

Usage of Land Use/Land Cover and Anthropogenic Parameters in Prioritizing Conservation in Sub Watersheds of Upper Pulangi River

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ABSTRACT

Most part of the Philippines is located within watersheds. The best unit for managing natural resources like land and water is a watershed. This study aimed to prioritize the nine sub watersheds of Upper Pulangi River for conservation and rehabilitation using land use and land cover and anthropogenic parameters. Land cover and land use was analysed using remote sensing and GIS techniques to identify and delineate its categories. In terms of anthropogenic parameters, watersheds with the most extensive and highest human alterations, such as surface mining/quarries, illegal logging, land conversion to agriculture, kaingin, built-up areas, and upland settlers, were assigned the top priority for conservation. Watershed prioritization is the process of ranking different sub-watersheds in the order in which they must be addressed for soil conservation measures. Out of the nine sub watersheds being studied, the results showed that Sawaga sub watershed has the high priority for conservation followed by Maapag, Upper Pulangi, Taganibong, and Malingun sub watersheds with medium priority. Panlibatuhan, Tigwa and Taganibong sub watersheds fall under low priority while Manupali sub watersheds has the lowest priority due to its favourable vegetation cover and existing conservation and rehabilitation projects. It is recommended to watershed managers of Upper Pulangi river to prioritize and consider for funding the rehabilitation and soil conservation measures for Sawaga sub watershed. The methods used in this study can be applied to other watershed management under limited resources.

INTRODUCTION

Land use and land cover (LULC) change are significant causes of environmental change. The term "land cover" denotes the biophysical state of the Earth's surface and near subsurface and includes the vegetation that covers the land surface as well as other components of the physical environment (Iqbal and Sajjad 2014). Data on land cover shows how much a region is covered by various land and water types, including forests, wetlands, impermeable surfaces, agricultural, and others. Both wetlands and open water are forms of water. Land use demonstrates how humans utilize the landscape, whether for mixed services, conservation, or development. Understanding and evaluating the consequences of landscape changes on the atmosphere, climate, and sea level require a thorough understanding of land use and cover (Meyer and Turner, 1992), knowledge about land development, loss and degradation (Anderson et al., 1976) land management consideration (Luysaert et al., 2014; Pongratz et al., 2018) analysis of change detection (e.g., the place where the change takes place, the kind of change, and the method by which the change is) (Jansen and Gregorio, 2002) and using monitoring tools to manage natural resources, monitor the landscape, and modify policy (Kumar et al., 2019). Most of the world's watershed degradation is thought to be caused by changes in land use and/or cover (Sarma and Saikia, 2011). Changes in LULC, particularly in areas where water availability is constrained, could lead to a worsening of water quality as well as an increase in water scarcity (Aghsaei et al., 2020). In most regions of the world, watershed degradation brought on by changes in land use and land cover is widespread.

The natural ecosystem is being severely impacted by the growth of cultivated area at the expense of natural vegetation (Tolessa et al., 2020). This ongoing growth of cultivated land is a significant contributor to land degradation, which poses a larger risk to soil fertility (Kidani et al., 2019). Significant ecological changes, land degradation, and landscape changes, and a shift in biodiversity have been caused by anthropogenic activities on a global, regional, and local scale in many regions that were once forested (Nedd et al., 2021). The Earth has been divided into watersheds by runoff, and humans have claimed many of them; since then, societies have settled in the watersheds and utilised the resources there to create activities aimed at welfare (Nooka Ratnam et al., 2005). The hydrology of streams and rivers is also impacted by human activity through changes in land use, such as urbanization, the conversion of forests into agricultural land, or other detrimental behaviours (Nooka Ratnam et al., 2005). The main factor contributing to watershed degradation, especially in developing nations, is improper and haphazard use of watershed resources without any long-term conservation efforts (Sarma and Saikia, 2011).

Watershed management is the integrated use of land, vegetation, and water in a geographically distinct drainage area for the benefit of its population, to protect or conserve the hydrologic services that the watershed provides and reduce or avoid negative downstream or groundwater impacts (Babur and Kara, 2017; Darghouth et al., 2008; Tomer, 2005). Watershed management is also important in order to deliver the right goods and services while minimizing the

impact on the soil and watershed resources (Wang et al., 2016); also to ensure that there is a sufficient supply of high-quality water to support both human society and natural ecosystems (Tomer, 2005). Watershed prioritizing has become more important in natural resource management in the context of watershed management and conservation so that preventative and corrective interventions can be planned and implemented successfully (Sarma and Saikia, 2011).

Remote sensing and GIS have been used in the watershed prioritizing efforts for conservation and development (Arun et al., 2005; Nooka Ratnam et al., 2005; Puno and Puno, 2019; Sarma and Saikia, 2011; Suresh et al., 2004). The information generated with respect to geomorphology, soil, land use/land cover through remote sensing can be interpreted for various themes, including for improved management and conservation of these resources on a watershed/village basis, land capabilities, irrigability, and crop compatibility (Bodhankar et al., 2002; Sharma et al., 2004).

Previous studies demonstrated sub-watershed prioritization based on land use/land cover change analysis (Iqbal and Sajjad, 2014; Javed et al., 2009, 2011; Puno and Puno, 2019; Sarma and Saikia, 2011; Suji et al., 2015). The ranking of sub-watershed units according to the severity of denudation brought on by rapid soil erosion and critical conditions in drainage areas is known as sub-watershed prioritization (Pandy et al., 2007). In the present study, land use and land cover and anthropogenic activities are studied and analysed to prioritize sub watershed of the Upper Pulangi River situated within the province of Bukidnon, Mindanao, Philippines.

METHODOLOGY

The nine sub watersheds of Pulangi River in Bukidnon are selected for the present study as shown in figure 1. Pulangi River is the longest river in Bukidnon and the 4th longest river in the Philippines which is located at the latitude and longitude of 7°01'60.00"N and 124°29'59.99"E, respectively. It travels across the majority of Bukidnon's cities and municipalities and is 320 kilometres long.

The Upper Pulangi River Basin is a significant carbon stock depository and home to a variety of animals. The river provides water for the Pulangi IV Hydro-electric Power Plant, a major contributor to Mindanao's need for electricity. Additionally, the river is directed to a number of significant irrigation systems, ensuring rice production for the community and other settlements (Paringit and Puno, 2017). The province of Bukidnon's economy is mostly dependent on agriculture, including farming, fishing, trade, and commerce. Major crops grown in the province include rice, corn, sugar, coffee, and cassava (Province of Bukidnon Brief Information, 2014).

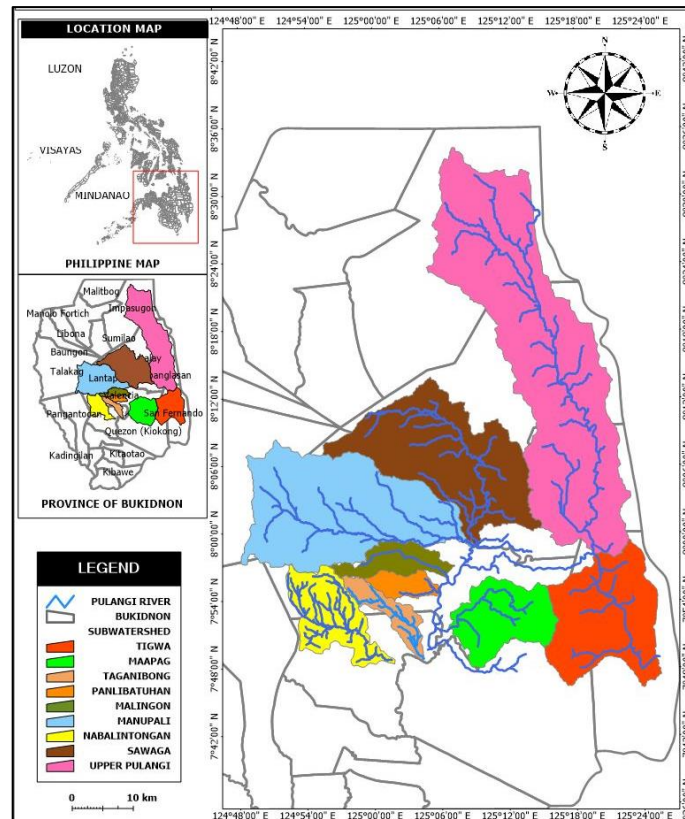


Figure 1. Map of the study area

Land Use/Land Cover Data

The Digital Elevation Model (DEM) and LULC year 2010 of the nine sub-watersheds were obtained from the Geo-informatics for the Systematic Assessment of Flood Effects and Risk for Resilient Mindanao (Geo-SAFER Mindanao). Geo-SAFER Mindanao is a two-year research program funded by the Department of Science and Technology and the Philippine Council for Industry, Energy and Emerging Technologies Research and Development that aims to produce a highly detailed Flood Hazard Maps using Light Detection and Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (IFSAR) technologies and expected to benefit 121 Local Government Units located in Mindanao. LULC change analysis is being identified as an essential parameter in watershed management and study, and it has been dealt with great emphasis in many recent works (Chauhan and Nayak, 2005; Javed et al., 2009; Shetty et al., 2005). Based on the classified satellite image of LULC of the sub-watersheds, prioritization was carried out. Specific LULC of the year 2010 with 89% accuracy (NAMRIA, 2018) was used in this study. LULC was then categorized into five types: forest, cultivated, shrub, grassland, and built-up. Other LULC, like inland water, were confined in relatively small areas and were thought not to have an impact on the whole priority process. LULC was expressed in percentage to account for the proportional effect by size in the prioritization process, assuming that proportioning is appropriate because other sub-watershed have larger forest areas, however, it is relatively more minor when expressed in percentage (Puno and Puno, 2019).

As to ranking method, the parameter with the largest area % of agricultural, grassland, built-up, and shrubs received the highest rating, while the parameter with the highest area percentage of forest land received the lowest ranking. A compound value (Cp) was calculated by adding the parameter rankings for each sub-watershed; the lower the Cp number, the higher the priority (Iqbal and Sajjad, 2014; Javed et al., 2009, 2011; Suji et al., 2015).

Anthropogenic Data

Anthropogenic activities such as farming, clearing forests, building roads, and mining can put too much soil and particulate matter in rivers. Changes in land-use are clearly indicative of anthropogenic activities, which are frequently seen as key contributors determining any change in watershed characteristics (Brendel and Soupir, 2017; Javed et al., 2011; Waiyasusri et al., 2016). Additionally, human population has effects such as strain on natural resources, migration/urbanization, and a sharp rise in social spending (Gumma et al., 2016). Prioritizing watersheds for a sustainable development and halting migration to urban areas was given higher priority for areas with a higher population (in rural areas) (Bah et al., 2003; Page et al., 2010).

The extent of human activities within the nine sub-watersheds of Pulangi River was assessed through an interview of the In-charge personnel from the Department of Environment and Natural Resources – Provincial Environment and Natural Resources Office Bukidnon (DENR-PENRO). DENR-PENRO Bukidnon is the office-in-charge of the nine sub-watersheds being studied. The said office justified and recommended conservation and rehabilitation of the nine sub-watersheds of Pulangi River based on their observation and actual data on the extent of human activities therein. Watersheds with the most extensive and highest human alterations, such as surface mining/quarries, illegal logging, land conversion to agriculture, kaingin, built-up areas, and upland settlers, were assigned the top priority for conservation. The watershed with the second-largest average area of human alterations was designated as the second priority for protection. Lastly, the watershed with minor human alterations was assigned the least priority for conservation. The numbers of existing conservation and rehabilitation programs within each sub watershed were also considered to moderate erodibility.

Priority Indices

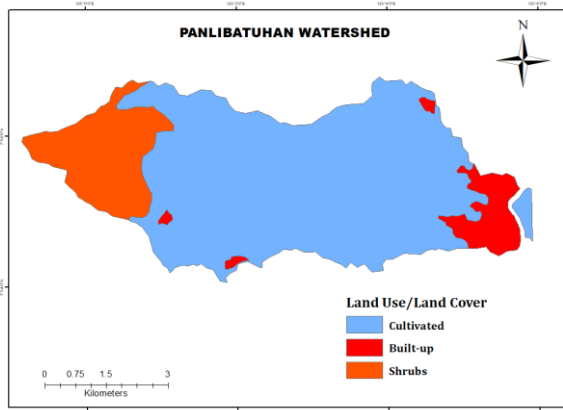
The combined compound value of LULC and anthropogenic factors was used to calculate the final priority ranking of the nine sub-watersheds. In the final ranking method, the sub watershed(s) with the lowest cumulative compound value received the highest rank (one), and the next lowest value received the second-highest rank. On the other hand, the lowest rank was assigned to sub watershed/s with the highest combined compound value of LULC and anthropogenic parameters. Based on the average value, the final priority criteria were then classified as follows: <3.0 - Very high priority; 3.01–4.00 - High priority; 4.01–5.00 - Medium priority; 5.01–6.00- Low priority; and

>6.1 - Very low priority (Gumma et al., 2016; Waiyasusri and Chotpantararat, 2020) and were shown through the priority index map.

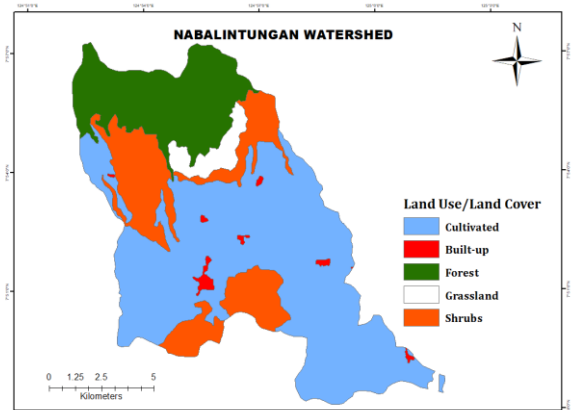
RESULTS

Land Use and Land Cover (LULC) Analysis

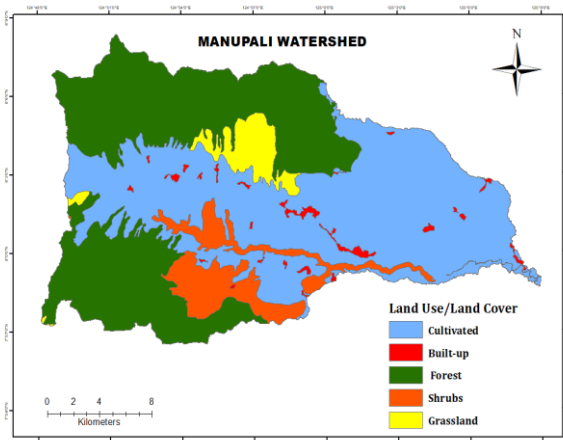
There were five identified LULC categories in the sub-watersheds: forest, cultivated, grassland, built-up, and shrubs. In terms of forest area, Upper Pulangi (fig. 2I) showed to have the highest percentage followed by Tigwa, Manupali, Nabalintungan, Sawaga, Maapag, and Malingun respectively. Figure 2A and H show that Panlibatuhan and Taganibong sub-watersheds showed no forest area, implying more erosion risk. Shrubland was more evident in Taganibong followed by Malingun, Nabalintungan, Panlibatuhan, Manupali, Tigwa, Upper Pulangi, and Sawaga respectively. A higher percentage of shrubland was assumed to accelerate the rate of soil erosion. Thus, it needs consideration for soil conservation. The cultivated area was common in all sub-watersheds. The highest cultivation was found in Panlibatuhan sub watersheds (fig.2A), while the lowest was in the Tigwa sub-watershed (Fig. 2F). Most of the sub-watersheds have cultivation of more than 50% of their total area. This implied more risk of erosion as cultivation was assumed to hasten the rate of soil degradation. Grassland was higher in Maapag sub-watershed (fig.2E) while lowest in Panlibatuhan and Malingun sub-watersheds. A higher percentage of grassland was also expected to hasten the erosion rate. Thus, Maapag sub-watershed needs immediate attention for conservation. Built-up areas were also taken to speed up the risk of erosion. Built-up areas were higher in Upper Pulangi (fig.2I) while lower in Taganibong and Panlibatuhan sub-watersheds (Fig. 2H&A). Upper Pulangi and Tigwa sub-watersheds were the two most prone to erosion in built-up areas; hence they need immediate attention for treatment and conservation measures.



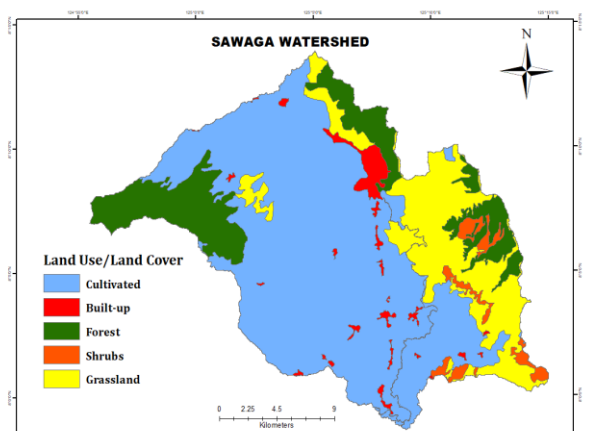
(A)



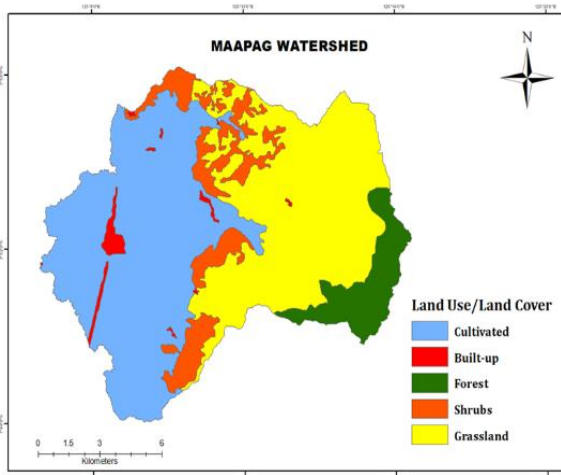
(B)



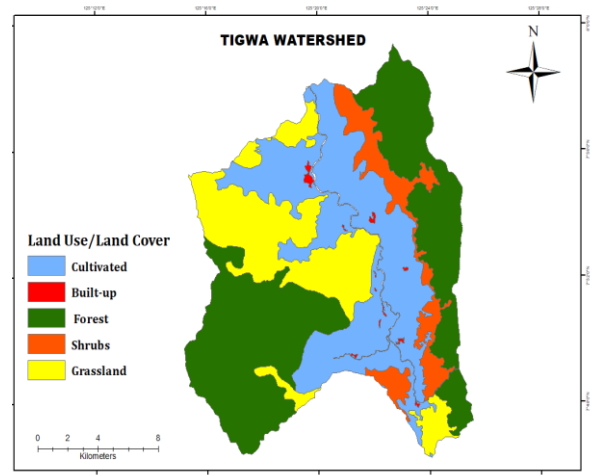
(C)



(D)



(E)



(F)

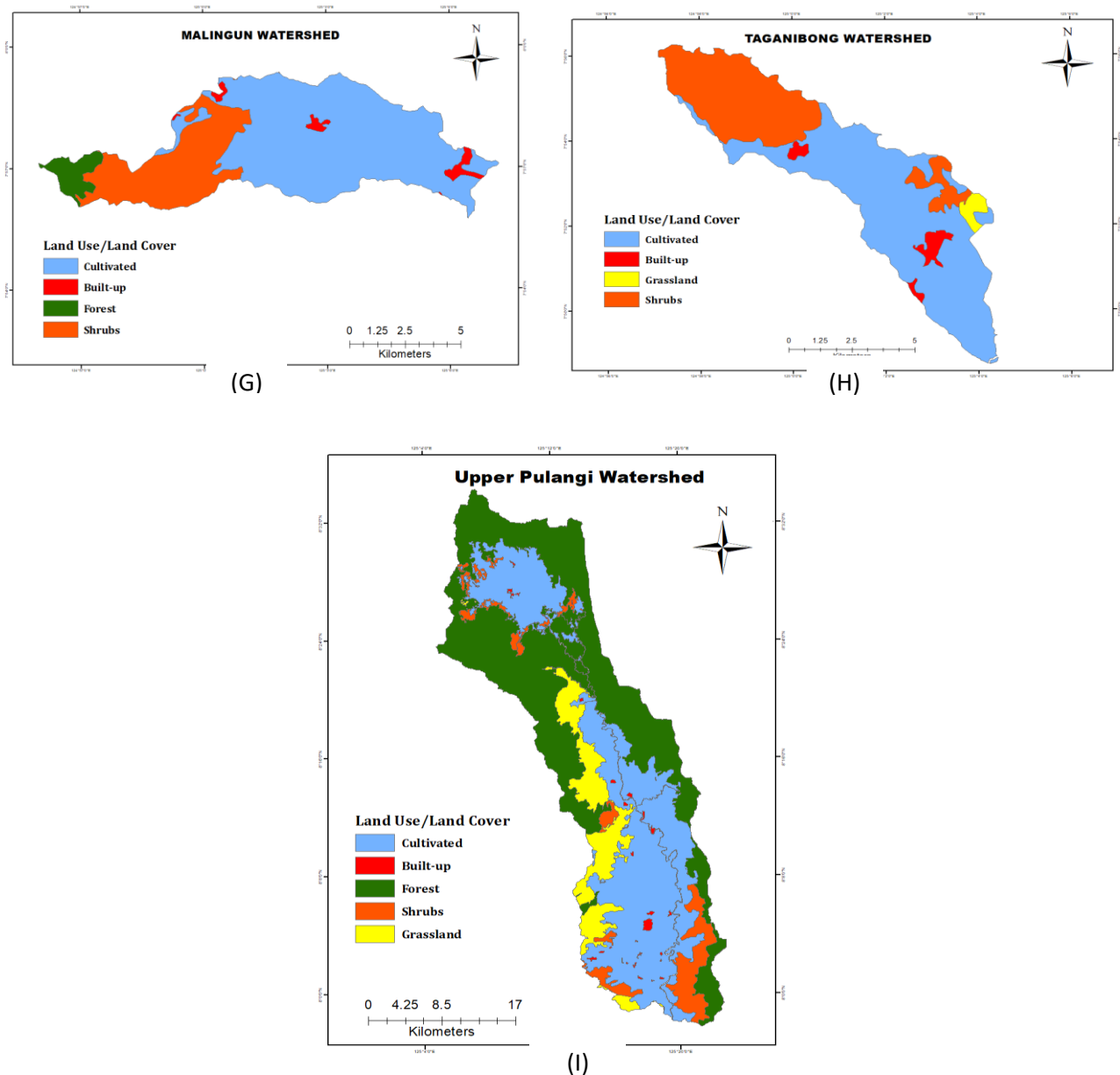


Figure 2. LULC categories of each sub-watersheds

Prioritization of Sub watersheds based on LULC Parameters

The ranking involved giving the top priority to the parameter with the greatest percentage of cultivated, shrubs, grassland, and built-up areas, and the last priority to the parameter with the greatest percentage of forest cover (Iqbal and Sajjad, 2014; Javed et al., 2009). The final ranking was then calculated by averaging the ranks of each single LULC parameter (Table 1). Results show that Taganibong and Panlibatuhan watersheds were the top priority for conservation. At the same time, Upper Pulangi has the very low priority due to a lesser percentage of cultivated shrubs, grassland, and built-up and had dominant forest vegetation, which is believed to prevent soil deterioration. These results are not static as they are subject to changes if the LULC of the watersheds also changes.

Table 1. LULC of the sub-watersheds of Upper Pulangi River

Watersheds	Forest		Shrub		Cultivated		Grassland		Built-up		Compound Rank	Priority
	Area (%)	Rank	Area (%)	Rank	Area (%)	Rank	Area (%)	Rank	Area (%)	Rank		
Taganibong	0.00	1	33.6	1	61.4	4	1.87	7	3.07	2	3.00	VH
Panlibatuhan	0.00	1	15.57	4	77.40	1	0.00	8	6.60	1	3.00	VH
Malingun	4.45	3	25.67	2	67.58	2	0.00	8	2.30	4	3.80	H
Maapag	7.53	4	10.19	5	43.35	7	37.4	1	1.48	5	4.40	MP
Sawaga	15.53	5	2.35	9	61.6	3	17.83	3	2.52	3	4.60	MP
Nabalintungan	18.82	6	19.3	3	57.5	5	3.25	6	0.90	7	5.40	LP
Manupali	38.97	7	8.19	6	47.7	6	3.98	5	1.15	6	6.00	LP
Tigwa	39.86	8	8.06	7	30.65	9	20.25	2	0.36	9	7.00	VL
Upper Pulangi	43.25	9	6.77	8	37.3	8	9.15	4	0.56	8	7.40	VL

VH = Very high priority, H = High priority, M = Medium priority, L = Low priority and VL = Very low priority

Anthropogenic Parameters

The natural environment has been profoundly affected by humankind's presence on the earth and its landscape modification (Iqbal and Sajjad, 2014). Anthropogenic alterations of the natural landscape using agriculture, forestry, and urbanization have increased. The anthropogenic analysis is an essential parameter as human disturbances impact river basins by reducing the quality and services provided by the aquatic ecosystems (Shen et al., 2017). Prioritization was carried out based on the observed data of human activities within watersheds coming from the Enforcement Division, PENRO-Bukidnon. The said office ranked the nine sub-watersheds based on the severity and extent of human activities. The ranking was done by assigning the highest rank to the watershed/s with the highest area of mining/quarries, illegal logging, upland settlers, land conversion to agriculture, kaingin, and built-up areas. The lowest rank was assigned to the watershed/s with the lowest area of such human activities mentioned. Ranks of individual anthropogenic parameters were then averaged to arrive at the compound values for the final ranking (Table 2). Results showed that the Sawaga and Upper Pulangi sub watershed had the highest priority for conservation as it had the highest average number of

human activities within its area. Manupali and Panlibatuhan watersheds were the last priority due to the lower rate of anthropogenic activities, which are assumed to have a lesser effect on the soil from degradation. Existing conservation and rehabilitation programs/projects of government and non-government agencies were assumed to be prevention and means for soil conservation. Based on the authors' interview with PENRO-Bukidnon personnel (Table 3), the Manupali watershed appeared to have the highest number of existing conservation and rehabilitation programs/projects, followed by the Sawaga, Maapag, Tigwa, then Upper Pulangi, Malingon, and Nabalintungan. Panlibatuhan and Taganibong watersheds were found to have no existing conservation and rehabilitation programs/projects, suggesting having a higher risk for soil degradation and needing more attention for protection.

Table 2. Prioritization for conservation of the sub-watersheds based on anthropogenic activities.

Pulangi River Sub-watersheds	Anthropogenic Activities & Rank						Compound Rank	Priority
	Mini ng/ Quarry	Illegal Logging	Upland Settlers	Land Conversion to Agriculture/ Farmland	Kaingin	Built-up areas		
Sawaga	2	2	2	1	1	1	1.50	VH
Upper Pulangi	3	1	1	2	3	2	2.00	VH
Tigwa	4	3	4	4	2	3	3.33	H
Maapag	1	4	7	5	8	5	5.00	MP
Malingon	5	6	8	7	4	6	6.00	LP
Nabalintungan	6	7	6	6	6	7	6.33	VL
Taganibong	7	8	3	8	5	8	6.50	VL
Manupali	9	9	9	3	9	4	7.17	VL
Panlibatuhan	8	5	5	9	7	9	7.17	VL

VH = Very high priority, H = High priority, M = Medium priority, L = Low priority and VL = Very low priority

Table 3. Existing Conservation and Rehabilitation Projects/Programs of the sub-watersheds

Pulangi River Sub-watersheds	Existing Conservation and Rehabilitation Projects/Programs
Manupali	<ul style="list-style-type: none"> • Integrated Natural Resources and Environmental Management Project (INREMP) • National Greening Program (NGP) • International Center for Research in Agroforestry (ICRAF) • Muleta Manupali Watershed Development Project (MMWDP)
Sawaga	<ul style="list-style-type: none"> • Integrated Natural Resources and Environmental Management Project (INREMP) • National Greening Program (NGP)
Maapag	<ul style="list-style-type: none"> • National Greening Program (NGP) • Forestry Sector Project (FSP)
Tigwa	<ul style="list-style-type: none"> • National Greening Program (NGP) • Forestry Sector Project (FSP)
Upper Pulangi	<ul style="list-style-type: none"> • National Greening Program (NGP)
Malingon	<ul style="list-style-type: none"> • Mountain View College (MVC) Forest Reserve
Panlibatuhan	--
Taganibong	--
Nabalintungan	<ul style="list-style-type: none"> • National Greening Program (NGP)

Priority Indices based on the compound LULC and Anthropogenic Parameters

The mean compound values were computed from the LULC and anthropogenic parameters for the final prioritization of sub-watersheds (Table 4). Results show that the Sawaga watershed receives the highest priority with a 3.05 mean compound value. Due to its weak biophysical qualities, which are related to the combined effect of LULC and critical anthropogenic factors, it suggests a high vulnerability to deterioration. Higher percentage of cultivation and more harmful human activities was observed in Sawaga watershed, which is assumed to hasten erosion rates. Watershed under the highest priority would mean greater erosion, while the lowest priority would mean less erosion. Appropriate conservation measures are highly recommended for the sub-watersheds under higher priority for soil and water resources (Meshram and Sharma, 2017). Maapag sub watershed received the second rank with medium priority due to the large presence of grassland with lesser percentage of forest areas. Upper Pulangi, Taganibong and Malingun sub watersheds were also under medium priority. Upper Pulangi sub watershed was also exposed to human alterations while Taganibong sub watersheds had no existing

conservation and rehabilitation project. Malingun sub watershed has higher cultivation percentage (76.58%) with little forest areas (4.45%). Therefore, erosion control is necessary to stop the soil from degrading further (Eriksson and Kidanu, 2010; Hugo Durán Zuazo & Rocío Rodríguez Pleguezuelo, 2008; Zhang et al., 1996). On the other hand, the Manupali sub-watershed received the lowest priority and was observed to have good vegetation cover with different existing conservation and rehabilitation programs/projects. The GIS application tool generated a priority index map (Fig. 3) based on the final priority values.

Table 4. Priority indices of sub-watersheds

Sub watersheds	Compound for LULC	Compound for Anthropogenic	Mean Compound	Final Priority
Sawaga	4.60	1.50	3.05	H
Maapag	4.40	5.00	4.7	MP
Upper Pulangi	7.40	2.00	4.7	MP
Taganibong	3.00	6.50	4.75	MP
Malingun	3.80	6.00	4.9	MP
Panlibatuhan	3.00	7.17	5.09	LP
Tigwa	7.00	3.33	5.17	LP
Nabalintungan	5.40	6.33	5.87	LP
Manupali	6.00	7.17	6.59	VL

VH = Very high priority, H = High priority, M = Medium priority, L = Low priority and VL = Very low priority

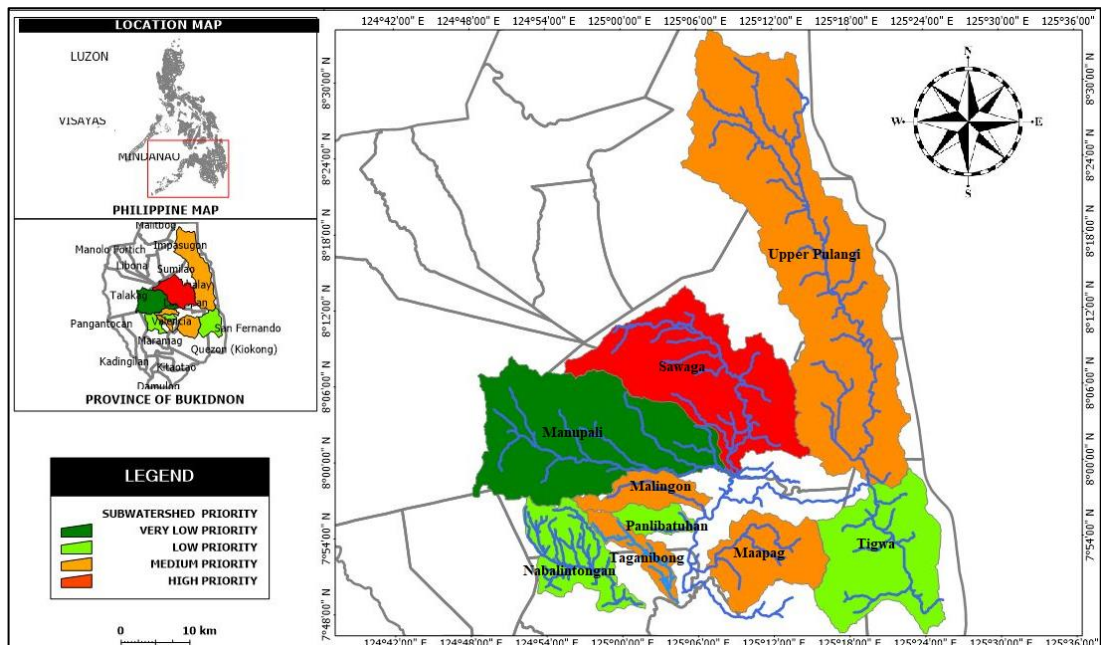


Figure 3. Priority Index Map

CONCLUSIONS

The study showed the prioritization of sub watersheds based on LULC change and anthropogenic analysis. It also demonstrated the used of available secondary data with the application of remote sensing and GIS in prioritizing sub watersheds for the conservation and sustainable development of our natural resources. Prioritization results based on LULC category shows that Taganibong and Panlibatuhan sub watersheds falls under very high priority. However, on the integration of anthropogenic parameters, Sawaga sub watershed appeared to have high priority while the others fall under medium, low, and very low priorities. The study offers important data that aids watershed managers and planners in making educated decisions and taking appropriate action about creating a strategy for watershed management, for programs to save soil and water, and for project implementation with minimum resources.

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