

Peatland under pressure: The future of carbon storage in Leyte Sab-a Basin Peatland, Philippines



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Abstract Leyte Sab-a Basin Peatland (LSBP) in the Philippines is estimated to store enormous amounts of C-stocks that could influence the global representation of tropical peat carbon. However, this unique ecosystem has been experiencing threats that need to be studied, hence the study. Ecosystem threats were analyzed using the Driver–Pressure–State–Impact–Response (DPSIR) Framework. Key Informant Interview (KII) and QGIS were also used to assess the other ecosystem factors. Major driver (D) were sociodemographic factors, scientific and technological, sociopolitical, religious values, and biophysical features. It has become clear that the poverty of the surrounding community and the demand to increase the productivity of the peatland have put enormous pressure on the system. Degradation of the peatland started decades ago due to draining and agricultural conversion which is considered as the significant pressure (P). State (S) of carbon stocks has a very high monetary value of \$1.4B for a 3.5 ha of peatland. However, community responses focus on productivity and not on peatland conservation impacts (I). Most alarmingly, the function of the peatland as a sink of carbon will shift to being a source that could pose higher carbon emissions into the atmosphere. Given the current state of the land with its high carbon content and high-standing water, more threats and issues will arise in the future if not addressed today. Hence, as part of the responses (R), reframing management through landscape services can balance productivity and carbon storage. Formulation of policy for conservation would be helpful and consideration of multiple use of the peatland is deemed best to consider both the peatland and the community around it.

Keywords: DPSIR framework, tropical peatland, carbon sequestration, land-use change, swamp forest, marshland

1. Introduction

Tropical peatlands add to earthbound C stockpiling in terms of their aboveground biomass and major thick peat stores. Owing to their temperament, peatlands speak to a critical long-haul sink for atmospheric carbon dioxide (CO₂) (Rowland et al., 2021); consequently, their soundness has significant ramifications. The Southeast Asia peatland arrangement started during the mid-Holocene, approximately 6000–8000 years ago, and works as a long-haul C sink (Wong et al., 2022; Dommain et al., 2014). Sequestering carbon from the atmosphere adds to the carbon stored in soils. This potential could be a natural solution for reducing greenhouse gas (GHG) emissions. However, carbon capture and storage ability could only be strengthened if peatland habitats are functioning and healthy.

Numerous peatland zones are being harmed and corrupted, and as of now, they are losing carbon and should be re-established. In Indonesia alone, the original area of 209,000 km² was reduced to 100,000 km² in 2010 (Miettinen et al., 2012), but a large portion has been restored by rewetting to subsidize reduction and forest regrowth (Hooijer et al., 2024). Persistent environmental change, particularly drainage construction and clearing for agriculture, threatens peatland stability and increases its susceptibility to fire. Land-use changes cause alterations in their environments, permitting the decomposition of accumulated organic matter, leading to the release of carbon and a decrease in the size of their carbon stores (García Lino et al., 2024). Leyte Sab-a Basin peatland (LSBP) is the second-largest peatland in the Philippines. It comprises 3,088 ha (31 km²) (Bobon-Carnice et al., 2023) and has a share of agricultural use.

These findings have contributed to the analysis of the Leyte Sab-a Peatland Basin as an ecosystem. If the carbon sink shifts to a carbon source, this already presents evidence of the vulnerability of the peatland to anthropogenic activities that can alter its function. The recalcitrance of organic matter to decomposition reveals the sensitivity of CO₂ emissions to changes in the climate and land cover of a peatland ecosystem. The kinds and amounts of nutrients measured in the soil can indicate its suitability for supporting particular crops, hoping that it also fits the community's preference for which crop to grow. Hence, this study sheds light on the relevance of peatland to the conversion of agricultural land. Ultimately, it redounds to the kind of management and its implementation in the peatland ecosystem.



This study continues to use the DPSIR analysis framework to describe the local community's possible responses, considering the socioeconomic component. It is vital to reflect on the local community, which directly benefits from untouched or converted peatland. This component also situates the biophysical changes caused by human alterations and forms a part of the peatland's ecological system. Within this context, all the information was consolidated, including stakeholders' values and perceptions of the peatland, socioeconomic concerns, and patterns of resource use.

Moreover, this study analyzes the threats to Leyte Sab-a Basin peatland that could ruin its integrity and function by examining the possible negative effects of anthropogenic activities. These threats may also hinder the ability of LSBP to mitigate greenhouse gas emissions in the present and future. As threats are recognized, it becomes more imperative to characterize and map other peatlands in the Philippines, in addition to the Leyte Sab-a Basin Peatland. Finally, this study will identify the state of peatlands, their anthropogenic impacts, and their responses to aid in the recommendation of appropriate sustainable management of LSBP.

2. Materials and methods

This paper is based on the study of Bobon-Carnice et al., 2023, which included key informant interview (KII) results. An analysis of ecosystem threats was conducted via the OECG-developed Driver–Pressure–State–Impact–Response (DPSIR) Framework (OECD, 1993). The framework provides a structure where indicators of environmental quality and the resulting present and future impacts of political choices can be presented to policymakers (Ahmad et al., 2024). The DPSIR framework could provide chain links starting with “driving forces” (human activities, economic sectors) through “pressures” to “states” (physical, chemical, and biological) and “impacts” on ecosystems, human health, and functions, which eventually lead to political “responses” (indicators, prioritization, target setting). The Quantum GIS software tool was used for maps and related data. Map data from the Google Satellite, Database of Global Administrative Areas (GADM), and National Mapping and Resource Information Authority (NAMRIA) were also used to generate maps for this study.

3. Results and Discussion

Figure 1 summarizes the drivers, pressures, state, impact, and responses of the peatland as an ecosystem. The current state of the peatland has already been described. The basin is considered the most significant water catchment area in the province of Leyte (Bobon-Carnice et al., 2023) (Figure 2). If the whole watershed is considered, three major rivers drain into the basin along with small creeks and rivers: the Dao River from the northeastern portion, the Mainit River, and the Palo River from the southern portion. Owing to these rivers, the water level alone in the innermost portion can reach five meters. The height can fluctuate more and vary with depth during rainy days. The observation of portions of the swamp to be permanently submerged in water is not surprising. Moreover, peatlands have high carbon contents that are dynamic and under threat of being released into the atmosphere.

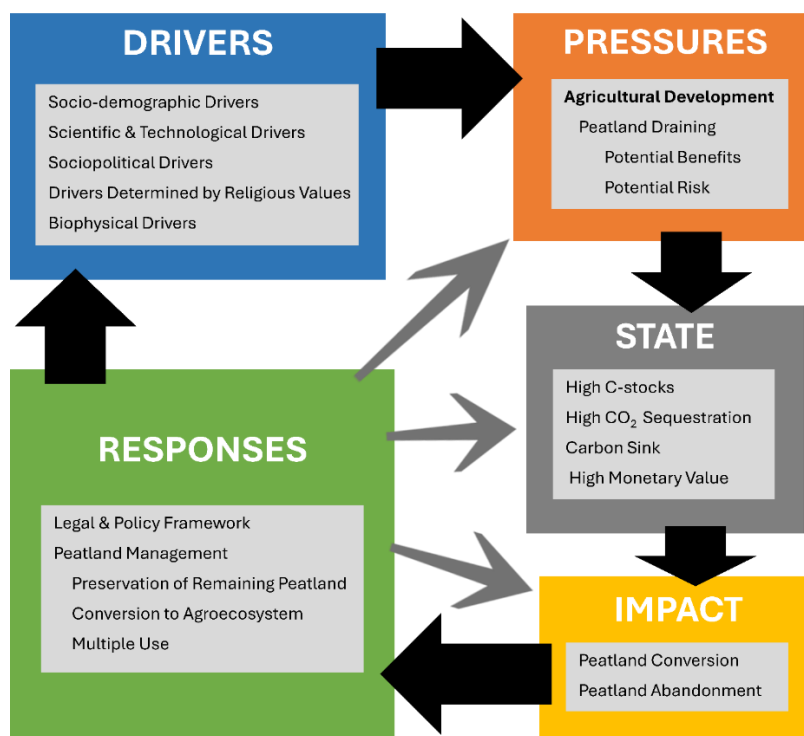


Figure 1 DPSIR of Leyte Sab-A Peatland (LSBP) with improved social awareness as one of the community responses.

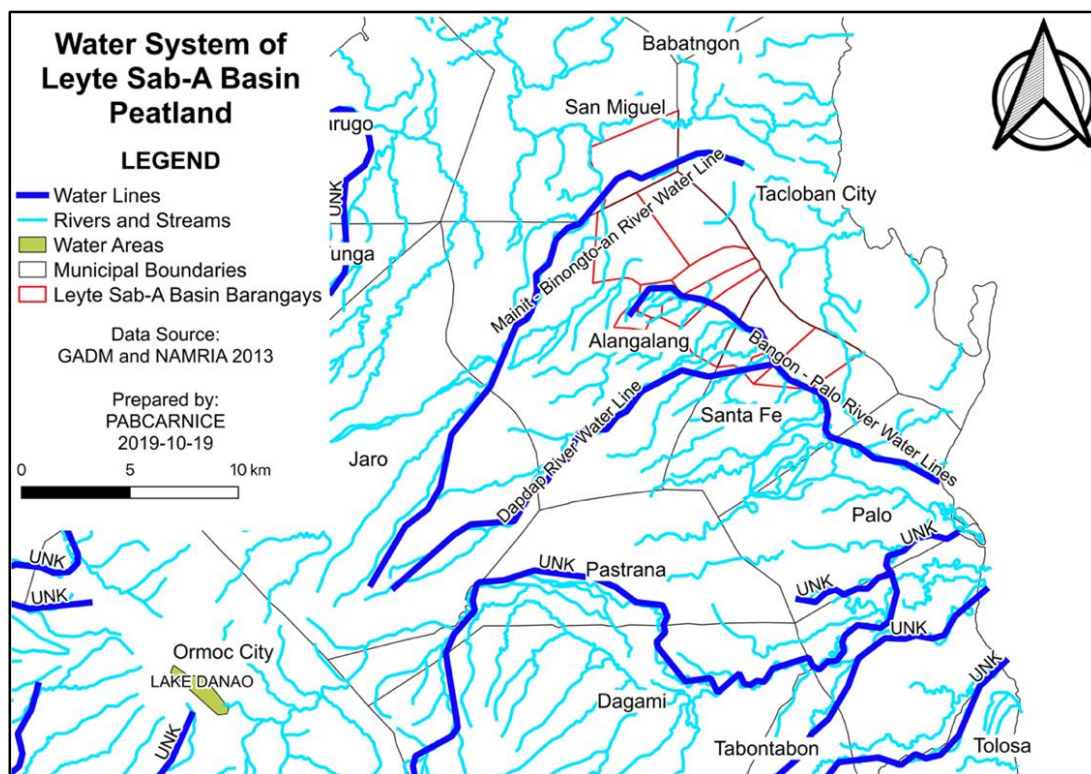


Figure 2 Water system that connects to Leyte Sab-A Basin Peatland (LSBP), Philippines.

3.1. Drivers

Drivers in the DPSIR framework are defined as the “root causes” of the pressures being put into the environment (Oenoto et al., 2023). These are natural or human-made processes and broad and macro societal and economic issues. The United Nations has adopted 17 sustainable development goals (SDGs) to address environmental sustainability issues related to land degradation (Zhao et al., 2023), and upon analysis, these drivers also hold right in the peatland ecosystem and are described as follows:

3.1.1. Sociodemographic, socioeconomic, scientific, and technological drivers

The demographic driver in the current state of Leyte Sab-a Basin Peatland is the population size of its surrounding communities. There are complex interactions between the population and the peatland ecosystem. The distribution of the households and their members also suggests their expectations in the peatland. Whether considered idle land or a valuable economic resource, peatlands are impacted by economic drivers that influence the demand for the ecosystem services they provide. Furthermore, researchers have considered scientific and technological drivers as actual limitations of the current management scheme in peatlands. There are many gaps in the research on peatlands, especially in the Philippines (Pacoma et al., 2024). The drivers explained above Figure 1 do not stand alone. They interact with one another and drive the pressures of the peatland directly and indirectly. Socioeconomic drivers exert the most considerable pressure on the peatland ecosystem.

3.1.2. Sociopolitical Drivers

Among the drivers, sociopolitical factors appear to have less influence on peatland. The existing political conflicts constitute the ongoing private–public land debate. In the early 1970s, peatland was the focus of the BANCORM Farm Services Corporation for agricultural development, specifically for solving flooding and schistosomiasis problems. However, this was not a success. Later, to continue BANCORM, the government created the Leyte Sab-A Basin Development Authority (LSBDA) under Presidential Decree No. 625 on December 26, 1976. Development has expanded, which includes irrigation and water supplies, circumferential road construction to access most swamp areas, cattle fattening, backyard farming, tree farming, handicraft making, and resettlement and the distribution of farm lots, which includes complete technical and credit/loan assistance for agricultural development (ADB, 2000). The area coverage of LSBDA was estimated to be approximately 88,000 hectares, including 23,302 hectares of private property. Even if everything was all assisted, according to locals, the project failed because of low production. Hence, beneficiaries were not able to pay their loans. As the peatland becomes alienable and disposable, the management of this property by the household has also varied. With low productivity, many decide to abandon it. New generations of cultivators now face a conflict of rights on who owns that piece of peatland they are cultivating. The root of



conflict rights can be traced back to 1991 under Executive Order No. 465, placing LSBDA under the control and supervision of the Board of Liquidations (BOL) and then authorizing the Department of Agrarian Reform (DAR) to distribute these lands to settlers or agrarian reform beneficiaries (ADB, 2000). Consequently, owing to the absence of LSBP delineation and mapping, lands that were distributed cannot be determined with certainty. To date, there are areas that even locals cannot access due to very dense forests, high water levels, and boggy portions, and it seems doubtful if the DAR had undertaken any cadastral survey before the distribution of lands. Some locals assert ownership in forested and bogged areas by continuously clearing swamp forests and cultivating rice in patches.

3.1.3. Drivers determined by religious values

The researcher has decided to explore this type of driver because of the increasing influence of one religious group in the surrounding community. The Iglesia ni Cristo (INC), a religious group, built a self-sustainable resettlement community in Brgy. Langit, Alang-alang, which is now called the Sitio New Era (Figures 3 and 4). During the Marcos era, land grants were distributed to turn Leyte Sab-a Basin Peatland into an agricultural area, which was when the migration of INC followers started to resettle in this area. This religious group has been able to establish settlements and facilities to cater to the economic needs of its members, especially Typhoon Haiyan survivors. Several eco-farming sites, aquaculture ponds, rice fields, mushroom facilities, garment factories, and fish-drying plants are being maintained. Drying and hauling facilities are also evident. This further shows how having one set of values can drive the whole community in a new direction of peatland management. The same results from DPSIR framework studies were observed for marine litter issues in the Windward Islands (Graham, 2023) and ancient tank cascade systems in Sri Lanka, where religion played a major role in cultural services (Amarasinghe, 2022).



Figure 3 Map showing the sustainable resettlement community, Sitio New Era, Brgy. Langit, Alang-alang, Leyte, Philippines.

3.1.4. Biophysical Drivers

These drivers describe the inherent characteristics of the ecosystem that drive the type of services it can serve. Because Leyte Sab-a peatland is a basin, this characteristic has posed limitations and opportunities for people. The presence of standing water can limit the type of crop to be planted and even the ease of navigation. In contrast, there are many opportunities for fishing and other aquaculture activities. Consequently, local accounts from older people who have been inhabiting the area for a long period of time support the fact that peatland is a wetland forest accessed mainly for gathering wild plants and hunting wild animals. These results were observed in southern Italy with coastal wetland restoration, where hunting is suggested to be regulated (Cammerino et al., 2024). The uplands surrounding the peatland were the first areas that were encroached upon where kaingin activities were already evident and went down to the lower part of the peatland, especially after the full construction of the main drainage canal (Figure 5); moreover, the water among the pools inside the peatland has a clear black to dark brown color.



Figure 4 Photo showing the swamp forest on the left, the sustainable resettlement community (see residential and building roofs), Sitio New Era, and Brgy. Langit, Alang-alang, Leyte, Philippines.



Figure 5 Map showing the main drainage canal from the BANCOM 1970 project at San Miguel Bridge, Brgy. San Isidro, Santa Fe, Leyte, Philippines.

3.2. Pressures

The pressures are the threats, risks, and vulnerabilities of the peatland. Hence, the ecosystem is being “pressured” by drivers to pursue certain anthropogenic activities or endeavors (Bosma & Hein, 2023). Human activities have influenced the present state of peatland in the past. Primarily, land conversion continues to persist. The primary “pressure” in LSBP is agricultural development. The researcher analyzed all the gathered information, integrated into the analysis, and found that peatland drainage and conversion have potential benefits and risks.



3.2.1. Agricultural Development – Potential Benefits of Peatland Draining

Draining the remaining wetland in the Leyte Sab-a Basin could lead to possible benefits directly related to agricultural development—assuming that these areas will be integrated into irrigation system service coverage to improve efficiency, possibly leading to the maximization of agricultural gains. Additionally, cutting through wetland patches would allow efficient planning, implementation, maintenance, and water distribution schemes, maximizing project benefits. Furthermore, the area for rice cultivation and the intensity of crops will expand, increasing farmer productivity, yield, and income per hectare. In addition, land conversion and increased farm activities also generate employment. A substantial reduction in plant pests is possible if areas covered with sedges and grasses are cleared and boggy spots are drained since these areas are good breeding places for plant pests (Pramudi et al., 2024). Compatible farmers can integrate fish and wetland rice cultures if efficient drainage minimizes flooding and can be controlled (depth and duration). This will increase farmers' incomes and promote nonchemical approaches to pest management in peatlands (Rakuasa & Latue, 2023). Due to the rich organic matter of this peatland, the eventual cultivation of this drained peatland may lead to increased fertility and may no longer require the application of commercial organic fertilizer except for some specific mineral deficiency.

During field observations, the soil type in the rice fields was a mixture of peat and mineral soils. This is probably because of erosion from the ridges of the surrounding mountains, depositing mineral soils at the foot of the hill. This could explain why rice fields that persist over time are those located at the outer portion of the basin, closest to the foot of the mountain. Although this production is lower than the regional and national average, the yield of rice paddies over a mix of peat and mineral soils is greater than that of those planted in the inner portion of the basin over peat or soil with a relatively high peat content (Bobon-Carnice et al., 2023), according to local rice growers. Good yields of rice have been reported in Brgy. Langit (Figure 6) and is planted over mixed peat-mineral soil. Additionally, these paddies are located close to the river and cross the barangay. The river sediments were found to be peat under alluvial soil. Therefore, nutrient-rich alluvium is a factor in the growth of crops in the area.



Figure 6 These rice fields at Brgy. Langit, Alang-alang, Leyte, Philippines reported good yields.

Interestingly, there is also a reported active log in Brgy. San Isidro. In the same way, the rate of methane emission will be reduced if peatlands are converted to agricultural use (Balode et al., 2024; Jovani-Sancho et al., 2023). Methane is a potent greenhouse gas that causes global climate change. Anaerobic conditions in marshland ecosystems produce high amounts of methane due to their highly reduced conditions. Drainage improvement allows the soil to be periodically oxidized, considerably reducing methane gas production.

3.2.2. Agricultural Development – Potential Risks of Peatland Draining

If the remaining swamp forest and marshland are drained, they will ultimately be transformed into agroecosystems. It poses severe negative impacts and risks that it poses severe negative impacts and risk that might not be reversed. The ecological niche for beneficial wildlife will be dislocated. These predators, i.e., avian species that prey on plant pests, are directly affected. Although this might not create rapid build-up and severe imbalance of harmful insect species, this imbalance could still be controlled through integrated pest management (IPM) or environmentally friendly means (Liu et al., 2023). A transect

survey revealed that the converted agricultural land is concentrated in the western portion of the peatland. It connects to the Sapaniton River at the northern and southern tip through the Palo River (Figure 2). Despite the lack of available data on these rivers' turbidity and sedimentation/siltation before the 1970s, it could be hypothesized that these areas' high turbidity data are due to this project (ADB, 2000). Total draining remarkably increases turbidity, siltation, and sedimentation downstream. Soils and sediments will also be carried out, and the water quality of receiving water will strikingly deteriorate, eventually making its way to the ocean, leading to another environmental problem. Stakeholders utilize river water for washing and bathing; hence, they are subsequently affected, same as the aquatic life. Overall, the accumulation of eroded sediments affects the efficiency and capacity of river flow during flood events. Flooding after draining can also occur (Tuohy et al., 2023). If the remaining marshland depressions that store/retain flood water and serve as water catchments are transformed and cultivated, flash floods may occur during heavy rains. Human settlements near the basin (Figure 7) will likely be affected, and adjacent areas could also be flooded, thus damaging their crops. Large peat areas have been converted into rice paddies. However, the massive BANCOP project has failed massively, resulting in abandonment. The land was once again perceived as an idle resource.



Figure 7 Residents living on the fringes of the Leyte Sab-A Basin Peatland. Taken in Barangay San Isidro, Santa Fe, Leyte, Philippines.

Unwanted grasses, sedges, and other weeds proliferated. Remnants of BANCOP initiatives can still be found in peatlands, such as the large drainage canal bridge from the BANCOP area in Brgy. San Isidro (Figure 5). The extensive roots of grasses and sedges, along with the plant biomass, formed a dense floating mass of grasses over the peatland, especially in the inner portion of the basin (Figure 8). Observed abandoned lands in Brgy. Langit and peat subsidence can also be observed.



Figure 8 The inner portion of the peatland basin, where dense floating mass grasses and tikog can be observed, is mostly taller than a normal person.

Furthermore, because of the deposition of organic materials in marshlands, their support for plant anchorage and proper growth could be constrained since these marshes are weakly aggregated and foothold. Although micronutrients were found to be very high, their available form for plant accumulation is still unknown, and these limitations may affect the agricultural productivity of the area; hence, the BANCOC project failed. This problem can be effectively addressed by regularly monitoring the peat–soil mixture area for possible future fertilization and soil amendment adjustments. Regardless, the potential impacts of agricultural development could cause environmental pollution from the increased use of agricultural chemicals.

3.3. State

In a previous study (Bobon-Carnice et al., 2023), the aboveground and belowground carbon stocks of different ecotypes were described. The next question is whether the LSBP is considered a carbon sink or source. Global carbon (C) sinks and reservoirs must be magnified and maintained (Fagorite et al., 2023). The temperate peatland ecosystem has a mean annual net production of $110+83 \text{ gCO}_2\text{-C}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ of atmospheric carbon dioxide (CO₂) (Poczta et al., 2023). Anthropogenic disturbances through drainage, deforestation, fires, and peat extraction significantly affect the biogeochemical and ecosystem functions of peatlands (Kunarso et al., 2024). Peatland drainage and deforestation/clearing to pave the way for agricultural development were found to constitute the general landscape in the study area. The removal of vegetation relatively increases CO₂ emissions to the atmosphere, and aside from intentional drainage, the water table also relatively decreases, which in turn, aerobic decomposition increases (Tolunay et al., 2024).

Here, estimated inventories of present peat aboveground and belowground C stocks of different ecotypes were quantified. Among all four (4) ecotypes, swamped forest (SF) resulted in the highest total C-stocks among the four ecotypes at $15,984.83 \text{ Mg ha}^{-1}$ (Bobon-Carnice et al., 2023), followed by marshland (ML), which resulted in $15,289.13 \text{ Mg ha}^{-1}$, which was not significantly different from each other. Agricultural land (AL) and agro-forestry (AF) were not significantly different but were significantly different from both ML and SF. AL resulted in $8,459.72 \text{ Mg ha}^{-1}$ C stocks, whereas AF resulted in $7,717.28 \text{ Mg ha}^{-1}$ C stocks. A detailed map of the extent of this peatland is still lacking. However, on the basis of the existing soil map (ADB, 2000), peat–soil analysis, direct and field transect–walk surveys, and existing vegetation, an estimated delineation of the remaining swamp forest and marshland in the LSBP has been drawn (Figure 9). Since there was no significant difference between SF and ML in terms of their C stocks, their delineation in the map was merged. It is difficult to delineate AFs and ALs since their main difference is that only patches of trees are found in AFs. Using the QGIS application, Google satellite map, and data from the Database of Global Administrative Areas (GADM), the estimated total area of remaining SF and ML is 1,731 ha, which means that the remaining areas are AF and AL, with approximately 1,357 ha based on the LSBP aggregate estimate of 3,088 ha (Bobon-Carnice et al., 2023).

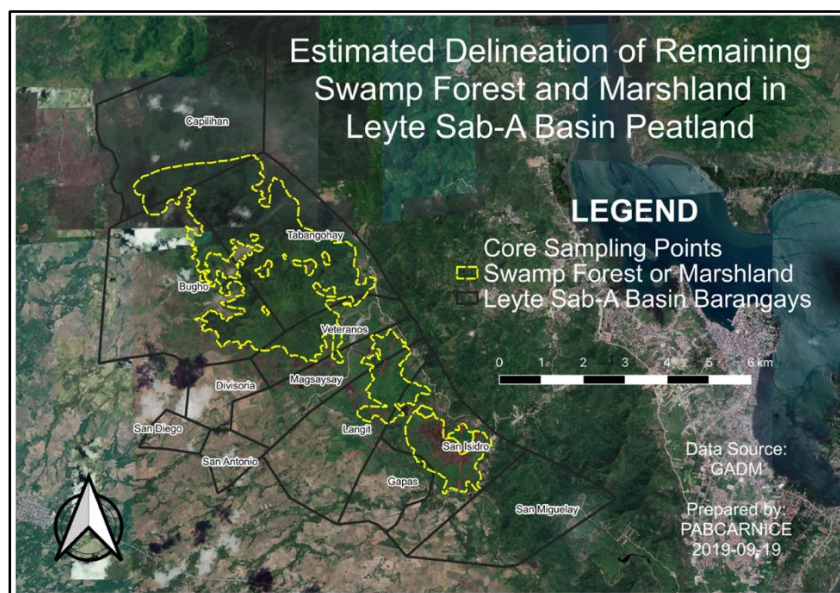


Figure 9 Map showing the estimated delineation of the remaining swamp forest and marshland areas in Leyte Sab-A Basin Peatland.

The total C stock of SF and ML was $27,067,647 \text{ Mg}$ (27.07 Tg), which was 71% of the total C stock, whereas the total C stock of the combination of AF and AL was $10,976,773 \text{ Mg}$ (10.98 Tg), which was only 29% (Table 1). The same percentage of total CO₂ sequestered from both combined ecotypes was rendered: SF and ML produced $99,338,264.49 \text{ Mg}$ (99.34 Tg) of CO₂ (71%), and AF and AL produced $40,284,756.91 \text{ Mg}$ (40.24 Tg) of CO₂ (29%). The total C stock that the LSBP could store was $38,044,420 \text{ Mg}$ (38.04 Tg), and it could sequester $139,623,021.4 \text{ Mg}$ (139.62 Tg) of CO₂ in 3,088 ha (Table 1). If LSBP was not



converted in the 1970s and was preserved, it could have C stock of 48,287,056 Mg (48.29 Tg) (3,088 ha*15,637 Mg mean C stocks ha⁻¹ [SF and ML]) and sequestered 177,213,495.52 Mg (177.21 Tg) of CO₂. In the span of ~48 years (1970–2018), due to agricultural development, the peatland already lost 10,242,636 Mg (10.24 Tg) of C stocks, and 37,590,474.12 Mg (37.59 Tg) of CO₂ sequestered. Despite this, peatland is still considered a carbon sink since the amount of C stored in unconverted peatlands is still high compared with areas converted to agricultural use. However, if clearing and conversion for agricultural development continue, it will become a C source.

Table 1 Total C stocks and CO₂ sequestration estimation of different ecotypes on the basis of the estimated delineation of LSBP and its monetary value.

Ecotype	Mean C Stocks (Mg ha ⁻¹ C-stocks)	*Area (ha)	Total C Stocks (Mg)	**Total CO ₂ Sequestered (Mg)	***Monetary Value (US\$)
SF and ML	15,637	1,731	27,067,647	99,338,264.49	993,382,645
AF and AL	8,089	1,357	10,976,773	40,284,756.91	402,847,569
TOTAL		3,088	38,044,420	139,623,021.40	1,396,230,214

*Area based on estimated delineation; whole peatland is estimated to be 3,088 ha (NAMRIA, 1995). **1 Mg of C = 3.67 Mg of 'carbon dioxide equivalent' (CO₂^e) (IPCC, 2000). ***1 Mg of CO₂ = US\$10.00 (World Bank, 2020).

Southeast Asian peatlands cover 23,702,930 ha (Omar et al., 2022), which yields an estimated conservative carbon storage of 69 Gt (Page et al., 2011) but is then reduced to 50Gt (Page & Rieley, 2018) after 7--8 years, with a range of peat thickness from 0.5--20 m (Omar et al., 2022). Consequently, such calculations excluded some papers from the Philippines, Thailand, and Vietnam because fewer papers have been published about their extent, and only those articles published before 2022-2021 were considered. Such data could increase if these newly published articles are considered. In the present study, LSBP could store 0.038 Gt (38,044,420 Mg) of C (Bobon-Carnice et al., 2023), and such data should be included in the C data inventory in the Philippines in addition to the C stocks of forest ecosystems and their conversion (Carnice & Lina, 2017; Lasco & Pulhin, 2009). Even though the Philippines has less responsibility or commitment to reduce or limit its anthropogenic emissions of GHGs since it is not part of the Annex I Country Party to the United Nations Framework on Climate Change (UNFCCC), the country has already started its efforts since 1991 to address the issues of climate change (Dulce, 2024; Merilo, 2001). The country was able to conduct a national GHG emissions inventory in 1990 and 1994, and the Philippines released a total equivalent amount of 100,738 tons of CO₂ into the atmosphere in 1994 (Merilo, 2001). Forest GHG emissions were also evaluated from 2001-2020, resulting in 29.73 Mt of CO_{2e} (Fallarcuna et al., 2023). However, these values are still minimal compared with those of developed countries.

Furthermore, the monetary value of LSBP stored C on the basis of the computed CO_{2e} equated to US\$1,396,230,214 (Table 1). Carbon sequestration as a peatland ecosystem function is often neglected unless it has monetary value. The higher the amount of C stored is, the higher its CO₂ equivalent and the higher its economic value. This further emphasizes managing peatland ecosystems sustainably, which will considerably contribute to climate change mitigation.

A follow-up study has already been conducted and revealed that LSBP marshland has emitted 37.42 mg/g CO₂ in a span of 120 days of incubation, which means that, if calculated in the long term, this peatland could be a carbon source (Bobon-Carnice et al., 2025). Additionally, a detailed and extensive survey and peat examination, especially in the northern part of the LSBP (Barangay Capilihan, San Miguel, and Barangay Tabangohay, Alang-alang), should be performed to delineate further and verify the extent of the peatland.

3.4. Impacts

The macroeconomic trajectories driving these pressures are agricultural development and the demand for increased land productivity. This aspect has been intensely discussed in the Socioeconomic Concerns and Patterns of Use section of this research (under review), which focused on agricultural development that paved the way for clearing swamp forest areas and the usual succession of vegetation in the peatland.

3.5. Responses

Previous subchapters have identified drivers, pressures, states, and impacts. Considering those, "responses" were formulated, which focus on policy formation and legislative declaration.

3.5.1. Legal and Policy Framework

LSBP is categorized under the "wetland" landscape, which includes marshes, swamps, and bogs. As a consequence of several cases of wetland alteration, conversion, and reclamation to cater to development activities, the regulatory framework for wetland management has evolved gradually globally and in the Philippines. To date, only a few papers have been published about wetlands/peatlands, focusing on the carbon storage of Caimpugan peatlands in Agusan Marsh, Philippines, and its role in greenhouse gas mitigation (Van Leeah & Lasco, 2012), LSBP, which has focused on the impact of land use conversion on C-

stocks (Decena et al., 2021), total carbon storage and sequestration (Bobon-Carnice et al., 2023), and avifauna composition and communities (Matutes & Densing, 2022). Many wetlands can be found in the country; however, no specific and comprehensive wetland national policy and legislation exist. The protection of wetland areas could be closely related to national park legislation. Wetland-related issues have been surfacing, and legislation is insufficient to cover and protect wetlands.

The LSBP falls under the category of “Strict Nature Reserve.” It is under the National Integrated Protected Areas System Act of 1992. It is defined as an area possessing some outstanding ecosystem features and/or species of flora and fauna of national scientific importance maintained to protect nature and maintain processes in an undisturbed state to have ecologically representative examples of the natural environment available for scientific study, environmental monitoring, education, and maintenance of genetic resources in a dynamic and evolutionary state (RA No. 7586). Hence, based on its category, the peatland ecosystem is crying out for protection and maintaining its undisturbed state, or at least since it has already been disturbed, to protect the remaining swamp and peatland areas.

Additionally, considering the international context of these legislations, the Ramsar Convention, the Convention on Wetlands, is an intergovernmental treaty providing the framework for conserving and wise use of wetlands and their resources (Gell et al., 2023). The convention was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. It entered into force in the Philippines last November 8, 1994 (RAMSAR Convention of 1994) and has seven (7) sites designated Wetlands of International Importance (Ramsar Sites) (Rattan et al., 2021). These include Las Piñas – Parañaque Critical Habitat and Ecotourism Area (LPPCHEA), Naujan Lake National Park, Olongapo Island Wildlife Sanctuary, Puerto Princesa Subterranean River National Park, Negros Occidental Coastal Wetlands Conservation (NOCWCA), Agusan Marsh Wildlife Sanctuary and Tubbataha Reefs Natural Park. Efforts should be intensified for the Leyte Sab-a Basin to be part of these Ramsar Sites and for at least one policy declaration to conserve peatland.

3.5.2. *Implications: Relevance to the management of peatlands*

The researcher proposed three (3) potential scenarios for LSBP management: the preservation of remaining peatlands, conversion to an agroecosystem, and multiple uses.

3.5.2.1. *Peatland Management – Preservation of Remaining Peatlands*

The Leyte Sab-a Basin has high scientific and educational value basic research concerning such an ecosystem in the Philippines is lacking. Because of its unique ecosystem, its intrinsic value is considered very high since one can find such an ecosystem in only a few areas of the country. Its aesthetic and landscape value can provide high recreational and ecotourism value if managed and advertised properly, as supported by a study conducted in Sumatra, Indonesia (Yunus et al., 2024). The western portion of the LSBP has mostly been converted to agriculture, specifically into rice fields. On the basis of the visual assessment and informal interviews, most are subsistence farmers who thrive on seasonal cultivation in boggy portions and who have reclaimed adjacent patches of wetland forests (Figures 10 and 11). Socioeconomic implications will be affected if the whole LSBP is preserved. People who have already established their residence in these areas will likely be displaced if their source of income is cut. If there is an opportunity to apply as beneficiaries of land distribution by the Department of Agrarian Reform, they might not be eligible to apply if they relocate. These economic problems may lead to another social problem. With positive prospects, a sustainable way of managing peatland can be used to provide low-impact economic opportunities while simultaneously enhancing its ecological integrity and sustaining the resources that can be extracted from the peatland. Tikog gathering, housing materials, fishing, and hunting are some of the consumptive uses of peatland resources that provide sources of income and food to communities that, if aided with help, can be further developed. Moreover, its aesthetic value is hypothesized to be high because of its unique and diverse landscape ecosystem, which may appeal to tourists, environmentalists, and scientists. Consequently, if the remaining peatlands are preserved, the problem with exposure to schistosomiasis infection might not be due to its suggested management (draining the peatlands). Hiller and Fisher (2023) proposed the same urgent call, where large “intact” natural areas should be critically and sustainably preserved.

3.5.2.2. *Peatland Management – Conversion to Agroecosystems*

Most of the responses is to manage peatlands not as wetlands but as agroecosystems. The following sections analyze peatland as a modified agroecosystem by incorporating principles in landscape ecology. Figure 12 shows a typical crop–livestock integration with inputs and outputs of capital, energy, materials, and information. Agroecosystems are modified and managed to produce food, fiber, fuel, and other necessities (Caporali & Caporali, 2021). The system has strong links within but relatively weak links outside. Thus, even if there are hierarchies from the field to the farm level into a catchment, for example, agroecosystem analysis at the peatland landscape level can be quite challenging. The goal is to earn from all the inputs invested. The human system plays a role in soil management, tillage, other cultivation operations, and irrigation and decision-making to maintain a healthy crop or livestock for harvest. One can deduce that the value system operating in a typical agroecosystem analysis is that the success of farm operation or productivity of the land is measured in yield per unit of cultivated land. This

result undervalues the true potential of this modified system because the peatland turned into agricultural land other services to provide services other than provisioning services.



Figure 10 The area in the middle was previously a swamp forest. This material has been cleared and transformed into rice fields but has resulted in low production. Then, it was abandoned and is now dominated by sedges and grasses. Taken in Barangay Langit, Alang-alang, Leyte.



Figure 11 Patches of trees in a boggy area in Barangay Langit, Alang-alang, Leyte.

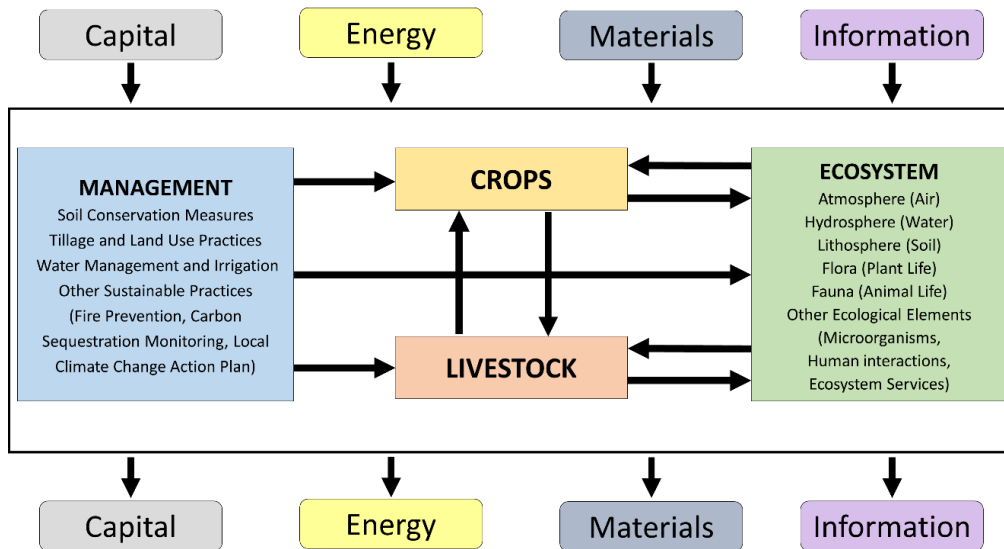


Figure 12 Agroecosystem analysis model of a typical farm (adapted from Caporali & Caporali, 2021).

If a peatland as massive as LSBP is transformed into an agroecosystem, there will be a definite change in the landscape. To describe this change, the modified agroecosystem must be analyzed by incorporating the creation of landscape services via the pattern-process-value chain (Termorshuizen & Opdam, 2009; Figure 13). The spatial pattern determines the function, influencing energy flow, materials, and organisms. One can also describe the agroecosystem in terms of the functions that it can deliver or realize. Logically, the landscape services that an agroecosystem provides for humans are the functions that the system is able to understand.

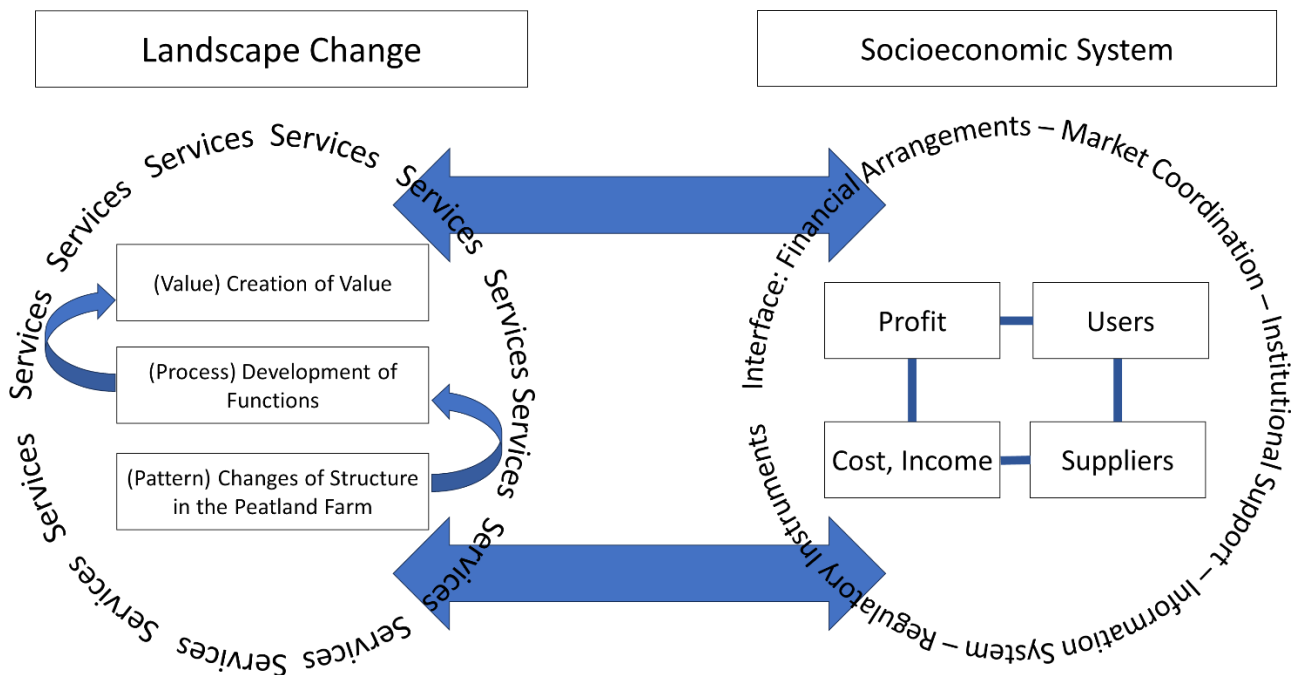


Figure 13 Modified agroecosystem analysis with pattern process value in the development of landscape services (adapted and modified from Termorshuizen and Opdam, 2009).

The pressure on land to produce food threatens the other services that agroecosystems provide. As decision makers, humans modify the landscape structure to achieve prioritized landscape services: producing more food. This shows that Man places the highest value on providing food and lesser amounts on other services, such as providing habitat for fauna and flora or maintaining good water quality downstream. Functions continue to exist even without human intervention. In the structure-pattern-value chain, functions are translated into services when people value them. In our modified analysis, the landscape is viewed as a value-delivering system. Although Man prioritizes certain services, landscapes are expected to fulfill many functions all at the same time and, in actuality, deliver more services than Man can recognize. Therefore, we need landscapes that are

of better quality. In our modified analysis, the agroecosystem has strong links within and even stronger connections outside. As part of the socioeconomic system, Man is limited in managing the system and creating values that would deliver landscape services to him (Stokes et al., 2023). It is also emphasized here that Man is not only the producer that generates the costs but also the users of the services. They also receive benefits other than food, fuel, and fiber, as well as protection from floods and landslides (Satama-Bermeo et al., 2024), and their future children and grandchildren can also be “users” and benefit from fresh air and water and a less warm planet concerning climate change.

3.5.2.3. Peatland Management – For Multiple Use

Since most of the western part of the LSBP has already been reclaimed for agriculture and the northeastern to eastern parts are still dominated by swamp forests and marshes, the researcher suggests managing peatland for multiple uses. For ecological and biodiversity considerations, the northeastern part of the eastern part will be preserved, where the swamp forest and marshland are still largely intact, and the western part will be converted into an agricultural area. This management scheme is considered a practical and sustainable option that will still cater to the economic needs of the surrounding community and preserve the peatland ecosystem. On the basis of the physical attribute, this is feasible. The northwestern parts that cover the Barangay Bugho and Magsaysay, Alang-Alang, and some parts of Barangay Capilihan, San Miguel, and the southern tip of the basin, which is already part of Sante Fe, are covered with Palo clay loam and peat–soil mixtures that are estimated to cover 1,349 ha (Bobon-Carnice et al., 2023). This northwestern part can drain via the Danao River to the Sapaniton River, which connects to the Mainit River System and Binongto-an River, the primary water line and irrigation canal (Figure 2). The southeastern part can drain through the Bangon–Palo River, exiting San Pablo Bay. Improving and integrating irrigation systems will help rainfed rice fields reduce flooding incidents and consider fish culture as another livelihood. If the western side is drained, the eastern part will not be affected since their draining areas are different and will help preserve this side of the basin, which is estimated to be 1,739 ha (Bobon-Carnice et al., 2023).

4. Conclusions

It was hypothesized that LSBP started to degrade due to draining and agricultural conversion decades ago. It continues to deteriorate without a proper recommended management scheme and community-based management intervention. The pressure effect of agricultural development, driven by the demand to increase the productivity of the land, has been evident and reported through various interviews. Using DPSIR as the framework of analysis, it has become clear that the demand to increase the productivity of peatland has put high pressure on the system, specifically to develop land for agricultural purposes. Additionally, the community explored previously unreachable areas to gather more food and fuelwood and cleared these areas to pave the way for agricultural activities. However, the responses of the community are clustered around meeting the pressure. In response to the pressure of agricultural development, the local community voiced the need for better policies for agroforestry and crop-livestock enterprises. Protection and conservation of the peatland have been perceived as secondary. In the analysis, the people do not respond to the impacts. If they do, it will pave the way for more sustainable peatland management. Therefore, examining the preferred agroecosystem through the lens of landscape services is necessary. In this way, the management of peatland turning into agricultural land will focus on increasing productivity and other ecosystem services, such as being a carbon sink.

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Ethical considerations

Indent the study, approval was obtained from the Department of Environment and Natural Resources, Region VIII, Philippines, with a gratuitous permit (DENR-GP No. R08 2017–36). Prior to the interviews, all key informants (KIs) voluntarily provided their consent. Furthermore, approval from the local government of all municipalities involved, including barangays, was obtained before proceeding with the data collection. The researcher ensured the confidentiality of the informants’ personal data.

Conflict of interest

The author states that there are no conflicts of interest.

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