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The last stand of a watershed forest in Southern Philippines: a case study of land cover and biodiversity

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Abstract. *Tabora JAG, Ancog RC, Sanchez PAJ, Arboleda MDM, Lit IL Jr, Tiburan CL Jr. 2023. The last stand of a watershed forest in Southern Philippines: a case study of land cover and biodiversity. Biodiversitas 24: 1438-1449.* Land Use Land Cover (LULC) maps using remote sensing technology became popular due to their contribution to spatial information useful for threat determination, biodiversity conservation, and landscape management. Our area of interest in this paper is a watershed in the southern Philippines with no published land cover maps and low biodiversity records. The watershed was a resettlement area originally covered by forest but slowly converted to an agricultural landscape. It was declared a watershed and forest reserve to conserve the primary forest. This paper shows the first spatiotemporal display of Land Use Land Cover change of the watershed to describe the potential threats to the landscape. The land cover change shows a 58% reduction in primary forest cover from 1973 to 2021. In contrast, the croplands have increased by 117% in the same time frame. The Land Use Dynamics Index hints at the landscape's socioeconomic and political situation in the past. In addition, the biodiversity surveys show multiple threatened organisms in the remaining forest. The biodiversity data distinguish between ecosystem types, while the threatened species mapping suggests potential wildlife refuges. The spatially explicit land cover and the location of the threatened species map suggest potential areas for conservation and management.

Keywords: Biodiversity, land use dynamics index, land-use land-cover, threatened species, watershed

INTRODUCTION

Flood frequency and flood-induced mortality are high in the Philippines (Hu et al. 2018). As is common knowledge, watersheds that transport water from mountainous regions to lower elevations are where flooding begins. Extreme flooding results from various factors, but it also signifies that the watershed's ecosystem is threatened. Forest cover is associated with several global problems, including biodiversity loss, land degradation, and climate change. (Grantham 2020). Land-use-land-cover mapping is one of the most useful methods for revealing concerns with forest cover. Many human activities have altered natural ecosystems, which can be displayed by Spatio-temporal Land Use Land Cover (LULC) remote sensing maps (Eddy 2017; Wang 2021; Thoha 2022). Any change in LULC affects ecosystem function and habitat quality (Aneseyee et al. 2020; Tang 2020). To give a preliminary understanding of the landscape change, a comparison of land cover from a temporal perspective is necessary (Edwin 2019). The land use dynamics index (Shi 2012) effectively gauges the rate of land cover changes because it includes the time element in its algorithm rather than just percentages of change in some LULC presentations.

Over 100 publications since 2000 have global spatial maps dealing mainly with conservation prioritization (Wyborn and Evans 2021). The UN's food and Agriculture Organization (2020) also produced global, and country reports helpful to evaluate the overall forest scenario. Undoubtedly, the global scenario provides the overall situation of forest cover, biodiversity, and land-use conflicts; however, the information is not directly beneficial to the Local Government Units (LGU) in charge of the actual management planning and conservation on the ground. Global maps may misrepresent local scenarios, reduce the actual heterogeneity and complexity, and display Western scientific knowledge's dominance over local knowledge (Wyborn and Evans 2021). In addition, Schmidt-Traub (2021) mentioned that the lack of actionable local maps is a crisis identified in the recent United Nations Framework Convention on Climate Change (UNFCC) and National Biodiversity Strategy Action Plans (NBSAPs) assessments. Thus, localized data is necessary for on-site description for decision-making and management. We believe that hotspots have pressure points where conservation budgets and actions will be most effective and impactful. Thus, this paper focuses on one watershed with low biodiversity records and no published LULC maps describing potential habitat threats.

In addition, biodiversity information gaps are still frequent in a developing country like the Philippines, especially in areas with political, insurgency, and other problems that limit access to data gathering in the southern islands. Baseline information on protected areas (PA) is required to understand the effectiveness of interventions and aid in their design and management (Feng et al. 2022). Likewise, the industry sector has expressed their need for the list of threatened organisms to preclude committing violations and penalties and aid in site selection for development (Melstrom 2017). Baral et al. (2014) mentioned that LULC and biodiversity data are necessary for conservation and management planning. Furthermore, finding the best refugia with consideration of the potential to protect species is essential to conservation management (Selwood and Zimmer 2020). LULC has been widely used in terrestrial habitat suitability models to determine the best habitat for specific organisms (Varatharajan et al. 2018), ecosystem service (Kindu et al. 2016), habitat evaluation (Aneseyee et al. n.d.), and modeling (Sharma et al. 2018).

This paper aims to describe the potential habitat threats of a watershed in the Southern Philippines by combining landscape mapping and biodiversity surveys. Our specific objective is to present the LULC maps in different timestamps, compare the biodiversity of the primary land cover types, and finally, list the threatened endemic plants and vertebrates from the biodiversity data. The purpose of this information is to supplement global modeling, predictive modeling, and local landscape conservation management and decision-making. For example, species distribution modeling requires location data from areas of interest as input to the algorithms to determine potential corridors, habitats, clumping, and evaluation of areas of importance (Liu et al. 2018; König et al. 2019). More importantly, the spatially explicit LULC scenario may reveal potential threats to the landscape. The biodiversity data may provide local information decision-makers can directly utilize for potential conservation and management planning or environmental evaluation.

MATERIALS AND METHODS

Description of the watershed

The Libungan River Watershed Forest Reserve (LWFR) is enlisted as a protected area in the province of Cotabato in Central Mindanao in the Southern part of the Philippines. This landscape was primarily covered by forest but was assigned as a resettlement area and slowly transformed into croplands (Figure 1). To respond, the government established the watershed and forest reserve in 1990 following Presidential Proclamation No. 563 of the Philippines. The purpose of this declaration is to conserve the forest. The watershed covers 52,820 hectares drained by a ±60 Km long Libungan river. The river supplies water to over 10 thousand hectares of rice fields, supporting over 8,000 farmers in the province. Due to its expanding ecotourism sector, the construction of a hydroelectric power station, and expanding river quarry activities, this watershed's health demands attention. The local government units (LGUs) are also concerned about the size and frequency of floods during the rainy seasons and the drop in water levels during dry seasons (National Irrigation Administration-Midsayap, unpublished data). The LWFR is located within Alamada and Libungan towns of the North Cotabato Province, Philippines (Figure 2). There are two major land use assignments in the landscape, the Timberland and the Alienable and Disposable (A&D) lands. The DENR categorized these land use assignments for management zoning. The Timberland is intended for conservation, while the A&D is primarily for development. However, even before the area had these land use designations, settlers already occupied the A&D and the Timberlands for crop production.

The A&D land use assignment occupied a relatively flat valley with 19,236 hectares, 36.41% of the watershed. Locals can own privately titled lands and develop agriculture and business enterprises in A & D. This valley slowly increases in elevation northward. The lowest elevation in LWFR is around 28 meters above sea level (masl), located at a river bed on the southernmost part of LWFR within A&D.

Meanwhile, the Timberland land use assignment is located at the mountainous periphery of the landscape with a total area of 33,592 hectares is equivalent to 63.59% land area occupied. The west-side Timberland had steep slopes of more than 30 degrees, with the highest peak of 978 masl. The eastern mountain range is semi-undulating, with low slopes, and the highest peak reached 828 masl. The gentle rolling to steep slopes of northward Timberland has the highest peak of 2,784 masl. The Timberlands are a natural resource conservation area that limits development projects.

The current population centers only occupy around 3% of the total area, however, most locals run sizable farms in contrast to the constructed environment. Most of the developed infrastructure in this rural area consists of roads, homes, businesses, and other essential facilities for agricultural communities. Our sampling points for habitat description are scattered all over the landscape to represent the A&D and the Timberland (Figure 2). Rapid biodiversity assessment was done on the sampling points considering endemic flora and fauna only. The intensive biodiversity sampling was done in the interphase area of closed forest, open forest, and cropland at the northernmost portion of the sampling points.

Mapping

We collected free images from USGS Earth Explorer for land cover classification for 1973, 1989, 2011, and 2021. The temporal comparison of land cover was from Landsat 1-5 MSS images for 1973 and 1989 thematic maps. The images for 2011 were from Landsat 4-5 TM C1, while the 2021 image was from Landsat 8 OLI/TIRS/C2L2. The satellite images were processed with Semi-automatic Classification Plugin (SCP) by Congedo at QGIS v3.26.3. Resampling was done to 1973 and 1989 Landsat images from 60 m^2 resolution to 30 m^2 to have similar resolutions with other maps. We validated the land cover of maps with other satellite images taken at ±3 years around the featured year. All bands were converted to reflectance with an atmospheric correction before collecting training inputs for the land classification procedure.

Figure 1. The rolling landscape of LWFR shows areas converted to croplands. Some settlements can be seen on the left

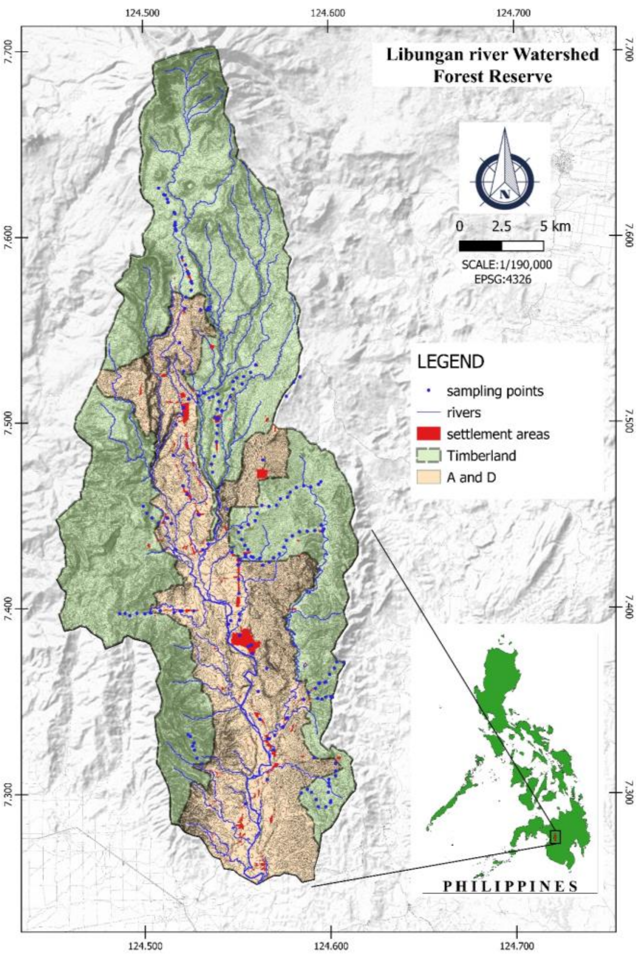

Figure 2. The Libungan River Watershed and Forest Reserve boundary, land use classification by the Department of Environment and Natural Resources, inset: Relative location in the Philippines.

We created training inputs for the different land cover types based on color variations of satellite RGB band combinations and cross-referenced them to ancillary maps. The land cover classification was adopted with minor modifications from the classification presented in Good Practice and Guidance for Land Use, land use change, and forestry by the Intergovernmental Panel on Climate Change (IPCC) by Penman et al. (2003). The macro-classifications are forest, grassland, and cropland. We performed accuracy testing using the SCP plugin in QGIS. Furthermore, to evaluate the accuracy of land cover assignments, we used Google Earth Pro™ images of years (1984, 1989, 2011, and 2021), local historical maps, and 220 habitat description waypoints as ancillary data and ground control points (GCP). Note that there are no Google Earth images and local maps for 1973 LULC resulting in lowered map accuracy. However, the anecdotal information from locals confirms some of the closed forest and cropland locations during the 1970s.

Our classification categorizes 'Forest' as a landscape dominated by stands of endemic flora further sub-classified into the open (with <40% canopy cover) and closed (>40% canopy cover) forests. This classification removed some tree covers of rubber plantations and other agroforests (Figure 3).

Grasslands are areas predominantly covered by grasses with few stands of trees. Grassland is sometimes categorized as 'wooded grassland' or savanna. There are no natural grasslands in LWFR; instead, the grassy areas resulted from logging and swidden farming, thus sporadic trees. Savanna is a transition ecosystem from forest to grassland (Baudena et al. 2015); since this ecosystem is predominantly grasses in LWFR, we limit this definition to grasslands based on IPCC 2003 Guidelines' macro classes in this paper. Man-derived savanna is affected by precipitation and fire regimes in Southeast Asia, while forest-centered landscape rehabilitation and agricultural expansion decrease the savanna-occupied areas (Miettinen et al. 2014; Buisson et al. 2019; Pletcher et al. 2022).

Croplands, on the other hand, are areas predominantly occupied by annual and perineal crops. Tree plantations were identified based on their locations by cross-referencing the ground-truthing data. Tree plantations were also identified by the foliage shape and straight rows planting pattern.

The rate of change was determined using Land Use Dynamics Index as presented by Shi (2012) using the formula:

$$K = \frac{UB-UA}{UA} \text{ x } \frac{1}{T} \text{ x } 100\%$$

Where:

K : The land use dynamics index that measures the rate of change

UA : beginning of the period of LULC being compared

UB : end of the period of LULC being compared

T : length of time; in this study, we refer to the number of years

Figure 3. Collage of images from LWFR showing the four major land cover types. The top left is a converted landscape to croplands with mixed growth of vegetation; the bottom left is interphase from closed forest to grassland; on the right is a closer look at open forest, closed forest (inner side of the forest) and grassy areas. A: Closed forest, B: Open forest, C: Grassland (wooded grassland), D: Croplands (perennial and annual crops). LWFR, 2021

Biological component survey

The biodiversity survey was spearheaded, supervised, and authorized by the DENR. We collected no voucher specimens for plants, and all trapped animals were released on the site of capture. Wildlife documentation was limited to the collection of biometrics and photo-documentations. At the same time, experts in the taxonomy of flora and fauna processed the identification of organisms. Previously mentioned sampling points are scattered throughout the landscape to catalog native or endemic plant and vertebrate species in a rapid survey and describe the land cover type. We selected areas representing the A&D and the Timberland areas following existing roads and trails with 500 to 1km intervals between points. In addition, we established a 2 km transect for biodiversity data collection in the interphase between forest, open forest, grassland, and cropland to represent major land cover type biodiversity. This transect is a permanent data collection transect established by the DENR.

The conservation status for each species collected was determined based on the DENR Administrative Order (DAO) No. 2017-11 for plants and DAO No. 2019-09 for vertebrates, plus the IUCN Red List 2020 online search engine to produce a threatened species list. Finally, the threatened species' location was laid-over to the 2021 LULC.

Plant survey

We established a modified Whittaker nested vegetation sampling (Wang et al. 2019) using $10m^2$ and $100m^2$ x 20 subplots in a 2 km belt transect. A simple biodiversity analysis was done to describe the different land cover differences.

Shannon diversity index is calculated using the formula:

$$H' = -\sum_{n=1}^{n}(p_i * \ln p_i)$$

Where:
H : Shannon diversity index
p_i : the proportion of individuals of *i*-th species in the whole community with a formula :

$$p_i = \frac{n}{N}$$

Where:
n : individuals
N : total number of individuals

Bray Curtis similarity index is calculated using the formula:

$$BC_{ij} = 1 - \frac{2Cij}{Si+Sj}$$

Where:
i & j : are the two sites,
Si : the total number of specimens counted on site i,
Sj : the total number of specimens counted on site j,
C_{ij} : the sum of only the lesser counts for each species found on both sides.

Fauna survey

Fauna survey points and transect is similar to the plant survey. The bird species list is collected using the eight-minute fixed-radius point-count method (Taulman 2013) every 100 meters when the bird activity is assumed to be highest. Two expert observers recorded all birds encountered at every sampling point (either seen or heard) within a 35 m radius with a guidebook as a cross-reference (Dickinson et al. 2000).

Amphibians and reptiles were collected by opportunistic sampling using hand grabbing along a 2-kilometer transect between 6 to 10 pm of a sampling day. The samples were identified on-site using taxonomic keys (Sanguila et al. 2016) and released after the process.

Bat (Volant mammals) sampling was done using mist nets (6m x 12m, 6mm mesh size). Nets were set up across flight paths, such as trails and areas along breaks in vegetation, and opened from 5 pm until 5 am. Bats were identified based on their biometrics and appearance, referencing the classification key of Ingle and Heaney (Ingle N 1992).

We used baited commercially available live traps to capture small (<3 kg) non-volant mammals. The live traps were laid out per habitat type for several days. We established an average of 20 traps in the transect line. On the other hand, large cryptic mammals were identified with visual observations, tracks, marks, and fecal droppings. Biometrics and visual observations were cross-checked with Philippine mammal field guides (Heaney et al. 1998; 2016). We followed proper handling guidelines in capturing and processing samples (Sikes 2016).

Taxonomy experts handled the capture and identification of each vertebrate group. Each animal sample was identified based on taxonomic keys, books, and monographs. The sampling for each vertebrate group lasted until the species richness curve plateaued. All samples were released back to the capture site after processing and identification.

RESULTS AND DISCUSSION

We detected four primary LULC types in LWFR landscape, i.e., closed-canopy forest, open-canopy forest, grassland or wooded grassland, and cropland. Based on FAO -UN Land Cover Classification System, the closed-canopy forest and the open-canopy forest can be categorized into Natural and Semi-Natural Terrestrial Vegetation, while the grassland and cropland can be categorized into Cultivated and Managed Terrestrial Areas. The following subsections present the changes in the LULC in four "timestamps," i.e., 1973, 1989, 2011, and 2021 (with LULC classification accuracy of 78, 92, 93, and 90, respectively).

Land cover change

Closed forest covered 35.32% of 52.8 thousand hectares in 1973 (Tables 1, 2; Figures 4, 5), making it the most expansive land cover type in that timestamp. By 1989 the closed forest reduced to 23.89% of the landscape. This reduction from 1973-1989 is equivalent to -2.02 in the Land Use Dynamics Index (K%), which considers time (year) in its algorithm. After Timberland's declaration in the watershed, the rate of forest removal between 1989-2011 lowered to -1.35 K%. However, more aggressive forest removal is seen between 2011 to 2021 with a dynamics rate of -2.58 K%. Agro-industrialization happened recently, resulting in peaks in the last ten years only.

In 2021 the closed canopy forest covered roughly 15% of the watershed, a 57.9% reduction of forest cover from 1973. The closed forest K% dynamics between 1973-2021 is -1.21. The general decrease rate in 50 years is relatively slow compared to other areas with mining or logging concessions (Gatto et al. 2015). The rate of decrease gives a general impression of a low-income agricultural landscape, low population growth, division of land parcels, and loss of land productivity (Rai et al. 2017). Meanwhile, the fluctuations can illustrate poor or varying political will and land tenure insecurity. During field surveys, the observed emerging threats to the closed forest were logging and increasing cropland. Currently, the closed forest is limited only to the northern tip of the watershed. Based on Global Forest Watch, the area's most significant tree cover loss was in 2016. The closed forest is gone on the east and west Timberlands of the watershed, leaving only the remaining forest on the north of the landscape (Figure 5). Locals relate the forest loss to flash floods after monsoon rains.

Open-canopy forest (or open forest) resulted from logging the closed forest in LWFR. There was a reduction of its cover between 1973 to 1989 by -2.08K% due to grassland and cropland expansion. This expansion indicates a more active engagement of the locals in the area by introducing annual crops. While in 1989 to 2011, there was an increase in the land cover of open forest (+1.07K%). This increase is attributed to the further removal of trees from the closed forest regrowth of some areas and the effect of planting perennial crops by local farmers. On the other hand, there was an accelerated drop in open forest cover from 2011 to 2021 (-3.55) due to the expansion of croplands. Banana plantations, for example, were established in the highlands of LWFR starting in 2017, occupying the open forest. Generally, open canopy forest cover was reduced from 1973 to 2021 by -1.07 K%. Most of these reductions are due to cropland expansion.

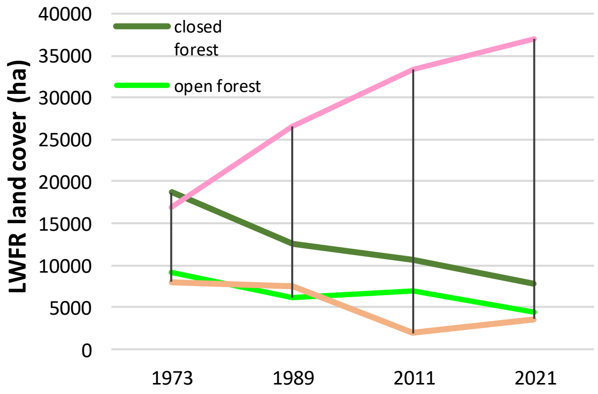

Figure 4. Land cover change trend in four-time stamps in LWFR.

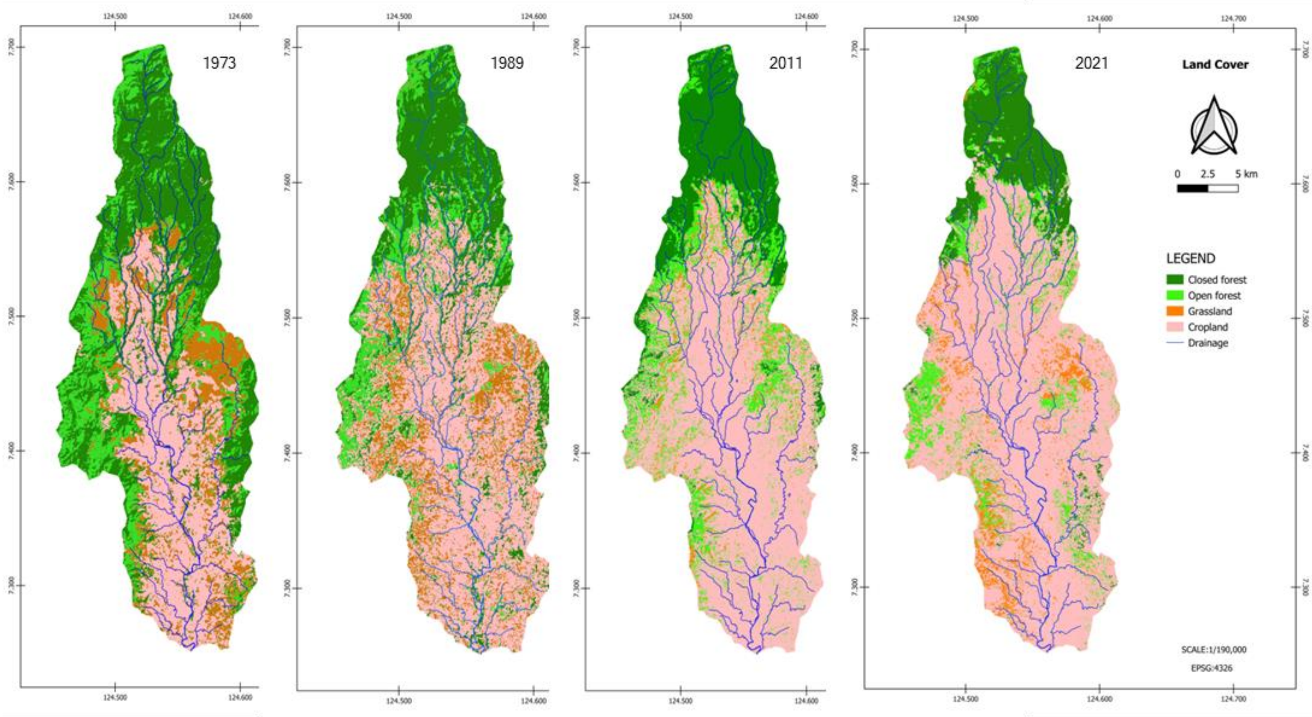

Figure 5. Spatio-temporal change of primary land cover in LWFR in 4-time stamps

Table 1. Land use/land cover of LWFR from 1973-2021. The % cover is shown in parentheses

Year / LULC	Area covered by land use type and % cover			
	1973	**1989**	**2011**	**2021**
Closed forest	18,654.2 (35.32%)	12,616.90(23.89%)	10,578.40(20.03%)	7,847.00(14.86%)
Open forest	9,193.07(17.40%)	6,136.20(11.62%)	6,925.77(13.11%)	4,470.29 (8.46%)
Grassland	7,988.47(15.17%)	7,472.88(14.15%)	1,944.36 (3.68%)	3,566.49 (6.75%)
Cropland	16,975.30(32.17%)	26,584.20(50.33%)	33,368.80(63.17%)	36,938.10(69.93%)

Table 2. Land-use dynamics index between timestamps

Year / LULC	Land-use dynamics index *K(%)*				
	1973-1989	**1989-2011**	**2011-2021**	**1973-2021**	**Direction (50 years)**
Closed forest	-2.02	-1.35	-2.58	-1.21	Decreased
Open forest	-2.08	1.07	-3.55	-1.07	Decreased
Grassland	-0.40	-6.17	8.34	-1.15	Decreased
Cropland	3.54	2.13	1.07	2.45	Increased

As mentioned by Dixon et al. (2014), grasslands today range from man-made or culturally-made systems to naturally-made systems. There are no natural grasslands in LWFR, but when grasslands are present, it is usually a result of tree removal. Swidden farming, or the slash-and-burn farming technique, is widespread during the 1970s, leaving behind vast swaths of nutrient-poor marginal lands. This activity resulted in around 15% grassland cover in 1973, slightly reducing to 14% in 1989 (-0.40K%). By 2011 most grasslands have active agriculture development, such as corn, upland rice, vegetable farms, and other annual crops, dropping grassland cover to 3% (-6.17K%). The decrease in savannas worldwide due to tree encroachment was declared a risk for the ecosystem type in the IPCC 2022 report. Aside from human-induced activities, the reduction of grasslands may have resulted from changes in carbon dioxide levels, temperatures, and precipitation. These changes may affect grassland biodiversity or its grazeland function (H.-O. Pörtner, 2021). However, the impacts of the grassland dynamics in LWFR are not well studied. The 2011 LULC shows the grasslands conversion to 'croplands' on the west side of LWFR, while on the east side, grasslands were planted with rubber and oil palm farms. From 2011 to 2021, the grasslands increased (+8.34K%) by occupying previously open forest areas, recovering cattle forage areas, and replacing oil palm plantations at the east side of LWFR. In general, from 1973 to 2021, grasslands decreased at -1.15K%. Most of these reductions are also due to cropland expansion.

Cropland's initial landscape coverage of 32.14% is slightly lower than the forest cover in 1973. The influx of settlers resulted in a steady increase of croplands covering 50% of the landscape in 1989 from 1973 (+3.54K%). Moreover, a steady increase in cropland expansion of +2.13 K% (13%) between 1989 to 2011 and slightly slows down to +1.07K% (6%) between 2011 to 2021. In 2021, the croplands covered around 70% of the LWFR, a 117% increase from the initial land cover. The fifty-year cropland dynamics of +2.45 is fast replacing the closed forest and the other land cover types.

In summary, the 50-year direction of closed forests, open forests, and grassland decreased from 1973 to 2021. On the other hand, cropland is the only land cover that steadily increased in the same period. Cropland's trajectory is increasing while the closed forest's trajectory is the opposite.

To compare our data with existing LULC in the Philippines, the FAO Forest Assessment Report (FRA) country report of the Philippines 2020 mentioned an increase in forest cover from 2010 to 2015. However, in our local evaluation of the LWFR, the closed forests decreased from 2011 to 2021 by -2.58 K%. Landsat data revealed a significant open and closed forest cover loss from 2011 to 2018. The FRA country report is already average data, and the local data may be located at the lower part of the bell. As exemplified by our data, the local scenario of heterogeneity and complexity in the landscape is not explicitly portrayed in the national analyses. While countrywide or regional assessments of habitat loss, climate change, and extinction rates supplement on-site conservation information, this subnational data can give a better idea of the causes of deforestation (Bos et al. 2017).

The externalities observed in LWFR are the following, loss of biodiversity in deforested areas, increased risk of flooding and erosion, altered local climates, and decreased carbon sequestration. In addition, steep fluctuations in the water discharge and localized flooding were noted from on-site interviews and National Irrigation Administration-Midsayap, unpublished data.

The study by Tarigan (2018) in Southeast Asia declared that a watershed should contain more than 30% forest cover and a maximum of 40% plantation cover to maintain a sustainable water flow regulation ecosystem. However, the LWFR's 15% forest cover is just half of the ideal requirement; meanwhile, the cropland cover of almost 70% is almost double the maximum ideal cover mentioned by Tarigan.

Biodiversity and threatened organisms

Out of 165 plants found in the remaining forest of LWFR, 24 species (15%) have threatened conservation status based on combined DENR and IUCN documentation (Table 3). Most identified threatened plants were tree species and endemic to the Philippines. The samples from the transect covering cropland, forest edge, and inside the forest show that the diversity is highest in the closed forest (H’= 3.6), followed by the open forest (H’= 3.4), while lowest at the croplands (H’= 2.2) using the Shannon diversity index (H'). Our biodiversity analysis results show that forests are more diverse than croplands. Maxwell et al. (2016) showed that over-exploitation and agriculture are the major threat to biodiversity and threatened species. Our results also reflect the analysis of Zabel et al. (2019) that production comes at the cost of biodiversity in developing tropical regions. In the LWFR, the expansion of croplands has the intention to support the global markets of rubber, palm oil, and banana. Based on an extensive database analysis by Kehoe et al. (2017) across the Amazon and Afrotropics, species richness and abundance were lost because of agricultural expansion.

Meanwhile, the Bray Curtis cluster analysis (Figure 6) shows that the species assemblage is 46% similar between the closed and open forests, while the cropland species assemblage has a 9% similarity compared to the forests. This result also exhibited the frequency and abundance similarity in three land cover types. The result confirms the distinction between open forests to closed forests and between forests to croplands. The 46% similarity between closed and open forests is already midway. Around half of the species' frequency and abundance in the closed forest are already absent in the open forest. It is mentioned in this order because the Shannon diversity index above shows that the closed forest has the highest diversity. The croplands' similarity to the forest at 9% is already considered in a lower bracket. The few patches of endemic trees between farmlands may contain the remaining similarity with the forests. Note that the data collection did not include the crop species.

Table 3. Threatened plants and vertebrates in LWFR

Species name	Local name	Distribution	DENR	IUCN
Threatened plants				
Agathis philippinensis Warb.	Almaciga	Philippine Endemic	VU	-
Aglaia edulis (Roxb.) Wall.	Malasaging	Asia endemic	OTS	NT
Alocasia zebrina Schott ex van Houtte	Badiang	Philippine Endemic	VU	-
Alpinia elegans (C.Presl) K.Schum	Tagbak	Philippine Endemic	VU	-
Calamus merrillii Becc.	Palasan	Philippine Endemic	OTS	-
Calamus mollis Blco.	Uway	Philippine Endemic	OTS	-
Cinnamomum mercadoi Vid.	Kalingag	Philippine Endemic	OTS	LC
Cyathea contaminans (Wall. Ex Hook.) Copel.	Tree fern	New Guinea to India; Philippines	EN	-
Dacrycarpus imbricatus (Blume) de Laub.	Igem	Asia	OTS	LC
Dillenia philippinensis Rolfe, J. Linn	Katmon	Philippine Endemic	OWS	NT
Dipterocarpus grandiflorus Blanco	Apitong	Southeast Asia	VU	EN
Eucalyptus camaldulensis Dehnh.	Red river gum	Widespread	-	NT
Ficus ulmifolia Lam.	Isis	Philippine Endemic	OWS	VU
Hopea acuminata Merr.	Manggachapui	Philippine Endemic	EN	VU
Litsea philippinensis Merr.	Bakan	Philippine Endemic	OWS	NT
Oncosperma tigilarium (Jack) Ridl.	Anibong	Southeast Asia	VU	-
Pterocapus indicus Willd.	Narra	Indo-Malesia	VU	-
Shorea almon Foxw.	Almon	Malaysia (Sabah, Sarawak); Philippines	VU	NT
Shorea contorta Vidal.	White lauan	Philippine Endemic	VU	LC
Shorea negrosensis Foxw.	Red Lauan	Philippine Endemic	VU	LC
Swietenia macrophylla Jacq.	Large leaf mahogany	Widespread	-	VU
Syzygium hutchinsonii (C.B. Rob.) Merr.	Malatambis	Philippine Endemic	OWS	CR
Syzygium nitidum Benth.	Makaasim	Philippines, Caroline Is., New Guinea	VU	LC
Toona calantas Merr. & Rolfe.	Kalantas	Indo-Malesia	VU	DD
Threatened vertebrates				
Basilornis miranda	Apo Myna	Mindanao Endemic	VU	NT
Buceros hydrocorax	Rufous Hornbill	Philippine Endemic	EN	VU
Carlito syrichta ssp. carbonarius	Mindanao Tarsier	Mindanao Endemic	OWS	NT
Chloropsis flavipennis	Philippine Leafbird	Philippine Endemic	CR	VU
Dicaeum anthonyi	Flame/yellow-crowned flowerpecker	Philippine endemic	OTS	NT
Irena cyanogaster	Philippine Fairy-bluebird	Philippine Endemic	OWS	NT
Loriculus philippensis	Philippine Hanging-parrot	Philippine endemic	CR	LC
Macaca fascicularis (philippensis)	Philippine long tailed macaque	Philippine endemic	OWS	VU
Otus mirus	Mindanao highland scops owl	Mindanao endemic	OWS	NT
Penelopides affinis	Mindanao Tarictic Hornbill	Mindanao Endemic	EN	LC
Phapitreron amethystinus	Amethyst Brown Dove	Philippine Endemic	CR	LC
Prioniturus discurus	Blue-crowned Racquet	Philippine Endemic	OTS	LC
Pteropus vampyrus	Giant flying fox	Southeast Asia	EN	NT
Rhinomyias goodfellowi	Goodfellow's Jungle Flycatcher	Mindanao Endemic	VU	NT
Rusa marianna (nigella)	Philippine brown deer	Mindanao endemic	EN	VU
Stachyris plateni	Pygmy Babbler	Mindanao Endemic	OWS	NT
Sus philippensis (mindanensis)	Philippine warty pig	Mindanao endemic	VU	VU
Trichoglossus johnstoniae	Mindanao Lorikeet	Mindanao Endemic	VU	NT

Note: CR: Critically endangered, EN: Endangered, VU: Vulnerable, OWS: Other Wildlife Species (DENR), OTS: Other Threatened Species (DENR), NT: Near Threatened (IUCN), LC: Least Concern (IUCN), -: no record

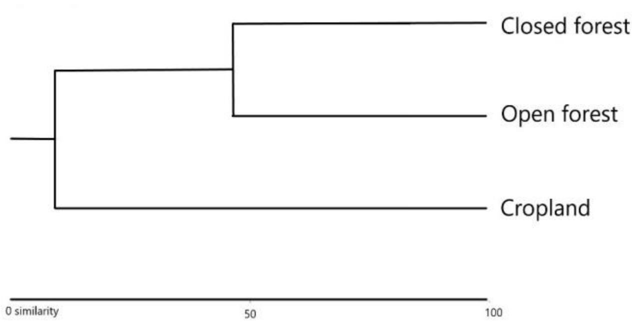

Figure 6. The Flora Bray Curtis Analysis of major land cover types in LWFR

Two research studies in the southern Philippines also conducted Bray Curtis analysis. That analysis resulted in a <50% similarity between forest sampling sites taken in different parts of Rajah Sikatuna Protected Landscape (Aureo et al. 2020) and >50% in a different study between samples in disturbed secondary growth forest taken in Mt. Apo Natural Park (Zapanta et al. 2019). On the other hand, our research compares the species similarity between forest and agricultural land sampling areas. Although the analysis may not be comprehensive, our results show implications that land cover affects biodiversity. Our results support the analysis by Sharma et al. (2018), showing that rapid loss of biodiversity (and decline of habitat quality) is caused by land use and land cover change.

We recorded 96 vertebrate fauna composed of 75 birds, six herpetofauna, six bats, and eight non-volant mammals. In addition, there are 19 species with conservation issues based on DENR threatened species listing and 15 species based on IUCN 2020 (Table 2). The group with the most threatened species was birds (14 species), and the other group was mammals (5 species). There are 43 threatened species listed from our sampling sites (Figure 7). The forest area of LWFR houses all of these species on the list. If we presume that these threatened species are the only threatened species in the LWFR forest of 78 km2, it is a high number per unit area compared to Europe's NATURA 2000 Black Sea region with 21 in 9,705 km² (Trochet and Schmeller 2013). These findings support the Philippine Biodiversity Conservation Priorities (PBCP) statement that the Philippines top the most threatened species per unit area globally.

The combined location of threatened plants in clustered points and the threatened animals in a black-gradient heatmap symbol show a conglomeration along the closed forest (Figure 8). Our biodiversity surveys resulted in the highest counts per 1 square kilometer area of 14 endangered plants in closed forests, four in the open forest, 2 in croplands, and 4 in riparian. On the other hand, threatened vertebrates have the highest count of 5 in the forest, 3 in open forest, two in croplands, and 2 in riparian per 1 square kilometer area. Based on this data, we presumed that the closed forest holds more threatened organisms than other LULC types.

Figure 7. Some of threatened vertebrates. A. *B. miranda*, B. *B. hydrocorax*, C. *D. flavipennis*, D. *D. anthonyi*, E. *I. cyanogaster*, F. *L. philippensis*, G. *O. mirus*, H. *P. affinis*, I. *P. amethystinus*, J. *P. discurus*, K. *R. goodfellowi*, L. *S. philippensis*, M. *T. Johnstoniae*, N. *R. marianna*, O. *S. plateni*, P. *P. vampyrus*, Q. *C. syrichta*, R. *M. fascicularis*

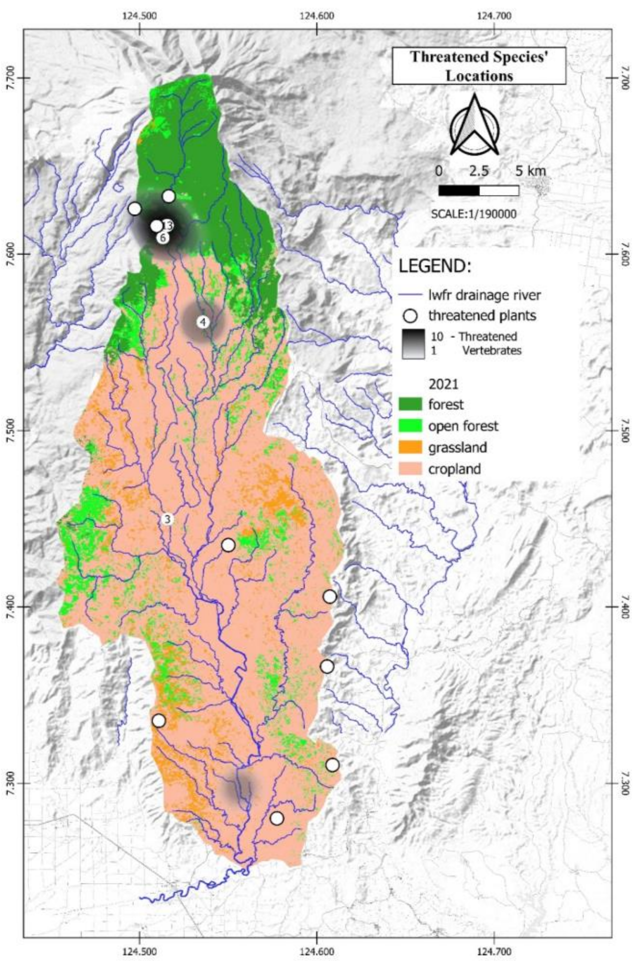

Figure 8. Locations of the threatened plants and vertebrates in LWFR over 2021 LULC, circles with a number represent accumulated location points of plants, darker black 'heat' symbol represents a high number of threatened animals

Threatened species were primarily found in the remaining forested area in northern Timberland. Some of the threatened species found outside the forest were in the riparian zones lined with natural and endemic vegetation or in patches of agroforest. The conglomeration of threatened species shows that the closed forest functions as refugia for a population of endemic wildlife. Therefore, the remaining forest in LWFR can be declared a local hotspot for being under-protected, small, and highly threatened.

To conclude, the LWFR land cover transition from 1973 to 2021 explicitly shows the rate of change and the remaining forest in the landscape. At the same time, the K% dynamics hint the local socioeconomic and political scenario in the last 50 years. The LULC maps show the dynamics of vegetation change from closed forest to open forest, wooded grassland, and cropland. The 50-year land cover change showed that half of the forest cover was removed while the croplands doubled their area and occupied most of the landscape. Conversion to croplands directly threatens forest land cover and the landscape's biodiversity. Biodiversity data and the number of threatened flora and fauna suggest that the forest is the last refuge for wildlife. The result also shows the need to balance agricultural production with conservation goals.

Moreover, to respond to the threats identified, we recommend the establishment of a Strict Protection Zone (SPZ) or a Critical Habitat declaration (CH) at the remaining forest of LWFR. Buffer zones can be established along with an SPZ allowing environment-friendly agriculture technology such as the Sloping-Agricultural-Land Technology or Rainforestation modified to support endemic wildlife. While there are no better alternatives yet, responsible agriculture production intensification and improved technology are options rather than converting some forest areas for croplands. Furthermore, increasing the economic potential in A & D areas by providing a more stable source of livelihood and employment may reduce the pressure on the remaining forest. A Payment for the Ecosystem Services or Bio-financing scheme can be installed and modified to better suit the LWFR situation to help finance conservation programs.

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