Cries of the Canopy: Forecasting the Fate of Forests in General Nakar, Quezon, along the Sierra Madre

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Abstract

This research utilized a quantitative-descriptive-computational methodology for determining forest area changes for the area encompassed by the Sierra Madre Mountain Range, and particularly for the area covered by the municipality of General Nakar in Quezon Province. Through geospatial information obtained from validated satellite images interpreted with geographical information technology, pixel area measurements for 2016, 2019, and 2022 were processed from formulaic calculations from a computational system. Determinations showed that there has been a gradual and consistent reduction with respect to forest area coverage throughout the duration, indicating a progressive and non-isolated form of deforestation. Further determinations from trend analysis indicated that such a progressive decline might be expected for at least the next few years, given the prevailing conditions. With such consistent reductions with respect to forest area coverage, such areas can be expected to be increasingly susceptible to vulnerabilities with respect to soil and water management. Nonetheless, despite such difficulties, such determinations verified and supported a scientifically valid method for localized forest area changes with equal efficiency through quantitative and computer-based calculations and analysis.

Keywords: Deforestation, Sierra Madre Mountain Range, Remote Sensing, Geospatial Analysis, Forest Cover Change

Introduction

Sierra Madre Mountain Range, also known as “the backbone of Luzon,” is the longest mountain range in the Philippines. These mountain ranges host incredible biodiversity, influence the climate, and mitigate disaster risks for the inhabitants of Luzon’s northeastern coast, as mentioned by Haribon Foundation (2023), Philippine Information Agency (PIA 2023), and the Climate Change Commission (2023). In this mountainous region, there is Quezon’s General Nakar town. It is noted for its dense forests. In reality, however, the challenge of deforestation has become significant because of increasing population pressure and development activities as well as historical logging activities (Philippine Star, 2025).

One of the indicators used when monitoring the environment globally is forest cover. FAO explains, "Forests cover about 31% of the Earth’s surface, but every year, 10 million hectares of forest disappear, mainly as a result of agricultural expansion, construction activities, and mismanagement of land" (FAO, 2020). Therefore, forest area expressed in hectares is used worldwide as a conventional measure used to determine changes associated with deforestation, carbon, and degradation of the environment. Use of indicators such as the change in forest cover within a given year and the annual rate of forest loss is widespread when monitoring the effects of climate change globally through UNFCCC.

However, with advances in remote sensing, for the first time, it is possible to monitor changes in forest cover consistently and in a comparable way across different countries or regions of the world. New global datasets, such as the Hansen Global Forest Change product, provide annual updates of forest cover and loss at fine spatial resolution and allow researchers to quantify the amount of existing forest, the year-to-year change in that forest, and the calculation of annual deforestation rates (Hansen et al., 2013). Common indicators derived from satellite-derived raster

data include forest area A_y, inter-annual change ΔA and the average annual loss rate L, which together constitute a good proxy of long-term forest dynamics provided that data are consistent and methods are standardized. These datasets have been widely applied in scientific studies to estimate forest loss trends and to project future scenarios using computational models.

On the national scale, all the way down to the local scene, especially here in the Philippines, we track forest cover by combining global data with maps the government itself produces. On a regular basis, NAMRIA, working hand in hand with the Department of Environment and Natural Resources or DENR, has been rolling out these land cover maps that classify where the forests are across the nation. These maps give very specific, location-based information on details of forest coverage, not just across regions, but also temporal changes, including on a level as specific as single municipalities.

Ecologically sensitive areas, like the Sierra Madre mountains, are not simply about the level of forests present in that area. This is because the actual level of the forests has direct effects on the integrity of the watershed area and disaster risk management. Take, for instance, the extent of General Nakar in the Quezon Province, where the degree of forested area and the corresponding rate of decrease indicate susceptibility. Pulling these variables from existing datasets links this work into global monitoring frameworks, while concurrently producing ground-truth evidence to guide conservation planning and policy decisions.

The Sierra Madre's importance to the environment is vast and cannot be overemphasized. It is a living habitat highway, a significant source of carbon, and a vital water source, serving as a constant lifeline to lowland inhabitants through the regulation of climate (Forest Foundation Philippines, 2019). In the lower part of the mountain ranges, in the vicinity of General Nakar, there is also a collection of characteristic plant and animal species, as well as crucial ecological services like flood regulation, habitat stability, and economic support to inhabitants in the locale (Forest Foundation Philippines, 2019). In the last assessments, however, there has been a steady decrease in the forest due to the degradation by means of illegal logging, conversion to agricultural land, road development, and urbanization (DENR, 2025, Forest Foundation Philippines, 2022). Such degradation mainly reduces the forest density and overstory, diminishing the role of the Sierra Madre mountain ranges as a buffer in the face of severe weather disturbances from typhoons, endangering environmental health in land and seashore areas alike (Climate Change Commission, 2023).

With the era of historical forest cover data, it is now a possibility to make quantitative assessments of history and forecasts for the future. Hence, this research aims to achieve three objectives: (1) determine the forest cover area in General Nakar, Quezon of the Sierra Madre Mountain Range for 2016, 2019 and 2022 from existing data sets; (2) identify the trend of forest cover from 2016 to 2022 based on calculated values of change in forest areal extent; and (3) estimate hectares of predicted forest loss that would transpire in General Nakar by years 2025, 2028, and 2031 organized based upon observed direction. The general objectives of this study are: to forecast quantitatively the loss of forest cover in the Sierra Madre Mountain Range with General Nakar, Quezon; to develop historical forest cover baselines; analyze patterns of change in forest loss; and, predict its continuation in the near future. In additional to its statistical contribution, the study aims to offer a scientific foundation for conservation and environmental protection in this region.

Literature Review

The forests are very reliant on environmentally friendly conditions, while a large forest like the Sierra Madre Mountain Range is considered important for keeping the balance within the environment in the Philippines. The range helps regulate the climate, mitigates flood, landslide, and typhoon effects, as well as provides habitation for various plants and animals. Recent studies on the environment have identified that it is a major environmental benefit for the whole of Luzon and the whole of the Philippines as regards environmental sustainability (Lasco et al., 2013; Perez et al., 2020; Climate Change Commission, 2024). The same has been observed by Forest Foundation Philippines in 2019 at a different level when it referred to the biodiversity and/or watershed role of the Sierra Madres as a disaster risk reduction and management system for the entire eastern portion of Luzon.

Though deemed important in ecological functions, nevertheless, a considerable extent of forest denudation has also been observed in the Philippines during the past decades. As per forest data of this country, not more than 7 million hectares of forested areas exist against the total 15 million hectares of forested lands (Philippine Star, 2025a; Department of Environment and Natural Resources [DENR], 2020). This again shows that there has been a considerable imbalance between protected forest land and actual forested land. More recent evaluations on land cover have confirmed that there has been an estimated reduction of 7.6% in total tree cover between 2001 and 2022, estimated at a loss of 1.42 million hectares of tree cover, thus leading to an increase in greenhouse gas emissions due to deforestation (Climate Change Commission, 2024). Similarly, satellite estimates conducted by Hansen et al. (2013) at a national level have also shown significant deforestation in tropical areas, proving that forest cover can indeed be quantified and that it does fluctuate significantly across different periods of time.

In light of this more general national context, the Sierra Madre range also remains subjected to heavy pressures of every kind that further worsen the degradation of the regional forests. According to conservation groups, the area of the Sierra Madre range that is lost every year due to kaingin, logging, mining, and development, including within protected sites, stands at around 9,000 hectares every year (Philippine Star, 2025b). Further investigation of forest clearing on the southern Sierra Madre range, as done by some localized research, has also found forest clearing to be irregular between municipalities, requiring localized analysis as opposed to generalization based on regional averages, as asserted by Sazon et al. (2020), with more recent research by Israel et al. (2024).

"Remote sensing and satellites remain crucial within the monitoring process of changes that occur within the forest covers. Datasets from globally produced Landsat images have made it feasible for the development of the basis on which the trend analysis for the degradation of forests shall be based on the various years that ensued. Cloud-based technologies such as Google Earth Engine within more contemporary research studies have made the efficiency of changes within forests with a better level of detail possible" (Israel et al., 2024; Perez et al., 2020). This is supported by the research by Peñaranda et al. (2020) within which Landsat multi-temporal images were shown to measure changes within the cover of the forests within the respective years with success.

Quantitative research, analyzing localized changes within forests, illustrates that there are varying deforestation rates within each municipality within the Sierra Madre ranges. Various reasons for these deforestations have been identified, including agricultural land expansion, illegal resource exploitation, as well as infrastructure development, creating a wide range of landscape changes within each municipality (Israel et al., 2024; Philippine Star, 2025b). Variations such as these indicate that localized forestry policies are needed, as opposed to a broad assessment conducted at a state level. Similar conclusions were reached by Garcia and Principe (2024), who found that forest disturbance trends detected through satellite indices vary significantly across local landscapes and require municipal-level analysis.

However, to address these threats, forest growth targets for the country were announced by the Philippine government through the DENR. There is a significant project to enable the growth of an extra three million hectares of forest cover by 2028 through the implementation of reforestation measures coupled with advancement in geospatial mapping for forest resources management (Philippine Star, 2024; DENR, 2020). However, reforesting or forest management initiatives can only be fully effective if accurate spatial data is available. For this reason, quantitative analysis for municipal areas can help project future trends on changes to forested areas before making recommendations for forest conservation. Although satellite data for forest areas is available, there are very limited forecasts for Projected Forest Loss at the municipal level, specifically for areas such as General Nakar, Quezon. This difficulty limits improvements for data from the National Datasets (Israel et al., 2024). Forecast-based studies in other forested regions have shown that historical trend analysis is an effective basis for projecting future forest loss, especially when long-term satellite records are available (Journal of Threatened Taxa, 2021).

It has been observed that the destruction of forests in the Sierra Madre range in the Philippines and across the country has been influenced by interrelated factors of the environment, socioeconomics, and governance. The continued use of quantitative remote sensing techniques and local predictive models is also important for informing the sustainable management and conservation of forests (Hansen et al., 2013; Perez et al., 2020; Climate Change Commission, 2024). This supports the necessity of integrating temporal variables and spatial measurements in forecasting forest cover change, particularly at the municipal scale where policy interventions are directly implemented (FAO, 2020).

Methodology

This study employs a quantitative–descriptive–computational research design, integrating mathematical modeling, geospatial analysis, and predictive computation to quantify forest cover loss in the Sierra Madre Mountain Range, specifically within General Nakar, Quezon. The approach is grounded in the application of a formula-based model designed to compute the average annual rate of forest loss over a defined temporal interval (Forest Foundation Philippines, 2025; Department of Environment and Natural Resources [DENR], 2023).

By using mathematical modeling techniques such as pixel-to-hectare conversion and prediction equations, the study aims to determine how forest cover in the Sierra Madre Mountain Range, particularly in General Nakar, Quezon, has changed over time and how much loss can be expected by 2025. Through the use of numerical evidence derived from satellite imagery and computational forecasts, this approach enables the analysis not only to describe the historical trajectory of deforestation but also to anticipate future scenarios of forest degradation under continued human pressures (Global Forest Watch, 2024). Mathematical tools are therefore essential for transforming geospatial data into meaningful hectare-scale insights, providing a robust foundation for ecological forecasting and conservation planning (FAO, 2020).

Forest cover data were obtained from validated repositories of the Department of Environment and Natural Resources and Forest Foundation Philippines, supplemented by high-resolution satellite imagery such as Landsat and Sentinel (DENR, 2023; Forest Foundation Philippines, 2025). These datasets were processed using Geographic Information Systems (GIS) platforms, including ArcGIS and QGIS, where raster classification techniques delineated forested from non-forested areas and zonal statistics extracted pixel counts for General Nakar (Gabriel et al., 2025). The resulting values were standardized to ensure comparability across years, and differences in forest cover were computed to establish the rate of decline.

To underpin this analysis, the study used existing satellite-derived land cover datasets to quantify forest cover within the Sierra Madre Mountain Range in General Nakar, Quezon. Forest cover estimates based on classified raster data show that the municipality had an estimated forest area of 81,914 ha in 2016, which reduced to 79,134 ha in 2019, representing a net loss of -2,780 hectares over the three years. An even larger reduction was observed in the period from 2019 to 2022 when the extent of forest reduced to 65,277 hectares (i.e., a loss of 13,857 hectares). These current forest cover values were extracted from publicly available land cover classification maps issued by the National Mapping and Resource Information Authority (NAMRIA), broken down using the Hansen Global Forest Change dataset, where both provide spatially explicit information for forest presence/absence at a 30-meter spatial resolution (Hansen et al., 2013; NAMRIA-2016, -2019, -2022).

Forest cover values for each reference year were gathered, and a computation approach using the formula was employed to arrive at the average annual rate of forest loss. For each time interval, the difference in counts of pixels classified as forest in hectares was divided by the number of years between the measurements to get the annual deforestation rate. From this, considering the observed decrease from 2016 to 2022, this was then subjected to extrapolation in forecasting the expected forest cover loss by 2025, 2028, and 2031. This provided quantitative evidence of the rate of deforestation in General Nakar and allowed the estimation of future forest degradation scenarios under the assumption that current trends continue. Based on actual satellite records and supported by a formula-based computation framework, a local yet statistically valid record of ecological vulnerability was presented to substantiate the identification of priority areas for targeted conservation strategies and resource allocations in line with the UN FAO 2020, and the Forest Foundation Philippines 2025.

Furthermore, the study applies a computational formula to quantify the average annual rate of forest loss between these time intervals:

$$A_y = N_y * \frac{R^2}{10{,}000}$$

$$\Delta A_{y_1 - y_2} = A_{y_2} - A_{y_1}$$

$$L = \frac{A_{y_1} - A_{y_2}}{y_2 - y_1}$$
$$A_y = A_{y_0} - L(y - y_0)$$

Where;
A_y = Forest area (in hectares) for year y
N_y = Number of forest pixels
R= The spatial resolution of each sample point or pixel, in meters
$10{,}000$ = Conversion factor from square meters to hectares
$\Delta A_{y_1 - y_2}$ = Change in forest area from year y1 to y2
A_{y_2} = Forest area in year y2
A_{y_1} = Forest area in year y1
y_1 = Initial reference year
y_2 = Final reference year
L= Rate of forest change per year (hectares/year)
$A_{y_1} - A_{y_2}$ = Total forest area lost between two years
$y_2 - y_1$ = Time interval between the two years
A_{y_0} = Forest area in the reference/base year y0
$y - y_0$ = Number of years since the base year

Results

Table 1. GENERAL NAKAR (2016-2022)

YEAR	FOREST COVER	CHANGES FROM PREVIOUS PERIOD	DATA TYPE
2016	81,914 ha	—	Observed
2019	79,134 ha	-2,780 ha	Observed
2022	65,277 ha	-13,857 ha	Observed

Table 2. GENERAL NAKAR (2025-2031)

YEAR	FOREST COVER	CHANGES FROM PREVIOUS PERIOD	DATA TYPE
2025	56,959 ha	-8,318 ha	Projected
2028	48, 640 ha	-8,319 ha	Projected
2031	40, 322 ha	-8,318 ha	Projected

Discussion

From the quantitative, geospatial, and computational results, it has become manifest and patent that there has indeed been a steady and persistent decline in the forest cover in the Sierra Madre Mountain Range in the area of General Nakar, Quezon, from the year 2016 to 2022, and it can very well be projected and foreseen that this steady and persistent decline would continue in the years to come. The steady and persistent decline in the pixel-based measurements for forest cover, once translated into figures involving hectares, would undoubtedly serve to confirm and validate the computation and assessment made above to the effect that there has indeed been no sporadic but instead systematic and persistent process of deforestation (FAO, 2020; Hansen et al., 2013; Peñaranda et al., 2020). Not to mention the measure and degree to which it has continued to threaten the increasing vulnerability to the Sierra Madre Range's fragile ecosystem, it bears mentioning and affirming here that the steady and persistent decline in the

forest cover would mean and would result in a steadily diminishing capability to regulate and control the waters and soil in the area (Lasco et al., 2013; Climate Change Commission, 2024; Sazon et al., 2020).

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Despite these challenges, however, this study offers a scientifically informed and well-designed assessment of forest cover change in the area of General Nakar. In fact, this study illustrates the need for an action plan for the sustainable management of forests in an attempt to conserve what can be left in the Sierra Madre ranges (Journal of Threatened Taxa, 2021; FAO, 2020). Thus, this study intends to contribute value to the noble cause.

Conclusion

Forest cover in the Sierra Madre Mountain Range within General Nakar, Quezon, has clearly decreased from 2016 to 2022, according to quantitative, spatial, and computational results. If current trends continue, projections show that this decline will continue. The systematic rather than isolated nature of forest loss is confirmed by the alignment of measurements based on pixels and hectares. Given the significance of the Sierra Madre for biodiversity conservation and disaster risk reduction, including climate resilience and landslide buffering, this emphasizes the region's ecological vulnerability (Llait, 2024).

The study offers vital information to the local community, including data-driven recommendations for environmental organizations, Bantay Gubat groups, and local government entities. By prioritizing areas for monitoring, reforestation, and protection, the spatially detailed maps and projections facilitate more successful community involvement in forest management. Research indicates that having access to scientific and geographic data improves local conservation efforts by strengthening governance and accountability (Chokkalingam et al., 2021).

Adaptive and evidence-based strategies, such as targeted reforestation of degraded areas with native species, increased enforcement of forest protection policies, and frequent assessments of forest cover, are advised to address the observed deforestation. When supported by localized research, government programs like the Expanded National Integrated Protected Areas System (ENIPAS) Act and projects utilizing geospatial monitoring tools offer a framework for policy that can successfully reduce the loss of forests. The Sierra Madre Mountain Range's long-term sustainability and resilience depend on the integration of scientific analysis, community involvement, and policy implementation (PhilSA & DENR, 2023).

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