Geospatial Technology in Disaster Prediction and Agriculture and Natural Resource Management

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ABSTRACT[1]

Natural disaster constitutes one of the major hazards that cause losses in the lives and properties; however, predicting disaster and its magnitude has eluded scientists and policy makers for centuries. For example, landslides prediction requires complex analyses, involving multitude of factors and need to be studied systematically in order to evaluate the hazard. The increasing computer-based tools are found to be useful in hazard mapping of natural disasters. One of such significant tools for natural disaster mapping is by using Geographic Information Systems (GIS) and technology, such as the use of remotely sensed data, global positioning satellites, and environmental modeling.

The recent disaster that occurred in Southern Leyte and the Northeastern part of Mindanao and the one that happened in Ormoc City in 1991 is a wakeup call to every Filipino. Something must be done! Using GIS technology we have identified at least 790 thousand hectares of "hotspots" all over the country that have similar configuration and characteristics as Leyte and Mindanao. These make these areas as potential sites for disaster. Landslide cause by heavy rain could also occur in an additional 3.3 million hectares and could trigger flooding in low lying areas of the country. Collateral damage could affect approximately 6.6 million hectares of agricultural and fishery, historical sites, infrastructures, and human settlements.

Results of the GIS analysis are presented in maps and statistics at the national, provincial, and municipal levels. Relief and 3D maps are also presented to a focus site in the Province of Laguna to demonstrate the potential of GIS as a tool in disaster prediction and management. The analysis also showed that the DA could play an important role in disaster management as approximately 80 percent of the "hotspot" areas are within its jurisdiction, the Network of Protected Areas for Agriculture and Agro industrial Development (NPAAAD).

The author also presents innovative solutions that range from short to long term investments in disaster prediction, resource management using watershed as the planning domain, and rehabilitation in the context of partnership and collaboration with the DA, DENR, NDCC, LGUs, NGAs, and NGOs. A framework for disaster prediction and management in the context of LGUs centered planning and community based driven is also being proposed.

GIS and technology can be a catalytic tool that could guide policy makers in disaster prediction, mitigation, and ANR management. Use in local governance, GIS technology can leapfrog the Philippine in the 21st century and the disaster in Leyte and Mindanao can be a thing in the past: NEVER AGAIN shall our people live in fear of being buried alive in a landslide.

[1] This paper was presented at the following seminars: (1) The DA-BAR executive committee and technical assistant group. CERDAF Conference Room, 3rd Floor, ATI Building, Quezon City. 13 January 2004. (2) The DA-GISNetwork Planning Workshops, 14 January 2004; (3) The DENR inter-agency meeting on the formulation of geohazard assessment and mitigation plan. 16 January 2004. (4) The GIS training participants of the SANREM-CRISP-SEA-UPLB-LGU of Bukidnon, 19 January 2004. UPLB-CFNR seminar series, 30 January 2004.

ABBREVIATION

ADB	Asian Development Bank
AFMA	Agriculture and Fisheries Modernization Act
ANR	Agriculture and Natural Resources
BAR	Bureau of Agricultural Research
BARSAIL	Bureau of Agricultural Research Spatial Analysis and Information Laboratory
BSWM	Bureau of Soils and Water Management
CLUP	Comprehensive Land Use Plan
CU	Cornell University
DA	Department of Agriculture
DENR	Department of Energy and Natural Resources
DEM	Digital Elevation Model
DILG	Department of Interior and Local Government
DSG	Decision Support Group
ESRI	Environmental Systems Research Institute (US)
FAO	Food and Agricultural Organization
FSR	Farming Systems Research
G-ICT	Geospatial Information and Communication Technology
GIS	Geographic Information Systems
GPS	Global Positioning Systems
ICT	Information and Communication Technology
LGU	Local Government Units
ME	Monitoring and Evaluation
MPDO	Municipal Planning and Development Officer
NAMRIA	National Mapping Resource Information Agency
NPAAAD	Network of Protected Area for Agriculture and Agro Industrial Development
NARS	National Agricultural Research Systems
NDCC	National Disaster Coordinating Council
NGA	Non Government Agencies
NGICH	National Geographic Information Clearing House
NGII	National Geographic Information Infrastructure
NGO	Non Government Organization
NIPAS	Network of Integrated Protected Area Systems
NRM	Natural Resource Management
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PDI	Philippine Daily Inquirer
PNE	Peoples Network for the Environment
RADARSAT	Radio Detection and Ranging Satellites
RDE	Research Development and Extension
RS	Remote Sensing
SAFDZ	Strategic Agricultural and Fisheries Development Zone
SPOT	Satellite Pour l'Observation de la Terre
USGS	United State Geological Survey
WB	World Bank

1. INTRODUCTION

Our country according to the Philippine National Red Cross (PNRC) led the world in the types and frequency of natural disasters and ranked fourth in the number of people killed or affected by floods, tsunamis, typhoons, landslide, earthquakes, volcanic eruptions and man-made disasters. It was because of this that the country has been chosen by aid organizations as a "laboratory" for new approaches in disaster mitigation.

In November 1991, a Mindanao-based Australian ecologist, Neil Fraser said that for as long as Filipinos regarded the earth and the environment as resources to be exploited and abused, a flood similar to that in Ormoc City that killed about 8,000 people and rendered about 50,000 residents homeless could occur anytime. Twelve years later, his prediction came true, and in a place not far away from Ormoc City. Heavy rains, severe deforestation and the mountainous terrain were blamed for the fatal mudslides according to a government weather forecaster. Heavy deforestation reduced the capacity of the land to hold water. He added "that before the deforestation of the area, there was no problem of flooding or landslide", PDI (2004)

Time and again, government officials, and ecologists have issued warnings on the possibility of more disasters occurring because of the deforestation of our mountains and watersheds. The Ormoc disaster was a front-page story for more than a week. It can be recalled that land conversion of forested areas for agricultural use was cited as one of the major causes of the Ormoc tragedy. But after the initial hue and cry, it receded from the public consciousness. The government and the people forgot about it. Now, the problem of deforestation is very much in the news because of the disastrous mudslides in December 2003 that occurred in Southern Leyte and part of Mindanao region.

The Department of Environment and Natural Resources (DENR) Secretary Elisea G. Gozun said that much of the landslide tragedy that hit Southern Leyte has to do with the improper use of forest land for agricultural purposes, noting that farmers in the affected areas opted to plant cash crops instead of trees. She said "one should, however, point out that this unusually heavy rain is one concrete manifestation of climate change," the secretary farther added, "that while the massive loss of forest cover and geologic factors were partly responsible, this areas had so far avoided landslides even though farmers started clearing upland areas in 1928 for coconut and other cash crops", DENR (2003). Indeed, weather patterns all over the world have been changing -- brought about by man's excessive release of greenhouse gases such as carbon dioxide and methane. This is exacerbated by the fact that there are fewer trees which serve as carbon sinks and absorb the carbon dioxide.

On the other hand, the Kalikasan-People's Network for the Environment (PNE) argues that contrary to the environment and natural secretary's statement, that the landslide in Southern Leyte is more than a natural disaster. "As usual, the government is quick to absolve itself of any responsibility or wrongdoing in the Southern Leyte landslide tragedy," said Clemente Bautista, national coordinator of environmental network Kalikasan-PNE. "The reason why these tragedies recur is that government, instead of getting to the real causes of the problems, quickly and conveniently adopts the force majeure excuse for these unfortunate occurrences", Kalikasan-PNE (2003).

As a consequence of the recent disaster, the government was providing medium- and long-term solutions in the affected areas. (1) relocating of houses to which the disaster victims will transfer to because the places from which they came are now hardly habitable, (2) building houses for some of the disaster victims using bamboo and logs confiscated from illegal loggers, (3) engaging in massive reforestation in these areas, using high-school and college students to plant trees as a matter of course prior to graduation. Three emerging questions: Firstly, are these the real solutions or are there other solutions more practical and at the same time more sustainable? Secondly, how could we determine the exact geographic location and area for the above measures? Lastly, should our planners be reactive or they should be more proactive?

We contend that a clear link exists between the incidence of natural disasters and deterioration of the country's natural resources. This is especially evident in the impact of deforestation, which by 1980 had destroyed 5 million hectares - almost one-third of the total forest area - 1.4 million of which were in critical watershed areas. The removal of forests in watershed areas has aggravated flooding and landslides by reducing the water-holding capacity of the soil on hillsides. Erosion from the loss of vegetation has not only depleted the soil of nutrients but also allowed rapid runoff of rainwater, as well as sediment build-up in rivers, reservoirs, and drainage channels. Siltation has decreased the storage capacity of riverbeds and reservoirs and reduced the life span of dams. If indeed global climate change was the culprit of this recent disaster, then the urgency of disaster prediction, mapping, and sustainable ANR management is imperative to save the lives of the innocent people living directly in these disaster prone areas, to its path, and those that will be flooded downstream.

Geospatial technology has found application in many branches of government that use georeferenced data. On the other side, any natural disaster is spatially represented and may also change in its temporal space. The wildfire, floods, and landslides can be mapped as polygon areas. These areas interact with many other features like natural vegetation, floodplain, roads, agricultural areas, and non-natural features. All this information can be of great value when it is surveyed and represented digitally in computer systems like GIS.

This study presents the use of GIS technology for disaster prediction and management. It elucidates the GIS techniques use in mapping, and how it could contribute in reducing the damage cause by natural disasters. It presented a characterization of disasters and how they can be managed currently. The problems encountered in the current use of GIS in disaster prediction and management, and the adoption of geospatial technology as an enabling tool to contribute to effective and efficient local governance. We included in this paper a review of the GIS technology, its applications in natural disaster management, and experiences in develop countries on disaster prediction which are presented in the next sub sections.

1.1 GIS Technology

A GIS is defined as a powerful set of tools for collecting, storing, retrieving at will, displaying, and transforming spatial data (Burrough and McDonnel, 1998). One of the main advantages of the use of this technology is the possibility of improving hazard occurrence models, by evaluating their results and adjusting the input variables. An important aspect of landslide investigations is the possibilities to store, treat, and analyze spatiotemporal data that are available.

The GIS applications have been growing dramatically in the last fifteen years. Covering almost all different spatial applications: land use, land cover, cadastral mapping that could lead to tax assessment, marine charting and topographic mapping, geology, geomorphology, and many others. The two main advances of GIS in relation to natural disaster management (NDM) are the integration and analysis capabilities. GIS data models accept the transferring of real world features to spatial data structure (like vector or raster). Beside the limitations of the current data models, it is possible to integrate in one system several type of natural features such as geology, soil, land use and land cover from remotely sensed data (raster model), roads, power lines, aqueducts (linear features) or wels, electric towers, sample points (point features).

For NDM, combining different sources of information is crucial due to the multidisciplinary and multidimensional characteristic of the problems. Disaster information is needed by decision-makers at many different levels and different scales. The Board on Natural Disasters of National Research Council in USA (National Research Council, 1999) has classified the information resources for decision making on disasters in six principal types: (1) base data, (2) scientific, (3) engineering, (4) economic, (5) environmental, and (6) response data.

In terms of GIS decision tools for NDM, Malczewski (1999) established that "the ultimate aim is to provide support for making spatial decisions". He explains how and in what extent GIS can provide the support required at each of the three stages of decision making: (1) intelligent, (2) design, and (3) choice. The summarized applicability is explained in the next three paragraphs.

In the **intelligent stage**, where the problem is defined, the spatial decision problem is the difference between the desired and existing states of a real-world geographical system, in this case the hazard, the risk or simply the disaster. GIS provide a unique opportunity to solve problems traditionally associated with data collection and analysis more efficiently and effectively. Moreover, it can also effectively present vast amount of information in a comprehensive form to decision-makers.

In the **design stage**, where the action alternatives are designed, the spatial decision alternatives are derived by manipulation and analysis of data and information stored in the GIS. In most of the current GIS, the modeling techniques required for decision makers are not suitable enough and the decision models operate in the background depending on the user's skills. Due to these problems, there is a need for integrated decision analytical techniques and GIS functions by incorporating analytical models directly into GIS or connecting GIS with an existing decision analysis system. Integrating decision support techniques into GIS was partially covered by some authors (see Tomlin 1990).

In the **choice stage**, where the alternatives are evaluated and selected, it is critical that the capabilities of the GIS in incorporating decision maker's preferences (e.g. weights assignment). GIS however, is very useful in the solution of spatial decision in conflicting areas. For the choice stage GIS will increase its applicability by aggregating the value based on classification algorithm in the GIS environment.

In general, GIS could provide good support for decision making; although some of the procedures still require spatial analytical skills, which most often decision makers do not posses. In many cases the improvement in software functionality could provide an easy interface with the users and can easily solve spatial decision problem. In particular, for NDM, there is still a need to survey the different types of decision-making techniques required for disaster management according to the different tasks in each phase and to the different levels of decision making. It is also important to research how they can be implemented in a GIS environment.

1.2 GIS and Remote Sensing in Disaster Management

Disasters are usually spatial events (floods, earthquakes, hurricanes, wildfires, hazardous spills, public unrest, famine, epidemics, and so forth). Mapping and information acquisition is vital for disaster management. GIS supports all aspects of disaster management. Disaster planning, response, mitigation, and recovery all become more efficient through the use of GIS.

Disaster planning involves predicting the risk of an event and possible impacts of the event to human life, property, and the environment. Once these factors are determined, effective planning can begin. Response requirements, protection needs (removing vegetation in the face of a wildfire, hardening bridge supports in the event of an earthquake, evacuation center developments) can be determined for areas of highest risk. This planning can be done effectively and quickly with GIS.

Disaster planning can be very powerful when modeling is incorporated into the GIS environment. Modeling allows disaster managers to view the scope of a disaster, where the damage may be the greatest, what and where lives and property are at highest risk, and what resources are required. Immediately following a large-scale event, one of the first tasks performed is locating disaster assistance centers based on the number of people affected and the availability of shelter facilities. GIS plays a natural role in this exercise. GIS is essential to effective preparedness, communication, and training tool for disaster management.

Emergency disaster management requires response, incident mapping, establishing priorities, developing action plans, and implementing the plan to protect lives, property, and the environment. GIS allows disaster managers to quickly access and visually display critical information by location. This information facilitates the development of action plans that are printed or transmitted to disaster response personnel for the coordination and implementation of emergency efforts.

Disaster management consists of three phases before a disaster occurs, (1) risk identification, (2) disaster mitigation, and (3) disaster preparedness, Two phases that happen after the occurrence of a disaster, (1) emergency response, and (2) rehabilitation and reconstruction.

Many types of information that are needed in NDM have both an important spatial as well as temporal component. Remote Sensing (RS) and GIS may provide a historical database from which hazard maps can be generated, indicating which areas are potentially dangerous. Remote sensing data should be linked with other types of data, derived from mapping, cadastral databases, measurement networks or sampling points, to generate hazard and risk information. GIS may model various hazard and risk scenarios for the future development of an area. Remote sensing data derived from satellites are excellent tools in the mapping of the spatial distribution of disaster related geo-data within a short period of time. Many different satellite based systems exist nowadays, with a large variety of spatial, temporal, and spectral resolution. These systems may detect the precursors of disastrous events as anomalies in a multi temporal analysis.

When a disaster occurs, satellite remote sensing systems may be used to monitor the disaster on a real-time basis and assist relief workers in planning of evacuation routes, coordination of search and rescue operations. Remotely sensed data integrated in a GIS could assist in damage assessment and monitoring, providing a quantitative base for relief operations and for the planning of rehabilitation and reconstruction. The framework for the integration of RS and GIS technology for ANR had been developed and promoted by many authors (see Godilano 1989).

1.3 GIS and Natural Hazards

A natural hazard is a term usually applied to extreme natural events that affect humans in one way or another. By definition, no natural hazard exists apart from human adjustment to it. Thus, the research and management of natural hazards includes the complicated interaction between humans and their environment.

Much of the information necessary for natural hazard analysis is geographic in nature, and since the problem is multidisciplinary, GIS is a good tool to keep track of the information. A few examples of data-sets that may be needed, depending on the nature of the hazard are: topography, soil, vegetation cover, road network, location of buildings, types of buildings, number of people in each household, sociological and demographic information about the population of an area etc.

There are essentially three parties that need spatial information on natural hazards: (1) public sector authorities, such as emergency managers and government agencies, (2) private citizens, and (3) researches. Also, the disaster cycle can be divided into the temporal stages of before, during, and after a disaster. Using these two dimensions, a matrix can be defined where each cell represents a given party's spatial information requirements at each stage in the disaster cycle:

For the **public sector** authorities need hazard maps that give an idea about the magnitude and distribution of the risk. The vulnerability of people and structures should be included. The public sector also needs to have an emergency plan, and to conduct an effective emergency management during and after a disaster. A significant challenge in emergency management is delivering the appropriate information to the proper party at the appropriate place and time in a useful form. GIS might become an extremely useful tool for emergency management combined with computer models of complex natural phenomena.

For the **private citizens** it is important to have up to date information about a potential natural hazard and guidelines translated in the local dialect about what to do in case of emergency. The World Wide Web and GIS on the web is an increasingly important tool in some parts of the world for such communication.

For the **researches** GIS can play an important role in (1) efficiently collecting, storing, analysing, and displaying large sets of geographically referenced data, and (2) facilitating attempts to develop new and more reliable models which can better reflect physical processes leading to catastrophic events, and (3) improve the possibility of mitigating the impact of such events.

1.4 Mapping Natural Disasters

Nowadays, the disaster management policy of different countries has been directed to improve the technology as tools, techniques and facilities by those who take operational decisions to improve the knowledge and/or response to natural disasters. One of the most important advances introduced are the new techniques for mapping natural disasters. The theoretical basics for these advances were established by UN-UNESCO in 1984, (Varnes, D. J., 1984).

There are different ways to creating disaster maps and the methodologies cover a wide range of approaches. Van Westen, C., (1993) classified the landslides hazard zonation techniques in four types: (1) inventory analysis where the landslide distribution, activity and density are surveyed to get general conclusions about the behavior of the event, (2) heuristic analysis based on expert opinions based analysis, (3) statistical analysis where map- parameters are mapped to apply bivariate or multivariate statistical analysis, and (4) deterministic analysis, where the physical and chemical models are executed to produce probabilistic maps.

This classification can also be valid for most of the other disasters and reach up to the risk step. One of the problems that crop up is that many research and projects outputs are in analogue format of digital hazard or risk map. In so doing, it has become static and wasted the opportunity to present the information in a digital-manageable way and to integrate this information with all other data from the area for an actual disaster management and planning.

Disaster prevention is maybe where the GIS could play the most active role. With the historic disaster inventory, the environmental parameters, triggering factors and elements at risk it is possible to do modeling in a GIS context to generate the susceptibility, vulnerability, hazard, and risk maps. They are very valuable for NDM since they provide information about the spatial variation of a potential disaster; how it can affect the human environment and which spatial strategy plan can be developed to reduce the potential disaster.

The other dimension of the NDM is the different levels of management. It is recognized that there are at least three scale levels that is applicable in the Philippines that corresponds to its political boundaries: (1) national, (2) regional, and (3) local. Abella (2004) recognizes some of the main GIS applications for each level and were adapted in the following list:

In the **national level**: (1) give a reference to the overall hazard situation and help to identify areas that need further studies to assess the effect of natural disasters on natural resources management and development potential, (2) used to identify less hazard-prone areas most apt for development activities, (3) identify areas where mitigation strategies should be prioritized, (4) recognize the number of people or type of infrastructure at risk, (5) keep updates of the national inventory of disasters, and (6) useful for disaster with national magnitudes like typhoons.

In the **regional level**: (1) integrate and update the inventory of disasters and the hazards and risk evaluations, (2) used to formulate less vulnerable development activities and/or mitigation strategies to lessen vulnerability to acceptable levels, (3) determine the conditions under which disasters are likely to occur (susceptibility), (4) useful for site location studies for large projects like dams, highways, power plants, etc., and (5) project integrated regional development plans.

In the **local level**: (1) creation and management of susceptibility, vulnerability, hazard and risk maps, (2) used in pre feasibility and feasibility sectoral project studies and natural resources management activities, (3) land use planning, (4) help planners to identify specific mitigation measures for high-risk investment projects, (5) locate vulnerable critical facilities for implementation of emergency preparedness and response activities, (6) identify critical resources in high-risk areas and adequately formulate mitigation strategies, (7) test "loss estimation models" for different disasters and several scenarios, (8) creation of preparedness and emergency plans testing evacuation routes and relocation of places like hospital, settlements, (9) control mobilization of resources and equipment, (10) control disaster locations and search and rescue operation, and (11) determinate the most affected areas by damage assessment.

1.5 Landslide Mapping

Landslide hazard and risk zoning and mapping for urban and rural areas is widely performed around the world (Siddle et al 1991, Lee et al 1991, Hutchinson and Chandler 1991, Morgan et al 1992, Carrara et al 1991, and 1992, Moon et al 1992). A landslide zonation map divides the land surface into zones of varying degrees of stability, based on an estimated significance of casuative factors in inducing instability. Engineers, earth scientists, and planners are interested in assessment of landslide susceptibility and hazard because of two purposes: (1) the landslide hazard maps identify and delineate unstable hazard-prone areas, so that environmental regeneration programs can be initiated adopting suitable mitigation measures; (2) these maps help planners to choose favorable areas for locating development schemes, such as building and road construction. Even if the hazardous areas can not be avoided altogether, their recognition in the initial stages of planning may help to adopt suitable precautionary measures.

The main factors which influence land sliding are discussed in Varnes (1984) and Hutchinson (1995). Normally the most important factors are bedrock geology (lithology, structure, degree of weathering), geomorphology (slope gradient, aspect, and relative relief), soil (depth, structure, permeability, and porosity), land use and land cover, and hydrologic conditions.

The methods used to assess probability of land sliding have been discussed by Leroi (1996). Traditional methods of landslide hazard mapping have been based on extensive fieldwork by expert geologists in potentially dangerous areas. This is slow, expensive and very labor intensive operation, and as such cannot be widely applied. With the increasing availability of high resolution spatial data sets, GIS, and computers with large and fast processing capacity, it is becoming possible to partially automate the landslide hazard and susceptibility mapping process and minimize fieldwork. Several studies have used GIS and statistics for landslide hazard and susceptibility mapping (Gupta and Joshi 1990, Wang Shu-Quiang and Unwin 1992, Pachauri and Pant 1992, Binaghi et al 1998, Guzzetti et al 1999, and Gritzer et al 2001).

2. Objectives

This study addresses the issue that has eluded scientists, planners, and policy makers in geographically targeting development programs and predicting where else disaster would likely to occur given similar criteria to that of what happened in 1991 and 2003. The following objectives will resolve this constraint:

1. Identifying the criteria and parameters that will provide the geographic locations of disaster prone areas at the national, regional, and local levels.
2. Developing the framework in using GIS technology as a tool in disaster prediction and ANR management.
3. Geographic targeting of hotspots using geospatial technology for tactical planning purposes.
4. Generating statistics for national and local government for strategic planning.
5. Identifying thematic areas where convergence activities among partners institutions could be develop.
6. Providing cost effective measures in disaster prediction and management, and
7. Improving local governance of disaster prone areas using GIS technology.

A GIS is an effective prediction tool for achieving the above objectives. This shall concurrently help in prioritization of administrative and financial inputs towards working out the gravity of hazard, scale of relief operations necessary and the requirement of financial resources. The capability of GIS to improve upon temporal and spatial data shall make the entire activity more dynamic and interactive for designing disaster management strategies.

3. THEORY AND METHODOLOGY

Quantitative prediction models for landslide prediction are based on spatial database consisting of several layers of digital maps and attribute data representing the casual factors of the occurrence of landslides. The methodology use in this mapping activity is the combination of three models, namely: (1) inventory analysis, (2) heuristic analysis, and (3) deterministic analysis to represent a quantitative measure of future landslide disaster in the different levels of governance.

The above model was based on two basic assumptions: (1) that future landslides will occur under circumstances similar to the ones of past landslides in the study areas or in areas in which experts have obtained their knowledge on the relationship between the causal factors and the occurrences of the landslides; and (2) that the spatiotemporal data representing the causal factors contained in the GIS database can be used to predict landslides.

The primary causal factors for landslide susceptibility mapping includes interpolated rainfall, slope gradient, land cover, soil texture, erosion severity, and hydrology were obtained and generated from the DA-BAR Spatial Analysis and Information Laboratory (BARSAIL). The base maps were then processed to create evidence layers for each thematic map. The boundary maps provided the distribution of affected areas based on administrative boundaries at the Provincial, Municipal, and Barangay levels.

3.1 Hotspots Map Generation

The input maps were combined after evidence layers were reclassified by assigning three disaster severity ratings, i.e. 1 = no landslide, 2 = evacuation, and 3 = search and rescue. The table below shows the ratings assigned in the attribute data for each thematic map.

Disaster Severity	Rainfall (mm)	Slope Gradient	Erosion Severity	Soil Texture	Land Cover
1 (not affected)	500-1000	0-8	Slight	clay, peat, bog, hydrosol	Closed canopy, mature trees covering > 50 percent, coral reef, fishponds derived from mangrove, lakes, mangrove vegetation, mossy forest, siltation pattern in lakes
2 (evacuation)	1000-1500	8-18	Moderate	loam, clay loam	Open canopy, mature trees covering < 50 percent, pine forest, other plantations, built-up area
3 (search and rescue)	1500-2000	18->50	Severe	gravel, lava, sand, rock, stony, mountain, rubble, sand dunes	Arable land with crops mainly cereals and sugar, coconut plantations, crop land mixed with coconut plantation, crop land mixed with other plantation, cultivated area mixed with brushland/grassland, grassland, grass covering > 70 percent, other barren lands

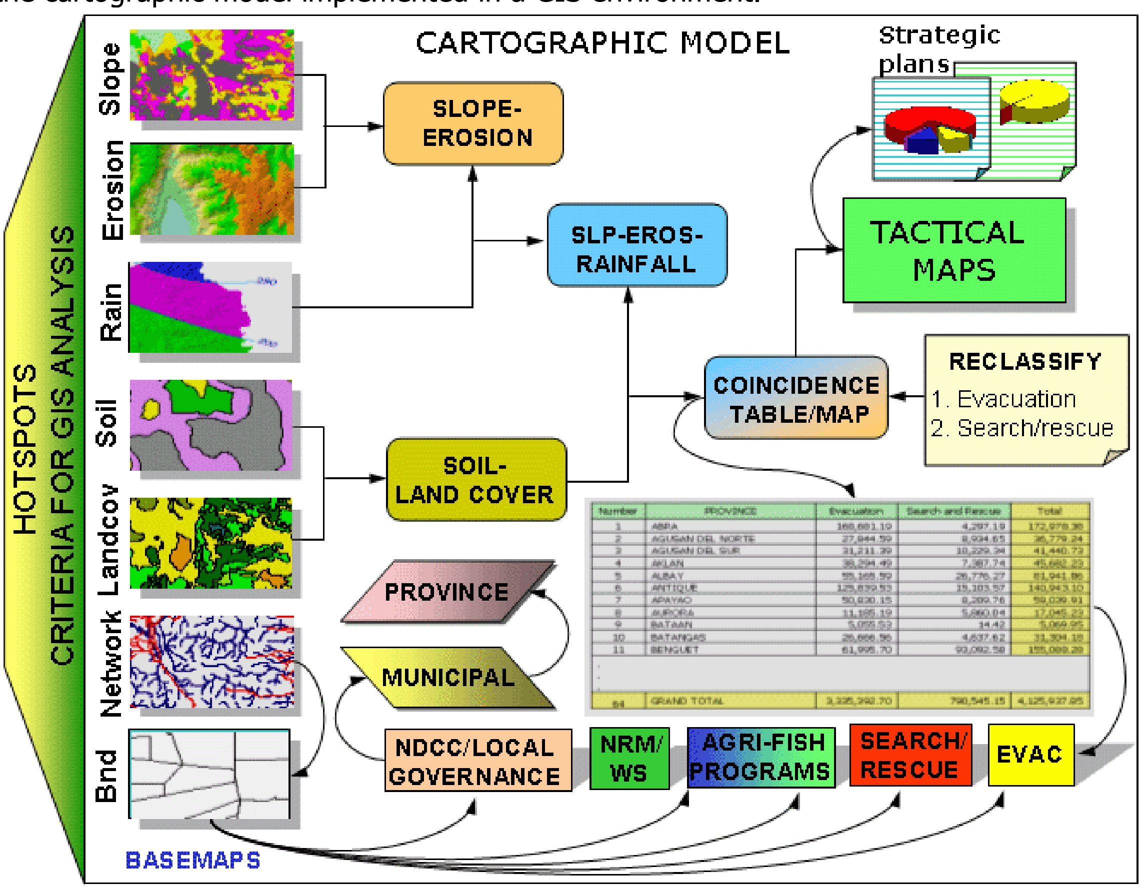
Using ArView 3.2, the maps were overlayed to create a table of coincidence matrix. In order to modify the membership values of each factor map and change the influence of each component, an additional "weight factor" (WF) in the range of 0 and 1 was used as a multiplier. This is overall weighting to express the expert's opinion on the estimated significance of each factor in causing instability. This approach could enable the modeler to make changes interactively with the GIS.

We believed that for landslides to occur, significant rainfall is only one contributory factor for the event to happen. We contend that landslide could be a function of:

$$\text{Landslide} = f_n\text{: } R_f + L_c + S_t + S_g + E_s * WF$$

where: R_f = rainfall; L_c= land cover; S_t = soil texture; S_g = slope gradient; E_s = erosion severity; and WF = weight factor (0,1)

The analytical capability of ArcView GIS software was used to solve the above formula. This resulted to a coincidence maps based on the five coverage used in the analysis showing disaster severity all over the country. The information was converted to "hotspots" and indicates the action that could be undertaken should heavy rainfall is accumulated in the identified areas. The final map where then composed to reflect potential disaster and flooded areas using the 0-3 percent slope gradient. To delineate areas of responsibilities between the DA and DENR, the identified "hotspots" were overlayed to the NPAAAD map, and the Network of Protected Area Systems (NIPAS). In so doing a total of 11 thematic maps were used in this study. The figure below shows the cartographic model implemented in a GIS environment.



4. Results and Discussions

The unique capability of GIS to capture, store and manage vast quantity of geo referenced data and its ability to incorporate appropriate natural resource models, have caused its adoption across wide sections of ANR management, especially in disaster prediction where management of spatial-data is pivotal for scientific analysis. As the typical landslide analysis demands, collection of numerous data, storing and using them in the analysis could be handled well in the GIS environment. Any spatially-distributed data geo-reference to the real world could be stored as points, lines and polygons (vector data model) or as continuous fields (raster data model).

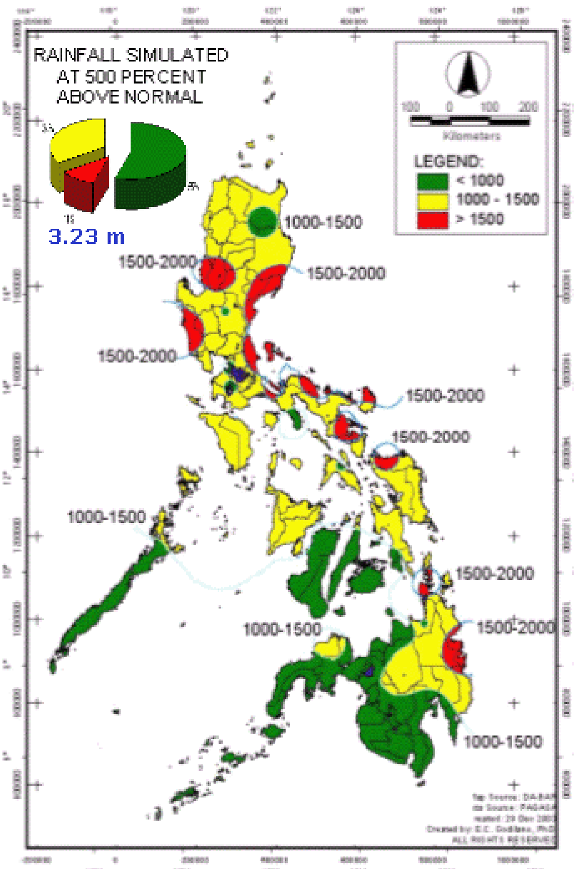
Beyond GIS being used as a spatial database, it assists in modeling applications through handling special form of data that would otherwise be compromised in conventional analysis. Also, GIS does not only serve as a database for parametric data, but also qualitative and quantitative data can be integrated through spatial relationships rather than through relationships between attributes that may not exist (Frost et al. 1997). Other GIS enabling capabilities such as: query languages and user interface permitting rapid modification of parameter values; convenient and quick updating of model parameters; overlay functions (where multiple maps are either visually or topologically combined) and its potential in visualization of data using the graphic features. This could assists scientists and policy makers in verifying data and information pertaining to the model and its applications; and developing relief maps and subsequent 3D themes, as they are common to many applications of ANR models (Miles et al. 1999). In particular, the ability of GIS to present data and analysis results in maps forms plays a key role in identifying the critical areas where more rigorous analysis and improved solution is required by its interactive visualization in a spatially optimized mode.

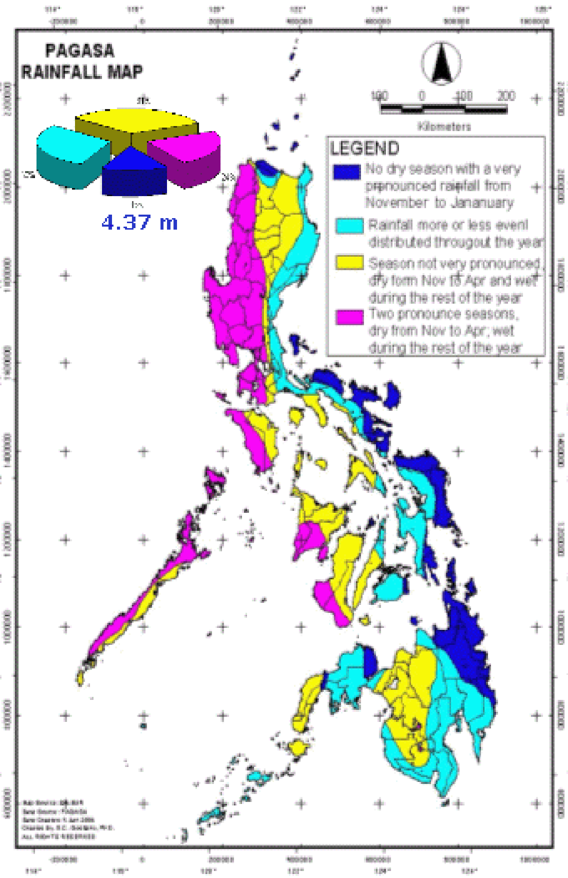
4.1 Rainfall Distribution

The disaster that happened in part of Mindanao and Leyte showed a significant increase in accumulated rainfall of 600 to 700 percent above its normal. From this information, we simulated the rainfall distribution all over the country at 500 percent above normal using the 30 years average annual rainfall from PAGASA. At this rainfall, we believed that landslide is only about to occur.

Results of the simulation analysis showed that the areas of greatest threats to landslide, i.e. at 1500-2000 mm of rain would cover at least 3.23 million hectares. Available rainfall map from PAGASA showed rainfall distribution where landslide would likely to occur and this covers at least 4.37 million hectares. This is approximately 35% more land area. The map below shows the comparison.

As a consequence of heavy rainfall, low lying areas could be flooded. Using GIS, estimated flood prone areas covers approximately 6.6 million hectares. In the flood prone areas, collateral damage to human settlements, agriculture, fisheries, historical sites, and infrastructures would be significant. We contend, however, that rainfall alone could not be use as a measure of landslide to occur in a given geographic location, it is the convergence of several factors as illustrated in the cartographic model.



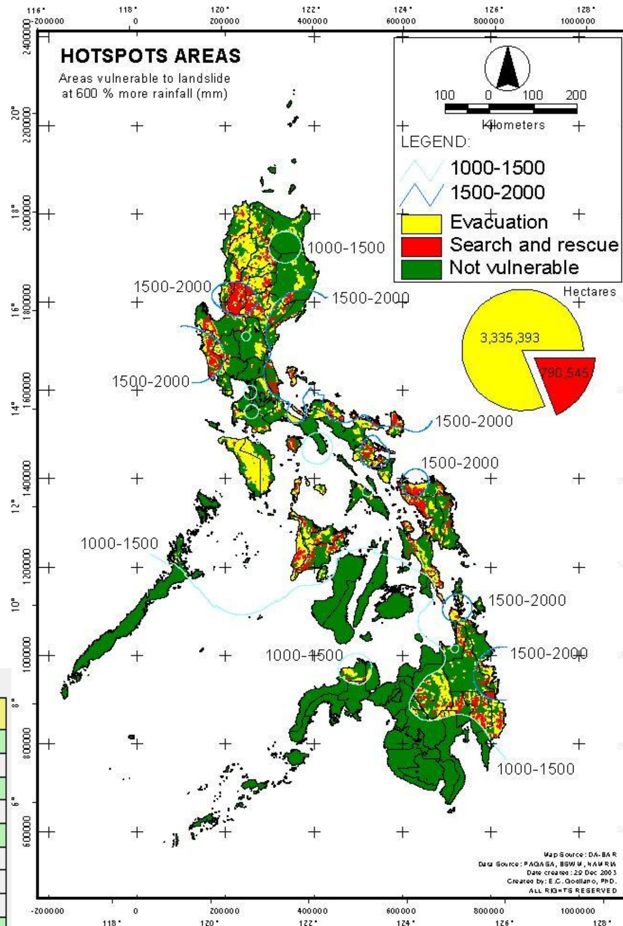


4.2 GIS Analysis to Produce Coincidence Map

Total "hotspots" areas at the national level where search and rescue operation commence are 790,545 hectares, while evacuation covers 3.4 million hectares. The table on the right and the map below shows the distribution at the regional level. This confirms that Region 8 where Leyte is situated is really susceptible to disaster having at least 108 thousand hectares. The CAR showed the highest area coverage of 143 thousand hectares. It is interesting to note that Region 7 showed no threats to landslide within the accumulated rainfall of 1,500 to 2,000 mm. Landslide that could happen in this area could not be attributed to the factors used in the model.

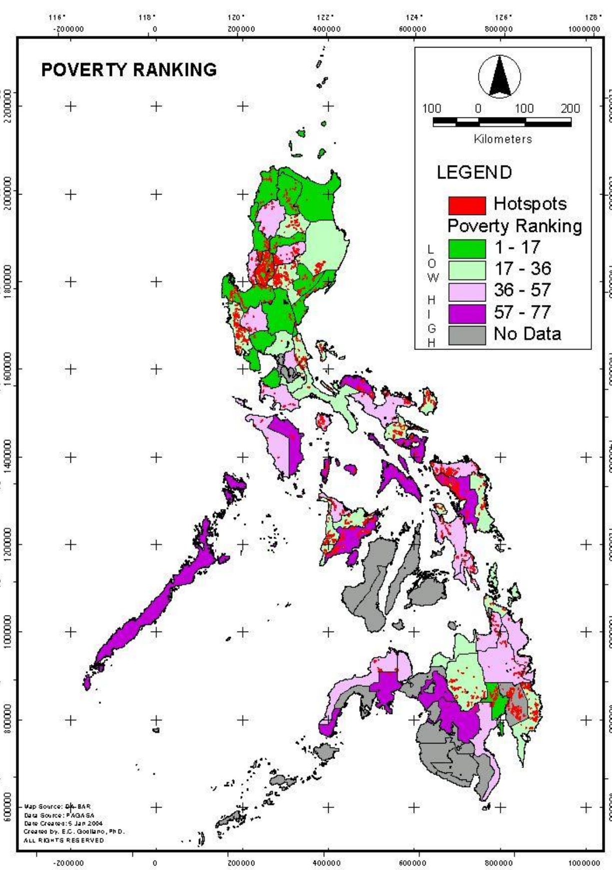
REGION	EVACUATION		SEARCH AND RESCUE	
	Hectares	Percent	Hectares	Percent
ARMM	4,937	0.15	292	0.04
CAR	507,666	15.22	143,135	18.11
I	280,704	8.42	62,038	7.85
II	229,112	6.87	66,879	8.46
III	152,518	4.57	61,205	7.74
IV-A	189,386	5.68	39,828	5.04
IV-B	486,442	14.58	18,986	2.40
V	272,279	8.16	81,182	10.27
VI	293,427	8.80	68,797	8.70
VIII	265,558	7.96	107,690	13.62
IX	45,154	1.35	6,087	0.77
X	152,811	4.58	25,333	3.20
XI	255,540	7.66	79,399	10.04
XII	32,345	0.97	2,538	0.32
XIII	167,516	5.02	27,157	3.44
TOTAL	3,335,393	100.00	790,545	100.00

Statistics at the provincial level showed that the province of Benguet, Zambales, Nueva Viscaya, Samar, and Pangasinan, are the top five provinces susceptible to landslide. The province of Leyte and Southern Leyte ranked 17th and 37th with 15.6 thousand and 4.7 thousand hectares. The table below shows the statistics generated at the provincial level. We would also like to emphasize that most of the severely affected provinces are in the higher bracket of poverty incidence as illustrated in the map below. Poverty incidence could imply different strategies in disaster preparedness or mitigation.



HOTSPOTS PROVINCES (Area in hectares)

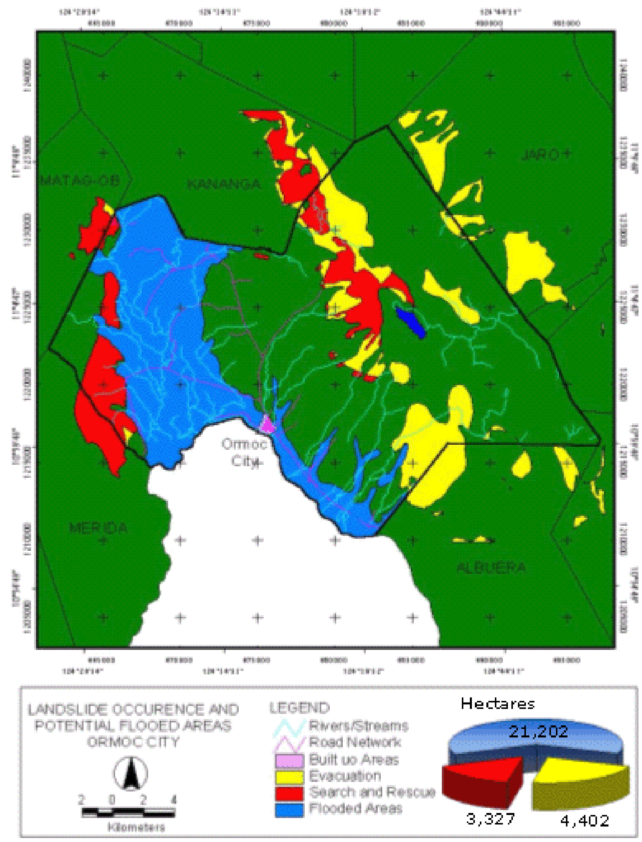
PROVINCE	AREA	PROVINCE	AREA
BENGUET	93,093	RIZAL	6,264
ZAMBALES	48,086	SORSOGON	6,103
NUEVA VIZCAYA	41,528	AURORA	5,860
SAMAR	41,305	ZAMBO DEL NORTE	5,426
PANGASINAN	37,131	ILOCOS NORTE	4,917
COMPOSTELA VALLEY	36,321	SOUTHERN LEYTE	4,705
ILOILO	35,460	BATANGAS	4,638
NORTHERN SAMAR	33,793	SURIGAO DEL SUR	4,536
ALBAY	26,776	TARLAC	4,495
QUEZON	25,591	ABRA	4,297
IFUGAO	25,345	MT PROVINCE	4,275
BUKIDNON	25,051	ROMBLON	4,206
DAVAO ORIENTAL	25,024	SURIGAO DEL NORTE	3,457
CAMARINES SUR	18,701	LAGUNA	3,321
CATANDUANES	17,414	OCC MINDORO	2,971
DAVAO DEL NORTE	15,820	NORTH COTABATO	2,538
LEYTE	15,590	BILIRAN	2,498
ANTIQUE	15,104	DAVAO DEL SUR	2,233
ISABELA	13,175	ORIENTAL MINDORO	2,078
ILOCOS SUR	13,075	NUEVA ECIJA	1,491
QUIRINO	11,259	MASBATE	1,222
CAMARINES NORTE	10,967	CAGAYAN	917
CAPIZ	10,846	PAMPANGA	894
AGUSAN DEL SUR	10,229	ZAMBO DEL SUR	661
EASTERN SAMAR	9,799	BULACAN	366
MARINDUQUE	9,687	LANAO DEL SUR	292
AGUSAN DEL NORTE	8,935	MISAMIS OCCIDENTAL	282
APAYAO	8,210	PALAWAN	44
KALINGA	7,915	CAVITE	15
AKLAN	7,388	BATAAN	14
LA UNION	6,916	TOTAL	790,545



4.3 Ormoc Revisited

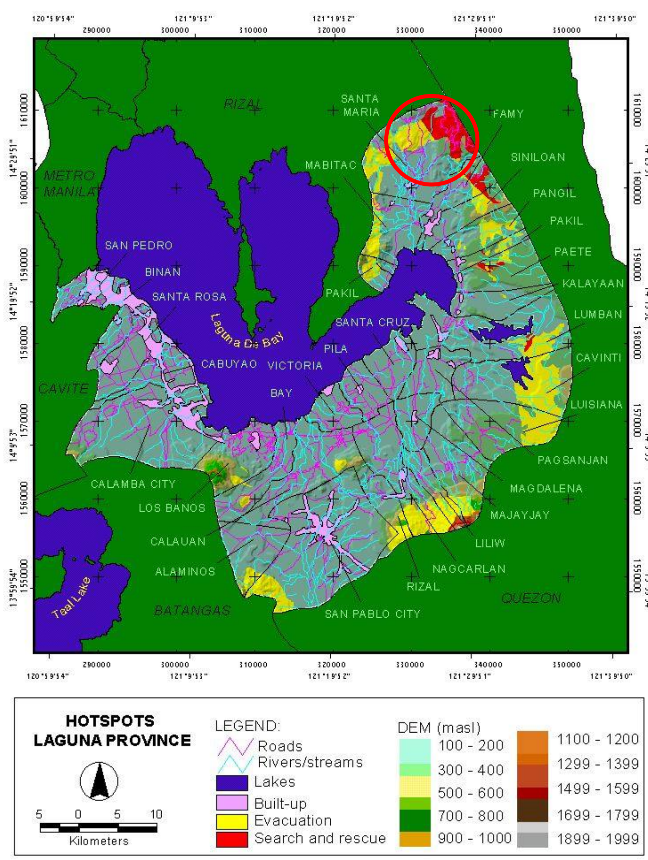
The disaster in Ormoc City that happened in 1991 blamed the loss of forest cover in the uplands, land conversion to sugarcane, coconuts, and improper land uses. Using GIS, the spatial distribution of hotspots areas are geographically located and interventions could likewise be site specific.

From the national level map, we focus on Ormoc City to provide geographically targeted interventions. The map on the right showed hotspot areas of 3,327 thousand hectares. This also shows two rivers systems that converged "at the North gate" of the City. One consequence of heavy rainfall is the occurrence of "flush floods" downstream. Flood prone areas within Ormoc City are approximately 21,202 hectares. Assuming a 50 percent soil loss (100 tons/ha according to IBSRAM, 2003), an estimated 1.1 million tons of soils was loss and possibly carried in the affected areas. With no significant intervention being done so far to address the above causes of the land slide, the possibility of the same disaster that happened in the city in 1991 in not remote.



4.4 GIS for Local Disaster Planning

GIS technology could derive maps and statistics at any level of governance. In this case we focus our analysis in the Province of Laguna and one of its Municipalities (Sta. Maria). The map on the right shows hotspots in Laguna Province. Calculated flood prone areas are approximately 47,387 thousands hectares. In addition, we have included road networks and hydrology. Relief map calculated from interpolated contour data shows depth. We could also derive a DEM that will further emphasize the magnitude of the potential threats. With

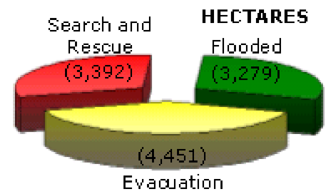


ArcView 3D Analyst, the 3D map could be animated by rotating the observer around the target, and vertical exaggeration factor calculated creating a visual impact.

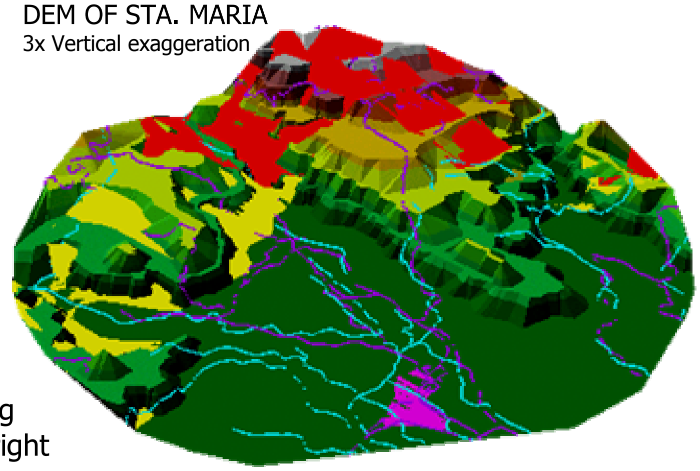
VULNERABLE AREAS IN LAGUNA (ha)

MUNICIPALITIES	EVACUATION	SEARCH and RESCUE
ALAMINOS	373.27	0.00
BAY	192.87	0.00
CALAUAN	166.74	0.00
CAVINTI	3,015.74	0.00
FAMY	217.94	520.22
KALAYAAN	19.91	0.00
LILIW	645.72	0.00
LOS BANOS	145.26	0.00
LUISIANA	1,862.35	0.00
LUMBAN	1,137.73	157.13
MABITAC	910.97	0.00
MAJAYJAY	469.97	0.00
NAGCARLAN	1,800.61	0.00
PAETE	297.19	173.69
PAKIL	850.91	14.39
PANGIL	907.12	0.00
RIZAL	609.77	0.00
SAN PABLO CITY	1,455.37	0.00
SAN PEDRO	34.00	0.00
SANTA MARIA	**2,856.65**	**2,350.22**
SINILOAN	417.48	104.53
TOTAL	18,387.57	3,320.18

Statistics showed that the Municipality of Sta. Maria has the biggest hotspots area of 2,350 thousands hectares and an additional potential area of 2,857 thousand hectares, flooded areas is about 3,279 hectares.



DEM OF STA. MARIA
3x Vertical exaggeration



Having a 3D model of the site could provide valuable information to further conduct GIS analysis at the village level. This is by locating barangays down streams that are along rivers and streams. The table on the right lists the vulnerable barangays and its population and households' statistics. The entire "poblacion" is in grave danger of replicating the Ormoc tragedy. This data could provide advance information on evacuation, relocation, relief operations, or for search and rescue operation should disaster happen.

STA. MARIA MUNICIPALITY STATISTICS (2000)

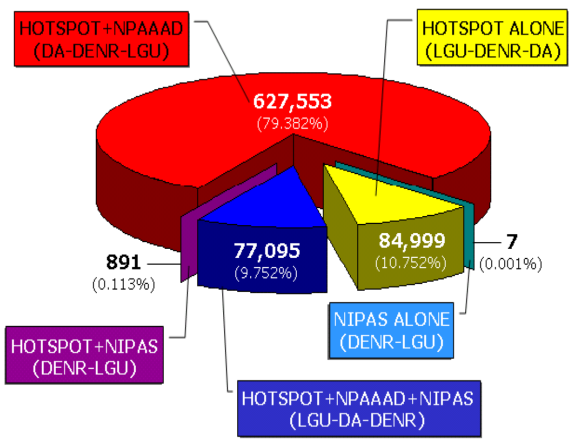
BARANGAY	TOTAL POPULATION	NO. OF HOUSEHOLDS
Adia	779	167
Bagong Pook	2,373	476
Calangay	1,097	215
Coralan	1,872	391
Inayapan	556	103
Kayhakat	1,056	205
Masinao	659	131
Pao-o	513	103
Parang Ng Buho	579	123
Barangay I (Pob)	849	161
Barangay II (Pob)	897	184
Barangay III (Pob)	870	184
Barangay IV (Pob)	669	142
Jose Rizal	1,062	217
Sub Total	13,831	2,802

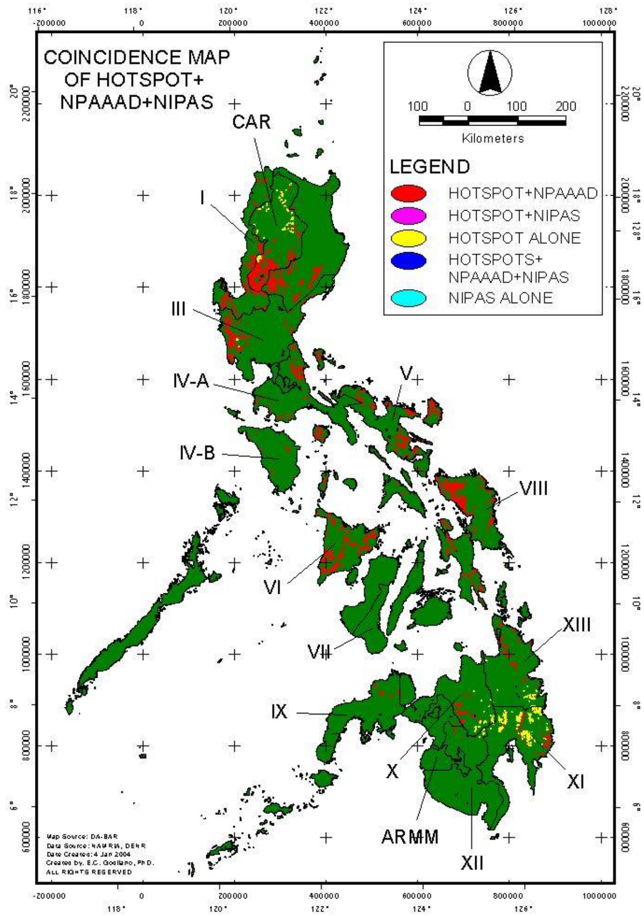
4.5 Dividing the Pie and Sharing Responsibilities

After the recent disaster, the national government formed a geohazard task force composed mainly of DENR, other agencies, except the DA. We argue however that the DA should play an important role in disaster planning and management especially in the formulation of strategic plans with the communities. Again GIS technology was use to clearly delineate this responsibility.

Hotspot at the level of search and rescue was overlayed to two base maps that will show coincidence of the DENR and DA responsibility. For the DENR, we used the NIPAS map and for the DA, the NPAAAD. We calculated coincidence statistics for the three maps. The map below and the accompanying figure show the coincidence map and statistics.

Statistics shows that the combination of Hotspots + NPAAAD which falls under the responsibility of the DA covers at least 79.3 percent of the total disaster area or 627, 553 thousand hectares. The combination of Hotspots + NIPAS covers only 11 percent of the total area or approximately 84,890 hectares. The combination of Hotspots + NPAAAD + NIPAS constitutes 10 percent of the total disaster area or 77,095 thousand hectares. Maps and statistics generated by GIS justify the important role the DA could play if given a bigger responsibility in disaster management.





5. Recommendations

The results of the GIS analysis indicate collaborative actions among the various level of governance at the local and national level. We also specifically focus on the role that the DA could play considering that majority of the affected area is under its responsibility. We also would like to emphasize that the programs and projects that could be developed in this study is not exclusive to one or two government agency alone, but rather a convergence of efforts to serve a greater good. Partnership, collaboration, and information and resource sharing are a necessity in national and local governance.

5.1 Local Level

1. **Providing rain gauges in identified disaster prone areas.** Our immediate concern is how to protect the vulnerable communities that lies along the path of destruction should similar events occur. We believed that portable rain gauges that are low cost should be provided to LGUs or produce locally using recycled container provided they are properly calibrated. Rain gauges could serve as an early warning device:
    - At 1000-1500 mm accumulated rainfall; identified communities should start evacuation,
    - At rainfall range of 1500-2000 mm accumulated rainfall, disaster had occurred: initiate search and rescue operations.
2. **Update the Provincial Physical Framework Plan** (PPFP). This is a very good start as new sets of government officials that will be elected in 2004 will automatically update their PPFP. The PPFP should delineate disaster areas and its mitigation measure, e.g. locating evacuation centers, command areas, etc.
3. **Update the SAFDZ and CLUP** (Strategic Agricultural and Fishery Development Zone) and Comprehensive Land Use Plan. SAFDZ is a requirement of CLUP, therefore disaster prone areas, evacuations centers; short and long term mitigation measures should be included in the plans.
4. **Institution and capacity building using GIS**. GIS is no longer a luxury for scientist and policy makers, it now becomes a necessity in local governance. There is a need to developed institutions or establishing GIS laboratories that are accessible to LGUs, likewise develop local capacity to enable LGUs to use GIS technology as a tool in planning and management. There are other GIS applications relevant of LGUs mandate, i.e. public serviced, fiscal management, local management, etc.
5. **Community awareness and participation**. Potential communities that could be affected by disasters should be fully aware of the threats to their lives and livelihood. They should be actively engage by local planners in any development projects, and should be provided with current information. The use of SMS (text messages) in communicating impending disaster should be use.
6. **Integrated planning and management**. A community-based centered planning and management should be the main trust of any program that addresses the above concerns. This however, should be supported with sound biophysical, engineering, socio-cultural solutions, and financial resources.

5.2 National Level

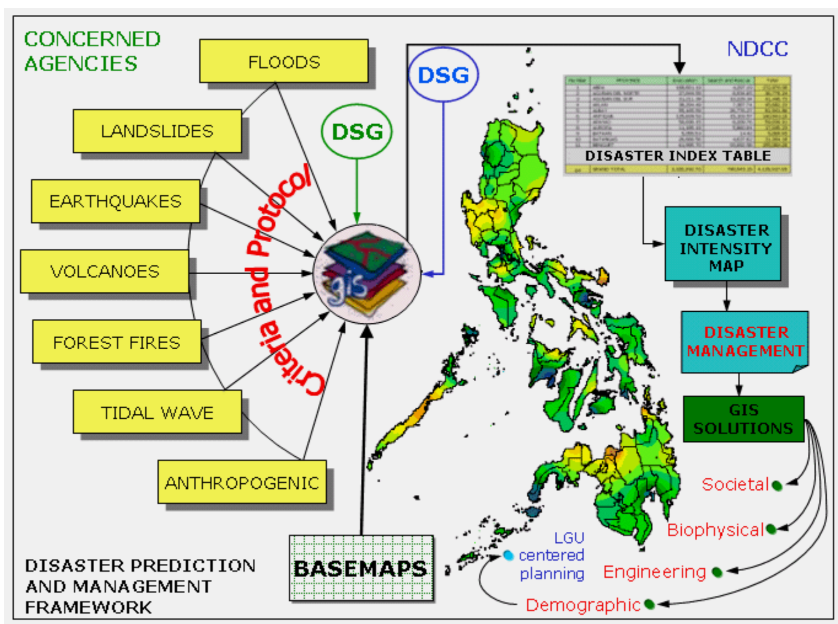
1. **Detailed analysis using RS and GPS data and ground truthing of results**. The results of this analysis relied on using secondary data. For example the land cover map used in this analysis was developed in 1994 and 1996 using SPOT and Landsat data. With the rate of deforestation going on and rampant land conversion, the use of satellite imagery is indispensable in disaster management and mitigation. GPS could be use in ground survey and monitoring and evaluation.
2. **Priority implementation of land use policy and conversion in the identified "hotspots".** We do not need to wait for the land use bill to be ratified. We need to

act now especially in those identified disaster sites. The government should also be aware that in most cases the identified "hotspots" are already inhabited where agricultural crops are planted. Converting these areas to forest cover is not an acceptable solution for subsistence farmers living in the uplands. There is a need therefore to integrate social-agro forestry in ANR planning.

3. **DA-DENR-NDCC-LGU partnership** in project implementation in the identified "hotspots". Developing/rehabilitating "hotspots" areas should be implemented in partnership mode among concerned agencies; sharing of information, responsibilities, and resources is required. One or two government agency alone cannot successfully solve this problem.

4. **Precision disaster management.** Government agencies and institutions that are mandated to create disaster maps, e.g., DOST-PhilVocs for lahar hazards, DENR-MGB for forest fires, DOST-PAGASA for climate, DA for crops, fisheries, and animals, and others. What is needed is to integrate all of the map output into a unified information showing disaster intensity index map. In doing so, planners and policy makers could easily identify geographic areas of disaster coincidence.

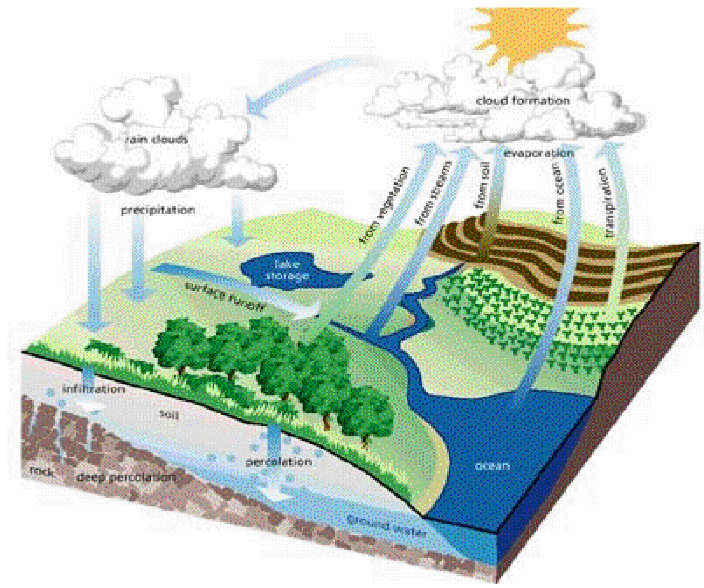
5. **Creating and interagency taskforce for disaster prediction and management**. Under the leadership of the NDCC, each agency responsible for disaster prediction should continuously update their maps using appropriate remotely sensed data and GPS survey. The NDCC on the other hand, should establish a "GIS Based War Room" complemented with competent GIS and technical staff. The NDCC could likewise play a pivotal role as the coordinating body on the various agencies involved in disaster prediction and mapping. GIS solutions should be LGUs centered and community driven which require the integration of societal, biophysical, engineering, demographic, and others. The figure above shows the proposed framework for a GIS based disaster prediction and management.



6. **Increase budgetary allocation in R and D**. While we have solve the problem of "where else" in the country such disaster could occur, the fundamental question now is do we have the technology to solve the problem? This could be only answered through geographically targeted research and development programs. Even the use

of GIS technology for disaster prediction and management and other ANR problems opens to many researchable questions.

7. **Adopt the watershed approach in ANR planning and management**. The watershed management concept should be the focus in disaster planning and management. Land uses activities and upland disturbances result in a set of consequences that can be examined and evaluated within a watershed framework. Upstream activities affect downstream opportunities and problems by influencing the flow of water, sediment and other waterborne materials through the system. The Figure on the right shows the dynamics in watershed that recognizes no political boundaries, a traditional planning domain in resource management, (FAO, 1987).



The fundamental challenge for researchers and planners in a watershed is scale. Because ecosystems are interconnected and interactive, effective rehabilitation efforts should be conducted at a spatial scale that includes all significant components of the watershed. This may pose institutional challenges because watersheds often cross political jurisdictions and include diverse economic and cultural subsystems. Concepts often point out that the watershed approach to area or regional development is usually compromised by political reality. The argument goes that the political boundaries and land holdings seldom coincide with watershed boundaries; and since things get done in terms of political jurisdictions, it makes much more sense to plan and act on the basis of such political boundaries.

8. **Established the national geographic information infrastructure (NGII) and the national geographic information clearing house (NGICH).** So many GIS base maps proliferate in the country. The DA-BAR has the most complete base maps today; its uses however, are presently restricted to research purpose. In addition, there is no unified basemaps for the country, this result to the production of decisions maps in different projection, accuracy, temporal dimension, and others. The NGII and NGICH which could be mandated to create a unified base maps and GIS enabled database to solve this problem. It should first reside under the office of the President and later on with the NAMRIA.

9. **A detailed project proposal should be developed and funded to address the above concerns.** Disaster prediction and management should be national concern, in so doing there is a need to integrate all the proposals generated by concerned

agencies that addresses their specific mandate. The proposals should be unified so that a coherent program for disaster prediction and management in the context of sustainable ANR development could be implemented. The framework suggested in the previous discussions could be a good start.

10. **Political will**. This is the bottom line, paying lip service to disaster management, distributing relief goods, visiting bereaved families are the images we see in newspapers and television sets. What happened in Leyte and Mindanao should served as a wakeup call to our policy makers. They should be proactive and not reactive, coupling this strategy with financial resources is vital to savings lives and costly rehabilitation.

5.3 Department of Agriculture

1. **Greater role of the DA in disaster management.** The DA main responsibility is to its clientele: the farmers and fisher folks. While we are certain that the results of the GIS analysis will stand on its own, there is a need to internalize this into the DA programs and activities. It is agriculture that takes the heaviest toll in every disaster that occurs in the country. Majority of our farmers and fisher folks have there livelihood in low lying areas and they are the recipients or perhaps the causes of landslides and floods. The DA therefore should be engaged in all disaster plans and activities.
2. **The DA should take the leadership** in disaster management as 79 percent of the "hotspot" area is under its jurisdiction. The DA and its attached Bureaus and Agencies concerned in NPAAAD should take the leadership in its jurisdiction but the project and programs should be implemented in partnerships and collaborative mode with the DENR, NDCC, LGUs, NGAs, NGOs, and other stakeholders. Areas of responsibilities have already been geographically delineated, in so doing, turf war could be avoided.
3. **Using geospatial technology** such as RS, GIS, and GPS as a decision support tools in Governance of DA programs and projects. The use of geospatial technologies is now a necessity for the DA and DENR. This could revolutionize the DA role and engagement with farmers and fisher folk. While we have demonstrated the role GIS can play in this project, it can do more. For example, the USDA had adopted GIS technology as there corporate planning tool in all USDA activities.

6. Conclusions

Any type of natural disaster is inherently a spatial-temporal problem, since it occurs in "an area" and in "a period" of time. Disaster management, consisting of several phases such as prevention, preparedness, response and recovery also has a strong spatial component. The importance of GIS for disaster management is relevant in two major aspects: (1) the analytical capability for decision making, and (2) the data integration capacity. Both aspects allow the integrated analysis of large amounts of different data in each disaster phase. The use of GIS for NDM can be graphically represented in three dimensions.

GIS is an ideal tool for disaster modeling owing to its versatility in handling a large set of data, providing an efficient environment for analysis and display of results with its powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world. This paper has demonstrated the ability of the GIS to incorporate the spatially varying data of slope gradient, soil properties, land cover, etc. in disaster prediction. The key factor in NDM mapping is the coincidence of several factors. Though in general, models are available, better interpretation and understanding of the disaster could be derived from them in a GIS environment. A typical hotspot area could then be evaluated in detail at the local level.

Using standard GIS overlay functionality we have examined the relationships between variables such as the base maps used in this study. Now we know that when a certain soil type coincides with a certain degree of slope we have a high potential for landslide and with GIS to show us where this could occur and map this as high risk. This is where we can use expert knowledge within the GIS environment to select combinations of variables which identify high risk areas.

To conclude, GIS and technology can be a catalytic tool that could guide policy makers, scientists, and planners in disaster prediction, mitigation, and ANR management. Use in local governance, GIS technology can leapfrog the Philippines in the 21st century and the disaster in Leyte, and Mindanao can be a thing in the past. Now we know the WHY, WHEN, and WHERE landslide could occur and WHO will be affected: NEVER AGAIN shall our people live in fear of being buried alive in a landslide.

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ACCURACY AND ERRORS ON THE MAPS ARE NOT THE RESPONSIBILITY OF DA-BAR OR THAT OF THE AUTHOR, NOR ARE THE MAPS MEANT TO RESOLVE CONFLICTING POLITICAL BOUNDARIES.

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Steeve completed his Ph.D. degree in August 1998 at Cornell University, Ithaca, New York. His major field is in Environmental Information Science. The tools used in this field are analysis of remotely sensed data, air photo interpretation, geographic information systems, global positioning systems, and environmental modeling. His minor fields are in resource policy and management, rural and environmental sociology, international agriculture, and sustainable development. While at Cornell Steeve, was a graduate teaching assistant for three-resource inventory, GIS, and RS courses in the Department of Soil Crops and Atmospheric Science.

Steeve also completed his M. Sc. degree in 1989 at the Asian Institute of Technology, Bangkok, Thailand. His major field is in Interdisciplinary Natural Resource Development and Management (INRDM), specifically using RS and GIS in ANR.

Steeve work experience is on varietal evaluation of rice and upland crops for intensive rice cropping systems, farming systems, crop-livestock research and integration, land use planning, rural poverty mapping, and community-based watershed management. Steeve work engagement is always in collaboration and partnership with the NARS, NGAs, and NGOs in various countries of South, Southeast Asia, North America, Central America, and Africa.

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