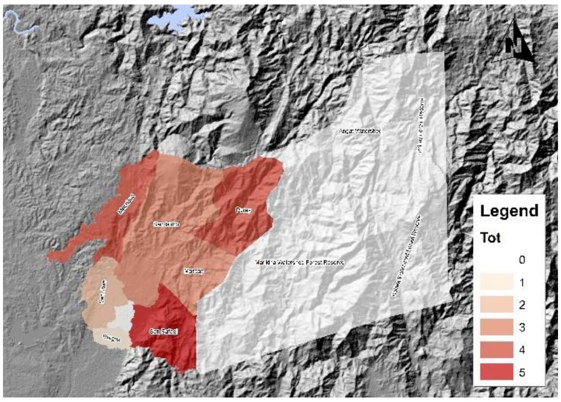

Figure 9. Frequency of drivers of deforestation and forest degradation in Rodriguez

5. CONCLUSIONS AND RECOMMENDATION

Deforestation and forest degradation continue to be a persistent issue in the Southern Sierra Madre. Observations in General Nakar, Quezon, and Rodriguez, Rizal, confirm that deforestation and forest degradation remain prevalent. The results of land cover assessment reveal an ongoing decline in forest coverage in both of these municipalities.

This research underscores the significance of employing innovative tools, such as cloud computing in Google Earth Engine, for monitoring and assessing the state of forests in the country, particularly in critical regions like the Southern Sierra Madre.

The reduction in forest cover that we observed was corroborated through community mapping and a comparison with secondary data sources, including the NAMRIA land cover maps and the LAWIN data from the DENR. These supplementary data sources provided valuable context for our remote sensing and GIS analysis results.

Future studies could consider incorporating higher resolution satellite imagery and utilizing unmanned aerial vehicles to collect data and evidence related to activities contributing to changes in forest cover.

ACKNOWLEDGEMENTS

We would like to extend our sincerest thanks to the Forest Foundation Philippines, Local Government Units of General Nakar, Quezon and Rodriguez, Rizal, the Department of Environment and Natural Resources, and the various stakeholders who have been involved in the conduct of this research.

REFERENCES

Bankoff, G. (2007). One island too many: reappraising the extent of deforestation in the Philippines prior to 1946. Journal of Historical Geography, 33(2), 314-334. doi:10.1016/j.jhg.2006.06.021

Carandang, A. P., Bugayong, L. A., Dolom, P. C., Garcia, L. N., Villanueva, M. B., & Espiritu, N. O. (2013). Analysis of Key Drivers of Deforestation and Forest Degradation in the Philippines. Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Retrieved March 2023, from https://forestry.denr.gov.ph/redd-plus-philippines/publications/Analysis%20of%20key%20drivers%20of%20deforestation%20and%20forest%20degradation%20in%20the%20Philippines.pdf

Department of Environment and Natural Resources. LAWIN Forest and Biodiversity Protection System Launching (2016). Retrieved from https://forestry.denr.gov.ph/index.php/lawin-forest-and-biodiversity-protection-system

Forest Management Bureau - Department of Environment and Natural Resources (FMB-DENR). (2010). 2010 Philippine Forestry Statistics. https://drive.google.com/file/d/116lKF0F_nQC5yQrhJRljH8WpubwTYVTx/view

Future of Forest Work and Communities. (2023, June). GENERAL NAKAR (Multiple communities). Future of Forest Work and Communities.

Google Earth Engine. A planetary-scale platform for Earth science data & analysis. https://earthengine.google.com/

Kummer, D. M. (2006). Deforestation in the Philippines, 1950–2000. In Muddied Waters Historical and Contemporary Perspectives on Management of Forests and Fisheries in Island Southeast Asia (Vol. 200, p. 350). https://brill.com/display/book/edcoll/9789004454347/B9789004454347_s015.xml

MENRO General Nakar. (2015, December). Gen. Nakar Forest Land Use. Gen. Nakar Forest Land Use: http://generalnakarmenro.blogspot.com/

Mutanga, O., & Kumar, L. (2019). Google earth engine applications. Remote Sensing, 11(5), 591.

NAMRIA (2015) National Mapping and Resource Information Authority. https://www.namria. gov.ph/

Perez, G. J., Comiso, J. C., Aragones, L. V., Merida, H. C., & Ong, P. S. (2020). Reforestation and deforestation in Northern Luzon, Philippines: Critical issues as observed from space. Forests, 11(10), 1071.

Salva, A., Santos, C., Santos, T., Lobrio, K., Estrella, S., Sioson, Z., . . . Banaguas, G. (2012). The Impacts of Climate Change on the Indigenous People: DUMAGATS. Lagumlalang: A Refereed Journal of Interdisciplinary Synthesis, 1(2). https://www.ejournals.ph/article.php?id=3000

Sazon, V. R., Lapitan, R. L., Villanueva, T. R., & Pulhin, J. M. (2018). Multi–Temporal Analysis of Land Cover Change for Disaster Risk Reduction Management in Infanta and General Nakar –Province of Quezon, Philippines. Ecosystems & Development Journal, 8(2), 41-49.

Viera, A. J., & Garrett, J. M. (2005). Understanding interobserver agreement: the kappa statistic. Fam med, 37(5), 360-363.

https://doi.org/10.5194/isprs-archives-XLVIII-4-W8-2023-313-2024