AES BIOFLUX
Advances in Environmental Sciences - International Journal of the Bioflux Society

Analysis of vegetation degradation using GIS and remote sensing at Lake Mainit watershed, Mindanao, Philippines

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Abstract. Lake Mainit is considerably the most important ecosystem in the Philippines given its diverse potentials for food and habitat requirements of various flora and fauna. However, degradation of habitats are occurring due to perpetuating human settlements and extensive unregulated activities. The immediate result is the changes in land uses and cover, which is manifested by diminishing vegatation cover in watersheds of Lake Mainit over time and space. This is the main objective of the study that used Geographic Information System (GIS) and Remote Sensing (RS). Results revealed that vegetation cover, as part of the watershed of the lake, is continually diminishing over 38 years of land utilization. This implied an urgent call of conservation and management of the concerned local government units and other stakeholders. This is to ensure its sustainability for the present and future generations.
Key Words: Lake Mainit, DEM, NDVI, watershed, LandSat.

Introduction. Covering an approximately 17,060 has, Lake Mainit is the fifth largest lake in the Philippines. The shores of the lake are being shared by the provinces of Surigao del Norte and Agusan del Norte which stretched an approximate total of 62.10 km (Lake Mainit Development Alliance – Environmental Management Plan 2014). Lake Mainit is flanked by mountain ranges at the north, east and west, with a broad aluvial plain at the south. The Malimono Ridge mountain range on the west separates the lake from Bohol Sea with an approximate elevation of 560 m (LMHGC ESIA 2013).

The forest cover of Lake Mainit has been fragmented and degraded into vast open grassland habitats, while some areas are converted into agricultural lands. Remaining forest cover in the watershed is currently threatened by various unregulated anthropogenic activities such as rural development, cryptic small-scale mining, and illegal logging of the remaining tree stands (Lake Mainit Development Alliance – Environmental Management Plan 2014). Lack of studies conducted for the watershed surrounding Lake Mainit is observed. Hence, this study was conducted to describe the extent of vegetation degradation expressed into digitized maps over a period of time in various municipalities traversed by the lake. The tools used are Geographic Information System (GIS) and Remote Sensing (RS) using archived LandSat vegetation imageries captured from different years.

Material and Method. Digital Elevelation Model (DEM) with a resolution of 30 m was used to get the 3 dimensional representation of the terrains's surface using GIS and RS. To determine the rivers in the DEM, an accumulation raster was created. This was attained by calculating the flow direction. An accumulation raster generated showed where the water flows. Each pixel contained a value that represents the number of pixels that accumulated by flow which then represent the river and stream locations. The results are further coverted from raster to polyline to obtain a better graphical

presentation. The same process was employed in delineating the vegetation cover within the watershed except for the "pour points" in which all pixels in a watershed accumulated. For vegetation cover, Normalized Difference Vegetation Index (NDVI) was employed. This index is an indicator which quantifies the amount of vegetation in a given area. Using Band Math in ENVI software, NDVI images were generated.

Results and Discussion. Lake Mainit watershed extended in the Provinces of Surigao del Norte from the north to Agusan del Norte going south. It covers nine (9) municipalities, two (2) of which, are in the province of Agusan del Norte. Among these municipalities, almost all of the land area of Tubod municipality is part of Lake Mainit watershed (Figure 1).

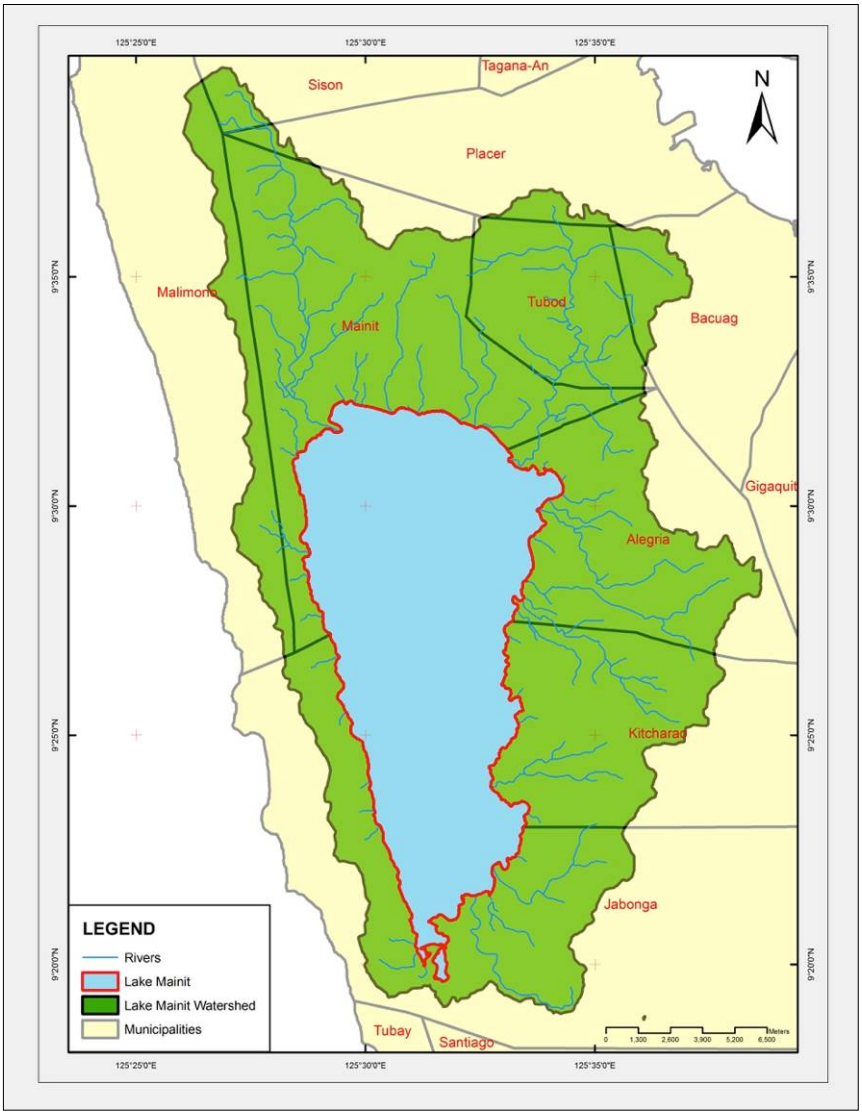

Figure 1. The municipalities of Surigao del Norte and Agusan del Norte that become parts of Lake Mainit watershed.

Lake Mainit watershed covers about 351.40 km^2 extending from the municipalities of Mainit and Tubod in the North; Alegria and Kitcharao in the east; Malimono in the west; and Jabonga in the south, which the water drains at Kalinawan River. Among these municipalities, about 29.11% or 102.30 km^2 of land area is under the jurisdiction of Mainit (Table 1). This is followed by Jabonga of about 17.84% or 62.70 km^2 and Alegria of about 15.82% or 55.60 km^2. Not far from Alegria is Kitcharao, which covers about 15.37% or 54.01 km^2. The Municipality of Sison covers about 1.2% of watershed which is about 3.39 km^2 (Lake Mainit Development Alliance 2014).

Table 1

Land area and coverage of each municipality with respect to Lake Mainit watershed

Municipality	*Province*	*Coverage (%)*	*Area (km^2)*
Jabonga	Agusan del Norte	17.84	62.70
Kitcharao	Agusan del Norte	15.37	54.01
Alegria	Surigao del Norte	15.82	55.60
Bacuag	Surigao del Norte	2.58	9.07
Mainit	Surigao del Norte	29.11	102.30
Malimono	Surigao del Norte	6.11	21.45
Placer	Surigao del Norte	1.49	5.23
Sison	Surigao del Norte	1.12	3.93
Tubod	Surigao del Norte	10.56	37.11
Total		100	351.40

NDVI showed that watershed vegetation cover of Lake Mainit has been decreasing for over 38 years of continuous utilization from 1976, 1996, 2002, and 2014. Although the extent and coverage of vegetation degradation were not thoroughly quanitified in this study, these areas are in the municipalities of Mainit, Alegria, and Jabonga. Some land portions in Kitcharao revealed the most non-vegetated areas, particularly near the lake shoreline. In Tubay to Malimono areas, it showed the minimal signs of disturbances yet as revealed by fully vegetated areas. It can also be observed that the non-vegetated areas are common to areas at lower elevations surrounding the lakeshores (Figure 2).

The identified watershed areas were subjected to various land conversions and degradation activities. The most prevalent cases were due to increasing inhabitants and settlements within the lake plains. Major land conversions were attributed to the growing developments undertaken by the two major provinces of Surigao del Norte and Agusan de Norte that bound Lake Mainit. These are prime areas used for development and industrialization. This could be due to their close proximity to CARAGA's most promising urban centers, namely, Surigao City and Butuan City. If left unchecked and unmanaged, the watershed economic and ecological functions, as exemplified by intact vegetation cover, could be impaired resulting to uncontrolled catastrophes and economic collapse. This is because, the watershed and vegetation in Lake Mainit are known sources of raw materials, energy, information and rich mineral deposits. In fact, some mining groups are already engaged in mineral exploration and extraction (ESSC 2007).

Majority of communities inhabiting the lake periphery depend on agriculture and fisheries as primary sources of livelihood. They unanimously affirmed that vegetation and watershed degradation are continuously happening. These created adverse impacts to their food and livelihood sources. The obvious manifestations are observed by a continuing decline of vegetation cover as attributed to intensive farming practices. This also affirmed the study at Nzioa River Drainage Basin that status on land use and land cover changes are due to intensification of agriculture practices (Twesigye et al 2011).

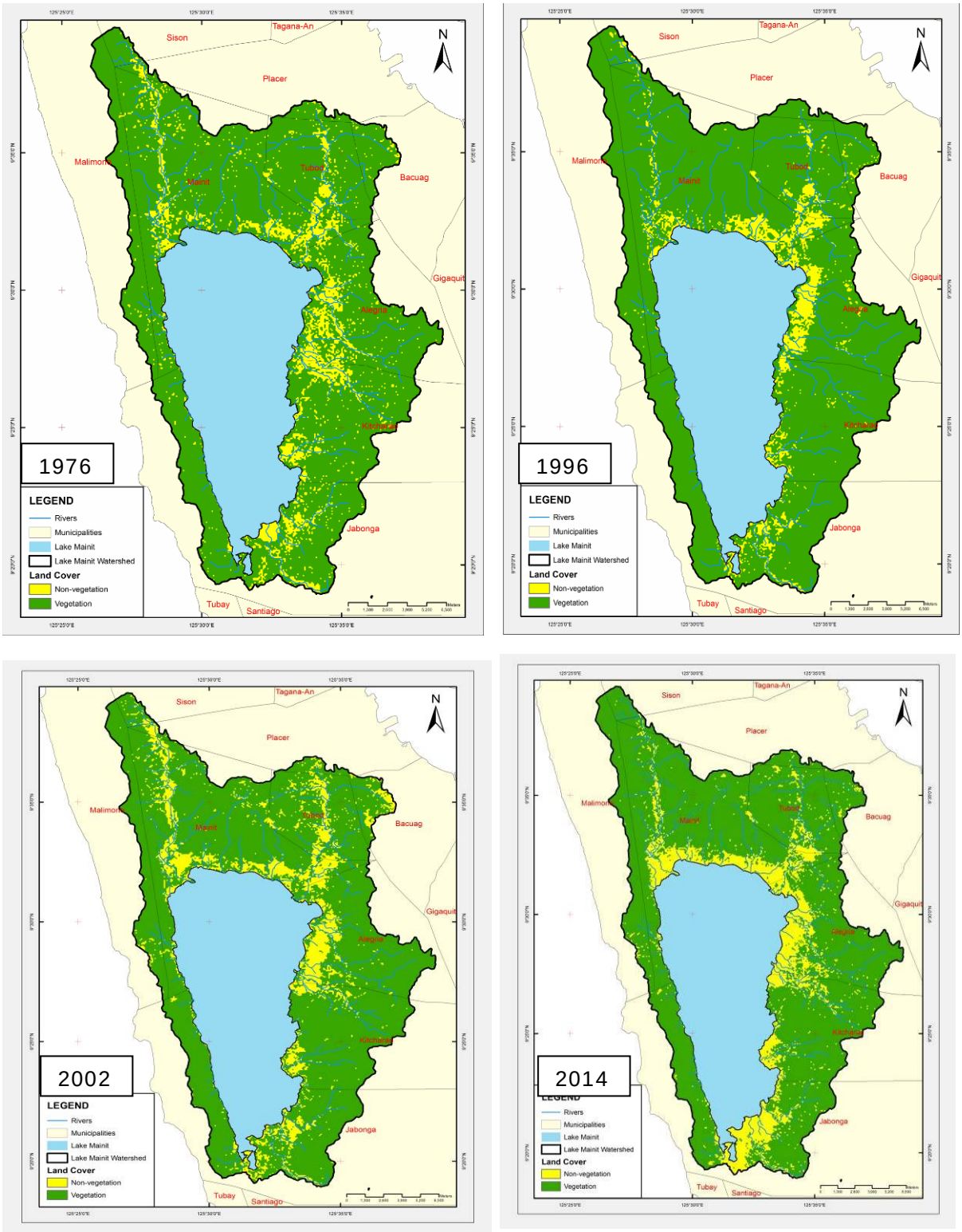

Figure 2. Degradation of vegetation cover in Lake Mainit watershed areas based on NDVI images from 1976, 1996, 2002, and 2014.

Conservation and management implications. Watershed conservation and management in Lake Mainit is challenged by regulating land use practices without compromising the provision of livelihood opportunities for the lake communities. Accurate delineation of a watershed plays an extremely important role in the management of watershed (Savant et al 2002). The delineated area would give data on the land usage, its changes over the years and the river flows in which appropriate management

initiatives could be drawn. GIS present the past and present state of watershed and landscapes to ensure optimal utilization of the available resources (Ma 2004; Tim & Mallavaram 2003). Also, watershed urbanization could modify characteristics of riparian ecosystems just like the study at Los Peñasquitos Creek in Coastal Southern California that stressed an increased urban land use in the watershed that resulted into significant increase in daily water discharges, dry season runoff, and flood magnitudes (White & Greer 2006). NDVI and GIS analyses suggested a scale approach in identifying areas to consider and focus on watershed resources in terms of management. A comparison data showed trends of land use practices over the years and would also arise urgent concerns needed for crafting appropriate management strategies.

Watershed management approaches had gained wider recognition across the country although many countries are already renowned in their water management approach technology using GIS. Furthermore, there are still many areas to consider on implementing and even improving successful watershed management programs. It requires certain level of financial capital, a community organization such as the Lake Mainit Development Alliance (LMDA) that should be equipped with enough intellectual and social capitals, and implementation of legal and institutional frameworks to support the watershed approach (ESSC 2007; Francisco & Rola 2004).

GIS technology such as the NDVI maps generated in this study is an integral component on advancing information, education, and communication (IEC) efforts by visualizing current status of forest and vegetation cover due to various extent of land uses. Landsat derived data such as NDVI provided widespread utility in forestry, agriculture, and watershed hydrology studies by establishing relationships on remotely based indices (Jackson et al 2004). The advanced IEC efforts would play a critical role in understanding the link between anthropogenic activites and watershed management. When the local community are made aware of the watersheds' role to their water supply and other natural resource services, it would provoke their interest and participation to watershed management activities.

Conclusions and Recommendations. GIS and RS had assessed the current diminishing vegetation cover of Lake Mainit watersheds over a period of 38 years of utilization. These areas covered the municipalities of Mainit, Alegria, and Jabonga, and in some land portions in Kitcharao. It also showed minimal signs of vegetation cover disturbance in Tubay to Malimono areas. The non-vegetated areas as a result of vegetation degradation were common at lower elevations surrounding the lakeshores. Further, it recorded land cover changes over time and space as a function of various anthropogenic perturbations.

Although not quantified in the study, but all concerned stakeholders have an estimate on how much extent and magnitude that vegetation cover degradation occurred for the past years, and on what predicted consequences it might create in the present and future generations. As such, this study might call some ground truthing activities by the local government units and other concerned stakeholders to validate information generated in these digitized maps. GIS and RS tools thereby enhanced vital information of topographical dilenation of watershed, streams and drainage systems, as well as in showing holistic picture of linking the upstream and downstream systems with timely and accurate information of spatial distribution of vegetation cover resources. It had generated useful environmental indicators like appropriate zones delienated for urgent actions of development and protection. This is a practical way of formulating efficient watershed management programs such as planning, preservation, conservation and even exploitation strategies. Further assessments relevant to this study are highly encouraged to arrive at proper and conclusive findings that need to be translated into proactive actions for conservation and management.

Acknowledgements. The authors are grateful for the support provided by the personnel of Jabonga municipality and LMDA for the relevant secondary data used in this study.

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Received: 30 April 2015. Accepted: 20 May 2015. Published online: 25 May 2015.
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How to cite this article:
Padilla R. F. Q., Crisologo E. S., Romarate II R. A., Vedra S. A., 2015 Analysis of vegetation degradation using GIS and remote sensing at Lake Mainit watershed, Mindanao, Philippines. AES Bioflux 7(3):409-414.