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Optimizing landscape value for man and nature: a case study of land-suitability mapping to conserve biodiversity in Lawaan, Eastern Samar, Philippines

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Abstract: We show how to identify "hotspot" biodiversity areas on which to base relevant policies and management options whenever traditional, community-based, resource management puts biodiversity conservation at risk, as is the case in Lawaan, Eastern Samar, Philippines. Digital spatial data integration revealed that the lower elevation areas are under the heaviest human pressure and also have the highest biodiversity. This calls for a set of procedures for engaging the full range of stakeholders to identify areas for preservation. Accordingly, we combined Social Based (SB) and Environmental Based (EB) maps to identify four different classifications and identify the locations of "very critical" and "critical" areas that need priority if biodiversity-conservation efforts are to be effective. We also report the results of deploying developed protocols that are designed to support regular updates, thereby accommodating stakeholder interests so that an environmentally-based, zone map can form a basis for consensus building and preservation-zone protection via community enforcement.

Key words: GIS, environmental zoning, optimizing, landscape value, biodiversity, conservation, ecological criteria, social criteria, land suitability mapping, local ecological governance, Lawaan.

1.0 Introduction

In many areas, nature is losing ground as various kinds of agro-ecosystems expand. Time series vegetation maps derived from image data are used, therefore, to document change in forest cover relative to non-forest ecosystems. Such land cover-change maps are more useful to resource managers if part of the mapping is derived from spatial data integration. That is, maps, remote-sensed data and geo-referenced ground data including their manipulation in a database system bring Geographical Information System (GIS)-based, natural-resource management into the information age.

Whereas GIS is usually used as a tool to serve either man or nature at one time or place, this study used GIS to serve both man and nature at the same time and place. Our method for doing this derives from the premise articulated during the United Nations Conference on Environment and Development (UNCED), or the Earth Summit, which was held in Rio de Janeiro, Brazil during1992, as well as its further elaboration in favor of biodiversity conservation and preservation at the signing of the Convention on Biological Diversity (CBD) in Nairobi, Kenya. The fundamental goal of this treaty is to support sustainable development by protecting and using biological resources in ways that do not diminish the world's variety of genes and species or destroy important habitats or ecosystems, and so biodiversity conservation has become an important concept in the thinking of government officials, conservationists, and even diplomats (Reid et. al., 1993).

Invoking both the 1992 Earth Summit and CBD in no way guarantees that biodiversity conservation will be better promoted. Take, for example, the Environmentally Critical Area Network (ECAN) of Palawan's use of GIS to save biodiversity. Palawan had its highest summits and their immediate surrounding slopes designated as strictly protected Core Zones, and these fragmented "cores" were surrounded by concentric rings of land use zones. For instance, the innermost ring was designated the "restricted forestry use zone", the next ring was called the "agro forestry buffer zone" and the outermost ring was labeled the "intensive agriculture land use zone". But such concentric zoning is unpopular with ecologists and naturalists because it is the lower elevation zones that have the higher biodiversity.

Aware that more biodiversity could be irreversibly lost through the core zone system, the present study forwards a participatory GIS-based protocol that maximizes the interconnectivity of habitats at all elevations to conserve, protect and preserve biodiversity (Turner et al., 1990 and Fry et al., 1992) while at the same time optimizing people's needs through the application of integrated science (ecology, economics, sociology, etc.) to meet food security and achieve the modest economic aspirations of stakeholders (Fry et al., 1992) around designated biodiversity conservation zones. Conflict should decrease because various interest groups, whether they value participation in the formulation of democratically-crafted policy and informed decision-making processes or not, will always engage in special pleading.

Clearly, protocols will have to be established, and stakeholders' capacity building has to be facilitated, and so local governance may come to uphold biodiversity conservation. This is now popularly termed *ecological governance*. It is a management regime that conserves biodiversity using local ecological and social criteria to authoritatively formulate strategies and policies that are issued and applied as an integral part of a covenant-building process. Note that a protocol developed from this experience can be used in other areas in the Philippines or elsewhere.

2.0 Review of related literature

The question "Where should land be forest and where it would be agriculture?" has been always contentious. Government policy in the Philippines has been slope-based - land greater 18 percent should be forest and shallower slopes should be agriculture (Revised Forestry Code, 1975). Moreover, the Bureau of Forestry recognized three categories of land - Public Land, Privately Owned Land and untitled land fit for agriculture (Alienable and Disposable Land (A and D)). It was not until later that other broad categories were recognized, such as National Parks, Forest Reserve, Wildlife Reserve, Proclaimed Watershed, Timberland, A & D and Private Land. Then, after the Earth Summit of 1992 the government enacted the NIPAS (National Integrated Protected Area System), which pooled the first four categories under one Protected Area (PA) category with the noble goal of preserving the country's biodiversity (Utting, 2000; DENR, 1990; Ong et al., 2002).

If the total land area of the Philippines is 30 million hectares, the value of natural terrestrial ecosystem for the Philippines should have had an initial value of P = 1. Land conversion by humans would then introduce a non-natural element (Q) for part of the total land area, hence P + Q = 1. Since, P is mutually exclusive to Q, any reduction of P is due to an increase in Q, i.e. P = 1 – Q. A time series reduction of P relative to increases in Q is represented by a declining value of the P/Q ratio, which is a convenient measure for describing deforestation. For example, in 1890 the forest cover of the Philippines was estimated at 17.4 million hectares and its P/Q ratio was 1.38. The series 1.38 (1890), 1.17 (1900), 1.27 (1934), 0.79 (1954), 0.69 (1964), 0.61 (1976), 0.32 (1980), 0.31 (1987), 0.25 (1990) and 0.24 (2000) shows a steady deforestation rate (Baguinon, 2007; Baguinon, 2008) and a century of forest fragmentation.

Moreover, the almost complete loss of lowland forest in the Philippines caused biodiversity loss that now can only be estimated from biogeography studies (Whitford, 1911; Merrill 1923-1926; Dickerson, 1928; Reckart, 1998; Heaney, 1993), and there is always the probability that species not yet discovered have already become extinct. While much biodiversity could be preserved by the PA endeavor, there is equal concern about conserving and preserving biodiversity in non-PA areas. These extend from coastal areas to the edges of remaining closed forests in rolling hills and mountain ranges, which often cut across watersheds (Dinerstein and Wikramanayake, 1993). Nevertheless, GIS can help estimate how much biodiversity has been lost and what can still be rescued.

2.1 GIS applications

Geographic Information Technologies (GIT) enable visualization of how the environment changes. Such changes then influence how people will view the physical resources base (Weiner et al., 1999; Rambaldi et al., 2002), and consensus building based on this can refer to land cover-change maps as well as methods for identifying biodiversity “hotspots”. For example, in the Cape Breton Highlands National Park, Canada, GIS was used to analyze the distribution of unique forest cover types that support rare flora and fauna, and a map depicting species richness was constructed so that centers of biodiversity could be identified (Colville et al., 1992). In addition, the Philippines’ first application of GIS technology was in late 1977 when the Forest Resources Inventory aimed to determine the country’s distribution of forest resources (Cabanayan, 1999).

However, socio-economic data is difficult to combine with other data layers, and this difficulty is further aggravated by the fact that answers to the very complex dilemmas of PA site management are usually colored by values, politics and environmental ethics instead of by science (Fry et al., 1992). Nevertheless, Godilano et al. (1999) claim that a GIS database lends itself to analysis that will enhance the credibility of an ecosystem approach to land use planning which uses digital data to provide a base level of information from which consistent land-use plans can be developed.

In recent years there has been a strong drive towards integrating GIS into community-centered initiatives, particularly to deal with spatial information-gathering, and decision-making. Researchers around the world have been working on different approaches known under a variety of abbreviations including, among others, PPGIS, P-GIS, CiGIS and MIGIS (Rambaldi, et al. 2002; Ball, 2002). All share the assumption that a system will place ordinary people in a position to generate and analyze geo-referenced spatial data and to integrate multiple realities and diverse forms of information. Rambaldi et al. (2002) rationalized this by providing a “bird’s eye view”, a relief model to widen stakeholders’ evaluative frames of reference on spatially defined issues like watersheds, linked ecosystems, tenure and access, thereby stimulating active learning and analysis. This would, in turn, enable broader public participation in environmental and public policy decision-making. Yet an essential prerequisite is current information about regional biodiversity.

2.2 Patterns of biodiversity in the Philippines

Coastal (mangrove and beach) vegetation on islands throughout southeast Asia, including Lawaan, East Samar, is practically the same, and at the back of beaches lowland dipterocarp forest intergrades with oak and mosses with increasing elevation (Whitford 1911). Also, at the summit of Mt Pulog is a 200-hectare, alpine formation dominated by grass and flora reminiscent of Himalayan highlands' flora. Closer scrutiny reveals differences in species composition from one island to the next due to the presence of endemic species. Whereas the highlands of Cordillera, Zambales and Mindoro have pine forests that are related to, or derived from Indochinese origins, shared dipterocarp species within Borneo are more like the biota of Sundaland. Many other species are shared between and among islands, some originating as far away as Australia via New Guinea, and these relationships are evidence that the islands have been directly or indirectly connected in the remote geologic past.

Recently, classification of vegetation in the Philippines has included transition type forests like mixed swamp and oak laurel forest (UPSEC, 1971) and ultramafic and ultrabasic forests have also been described (Ong et al., 2002). These different vegetation communities reflect the complexity of the environment across vertical and horizontal gradients, due to soil and climate, upon which living organisms have been superimposed. More varieties of habitats permit greater diversity of species and that mountain areas have greater species richness than flatlands because of their topographic diversity. But, Reckart (1993) claims that fruit bats are at their highest in diversity within lowland than highland forest. Looking from a broader scale, Whitmore (1990) maintains that many species are confined to only one or a few formations, suggesting that landscape habitat heterogeneity begets a richer variety of species. Consistent with this is the idea that the PA should include as many primary forests as possible and that they should have, together, the widest elevation range in a given faunal region (Heaney, 1993 and Reckart, 1993). All of these arguments are in the category of representatives of the PA (Poore, 1993; McNeely and Miller, 1984 cited in Reid et al., 1993) that provide maximum variation of species of economic importance.

This study is designed to facilitate representative preservation of habitat types along altitudinal gradients. It encourages, with the aid of GIS, the establishment of ecosystem corridor zones that cuts across landscapes or vegetation structures to cover all types of forest from the mossy down to the mangrove forest. In this way, all forest habitat/ecosystem types will be adequately represented - a basic presumption necessary for conserving the macro- and micro- genetic diversity therein. Through GIS, ecosystem corridors that connect representatives of different habitat types, at all elevation gradients, are developed.

2.3 Analytical frameworks and tools

The diverse characteristics of the decision-making situations associated with ecosystem and biodiversity management suggest that there is a need for a range of analytical decision frameworks (DAFs). A DAF is defined as a coherent set of concepts and procedures aimed at synthesizing available information from the relevant segments of an ecosystem management problem in order to help policy makers assess the consequences of various decision options. DAFs organize the relevant information in a suitable framework, apply decision criteria (based on some paradigms or theories), and identify the best options under the assumptions characterizing the analytical framework and the application at hand. It is important to note that none of the frameworks can incorporate the full complexity of decision making; and so they supply only part of the information shaping the outcome. And there are always hidden value judgments involved in the selection and application of DAFs anyway (Alcamo, et al. 2003).

Note that GIS produces representations of nature that highlight conventional forms of scientific spatial information, including data about the local environment. As a result, the politics of landscape and the social production of nature are frequently ignored, and so valuable local knowledge is marginalized (Weiner et al. 1999; Rambaldi, et. al. 2002). Also, developing countries do not have established procedures, and so ecosystem decisions appear to be more arbitrary.

The criteria considered important within any decision situation form different decision-making principles. For instance, the predominant criteria for a socially desirable or at least widely accepted decision outcome are rooted deeply in the historical traditions of managing the given ecosystem, in the prevailing social conditions (ranging from the values that local actors attach to ecosystem services to the existence and enforceability of property rights and government regulations), and in the economic conditions (level of development, distribution of incomes, and access to resources and social services). These principles can be used individually, or in combination to address specific ecosystem problems. As a result, a clear classification of methods and their application to real-world problems is sometimes difficult (Alcamo, et al. 2003).

The selection of DAFs to help craft socially just, acceptable and environmentally effective policies becomes a particularly delicate task (Alcamo, et al. 2003). Downs (2000) argues that cultural acceptability of any alternative practice is key, especially at the local scale of the village or indigenous population, so including this in the decision-making is important to achieve sustainability. There has also been increasing concern in recent years about integrating traditional values and knowledge into modern assessment and analytical decision frameworks (Goma et al., 2001; Paci et al., 2002). The latter's ultimate objective is to step beyond assessment and, by acknowledging the rights and environmental knowledge of indigenous communities, to make progress towards co-management of ecosystems (Faust et al., 2001; Alcamo, et al., 2003). That is, the context of the decision incorporates social and environmental dimensions. Although most decisions affecting ecosystems are private ones made by individuals as owners, operators, or users, such decisions are heavily influenced by the prevailing social norms, aspirations, existing rules and institutions (Alcamo, et al. 2003).

DAFs that may apply in this study includes descriptive DAFs that consider outcomes that may result from certain policies or actions, such as the concentric zoning policy (may result in possible extinction of lower areas of rich biodiversity); and deliberate DAFs that deal with the discovery of information from people and by people which may be derived from perception surveys.

3.0 Conceptual framework

Our framework is consistent with the need to integrate the environmental and social components, as advocated in the DAFs. That is, GIS technology is used to aid in assessing and analyzing land suitability and for managing biodiversity (Casas, 2006; Casas, 2008). In other words, zoning for biodiversity conservation is assumed to be a function of two major types of criteria – social and ecological, as explained in Figure 1. The landscape approach to zoning is used is such a way that the mosaic of different ecosystems/community types is identified, and possibly connected, in order to generate the desired ecosystems/biodiversity corridor zones. It integrates the chosen ecological and social criteria.

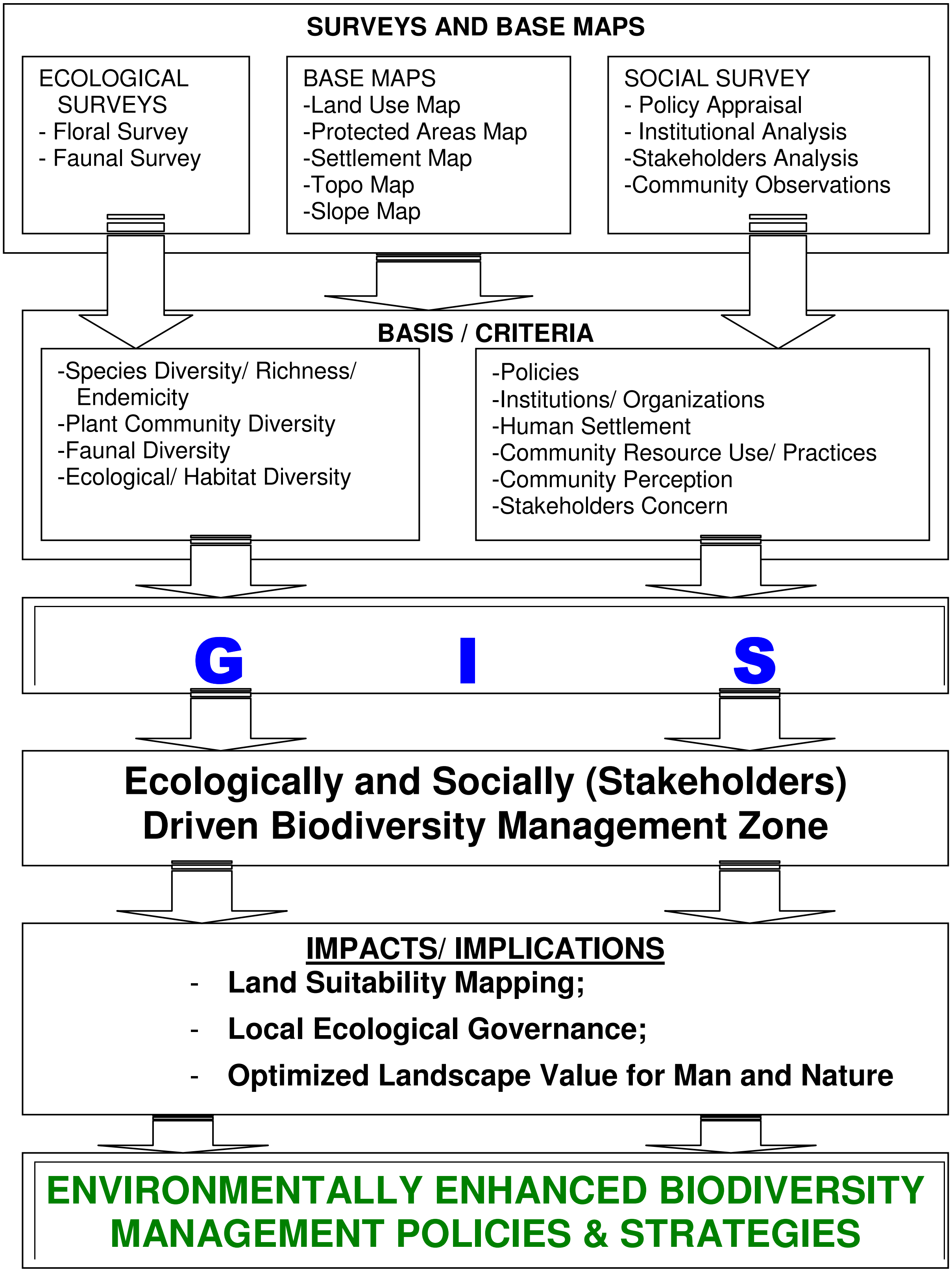

Figure 1 - A GIS-aided framework showing the relationships of variables and the expected outputs for biodiversity conservation in the municipality of Lawaan, Eastern Samar

Put differently:

Zoning = f (**Social Factors, Environmental Factors**)

where **Social Factors** are measured in terms of Policies, Institutions/Organizations, Human Settlement (population dynamics), Community Resource Use, Practices and Perceptions, and Stakeholders' Concerns

and **Environmental Factors** are bio-physical measures such as Species Diversity, Endemicity, Rarity, Vegetation Community Diversity, Ecosystem Habitat Diversity, Conservation Status, Slope and Elevation.

Shown in our framework is the relationship of different variables. Social and biophysical mapping provides the basis for GIS-based spatial analyses. Base map data were generated; integrated, digitized and evaluated using the identified social and ecological variables and criteria. The ecologically based and socially based maps then served as the spatial reference documents upon which subsequent analyses were based.

The overall outcomes take the form of geographically identified and located priority conservation areas, biodiversity corridor zones and a land use-suitability map that optimizes landscape value for man and nature simultaneously. Subsequently, appropriate conservation policies, management actions and strategies can be developed and prescribed.

4.0 Methodology

Our study used social and ecological criteria coupled with the application of the ARCVIEW GIS and for zoning/land use allocation that would enhance sustainable conservation of biodiversity. GPS applications determined geographic location readings on all of the attributes/criteria identified. The social aspect of the study involved perception surveys and the analysis of biodiversity policies and institutional mechanisms. Together, the social and ecological variables that were relevant for planning local biodiversity conservation strategy were integrated.

The GIS component of the study consists of three parts.

1) collection, evaluation and digitization of base maps to produce the needed thematic maps;
2) processing/overlaying of thematic maps and evaluation of results by integrating relevant biodiversity parameters, and
3) ecosystem / biodiversity corridor and hot spot/critical area identification, assessment and development of policies and management strategies/plans.

4.1 Location of the study

Samar is the third largest island in the Philippines. It has enough space for a diversity of habitats and it boasts highly productive Dipterocarp forests, mangrove resources and natural landmarks. Its rainforest is the habitat of the endangered Philippine eagle (*Pithecophaga jefferyii*) which enjoys protected status.

Lawaan is one of the twenty-three municipalities in Samar Island. It is located in the southwest part of the island (125°14'E-1255°14'E and 107°N-11°17'N) (Casas, 2008), and its forest reserve and watershed reservation comprise about 60% (10,735 ha) of the total land resources that are distributed across five *barangays* (districts), as shown in Figure 2. Its forest areas were classified as "open canopy with mature trees covering less than 50% of the area". The highest elevation within the site is 513 meters above sea level at the Round Peak.

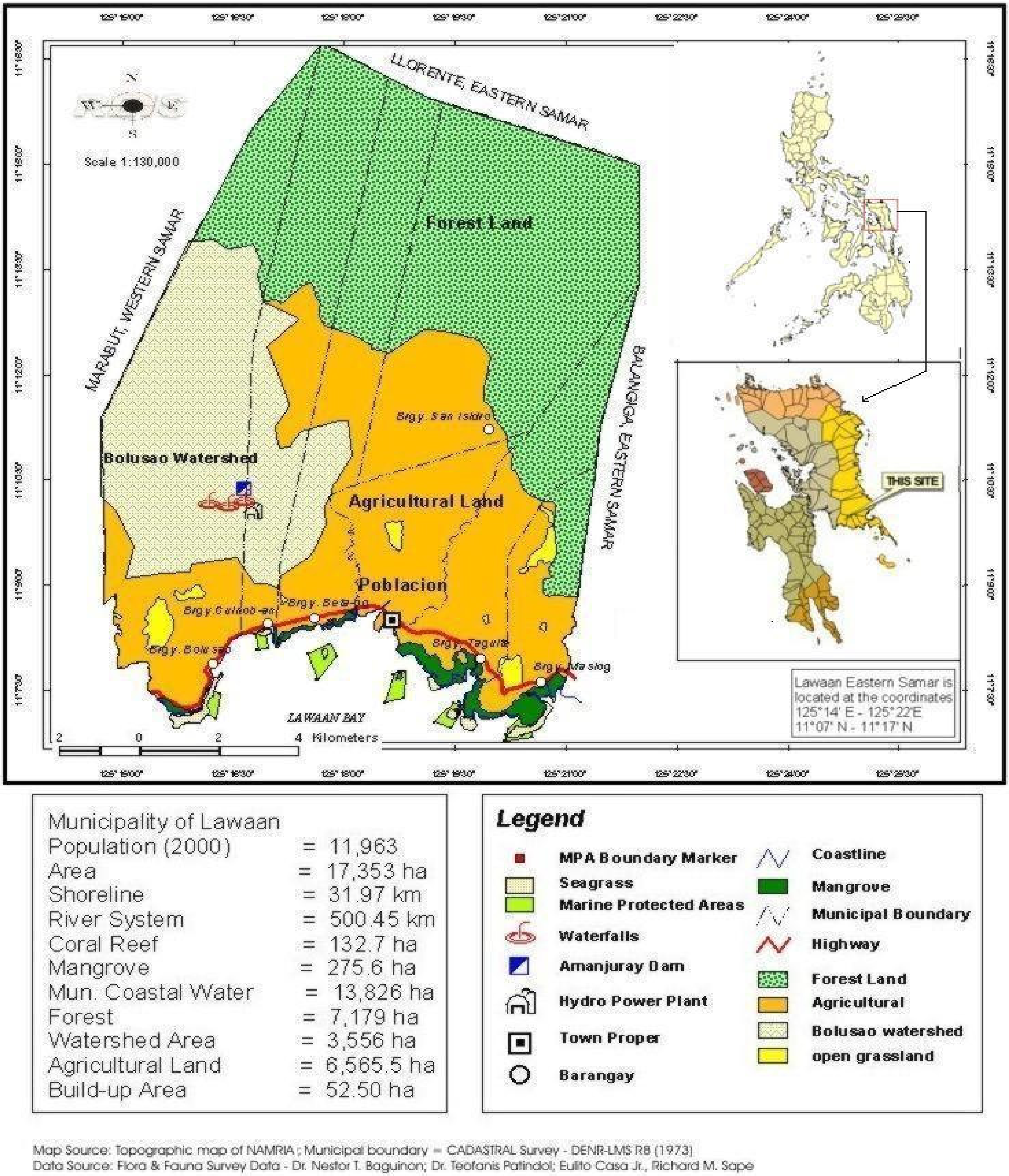

Fig. 2. Location and resource map of Lawaan, Eastern Samar, Philippines.

The presence of a watershed reserve that is ideal for ecotourism, and the biologically rich, but threatened, flora and fauna in its forest, constitute an ideal PA site for illustrating potential exploitation and contrasting/conflicting biodiversity conservation needs. Biologically rich flora and fauna, from ridge top to coastal/swamp areas, are under continuous threat from illegal gatherers/poachers, encroachment, cultivation and land-use conversion. Also, the presence of a Community Based Resources Management (CBRM) project within the site has created a level of environmental awareness within the community of stakeholders – a critical factor when zoning for both biodiversity conservation and sustainable use.

4.2 Unit of analysis

The unit of analysis for the study was the land area of Lawaan that covers the watershed reservation, the forest reserve and brushlands. Respondents were the PA/forest managers, people within dependent communities, and different stakeholder organizations. In addition, because the pursuit of their interests also affects land-cover change, analysis also included the roles of other regional and national bodies, the Samar Island Biodiversity Project (SIBP), and local groups.

4.3 Research design and data collection

To facilitate GIS mapping and analysis, ecological data (BI values) within different elevation ranges were gathered during the floral and faunal surveys. Data can be georeferenced (e.g. elevation range, slope range, river buffer width, etc.) and the different elevation-based classifications are: 0>100, 101>200, 201>300, 301>400, and ≥401 meters above sea level. Land use classification was guided by the prescribed management zones within the National Integrated Protected System (NIPAS: Republic Act 7586, 1992). The following maps were generated: Topography (Elevation and Slope Maps), Protected Areas Map, Settlement Map, Land Use Map, River Map and Watershed Map.

4.4 Stakeholder representation

The social survey was carried out between March and May, 2003 using personal interviews of 43 respondents from among three types of identified stakeholders - primary, secondary, and external organizations, and secondary data was also retrieved from various local and national offices.

Forest Edge Community (FEC) respondents were selected using a stratified random sample of participants at an environmental-awareness seminar and workshop, and so the views of the four upland barangays of Lawaan municipality were represented. Thirty (30) respondents qualified as forest dependents and so they were interviewed as primary stakeholders, with12 respondents being secondary and external stakeholders. Key informants, who provided additional qualitative data, were carefully chosen from among the responding stakeholders to truly represent their sentiments.

Representatives from selected stakeholders such as officers of GAs, SIBP, NGOs, POs and local key informants were gathered in an orientation and workshop for the focused group/round table discussions. This was necessary in order to clarify vague and conflicting data, resolve conflicting concerns and design management prescriptions and policies. A Delphi technique method was used to resolve conflicting interests until converged ideas and opinions were achieved. This process was necessary in order to attain a social consensus that redresses persistent issues within land-use allocation for biodiversity conservation.

4.5 GIS analysis

After the ecological and social data sets were assembled in the GIS, the overlay modeling capabilities of the system were employed. The GIS procedure is explained in the established protocol that developed from the actual process being followed, as shown in Figure 3.

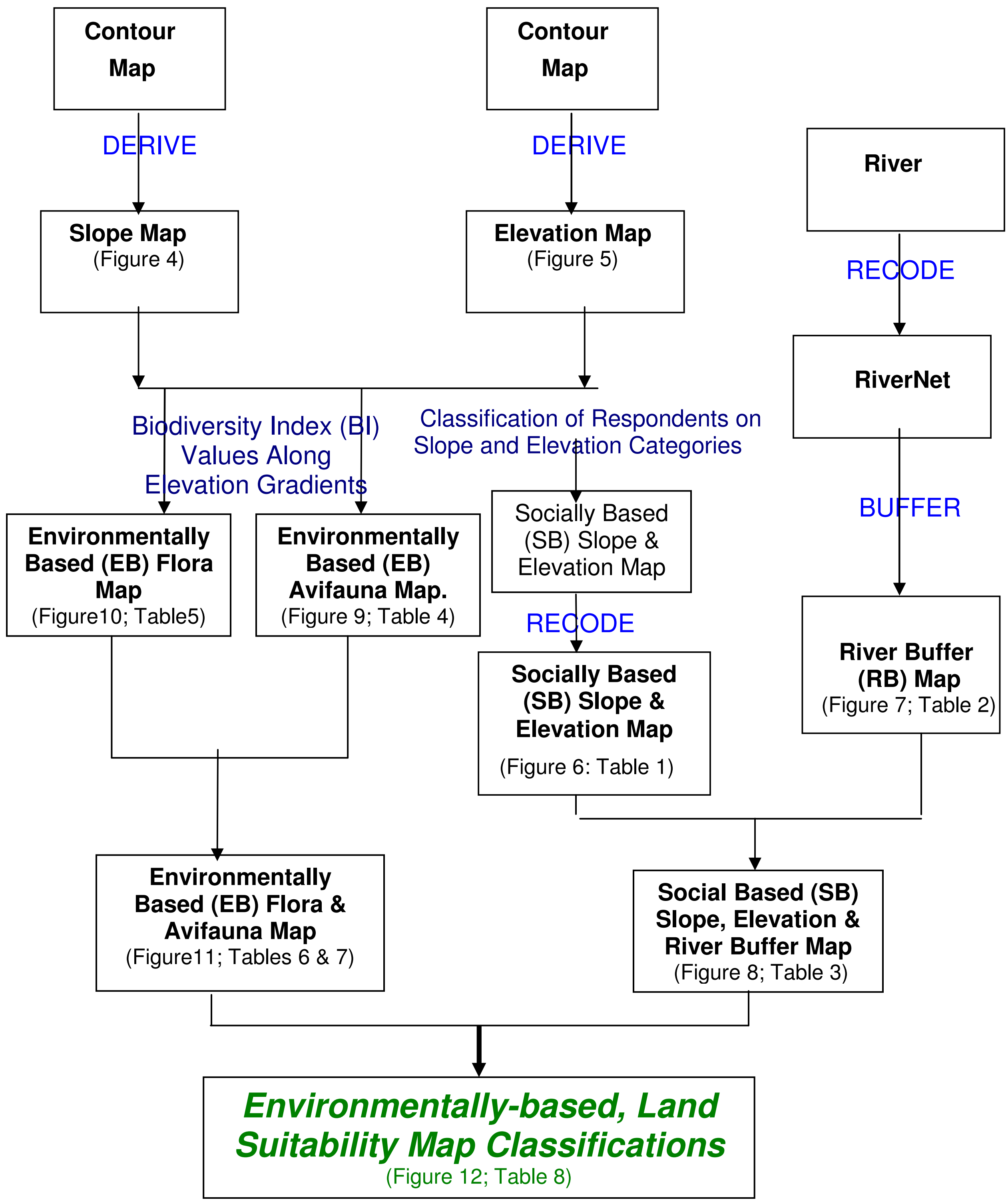

Figure 3 - Process path showing the detailed GIS steps in combining the social and ecological digital, spatial data. Maps and their corresponding attributes are described in the GIS overlay and analysis.

Recoding of the ecological and social data according to proximity established via overlay was guided by criteria consistent with the stakeholders' decisions that emerged from the application of the Delphi technique at local group discussions. The biodiversity corridor zones and hot spot/ critical areas were derived from application of *Spatial Analyst* in *ArcView*. Generation of the proposed biodiversity corridor zones was based on stakeholder perceptions derived from interviews. Overlaying combined the identified ecological and social criteria to achieve a single composite basis for a decision that conformed with the objective of biodiversity conservation.

5.0 Results and discussion

5.1 Established GIS mapping protocol

The protocol developed in this study framed and guided the following methodology:

1. *Gathering of reliable maps, aerial photographs and satellite data of the study site* - from authorized and reliable sources
2. *Referencing and digitization of the various maps* - allowing generation of a consistent format necessary for spatial analysis
3. *Plotting of socially based criteria onto the map* – for example, stakeholders' perceptions onto elevation, slope and river buffer/riparian zone classifications
4. *Selecting ecological criteria and assigning weights* - to come up with desired outcomes based on the zoning decision criteria. The BI values should be ranked form highest to lowest and used to derive weights which, in turn, are input to corresponding classifications for data overlay analysis
5. *Choosing decision criteria for matching ecological and social data* - to guide the classification of attributes in the overlay results and to generate prioritization of conservation sites as affected by the combination of both ecologically and socially based data
6. *Validating and ground-truthing in the field* - to verify the applicability of the prescribed classification criteria.

5.2 GIS overlay and analysis

To facilitate the overlaying analysis, all data were converted from vector to raster format. The pixel size available at the time of the analysis was 92m x 92m. This pixel size was derived from free elevation data supplied by the National Aeronautics and Space Administration, Shuttle Radar Topography Mission ((NASA- SRTM). The GIS mapping procedure that was followed is shown in Figure 3, and the maps generated from the analysis are briefly described below.

5.2.1 Contour map

This map was sourced from NAMRIA and it was digitized to indicate the contour lines of the study site. The slope map and elevation maps were derived from this data. However, in this study the researchers endeavored to link resources with users within a participatory, community-based approach informed by results of a perception survey conducted amongst stakeholders. This showed how resource users / stakeholders would allocate resources to conserve biodiversity. That is, a social-based map was drawn of stakeholders' perceptions - an overlay of the elevation, slope and river buffer map classifications as perceived by the stakeholders.

5.2.2 Social-based slope map

This map (Figure 4) represents the three classifications of slope ranges as provided by the respondents/stakeholders during the interview. The slope ranges and their classifications are: 0 – 18% = Agriculture / Sustainable Use; 18 – 50% = Sustainable Use/ Restoration; and above 50% = Restoration/ Strict Protection.

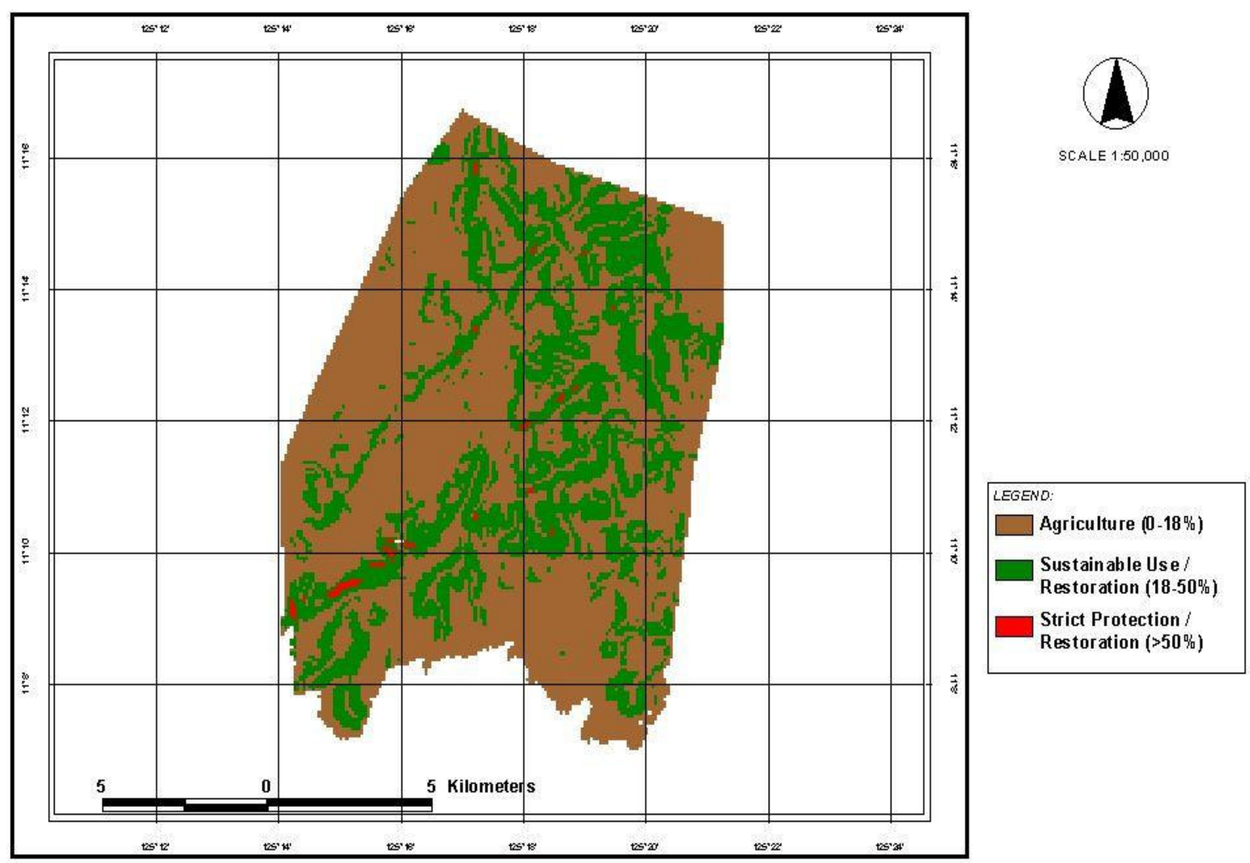

Fig. 4. Land Use Classification of Slope Map as Perceived by the Respondents of Lawaan, E. Samar

5.2.3 Social-based elevation map

This map (Figure 5) outlines the different elevation ranges, in meters above sea level, with their corresponding stakeholders' classifications. These are: 0 – 150 = Agriculture; 150 – 250 = Agriculture / Sustainable Use; 250 – 350 = Sustainable Use / Restoration; 350 – 450 = Restoration / Multiple Use; Above 450 = Habitat Management / Strict Protection.

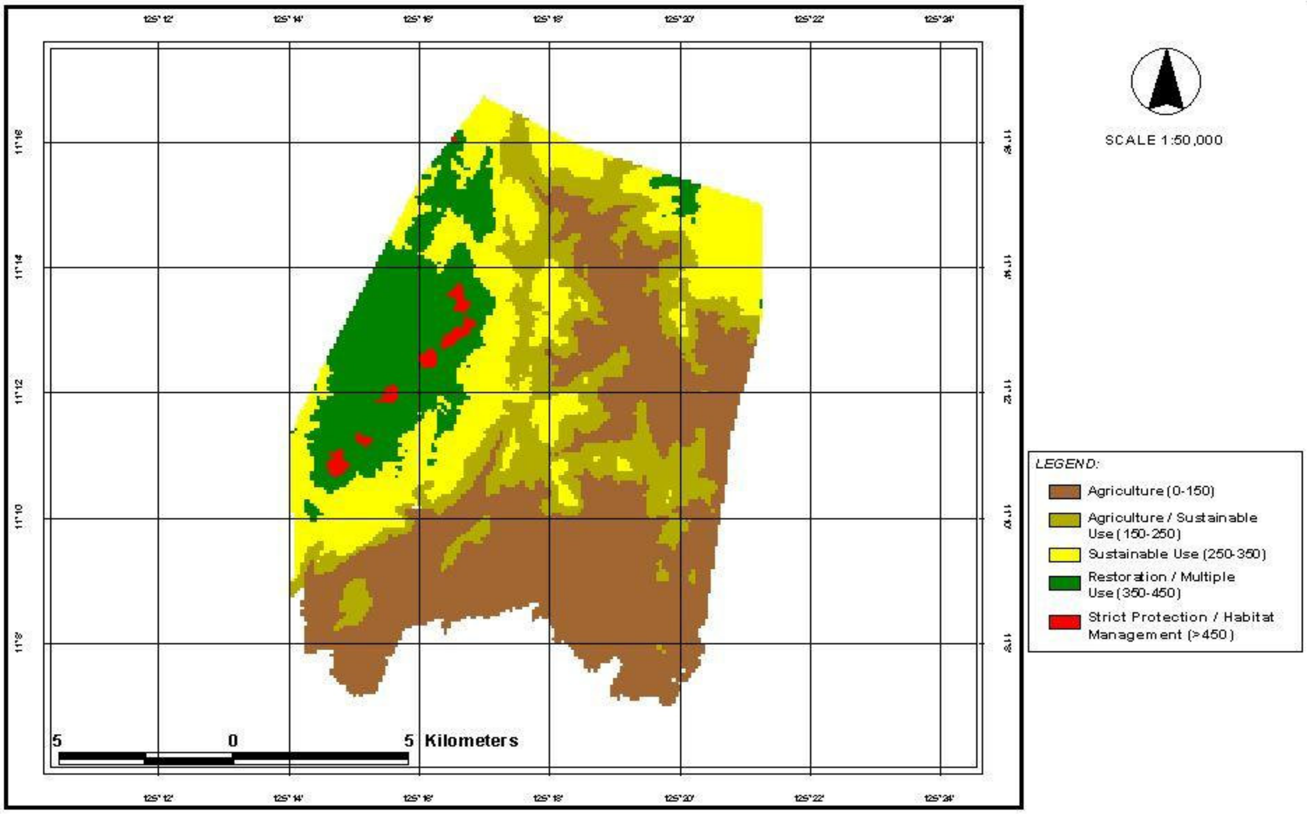

Fig. 5. Land Use Map Classification of Elevation Categories as Perceived by the Stakeholders

5.2.4 SB E/S map and SB E/S recode map

This map (Figure 6) represents the overlay of the Slope Map by the Elevation Map. In overlaying, Slope Map classifications were coded 1, 2 and 3 while the elevation ranges were coded 100, 200, 300, 400 and 500. This produced 15 combinations that were recoded with the consent of the stakeholders, using the following policy criteria:

- all areas with slope range above 50% are classified as either Restoration or Strict Protection Zone,
- no farming is allowed above 350 meters above sea level, and
- all areas with an elevation range more than 450meters above sea level and above 50% slope are classified as a Strict Protection Zone.

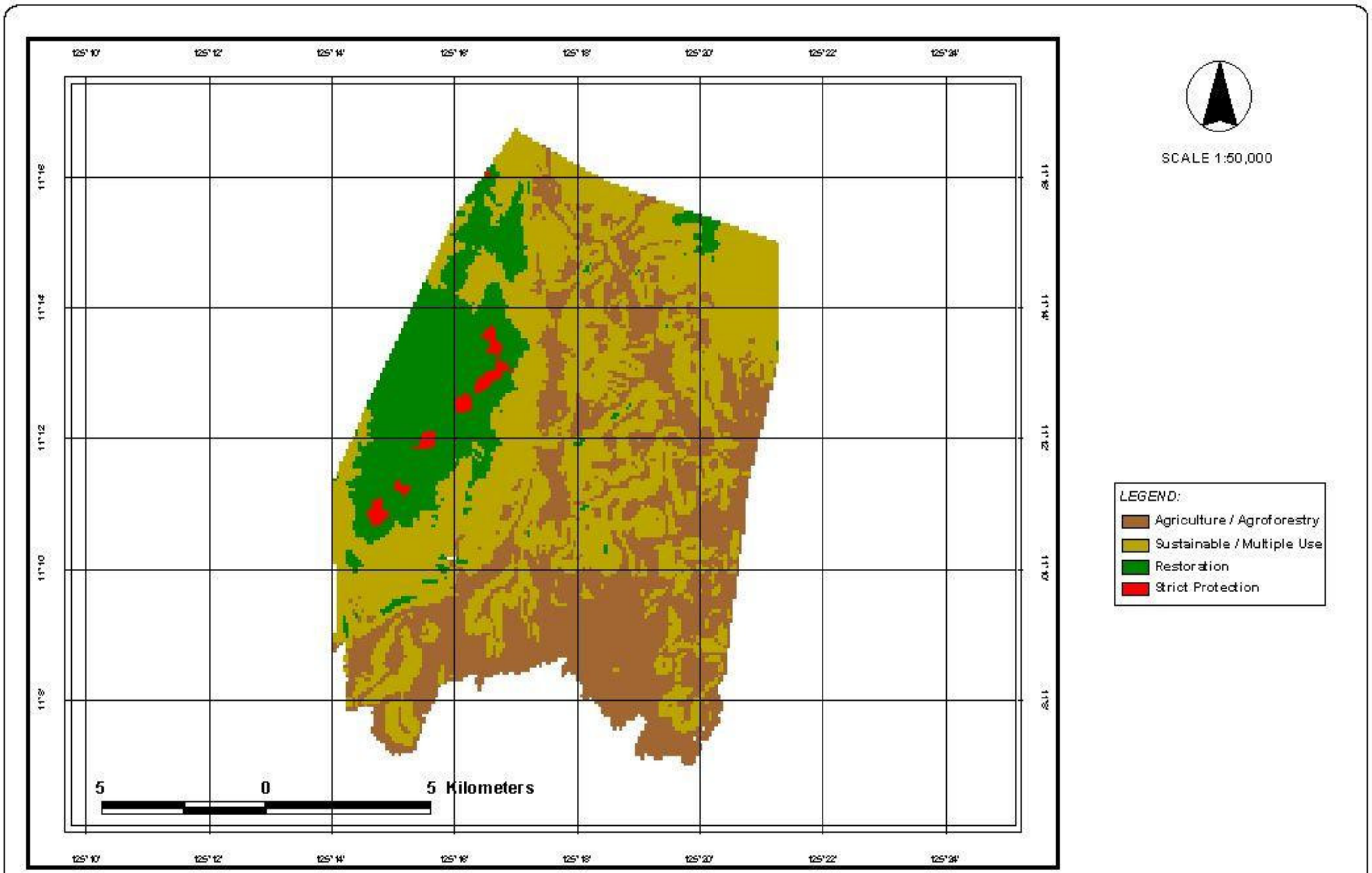

Fig. 6. Recoded Land Use Map Classification of Slope and Elevation Categories as Generated by the Respondents.

Table 1 shows the attributes of the four classifications derived from the combination of slope and elevation maps. Note that Agriculture/Agroforestry activities are confined to 250 meters and below with a maximum slope of 18%. Regardless of elevation, all areas above 18% in slope are classified as non-agricultural. A slope range of 18-50% at 0 – 250 meters is classified as Sustainable/Multiple Use, and the same classification is given on areas with slope of 0 – 18% but located at 350 – 450 meters above sea level. Areas with slope 50% and above, located at 0 – 350 meters are classified as Restoration sites, and a similar classification is assigned on areas with 18 – 50% at 350 – 450 meters above sea level. Lastly, all areas 50 % and above at 350 – 450 meters, and from 18 % and above at 450 meters and above, are designated as Strict Protection Zone.

VALUE	**CLASSIFICATION**	**ELEVATION RANGE** (meters above sea level)	**SLOPE RANGE** (percent)	**PIXEL COUNT**	**AREA** (hectares)
1	Agriculture/Agro-forestry	0 – 250	0 - 18	7061	5,976.4
2	Sustainable/ Multiple Use	0 – 250 350 – 450	18 – 50 0 - 18	9486	8,029.0
3	Restoration	0 – 350 350 – 450	50 & above 18 -50	3233	2,736.4
4	Strict Protection	350 - 450 450 & above	50 & above 18- 50 & above	186	157.4
	Total				**16,899.20**

Table I - Attributes of socially-based slope and elevation map classification value as perceived by the stakeholders/respondents of Lawaan, Eastern Samar, Philippines

5.2.5 River map

The RiverNet was derived from the River Map by assigning value of "1" to rivers and value of "0" to non-river areas. Yet apparently, a biodiversity corridor that can be established is the riparian/ river buffer, and all three groups of stakeholders supported this ecological criterion during the interviews. It is imperative, therefore, to establish and protect riparian buffer zones along streams if sustainable environmental management and ecosystem security is to be achieved, including improved channel stability and water supply, environmental sustainability and biodiversity.

5.2.6 SB river buffer/riparian map

This map (Figure 7) was generated by buffering rivernet by 50 meters on both sides. The 50-meter value is consistent with the majority of the respondents' suggestions for the river buffer's width. A total of 1,845.54 hectares is derived from river buffers, within four land use-classification zones. This map was then overlaid with the SB Map.

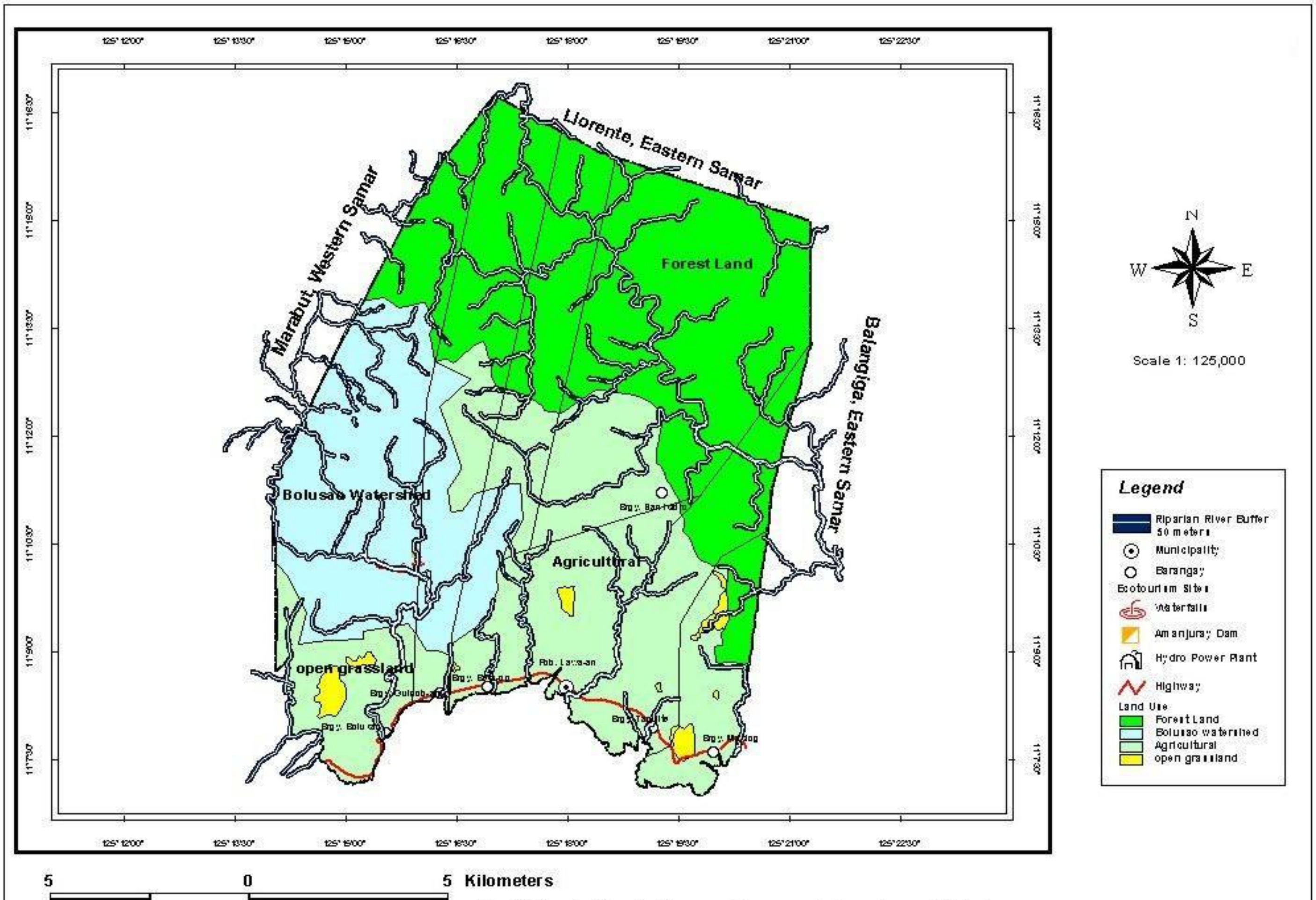

Fig. 7. Riparian/River buffer map of Lawaan, Eastern Samar, Philippines

The river buffer value in each classification is shown in Table 2. It indicates that the total area of the riparian/river buffer zone comprises 1,848.51 hectares or 11% of the total land area. This will be protected by means of an ordinance to extend the riparian/ river buffer zone from the highest elevation to the seashores - an “all elevation riparian area”

VALUE	DESCRIPTION	PIXEL COUNT	AREA (hectares)
1	RB in Agriculture/Agro-forestry	882	746.50
2	RB in Sustainable/ Multiple Use	989	837.09
3	RB in Restoration	309	261.54
4	RB in Strict Protection	4	3..38
	Total		**1,848.51**

Table 2 - Attributes of riparian/ river buffer map classification value as perceived by the respondents

5.2.7 Socially-based (SB) map

This map (Figure 8) was produced by overlaying the SB SE Map and the River Buffer (RB) map. The first two combined classifications suggested that areas within the given specifications (slope: 0 – 18%; and elevation: 0 – 250 meters above sea level) are applied to two different cases. The agriculture classification applies to alienable and disposable lands while agro forestry applies to areas that are found within the watershed and forest reserves. Similarly, the multiple-use classification applies to A & D, while sustainable use applies yo watershed and forest reserves.

Regardless of elevation, all areas above 18% in slope are classified either as Sustainable/ Multiple Use, Restoration or Strict Protection Zones. Slope ranges of 18 – 50 % at 0 – 250 meters and 0 – 18 % located at 350 – 450 meters are classified as suitable for Sustainable/Multiple Use. Areas with slope of 50 % and above and located at 0 – 350 meters, and 18 – 50 % at 350 – 450 meters are classified as Restoration sites. Furthermore, all areas 50 % and above at 350 – 450 meters, and from 18 and above at 450 meters and above are designated as Strict Protection.

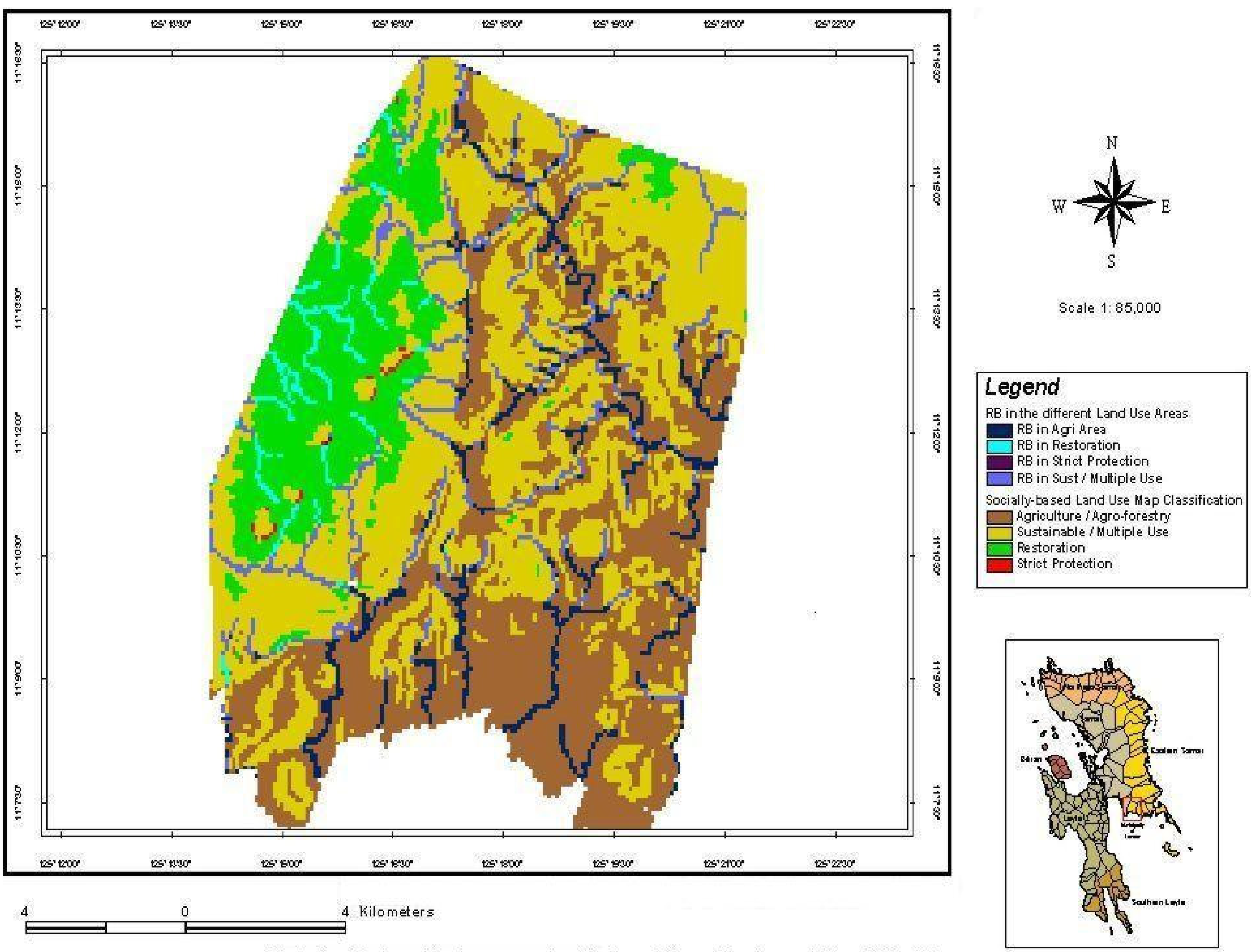

Fig.8. Socially-based land use map classification of Slope, Elevation and River Buffer (RB).

Note from Table 3 that in terms of area distribution, 34.75 % is allocated for "land for man", 47.79 % is allocated for "man and nature" combined, and 16.44 % is allocated for nature-restoration, protected zones. In a sense, the sustainable and multiple use classifications should serve as the buffer to the protected zone, and this could provide a social fence that would prevent access by resource users, thereby preserving land for nature.

CLASSIFICATION	SOCIAL BASED SE (hectares) (A)	PIXEL COUNTS	RIVER BUFFER (hectares) (B)	BALANCE (A - B)	PERCENT DISTRIBUTION
Agriculture/Agro-forestry*	5,976.40	882	746.50	5,229.90	34.75
Sustainable/Multiple Use**	8,029.00	989	837.09	7,191.91	47.79
Restoration	2,736.40	309	261.54	2,474.86	16.44
Strict Protection	157.40	4	3.39	154.01	1.02
Total	**16,899.20**	**2184**	**1,848.51**	**15,050.68**	**100**

Table 3 - Attributes of socially based elevation, slope and river buffer map classification values as perceived by the respondents/ stakeholders

Note: * Agriculture Classification applied on A & D lands with Slope range (0 – 18 %) & elevation range of 0 – 250 meters above sea level.
* Agro forestry farming on the Watershed and Forest Reserve (same specifications).
** Multiple Use on A & D lands where settlements are allowed
** Sustainable Use on Watershed / Forest Reserve (e.g. ecotourism) no clearing or farming.

5.2.8 Avifaunal diversity map Classification

Biodiversity indices were computed at different elevation ranges, ranking from the highest to the lowest values, and plotted on a map. That is, Figure 9 was derived from the avifaunal BI values and ranked from the highest to the lowest.

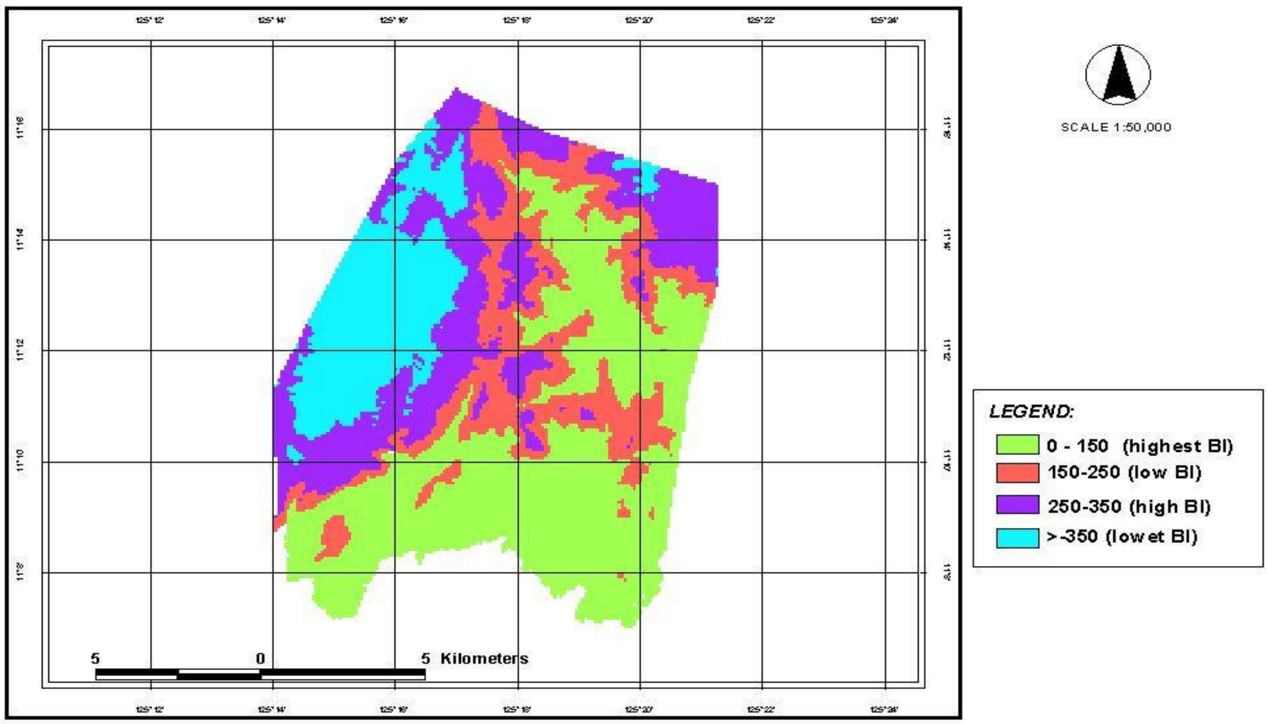

Fig. 9. Ecologically Based Avifaunal Map Classification

The ranking indicates the following levels of BI, namely, 0-150 meters (highest BI), 250-350 meters (high BI), 150-250 meters (low BI), and above 350 meters (lowest BI), as shown in Table 4.

STUDY SITE	**ELEVATION RANGES** (meters above sea level)	**TOTAL NUMBER OF SPECIES**	**TOTAL NUMBER OF INDIVIDUALS**	**SPECIES RICHNESS** (mean)	**SPECIES DIVERSITY** (mean)	**SPECIES DIVERSITY RANK**
1	0 – 150	23	223	1.54	2.41	1st-highest
2	150 – 250	16	125	1.43	2.06	3rd –low
3	250 – 350	31	382	1.58	2.21	2nd – high
4	Above 350	20	156	1.61	2.02	4th-lowest
Total		**41**	**886**	**1.54**	**2.18**	

Table 4 - Avifaunal biodiversity index ranking at different elevation ranges of the four study sites in Lawaan, Eastern Samar, Philippines

5.2.9 Floral diversity map classification

This is derived from the Floral BI values and also ranked in descending order as follows: 250-350 meters (highest BI), 0-150 meters (high BI), 350-450 meters (median BI), above 450 meters (low BI), and 150-250 meters (lowest BI), as shown in Figure 10.

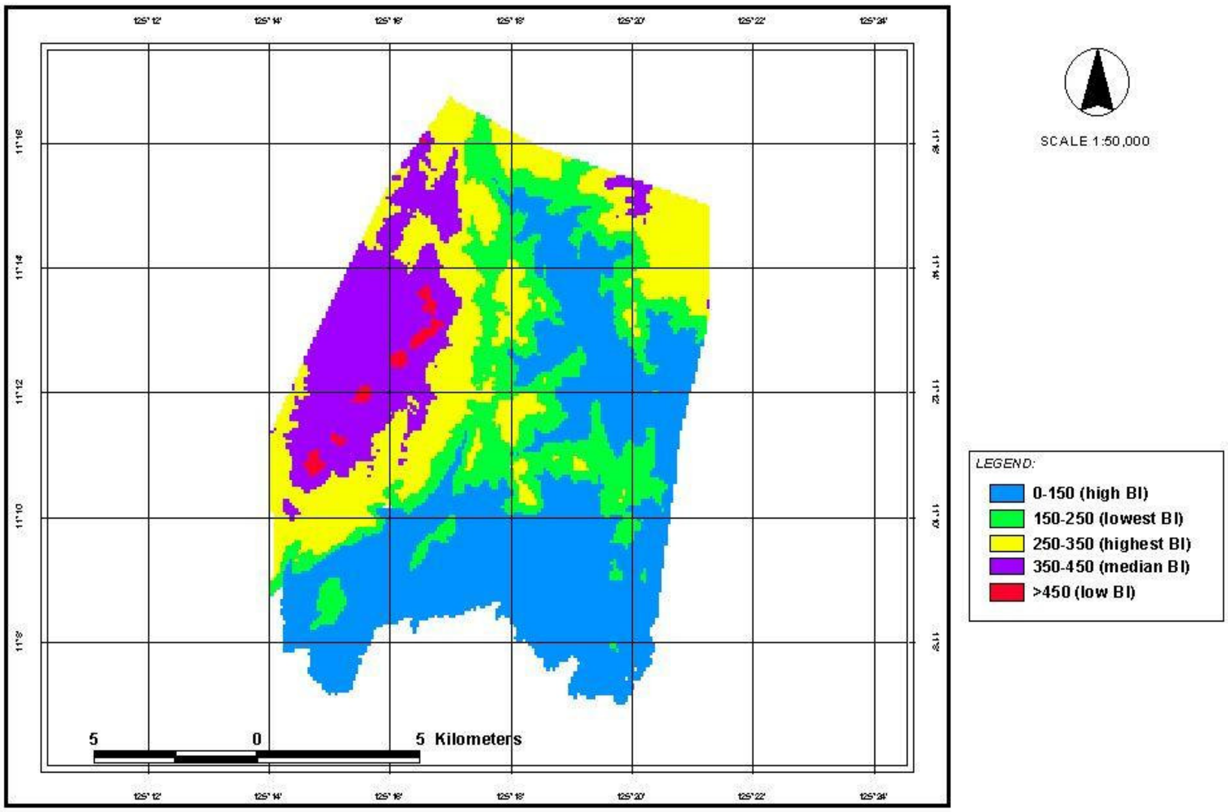

Fig. 10. Ecologically Based Floral Map Classification

In terms of rank, elevation range 250-350 meters indicated the highest BI while the lowest BI is found at elevation range of 150-250 meters, as set out in Table 5.

ELEVATION RANGES (meters above sea level)	**PLOT NUMBERS**	**TOTAL NUMBER OF TREES**	**SPECIES DIVERSITY** (mean)	**SPECIES DIVERSITY RANK**
0 – 150	25,25,27,28 & 29	127	2.4664	2nd – high
150 – 250	30 & 31 (heavily disturbed habitat)	42	1.4811	5th - lowest
250 – 350	1,2,3,4,5,6 & 24	233	2.7655	1st – highest
350 – 450	7,,,8,9,10,11,12,16, 17,20,21,22 & 23	304	2.4441	3rd –median
Above 450	13,14,15,18 & 19	162	2.3192	4th – low

Table 5 - Floral biodiversity index ranking at different elevation ranges.

5.2.10 Ecological-based map classification

This is the overlay of the Avifaunal and Floral BI maps (Figure 11). In overlaying, the BI values were assigned numerical weights based on their respective ranks.

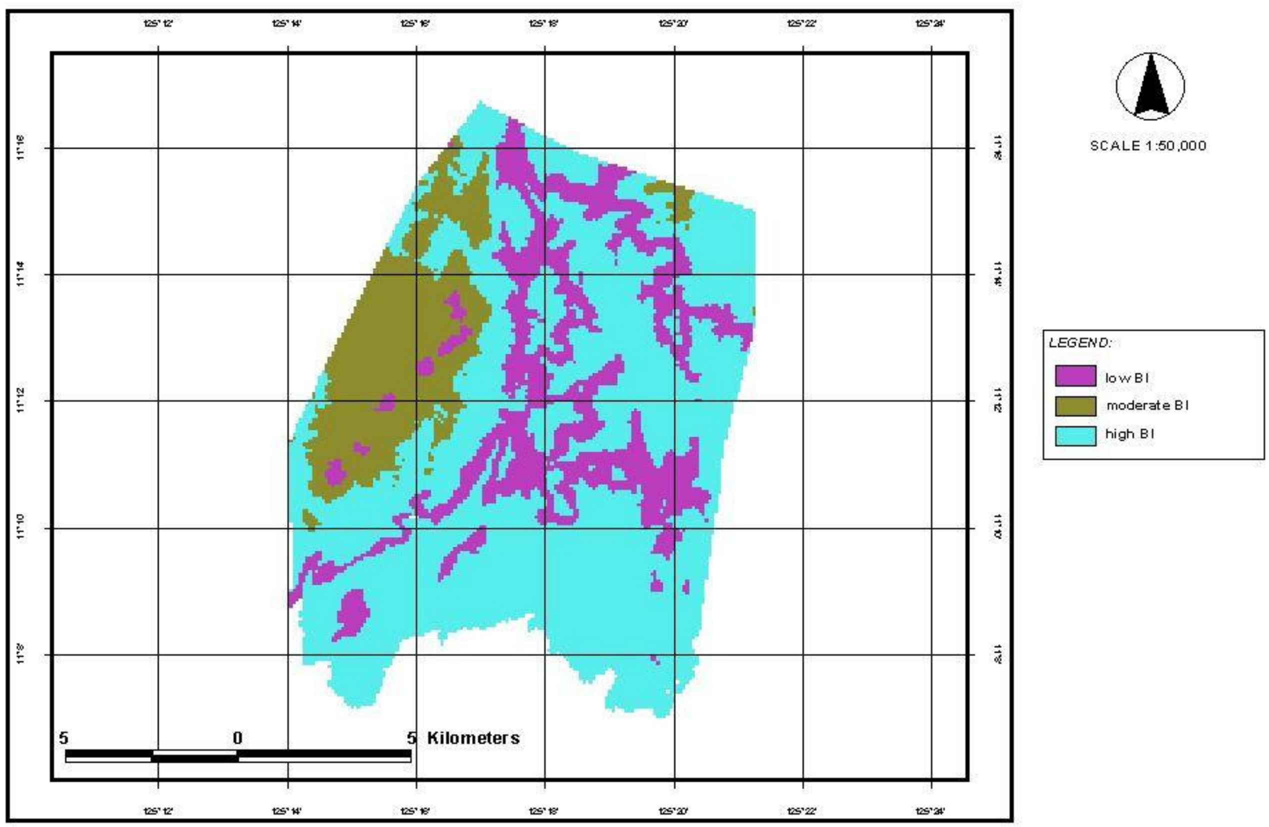

Fig. 11. Ecologically Based Avifaunal and Floral Map Classification

The highest combined value of avifaunal and floral BI is equivalent to 8 in both elevation ranges of 0-150 meters and 250-350 meters, while the lowest is 2 at 450 meters and above (Table 6).

ELEVATION RANGES (meters above sea level)	**AVIFAUNAL BI RANK**	**FLORAL BI RANK**	**TOTAL VALUE**
0 – 150	4 (highest)	4 (high)	8
150 – 250	2 (low)	1 (lowest)	3
250 – 350	3 (high)	5 (highest)	8
350 – 450	1 (lowest)	3 (median)	4
Above 450	-	2 (low)	2

Table 6 - Combined weights of avifaunal and floral biodiversity index (BI) values along different elevation ranges.

Hence 3 different ranks – 3, 4, and 8, were derived from the above table, and corresponding BI ranks are shown in Table 7. The highest BI had an area of 10,718 hectares, while the lowest covered 3,521 hectares.

VALUE	**BI RANK**	**PIXEL COUNT**	**AREA (HAS)**
3	Low BI	4,160	3,521
4	Moderate BI	3,143	2,660.2
8	High BI	12,663	10,718
Total			**16,899.20**

Table 7 - Attributes of the ecological (avifaunal and floral) based map classification

5.2.11 Environmental-based zoning map

This map (Figure 12) is the product of data integration via a SB Map and EB Map overlay. In overlaying, the SB map classifications were coded 1, 2, 3 and 4, while the EB map classifications were coded 3 (low BI), 4 (moderate BI) and 8 (high BI). This generated 12 combinations which were recoded using the following criteria:

Very Critical: Areas with high BI but classified as Agriculture/ Agro forestry.

Critical: Areas with low BI classified as Agriculture, with moderate BI classified as Agriculture and Sustainable/Multiple Use and with high BI classified as Sustainable/Multiple Use.

Less Critical: Areas with low BI classified as Sustainable/Multiple Use and Restoration, with moderate BI and with high BI classified as Restoration Zone.

None Critical: All areas classified by the respondents/stakeholders as Strict Protection Zone at three levels of BI values.

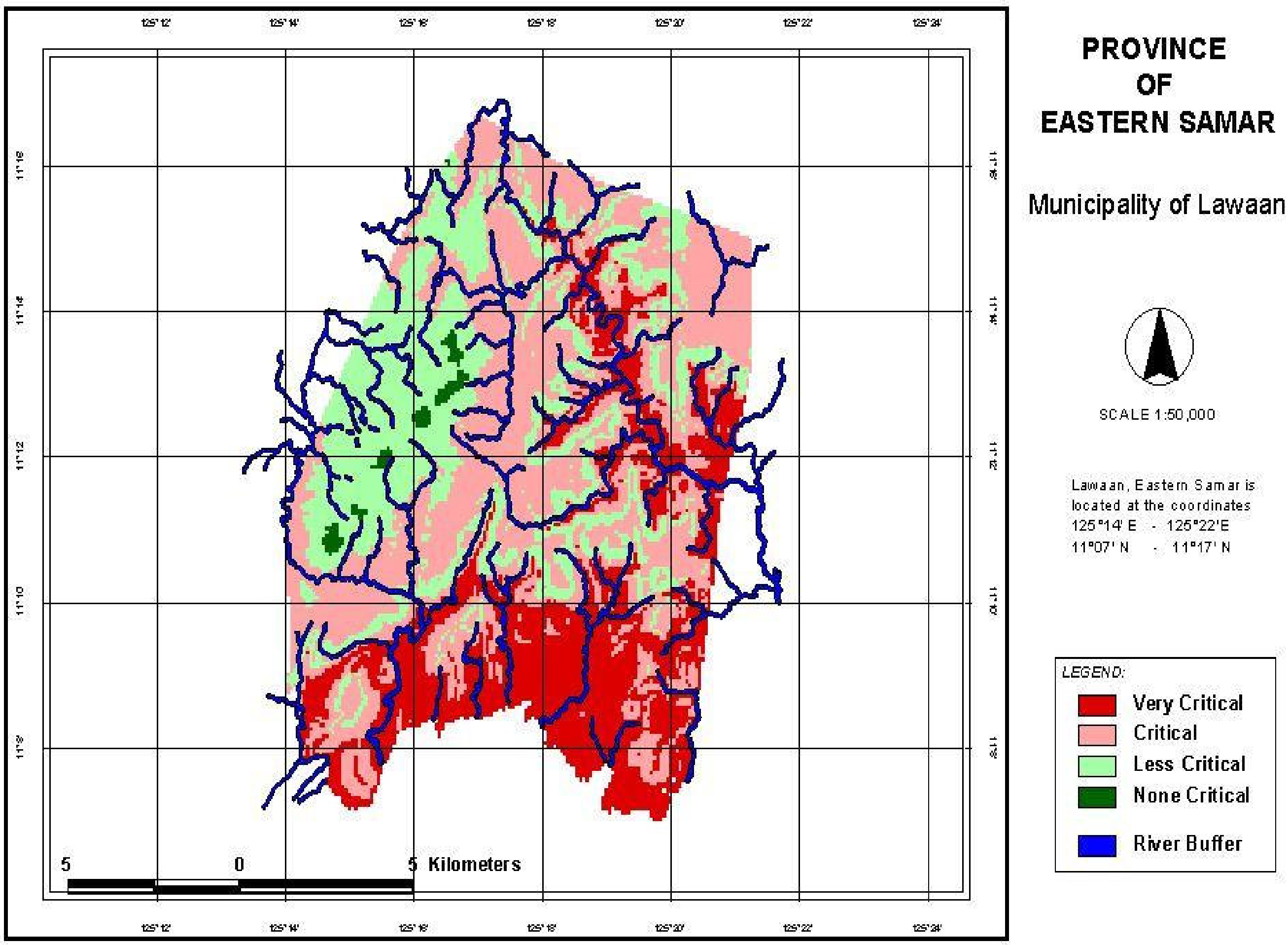

Fig. 12. Environmentally based land suitability map classifications of Lawaan, Eastern Samar, Philippines.

Table 8 shows the attributes of the four classifications for the combinations of SB and EB maps. Note that the very critical areas covered 26.91% or 4,547.70 hectares and critical areas have the highest value of 44.80% or 7571 hectares. The remaining areas are either smaller or non-critical.

This finding implies that urgent and proper management prescription is necessary to address biodiversity conservation concerns on the very critical and critical “hot spot” areas. It is here that biodiversity is constantly threatened by continuous human exploitation.

CLASSIFICATION	PRIORITY RANK	PIXEL COUNT	AREA (hectares)	PERCENT DISTRIBUTION
Very Critical	1	5373	4,547.70	26.91
Critical	2	8945	7,571.00	44.80
Less Critical	3	5462	4,623.00	27.36
Non Critical	4	186	157.40	0.93
Total			**16,899.10**	**100.00**

Table 8 - Attributes of the environmentally based land suitability map classifications of Lawaan, Eastern Samar, Philippines

6.0 Conclusion and recommendation

The above has described how mapping via spatial data integration used flora and fauna BI values as ecological criteria, in combination with elevations and gradients, to identify very critical or "hot spot" areas in ways that allowed. Hence a land use allocation/zoning process that emanates from the different stakeholders could inform a delineation of "land for man" and "land for nature" partition to serve as a social contract or "land use bible" – if supported by legislation. As such, it would strengthen ecological governance of regions. Hence results in this study could signal the end of traditional anarchy by rich and poor in forest management, thereby negating the danger of ruination via the tragedy of the commons.

GIS mapping and analysis shows the different degrees of management needs based on the BI and the socially-prescribed land use and management zones. Different levels/degrees of management prescriptions are required if corresponding on-site strategies are to be developed. For sustainable biodiversity conservation to be realized while funds are meager, priority should be given to very critical and critical areas. These are considered the "hotspot areas" where human activities constantly exert pressure on nature to the severe detriment of biodiversity values. The GIS protocols developed may be modified or improved in order to accommodate the peculiarities and uniqueness of any given landscape ecosystem.

This pioneering attempt to use GIS in order to integrate ecological and social criteria into zoning is part of an iterative process designed to optimize land use zoning for man and nature. As time goes by, needs, concerns, priorities, rules and policies may change, and therefore "the map" would change due to up-dated data. That is, a more refined process may be developed in the future to improve the outputs/results by incorporating variables hitherto ignored. It is sufficient to note, however, that through GIS mapping and analysis, decision guidelines are and can be provided to converge what some people see as the mutually exclusive and conflicting needs of man and nature.

Protected Area managers can follow the above protocols to meet their need for a land use plan which will preserve, and even restore biodiversity while balancing the needs of man and nature to preserve landscape values.

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References

Alcamo, J. & Bennett, E.M. (2003) - *Ecosystems and Human Well-being: A Framework for Assessment*, Island Press, Washington D.C.

Baguinon, N.T. (2007) - Biogeography and ecosystem health, presented at the *First International Scientific Convention - Community Participation and Biodiversity Education to Sustain Nature Theme,* May 2-4, Palawan State University, Puerto Princess City, Palawan, Philippines.

Baguinon, N.T. (2008) - Biogeography and tropical terrestrial ecosystem health. *Asia Life Sciences Supplement*, 2, 77-101

Ball, J. (2002) - Towards a methodology for mapping regions for sustainability using PPG, *Progress in Planning*, 58, 81-140

Cabanayan Jr, J.C. (1999) - Application of remote sensing and GIS in forestry, *Society of Filipino Foresters, Inc., Fifty first Anniversary and National Convention*, Waterfront Hotel, Cebu City, 26-28 August

Casas, Jr. E.V. (2006) - Enhanced GIS application for sustainable biodiversity conservation in Lawaan, Eastern Samar, Philippines, *Third Region 8 GIS Conference -Theme Discovering Potentials for Economic Growth and Sustainable Development Through GIS theme*, November 16-17, University of the Philippines

Casas, Jr., E.V. and N.T. Baguinon. (2008) - Environmental zoning for biodiversity conservation in Lawaan, Eastern Samar, Philippines, *Journal of Nature Studies*, 7(2), 107- 121

Colville, D. & Bridgland, J. (1992) - GIS evaluation of special preservation zones in a National Park. in Willison, J.H. (ed.) *Science and the Management of Protected Areas*, Elsevier. Amsterdam, 461-465

Department of Environment and Natural Resources (1990) - *Philippine Strategy for Sustainable Development – A Conceptual Framework*, January

Dickerson, R.E. (1928) - *Distribution of Life in the Philippines*, Bureau of Printing, Manila

Dinerstein, E. & Wikramanayake, E.D. (1993) - Beyond "Hotspots": How to prioritize investments to conserve biodiversity in the Indo-Pacific Region, *Conservation Biology*, 7(1), 53-65

Downs, T. J. (2000) - Changing the culture of underemployment and unsustainability, *Journal of Environmental Planning and Management,* 43(5), 601-621

Environmental Systems Research Institute (ESRI) (1997) - *ArcView GIS*

Faust, B.B. & Esmardon, R.C. (2001) - Introduction and overview: environmental knowledge, rights, ethics: co-managing with communities, *Environmental Science and Policy*, 4, 147-151

Fry, G.L. & Norris, S. (1992) - The Use of GIS in national park management in Norway: Practical and Theoretical Issues, in Willison, J.H. (ed.) *Science and the Management of Protected Areas*, Elsevier, Amsterdam, 453-460

Glowka, L., Burhenne-Guilmin, F. & Synge, H. (1994) - A guide to the conservation of biological diversity*, Environmental Policy and Law Paper No. 30*, IUCN Environmental Law Center, Biodiversity Programmes

Godilano, E.C. & DeGloria, D.S. (1999) - Natural resource policies and community-based approach to watershed management, presented to the *Workshop on Environmental Services and Land Use Change: Bridging the Gap between Policy and Research in Southeast Asia*, 31 May-2 June, Chiang Mai, Thailand

Goma, H.C., K. Rahim, G. Nangendo, J., Riley, & Stein, A. (2001) - Participatory studies for agro-ecosystem evaluation, *Agriculture, Ecosystems and Environment*, 78, 179-190

Goodwin, P. (1998) - “Hired Hands” or “Local Voice”: Understandings and experience of local participation in conservation, *Transactions of the Institute of British Geographers*, 23 (4), 481-499

Heaney, L.R. (1993) - Biodiversity patterns and the conservation of mammals in the Philippines, *Asia Life Sciences*, 2 (2), 261-274

Holtcamp, W. (1995) - Structure: Pieces of the landscape, *Eco-Web Journal*, September.

Johnson, N. (1993) - An introduction to the technical aspects of biodiversity and its conservation, Rietbergen, S. (ed.) *Earthscan Reader in Tropical Forestry*, Earthscan, London

Laurance, W.F. & Bierregaard Jr, R.O. (eds.) (1997) - *Tropical forest remnants: Ecology, management and conservation of fragmented communities*, University of Chicago Press, Chicago

Lewin, R. (1986) - A mass extinction without asteroids, *Science*, 234, 14-15

McNeely, J.A. & Miler, K.R. (eds.) (1984) - *National parks, conservation and development: The role of Protected Areas in sustaining society*, Smithsonian Institute Press, Washington, D.C.

Merrill, E.D. (1926) - *Enumeration of Philippine flowering plants*, Bureau of Printing, Manila

Ong, P.S., Afuang, L.E. & Rosell-Ambal, R.G. (eds.) (2002) - *Philippine biodiversity priorities: A second iteration of the national biodiversity strategy and action plan*, DENR-PAWB, CI (Phil.), BCP-UPCIDS, and FPE, Quezon City, Philippines

Paci, C., A., Tobin, & Robb, A. (2002) - Reconsidering the Canadian environmental impact assessment Act: A place for traditional environmental knowledge, *Environmental Impact Assessment Review*, 21(2), 111-127

Poitevin, J., Cool, N., Blyth, C., Westhaver, A. & Willman, J. (1992) - Implementing a GIS as a tool in natural resources management – Elk Island National Park, Alberta, in Willison, J.H. (ed.) *Science and Management of Protected Areas*, Elsevier. Amsterdam, 477-480

Poore, D. (1993) - The sustainable management of tropical forest: The issues, in Rietbergen, S. (ed.) *The Earthscan Reader in Tropical Forestry*, Earthscan Publications, London

Rambaldi, G. & Callosa-Tar, J. (2002) - Participatory 3-dimensional modeling: Guiding principles and applications, *ASEAN Regional Centre for Biodiversity Conservation (ARCBD),* Los Baños, Philippines

Reckart, E.A. (1993) - Diversity patterns of mammals along elevational and disturbance gradients in the Philippines: Implications for conservation, in *Asia Life Sciences,* 2 (2), 251-260

Reid, W.V., Barker, C. & Miller, K. (1992) - *Global biodiversity strategy*, World Resources Institute, Washington, D.C.

Reid, W.V., McNeely, J.A., Tunstall, D.B., Ryantd, A.B. & Winoggrad, M. (1993) - *Biodiversity indicators for policy-makers*, The World Resources Institute, IUCN

Republic of the Philippines (1975) - *Presidential Decree 705, Revised Forestry Code of the Philippines*

Republic of the Philippines (1992) - *Republic Act No. 7586* (An act providing for the establishment and management of National Integrated Protected Areas System (NIPAS), Defining Its Scope and Coverage, and for other Purposes)

Rietbergen, S. (ed.) (1993) - *The earthscan reader in tropical forestry*, Earthscan Publications Ltd., London

Turner, M.G. & Gardner, R.H. (eds.) (1990) - *Quantitative methods in landscape ecology*, Springer Verlag, New York

University of the Philippines (1971) - *Plants of the Philippines*, University of the Philippines Press

Utting, P. (ed.) (2000) - *Forest policy and politics in the Philippines: The dynamics of participatory conservation*, ADMU Press, Quezon City

Weiner, D. & Harris, T. (1999) - Community-Integrated GIS for land reform in South Africa, *Research Paper 9907*, West Virginia University, *http://www/rri.wvu.edu/wpapers/1999wp.htm.*

Whitford, H.N. (1911) - *The Forests of the Philippines. Part I. Forest types and products,* Bureau of Printing, Manila

Whitmore, T.C. (1990) - *An introduction to tropical rain forests*, Clarendon Press, Oxford

Wilson, E.D. (1985) - The biological crisis: A challenge to science, *Issues in Science and Technology,* 2, 20-29
