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Asia and the Pacific Symposium

Vulnerability Assessments to Natural and Anthropogenic Hazards

Editors:
Antonio M. Daño, Karen Rae M. Fortus,
Sim Heok-Choh

Extended Abstracts
from the symposium held in
Manila, Philippines
7–10 December 2010

Jointly organized by:
Ecosystems Research and Development Bureau (ERDB)
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Coastal erosion killing degraded mangrove forest

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Acknowledgements

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Appreciations should also be extended to Ms. Belen B. Belina, ERDB Administrative Officer, as well as the other APAFRI and ERDB staff for providing the administrative and secretariat support during the symposium.

KEYNOTE MESSAGE

HON. MANUEL D. GEROCHI
Undersecretary for Staff Bureaus and Project Management
Department of Environment and Natural Resources
Philippines

Dr. Sim Heok-Choh and Representatives from the Asia Pacific Association of Forestry Research Institutions;
Dr. Im Kyun Lee, representing the Korea Forest Research Institute;
Distinguished Guests and Participants from Asia-Pacific Countries;
Representatives from the Department Of Environment and Natural Resources;
Guests, Ladies and Gentlemen;

A Pleasant Good Afternoon to All!

Allow me first to extend my congratulations to the International Union of Forest Research Organizations (IUFRO) and the Asia-Pacific Association of Forest Research Institutions (APAFRI) for jointly crafting this very relevant and timely event. I am deeply honoured to be a part of this "Asia and the Pacific Symposium on Vulnerability Assessments to Natural and Anthropogenic Hazards". Especially so since our very own Department of Environment and Natural Resources (DENR) was tasked to host this symposium. I have noted with much appreciation the collaboration among the Forest Research Institute of Malaysia, the Korea Forest Research Institute, APAFRI, and our Ecosystems Research and Development Bureau (ERDB), the research arm of the DENR, which led to the successful holding of this four-day event in the historical city of Manila.

It will come as no surprise if everyone in this room will admit to being affected one way or another by issues and concerns on climate change. Particularly with the obvious and mostly devastating effects climate change has brought upon different ecosystems worldwide in most recent times. We are also aware that everybody seems to be taking great strides to understand and enhance awareness on this phenomenon. Past presidents and other well-known personalities have joined in to rally peoples towards meeting the challenges of global environmental change.

Somehow we have exposed our vulnerability to this new world order which came about as a result of our indifference to the dynamics of nature in the past many decades. The vulnerability of our ecosystems and life support systems was also brought to fore. Our watersheds and coastal areas, among other ecosystems are on the path of this imminent threat.

Approximately 70% of the land area of the Philippines' 30 million ha are watersheds. The country has a long coastline of over 36 000 km where about 60% of our local governments and communities are located. The Philippines is also along the typhoon path where an average of 20 or so tropical storms venture into our area of responsibility annually. These explain why our country is regularly at the receiving end of numerous disasters through the years.

In 2004, four successive strong typhoons struck the northeastern part of the country with heavy and continuous rains. Massive landslides buried an estimated two thousand residents, not to mention the havoc to crops and properties of the affected communities. The despoliation of the forest and uplands in the area was perceived as the main culprit.

Incidentally on the same year, our neighbouring Asian countries like India, Indonesia, Sri Lanka, and Thailand were shaken by destructive tsunamis created by an earthquake off the coast of Sumatra. Almost a quarter of a million people were lost. Although this phenomenon was not attributed to deforestation, the critical role of mangroves in reducing the impacts of killer waves in coastal areas was revisited.

Exactly a year ago last October, highly urbanized communities in the Metropolitan Manila area and nearby provinces situated along our largest lake and its tributaries experienced the worst flooding in recent history. Entire communities were devastated and isolated after typhoon "Ondoy" poured the equivalent of our annual average rainfall in only six (6) hours of continuous rains. Residents who survived being in the midst of two- or three-storey high raging floodwaters considered themselves very lucky. The floodwaters subsided in many areas only after four to five months, which made the lives of the affected residents quite miserable and for some, hopeless. Another typhoon codenamed "Pepeng" followed immediately and struck the rice- and corn-producing provinces in northern Philippines. Typhoon Pepeng's path was so erratic it made a record landfall three times that further intensified the damage to lives, crops and properties in several large mountain ranges in the region. This harrowing experience also raised concerns on food and water security.

Vulnerability assessment offers a momentary relief in our search for a safe refuge under this state of apparent helplessness. Vulnerability assessment has proven its usefulness in planning our interventions to anticipate, adapt to and confront the multi-dimensional threats of climate change. When applied to watersheds and coastal areas, this useful tool characterizes the inherent biophysical and socio-institutional aspects of these ecosystems and in the process, exposes areas that are susceptible to varying degrees of risks and hazards – erosion, landslides, flooding, water pollution, and biodiversity loss, among others.

Our department's research arm – the Ecosystems Research and Development Bureau (ERDB) and its counterparts in the DENR field offices conducted vulnerability assessment studies in 43 priority and critical watersheds covering an aggregate area of almost one million ha. We have 142 priority watersheds identified nationwide principally for food production and water source for power and domestic uses. The results of the studies will be used in the formulation of integrated watershed management plans which is anchored on a "ridge-to-reef" approach to sustainable development and management and spearheaded by our forest management sector. The results will also guide the concerned local governments and executives in the revision or updating of their respective comprehensive land and sea use plans. This data will also complement the geohazard maps and other related information that we gave earlier for a more thorough understanding of their ecosystems.

Another significant outcome in this endeavour is the formulation of the "Manual on the Vulnerability Assessment of Watersheds". I was informed this manual is now being finalized and would be ready before yearend. Once finalized and distributed, our technical staff, their partner agencies and collaborating organizations would have easy access to a user-friendly guide in conducting vulnerability assessment activities.

Our experience on vulnerability assessment will be shared to all. I strongly believe that by sharing experiences we will learn more about this very important and relevant subject and apply it where it will be most applicable and effective. Through your presentation of country papers, I am confident you will hone further your knowledge and skills on vulnerability assessment and much more. I am therefore hopeful that by Friday when this symposium ends many global environmental problems posed by climate change were covered in your discussions extensively and intensively, including the possible solutions. Consequently upon your return to your respective countries, I will be expecting that you will make a big difference in helping save lives and properties and in keeping our god-given resources more productive and equitable.

I wish everyone a very successful and productive symposium as well as an enjoyable stay in Manila.

THANK YOU AND *MABUHAY*!

Address for
Asia and the Pacific Symposium – Vulnerability Assessments to Natural and Anthropogenic Hazards

Dr. Abd Latif Mohmod
Director General, Forest Research Institute of Malaysia
&
Chairman APAFRI

Good afternoon, Ladies and Gentlemen:

On behalf of APAFRI, I would like to welcome all of you to this Asia and the Pacific Symposium with the theme: Vulnerability Assessments to Natural and Anthropogenic Hazards, here in Manila, the Philippines.

I would like to thank the Ecosystems Research and Development Bureau, Philippines, for hosting this symposium here. Many of you are aware that the fund for organizing this workshop is a portion of the Korean Government's contributions to the International Union of Forest Research Organizations (IUFRO). Since 2007, the Korean Government, through the Korea Forest Research Institute (KFRI), has allocated a portion of its contributions to IUFRO for activities to be carried out in the Asia Pacific for forestry practitioners of this region. APAFRI is honoured to be entrusted with the responsibilities of managing this portion of the fund. APAFRI has used the 2007 allocation for partially financed the International Conference on Traditional Forest-related Knowledge in Kunming China, the 2008 allocation for organizing an Asia Pacific Forest Health Workshop in Kuala Lumpur, and the 2009 allocation for an Asia Pacific Forest Products Workshop in Sri Lanka. Proceedings for these three events have already been published by IUFRO as IUFRO World Series Volumes 21, 24 and 27.

Ladies and Gentlemen:

Allow me to take this opportunity to briefly introduce APAFRI. APAFRI stands for Asia Pacific Association of Forestry Research Institutions. APAFRI's role is to act as a catalyst, facilitator, and information hub for forestry research in the Asia Pacific region. APAFRI aims to promote and assist in the development of the region's scientific research and development culture and capacity and to foster the establishment of institutional and professional collaborations among the region's forestry researchers. APAFRI's activities support sustainable management and utilization of forest resources at the local, national and regional levels. As of November this year, APAFRI's membership totalled 65 forestry research institutions, and 8 individual members. Most of the national research institutions and many universities in the region from Korea to Pakistan, and from China to Australia are members of our Association. Many of the participants present here today are staff members of active member institutions in APAFRI.

The establishment of APAFRI was prompted by the need to provide a viable institutional framework for research collaboration in the region. APAFRI was formally launched in Bogor, Indonesia in 1995 during a regional meeting of heads of forestry research organizations in the Asia Pacific. We have the Fifth General Assembly October last year, which has elected a new Executive Committee, chair by me, which would manage APAFRI activities for the next three years.

We are especially grateful to member institutions such as ERDB. When we were seeking partners to host an activity to utilize the funding from the Korean Government through the

Korea Forest Research Institute early this year, ERDB responded by suggesting to host this symposium. As the Secretariat is of limited capacity and capability, this offer had lifted a heavy burden off our shoulders. APAFRI is continuously looking for opportunities to jointly develop programmes and services for its membership and alliances. We would like to seek more cooperation and collaboration from you all, members and non-members, to assist us in servicing the forestry sector in the Asia Pacific Region better in future.

Thank you.

Overview of the Symposium

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The Asia and the Pacific Symposium on Vulnerability Assessment to Natural and Anthropogenic Hazards was held at the Traders Hotel, Manila, Philippines, 7–10 December 2010. It was jointly organized by the Ecosystems Research and Development Bureau (ERDB) and Asia Pacific Association of Forestry Research Institutions (APAFRI). Financial support was from the Korea Forest Research Institute (KFRI), through its contributions to the International Union of Forest Research Organizations (IUFRO).

The main objective of the symposium was to further enhance the capability and capacity of participants in conducting vulnerability assessment of various ecosystems. It served as a venue for exchange of knowledge and initiatives in vulnerability assessment. The symposium was also expected to come up with output materials that will be useful in preparing appropriate programmes/projects to deal with the inherent biophysical and socio-institutional characteristics of ecosystems and the stressors of the resources including the impacts of climate change.

The symposium was divided into three themes:

- Applications and Models
- Vulnerability Assessment of Coastal Zones
- Vulnerability Assessment of Watersheds
    - Soil erosion/landslide/flood/fire
    - Biodiversity loss/pollution

A total of 24 papers were presented, including keynote presentations of Dr. Rex Victor Cruz on vulnerability assessment of watersheds and Dr. Khali Aziz Hamzah on vulnerability assessment of coastal zones. The detailed programme is presented in Appendix I. The symposium brought together a total 45 local and international researchers, academicians and scientists from 14 countries across the Asia Pacific region.

Presentations

Keynote Presentations

Dr. Rex Victor O. Cruz, Dean of the College of Forestry and Natural Resources (CFNR), University of the Philippines at Los Baños, College, Laguna gave a presentation on "Watershed-based V&A assessment for Forestry/Biodiversity Sector." He emphasized importance of using the river basin approach in vulnerability assessment. Said approach promotes comprehensive and integrated development in terms of adaptation planning and mainstreaming of climate adaptation

Dr. Khali Aziz Hamzah, Programme Head of Geoinformation Program of Forestry Research Institute Malaysia (FRIM), presented his study on "Vulnerability assessment of coastal zones using geospatial technologies." The paper deals on analyzing and predicting the vast coastal zone areas at a landscape level and the use of geospatial technologies in the vulnerability assessment of coastal zones.

Symposium Presentation Themes

Theme 1: Models and Applications

1. Development and Application of a Geospatial-based Environmental Vulnerability Index for Watersheds to Climate Change in the Philippines
2. Incorporating Vulnerability Assessment Principles into the Integrated Strategic Environmental Assessment of the Northern Province of Sri Lanka
3. Vulnerability Assessment for Integrated Development of Natural Resources on Watershed Basis in Drought Prone Areas of Andhra Pradesh, India
4. Modelling Drought Hazard, Vulnerability and Risk: A Case Study of Bangladesh -
5. Analytical Framework on the Vulnerability of Rural Development in Semi-arid Area of Northern China: Assessment on the Scale of Community

Theme 2: Vulnerability Assessment of Coastal Zones

1. An Assessment of Stand Structure and Carbon Storage of a Mangrove Forest in Thailand
2. Adaptation Responses to Coastal Perturbations: The Case of Prieto Diaz and Baler Coastal Dwellers in the Philippines
3. Federated States of Micronesia Atoll Islands Climate Change & Food Security Vulnerability Assessment
4. Climate Change Adaptation and Vulnerability at Community Level in Indonesia

Theme 3: Vulnerability Assessments of Watersheds

A.) Soil erosion/landslide/flood/fire

1. Soil Organic Carbon Loss Through Soil Erosion in Agro-ecological Zones of Merek Catchment, Iran
2. Soil Erosion and Landslide Vulnerability Assessment of Mananga Watershed, Cebu, Philippines
3. Vulnerability Assessment of Cugman River Watershed
4. Assessment of the Vulnerability to Landslide of Lower Allah Valley Sub-Watershed at Mindanao, Philippines
5. Assessment of Flood and Landslide Vulnerability for Watershed Management Plan at Grindulu Watershed, Pacitan District, Indonesia
6. Landslide and Fire Vulnerability Assessment of Bued River Watershed within the Province of Benguet, Philippines
7. Development of Indicators for Assessing Susceptibility of Degraded Peatland Areas to Forest Fires in Peninsular Malaysia
8. Vulnerability Assessment to Biodiversity Loss: A Case of Western Himalaya of Nepal
9. Climate Variability Effects on Queensland's Vegetation Net Primary Productivity: An Analysis of 200-2006 MODIS Satellite Imagery
10. Wood-boring Beetle Communities in Korea White Pine Forest and its Implications to Ecosystem Vulnerability under the Influence of Climate Change
11. Effects of Fast-growing Trees on Pollution Level of Watershed Affected by Acid Mine Drainage from Abandoned Coal Mine
12. Climate Change Vulnerability and Household level Adaptation: A Study on forest dependent communities in Drought Prone area of West Bengal, India
13. Vulnerability and Adaptation Capacities of Agricultural Systems to Climate Change Threat

Posters Presented

1. Evaluation of Wind Throw Risk Due to Thinning (Japan)
2. Case Presentation on Peatland Management of Campaign Peat Dome (Philippines)
3. Participatory Climate Change Vulnerability Assessment and Capacity Analysis of Communities in Cavite, Luzon, Philippines (Philippines)
4. Vulnerability Assessment of Mt. Makiling Watersheds in Laguna (Philippines)
5. An Analysis of Natural and Anthropogenic Hazards and Vulnerabilities of Bito River Watershed, Masbate Using Geographic Information System (GIS) (Philippines)
6. Biodiversity Conservation in a Changing Climate: Role of Tribal Communities in Conserving Medicinal Diversity in the Tropical Forests of Central India (India)
7. Streamflow and Water Quality Assessment of Acid Mine Drainage Affected Tributaries of Taft River in Samar Island, Philippines (Philippines)
8. Adaptation Strategies to Climate Perturbations on Coastal and Agroforest Ecosystems in Eastern Philippine Seaboard (Philippines)
9. Biomass and Carbon Storage of Selected Mangrove Forests in the Philippines (Philippines)
10. Rapid Earthquake Damage Assessment System (REDAS) Software: A Risk Assessment Freeware Tool for Philippine Communities (Philippines)
11. Phytoremediation Potential of Selected Species in Acid Mine Drainage (AMD) Affected Raft River Watershed (Philippines)
12. Biomass and Carbon Sequestration of Mahogany and Narra Trees in National Power Corporation – Managed Watersheds (Philippines)

Vulnerability Assessment of Coastal Zones Using Geospatial Technologies

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Coastal zone in Malaysia is defined as comprising of an onshore component which has an inner landward limit 5km from the coastline (shoreline), and the offshore component which the seaward limit is the Exclusive Economic Zone (EEZ) (200 nautical miles from the shoreline). These costal zones are endowed with a rich diversity of living and non-living resources and a crucial segment of the nation's overall economy as well as her environmental well being and social order. Coastal zones are subjected to the impacts of long-term hazards such as chronic coastal erosion, potential sea-level rise, and global climate change. Coastal erosion may lead to ecosystem destruction and need to be assessed and monitored to prevent ecosystem degradation and economic loss to the nation.

In Malaysia it has been reported that more than 70% of the coastline is facing erosion in some states especially in Kelantan, Perlis and Selangor, as well as Sabah and Sarawak (NRE 2008). The local Drainage and Irrigation Department (DID) has listed 223 stretches of the coastline as being eroded, which made up 1,414 km of coastal fringe (Abdul Manan 2006). The sea level rise as a result from the climate change was identified as one of the factors leading to coastal erosion (Brunn 1962). On average it has been estimated that a 1 cm rise in sea level erodes beaches about 1m horizontally. In reality this figure varies based on the profile both of the beach and of the offshore waters over a considerable distance (Glazer 2006). Rising sea levels will further reduce friction from the underlying sediments, increasing the impacts of storm surges. This influence will clearly affect coastal development, coastal agriculture, and, importantly, coastal ecosystems including beaches, mudflats, and mangrove forests.

Even though an accurate and quantitative approach to predicting coastal change is difficult to establish, various attempts have been made to understand how a natural or modified coast will respond to sea-level change. There are several studies that focus on the changes of mangroves forests (for instance Abdul Samad 1998, Manassrisuksi *et al.* 2001). However, only a few of them have attempted to look at the perspective of coastal erosion effects on mangroves forest, especially by using remote sensing and GIS technologies. This study focuses on the prediction of the future impacts due to coastal erosion and sea level rise to the mangrove forest along the coast of Selangor. The objectives of the study are: (i) to estimate rate of erosion on the mangrove areas in the coast of Selangor; and (ii) to determine Coastal Vulnerability Index (CVI) due to sea-level rise at mangrove areas in the study area. A CVI is a map used to indicate the relative vulnerability of the coast to future sea-level.

Methodology

The study area is Selangor, one of the states in Peninsular Malaysia, that has about 90km length of coastline and almost 60% of it is covered with mangrove forest (Ong *et al.* 1991). According to the assessment made by Khali Aziz and Hamdan (2008), the extents of mangrove in Selangor reach up to 19,456.12 ha in 2007. The mangrove on the average has a width of 1.5–2 km.

There are three types of data used in this case study: satellite data (Landsat TM, and SPOT-5 XS), field observation data and supporting data. While the satellite images were used as the main input for CVI computation, a site investigation was carried out from 28–31 July at 18 selected locations to verify the results and to investigate severity of the erosion.

This study involved several processes, which can be generalised into three major parts: (i) image classification – to map the extents of mangrove areas, (ii) derivation of CVI variables, and (iii) CVI spatial modelling and mapping. The CVI ranks the followings in terms of their physical contribution to sea-level rise related coastal change: geomorphology, regional coastal slope, rate of relative sea-level rise, shoreline change rates (in this case, mangrove erosion rate), mean tidal range and mean wave height (USGS 2001, Hammar-Klose 2003). The rankings for each variable were combined and an index value calculated for highlights regions where the physical effects of sea-level rise might be the greatest. A CVI model which focuses on six variables which strongly influence coastal evolution, shown below was used (Hammar-Klose 2003):

$$CVI = \sqrt{\frac{(a*b*c*d*e*f)}{6}}$$

Where,

a = geomorphology
b = coastal slope (%)
c = relative sea-level rise rate (mm/y)
d = shoreline erosion/accretion rate (m/y)
e = mean tide range (m)
f = mean wave height (m)

Each variable was next assigned a relative vulnerability value from 1–5 (1 is very low and 5 is very high vulnerability) based on the potential magnitude of its contribution to physical changes on the coast as sea level rises.

Results and discussion

For the purpose of examination of data and information that have been collected, CVI was calculated for the coast of Kuala Langat, a district in the south of Selangor. The total length of Kuala Langat coast is about 48.73 km in which 41.57 km of the stretch is covered by mangroves. This area has been recognised as an area experiencing serious coastal erosion, especially along the belt of mangrove forest.

From the spatial modelling, CVI was produced for Kuala Langat district. From the total mangrove stretch along Kuala Langat coast, five relative coastal vulnerability categories were mapped as shown in Figure 1. This vulnerability is based on the calculated CVI ranks and is considered to be sensitive to the future sea-level rise. The impacts of the relative vulnerability were identified and verified from the site investigation. One of the main factors that contribute to the erosion is variation in coastal slopes. It is also affected by the extent of mudflat/tideflat at certain zones along the coast. The width of tideflat influences the rate of erosion in mangrove forest, in which the wider the tideflat, the lower the erosion impacts and vise versa. The tideflat acts as barrier to the mangroves that slowing down the wave actions and thus minimizes erosion.

Figure 1. Coastal Vulnerability Index to future sea level rise for the coast of Kuala Langat.

Conclusion

Various changes have been occurring in the physical features of the shoreline bordering mangrove. The mangrove is undergoing severe erosion. If this rate of erosion continues, mangrove will soon be exposed directly to the sea, where the wave action is high. This may result in the uprooting of trees that are exposed to high energy of wave. The coastal vulnerability index (CVI) for the Kuala Langat coast provides insight into the relative potential of coastal change due to future sea-level rise. This study indicates that information from remote sensing data together with other supporting data can be utilized to model the CVI and predict the future impacts to the mangrove ecosystem.

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Development and Application of a Geospatial-based Environmental Vulnerability Index for Watersheds to Climate Change in the Philippines

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Climate change has become a common concern by many countries across the globe. Over the past two decades, several studies have revealed changes in the global mean temperature at different reference periods. However, an increase of 0.6 ^{0}C above the pre-industrial levels in the 1990-2000 period are believed to be the best estimate of warming in the 20th century (Folland *et al*. 2001, IPCC 2007a). In fact, 11 of the 12 warmest years since 1850 were observed between 1995 and 2006 (IPCC 2007b). Atmospheric concentration of carbon dioxide (CO_2) has also increased from 278 parts per million (ppm) during the pre-industrial period to 379 ppm in 2005 (Rogner *et al*. 2007).

In the Philippines, climate change is becoming more evident as well. Based on the historical records of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), there has been an increasing trend in the number of hot days and warm nights in the archipelago over the last 40 years. The most destructive typhoons that caused severe damage to properties, agricultural crops and lives were also observed in the past two decades. The magnitude of these problems has become even worse in upland areas of the country where scarcity of resources and lack of coping mechanism are also prevalent. Hence it is important to have sufficient information on vulnerable regions so that effective and efficient management could be made and that limited resources could be optimized. This study is mainly focused on the development of a geospatial-based environmental vulnerability index for watersheds and related ecosystems to climate change in the Philippines. The results from the assessment can also be used to aid in the creation of a comprehensive mitigation and adaptation framework for the area. At the same time, this can be utilized to facilitate policy formulation and advocacy pertinent to problems associated with climate change.

Methodology

The model is called the Geospatial-based Regional Environmental Vulnerability Index for Ecosystems and Watersheds or in short, the GeoREVIEW model. Vulnerability in the model is defined based from the assessment report of the Intergovernmental Panel on Climate Change (IPCC) that referred to it as "the degree to which a system is susceptible to and is unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007a). GeoREVIEW is comprised of 21 indicators that are classified under three different components namely: exposure, sensitivity and adaptive capacity. Each indicator can also be categorized as a hazard, damage or resistance indicator. A scale of 1 to 5 is also developed to emphasize the degree of vulnerability for each indicator, 1 being the most resilient and 5 being the most vulnerable.

The threshold levels were determined using the Kolmogorov-Smirnov (K-S) statistical test or by using existing spatial-based methods and indices. The K-S test was used for most of the indicators in the model and it utilized four types of dataset to determine whether the data is normally distributed or not. These include the raw data and three data transformation methods (e.g. square root, natural logarithm and inverse or reciprocal). A significant value which. is less than 0.05 in the K-S test would mean deviation from normality otherwise it implies that the distribution of the samples is normal. The other indicators, on the other hand, were assessed using existing spatial-base methods and indices such as the Shannon-Weiner diversity index, the Strahler's method, the Normalized Difference Vegetation Index (NDVI), the Potential Biomass Density Index (PBDI), the Revised Universal Soil Loss Equation (RUSLE) and the Human Development Index (HDI), among others.

The model also generates an overall vulnerability point (OVP) to describe the classification level of the watershed or ecosystem in terms of its vulnerability to climate change. The OVP is evaluated from the cumulative weighted scales given for all the indicators divided by the maximum scale then multiplied by 100. Table 1 specifies the general classification and category of the overall vulnerability assessment of the watersheds to climate change using the computed OVP.

Table 1. Overall vulnerability classification system in the GeoREVIEW model.

Category	**Classification**	**Overall Vulnerability Point**
5	Highly Vulnerable	>90
4	Vulnerable	70 – 90
3	At Risk	50 – 70
2	Low Risk	30 – 50
1	Resilient	< 30

The GeoREVIEW model also provides an avenue to evaluate some policy-relevant issues associated with climate change. These measures are termed sub-indices. However, these sub-indices are mainly limited to problems related to natural disasters and the environment that normally beset most of the watersheds in the country. These are floods, drought, biodiversity loss, and erosion and landslides. The overall vulnerability classification in Table 1 is also used as reference to evaluate the sub-indices in terms of their severity and extent in the area.

Results and discussion

The results of the statistical test and reviews of existing spatial-based methods and indices are summarized in Table 2. It provides the threshold levels assigned in all scale categories for each of the indicator, the aspect of vulnerability and sub-indices associated with the indicators, and the unit of measurement. With this information, one can assess the vulnerability of various watersheds and related ecosystems to climate change in the Philippines. Comparative analysis could also be made using this method across vulnerable regions so that optimization in the allocation of resources among different watersheds can be achieved.

Table 2. Summary of all indicators in GeoREVIEW model.

Indicator	Aspect	Sub-Index	Unit	Scale 1	2	3	4	5
				Exposure Component				
Wet Season	Hazard	E, F	mm yr^{-1}	<286.7	286.7-430.7	430.7-646.9	646.9-971.7	>971.7
Dry Season	Hazard	D, E	mm yr^{-1}	<349.7	349.7-535.8	535.8-721.9	721.9-908.1	>908.1
Minimum Temperature	Hazard	B	$^0C\ yr^{-1}$	<0.20	0.20-0.60	0.60-1.40	1.40-2.99	>2.99
Maximum Temperature	Hazard	B, D	$^0C\ yr^{-1}$	<0.19	0.19-0.53	0.53-1.16	1.116-2.35	>2.35
Maximum Wind	Hazard	B, E	km $hr^{-1}yr^{-1}$	<11.26	11.26-23.50	23.50-40.21	40.21-61.37	>61.37
Elevation	Resistance	B, F	masl	>2393	1853-2393	1313-1853	773-1313	<773
Watershed Area	Resistance	B	ha	>16153	2241-16153	311-2241	43-311	<43
				Sensitivity Component				
Channel Size	Resistance	E, F	order	≥5	4	3	2	1
Landuse Change	Damage	B, D, E, F	% cover	>2	0-2	0	0--2	<-2
Threatened Species	Damage	B	no. of species $100km^{-2}$	0	0-5	5-10	10-15	>15
Biodiversity	Damage	B	H' value	>2.0	1.50-	1.0-1.50	0.5-1.0	<0.5

Indicator	Aspect	Sub-Index	Unit	Scale				
				1	2	3	4	5
Exposure Component								
					2.0			
Ecosystem Greenness	Damage	B, D	NDVI value	>0.4	0.3-0.4	0.2-0.3	0.1-0.2	<0.1
Biomass Potential	Resistance	D, E	PBDI value	85-100	70-85	55-70	40-55	<40
Erosion Potential	Hazard	B, E	ton ha^{-1} yr^{-1}	0-1	1-12	12-35	35-60	>60
Adaptive Capacity Component								
Human Development	Resistance	B, D, E, F	HDI value	>0.74	0.68-0.74	0.62-0.68	0.56-0.62	<0.56
Population Growth	Damage	B, E	% growth	<0	0	0-0.62	0.62-1.74	>1.74
Population Density	Damage	B, E, F	person km^{-2}	<127	127-308	308-633	633-1217	>1217
Number of Tourists	Damage	B, E, F	person km^{-2} yr^{-1}	<25	25-66	66-147	147-383	>383
Road Density	Damage	B, E	m ha^{-1}	<1.44	1.44-1.74	1.74-2.18	2.18-2.93	>2.93
Vegetation Cover	Resistance	B, D, E, F	land cover	forest	brushland	agroforestry	grassland	bare/ built-up
Soil Quality	Resistance	E, F	%OM	>4	3-4	2-3	1-2	<1

Note: Policy relevant sub-indices include biodiversity loss (B), drought (D), erosion and landslide (E) and flood (F).

This developed index could then be used to evaluate the vulnerability of the Mt. Makiling Forest Reserve (MFR) to climate change. MFR is a potential carbon sink located around 65 km south of Metro Manila. The reserve was established in 1910 and its management was only transferred to the University of the Philippines Los Baños in 1960, mainly for purposes of education and research. Based on the evaluation of the site, MFR generated an overall vulnerability point (OVP) of 57.30 that classified the reserve as “at risk” level. The results can be utilized further as inputs to developing a comprehensive and integrated framework for mitigation and adaptation strategies on climate change.

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Incorporating Vulnerability Assessment Principles into the Integrated Strategic Environmental Assessment of the Northern Province of Sri Lanka

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After many years of conflict and economic embargo, the Northern Province of Sri Lanka is opening up for rapid development and the government has launched a significant drive targeting resettlements, poverty reduction, and fast- track development. In order to facilitate and strengthen this development process and preserve the environmental and cultural heritages of the province, it was decided to carry out an Integrated Strategic Environment Assessment (ISEA) by incorporating the vulnerability assessment concept, specifically analyzing the conditions that are stressing the environmental resources.

The Northern Province covers about 14% of the total land mass of Sri Lanka. Its total extent, around 8,848 km^2 including Jaffna Peninsula and its isles, consists of five districts namely: Jaffna, Kilinochchi, Mullaitivu, Vavunia and Mannar. The province's population was estimated to be 1.3 million in 2007, or around 7% of the total population. The majority of the population are Sri Lankan Tamils, with a minority Sri Lankan Moor and Sinhalese population. Sri Lankan Tamil is the major language spoken in the province. After a 30-year long conflict that was centered around the northern and eastern provinces, the Sri Lankan government defeated the Liberation Tigers of Tamil Ealam (LTTE) in May 2009. During the three decades of conflict, the province was held back in terms of economic progress and human development. Recent surveys show high poverty levels (of around 37%) when the national average is around 15%. During the years 2005–2007, the share of Northern Province in total GDP was a mere 2.9%. With the end of conflict the government has launched a significant drive targeting resettlement, poverty reduction and fast-track development of the Northern Province. The Northern Spring 3-year development plan targets large infrastructures such as roads, railways, schools, hospitals, urban centers; as well as social development, livelihood enhancement, human settlements and revitalizing productive sectors. The Northern Province is rich in natural resources in its extensive coastal area, in its dense forests, and mineral deposits. Forests resources are largely intact due to many decades of conflict and the forest cover accounts to 50.7% of the total land area of the province (Forest Department 2009). From extensive sand dunes in Jaffna Peninsula, to quarry metal and clay for bricks the province is especially rich in mineral resources needed for construction.

Methodology

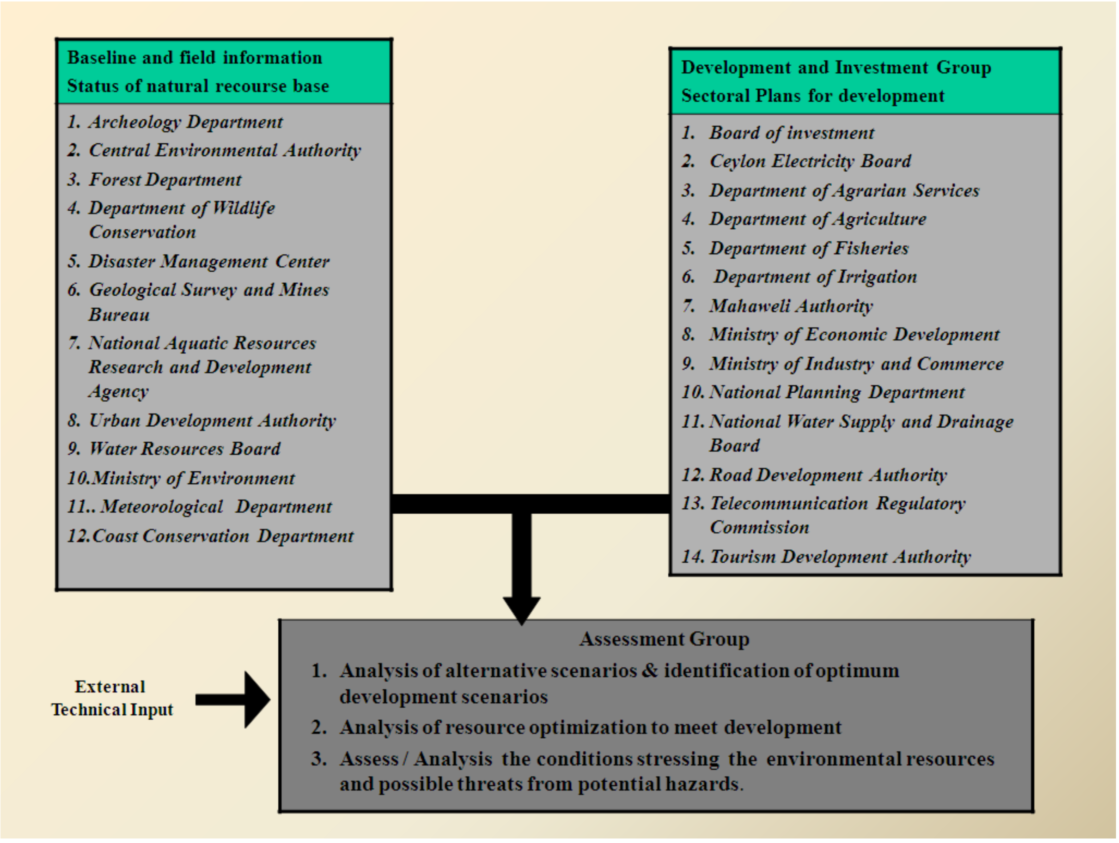
The process developed by Conner (2009) was adopted for this exercise. The process involves the production of a series of 'Opportunity Maps' with available data and with information gathered in the field studies. These maps will initially be produced with available information on natural/cultural resources of the Northern Province (MAP 01). In the next step, Information on current and proposed development plans will over- lay the resource information verified through field work (MAP 02). The final opportunity map (MAP 03) provides the basis for the spatial analysis of natural resources availability, extraction capacity and development/investment proposals to ensure optimum use of resource base to support the rapid and sustainable economic development of the Northern Province. During the production of the first Opportunity Map, only conservation-oriented agencies were involved. In order to address disaster risk reduction aspects and to assess the conditions that are stressing the environmental resources, information/data on possible threats from potential hazards were used in preparation of the MAP 01 and also further analyzed by the Assessment Group with the assistance of the working group for conservation-oriented agencies, while finalizing the last Opportunity Map.

The Integrated Strategic Environment Assessment (ISEA) is an advanced version of the Strategic Environmental Assessment (SEA) process involving more data integration and stakeholder inputs. Due to the broad nature, a SEA is performed using existing data. In contrast, an ISEA may collect additional data sometimes in the field and also engage multiple stakeholders to find solutions to emerging concerns (Central Environmental Authority 2010).

The unique feature of this ISEA for Northern Province of Sri Lanka is that it was carried out with the active participation of all relevant government agencies; both conservation-oriented agencies as well as development-oriented agencies. Objectives of this northern ISEA are:

- Facilitating development programmes of the Northern Province without undue problems and delays by identifying freely available land for development at an early stage, in order to prevent conflict situations arising at a later stage;
- Identification of environmentally sensitive areas that require protection;
- Finding solutions to environmental issues with integration of the disaster risk management in the Northern Province; and
- Finding solutions to resource limitations such as water and construction materials.

Figure1. Structure of the ISEA.



During the baseline phase, the collation of resources data, combination of different data layers and prioritization were carried out. During the development phase, identification of development needs and scenario development were done by the development agencies as an integrated exercise. During the assessment stage, conflict identification, analysis of alternative development scenarios, analysis of resources optimization and assessment of conditions stressing the environmental resources were conducted. Most importantly the necessary mitigation measures, and monitoring and review measures, were also addressed.

It is increasingly recognized that the conservation of some natural resources cannot happen without providing alternative livelihood solutions for local communities dependent on them. Global experiences illustrate that the successful integration of conservation and development continues to be elusive (Stevens 1997, Brechin *et al.* 2003). Therefore, most viable livelihood options and the priorities of the local communities are strongly considered throughout the process.

Results, discussion and recommendations

The ISEA for Northern Province has provided a number of useful outputs needed for policy makers, natural resources managers and development agencies. These outputs include: Opportunity Map of resource availability and development needs, alternative scenarios for resource optimization, planning tools for district and local government based on the new information, final maps of areas that could be developed and should be protected, and recommendations for sustainable development of the area. Exercise has also produced a mitigation plan and a monitoring plan to reduce development stress upon natural resources. The mitigation plan and monitoring plan specifically addressed the possible vulnerabilities or threats from potential hazards to the population and to the infrastructure development. In addition to that, the material needed for awareness and education programmes were also developed.

This integrated exercise reveals that the Integrated Strategic Environmental Assessment conducted for the Northern Province has created space for greater engagement of all stakeholders in a process of informed decision-making on the sustainable use of the natural resource base for accelerated development. It also provides tools for planning and long-term monitoring of the quality and quantity of natural resources in the region and help planners to address even the broader issues such as climate change adaptation. Finally, it is concluded that this process could be effectively adopted in making decisions in sustainable use of the natural resources for any major development scheme with a short period of time in an integrated manner.

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Vulnerability Assessment for Integrated Development of Natural Resources on Watershed Basis in Drought Prone Areas of Andhra Pradesh, India

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Watershed development programmes are important instruments in revitalizing rural economy in highly drought prone rain-fed regions of Andhra Pradesh, the fifth largest state in India. However, it is noticed that there is a huge imbalance in development of the natural resources and their extraction due to demographic and socio-economic pressures, monsoonal disturbances, and over exploitation of ground water and forests. The groundwater depletion has reached alarming levels with about 30% groundwater basins placed under Over exploited, Critical and Semi-critical categories. Households falling below poverty line and marginally above poverty line became vulnerable to marginal changes in environment (CESS *et al.* 2003, Vijaya Kumar *et al.* 2009, MANAGE 2008). Keeping the above in view, Government of India proposed to treat 17 450 micro watersheds covering 11.038 million ha in a span of 18 years with a financial outlay of $ 3.4 billion under an integrated watershed management programme (IWMP) in Andhra Pradesh (AP) from 2010–11 onwards. The drought vulnerability assessment study done in the above context analyzes drought frequency, trends, distress responses, causes of vulnerability, capacities lacking with the communities, and gaps in the government policies, so as to plan adaptation responses, capacities of the communities and measures needed for those adaptations.

Methodology

The demographic, physiographic, hydro-meteorological, socio-economic, technological, environmental, and political indicators were studied through situational analysis that include climate change Impact Matrix and Drought Vulnerability Assessment Matrix. Relevant government records and research studies were referred to for secondary data and primary data was collected through focus group discussions with various stakeholders. Weightages were given to vulnerability indicators for selection of project area and project proposals were prepared based on the study inputs.

Results and Discussion

The ten-year analysis of rainfall data revealed that 12 drought prone districts of AP suffered from below-average rainfall with no access to large scale surface irrigation, and there was 40% chance of drought year occurrence with reduction in crop yields by 29–62% over normal production. Future projections also suggested high uncertainty of precipitation and increased vulnerability, especially from November to May.

About 80% of the farmers are small and marginal farmers and 13% households are women headed. Low productivity of agricultural lands, degradation of common land due to increased grazing intensity, low investment capacity due to low per capita income, and low livestock productivity due to fodder non-availability, were some important features. Ground water irrigation ranged between 60 to 70% of total irrigation, hence overtaxing the groundwater resources. Quality and quantity of drinking water got adversely affected in drought years. Vulnerability increased due to cultivation of high water consuming crops, mono cropping, high cost of inputs (seed, fertilizers and pesticides), seed non-availability and dependency on groundwater irrigation. The distress responses consisted of reduced expenditure on nutrition, sale of assets including livestock, migration, debt trap, and suicide in extreme cases.

During 2009–10, 281 watershed projects (each with net area of 1000 to 5000 ha after excluding assured irrigated area) spreading over 1.21 million ha covering 1956 villages were identified by considering 11 important vulnerability indicators (Table 1).

Table 1. *Criteria and weightage for selection of Cluster watershed*

Criteria	Ranges and scores (figures in brackets)			
% of people below poverty line	> 80 % (10)	80 to 50 % (7.5)	50 to 20 % (5)	< 20 % (2.5)
% of disadvan-taged people	> 40 % (10)	20 to 40 % (5)	< 20 % (3)	
Actual wages	Actual wages are < minimum wages (5)	Actual wages = minimum wages (0)		
% of small and marginal farmers	> 80 % (10)	50 to 80 % (5)	< 50 % (3)	
Groundwater status	Over exploited (5)	Critical (3)	Sub critical (2)	Safe (0)
Moisture Index	-66.7 & below (15)	-33.3 to -66.6 (10)	0 to -33.2 (0)	
Area under rain-fed agriculture	> 90 % of total cultivated area (15)	80 to 90 % (10)	70 to 80% (5)	< 70 % (Reject)
Drinking water	No source (10)	Problematic village (7.5)	Partially covered (5)	Fully covered (0)
Degraded land	> 20 % of Total Cultivated Area (15)	10 to 20 % (10)	< 10 % (5)	
Land Productivity	low (15)	moderate (10)	high (5)	
Contiguity	Yes for both previously treated Watersheds (WSs) and Project Area (PA)..(10)	Yes for PA but no to previously treated WSs (5)	No for both previously treated WSs & within PA (0)	
No. of WSs in clusters	> 6 (15)	4 to 6 (10)	2 to 4 (5)	
Total	**135**	**80**	**36**	**2.5**

Watershed project planning

Systematic analysis of the entire surface drainage area was done by using GIS and other data sets for demarcating hydro-geological units on 1:50 000 integrated base maps showing drainage, village boundaries and forest areas at project level. Cadastral maps of 1:7920 scale were used for village level planning along with information on soils, forest areas, plantations, existing water harvesting structures and well inventory with GPS coordinates, remote sensing imagery with 5.8 m or 2.5 m resolution. Baseline survey information (GOAP 2009) was recorded for measuring and comparing the actual outcomes with expected outcomes to know the impact (improvement in water table, drinking water quality and availability, irrigation potential, cropping/landuse pattern, area under single-/double-/multi-cropping, milk production, annual income, area under horticulture, fodder and fuel wood). Detailed project reports were prepared through participatory net planning, and action plans covering drought adaptation initiatives comprising of natural resource management and livelihoods aspects (with emphasis on equity and empowerment) were proposed for implementation during the five years from 2010–11 onwards. Besides the above, training and capacity building activities for stakeholders and monitoring mechanisms at various levels were also incorporated in the plans.

Recommendations

Uncultivable, cultivable and marginal wastelands located in the ridge part of the watershed, mostly under ownership of the poor, are the source of surplus run-off and soil erosion. These farmers are caught in debt trap due to lack of resources, crop bore failure, and faulty agronomic practices. Since laying focus on the above lands is very essential, farming system based management of natural resources coupled with capacity building of the farmers requires immediate attention. Common property resource management duly addressing the usufruct rights is required for livestock management by the landless poor. Convergence of activities at various levels is important for providing access to the resources, enhancing the livelihoods, assets maintenance and creating enabling environment. Besides the above, giving the community a stake in monitoring the critical information such as rainfall data, and enhancing their ability in managing the watershed management processes would add to the value of overall project for vulnerability assessment and preparedness.

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Modeling Drought Hazard, Vulnerability and Risk: A Case Study of Bangladesh

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Drought is known as a deficiency of rainfall over a period of time within a geographic area resulting in a water shortage for some activity (Wilhite *et al.* 1987). Drought is a slow onset creeping phenomenon which has serious economic, environmental, and social impacts; and affects more people than any other natural hazard. In the context of global warming, most of the climatic models project a decrease in precipitation in dry season and an increase during monsoon in south Asia (IPCC 2007). This will cause a cruel combination of more extreme floods and droughts in the region. Many countries of South and Southeast Asia have already experienced an increased frequency of droughts in recent years. As drought is a recurring natural phenomenon, it cannot be prevented. Adaptive planning is necessary to cope with droughts through the analysis of their regional characteristics, vulnerability and risk. The aim of the present study is to model the spatial and temporal pattern of drought hazards, identify the vulnerability of various geographic populations to the impact of droughts and mapping drought risk zones of Bangladesh. Since its independence in 1971, Bangladesh has suffered from nine droughts of major magnitude (Shahid 2008). An analysis of the relative effects of flood and drought on rice production in Bangladesh indicates that drought is more devastating than floods to aggregate production. Therefore, initiative to reduce drought impact in Bangladesh is necessary for sustainable development of the country especially in the context of global climate change.

Methodology

For better understanding of droughts, it is necessary to characterize them by their duration, frequency and severity. Standardized Precipitation Index (SPI) method proposed by McKee *et al*. (1993) can be used for characterizing droughts by their duration, frequency and severity; and therefore, was used in the present study for the modeling of drought hazard in Bangladesh. To compute SPI, historic rainfall data of each station were fitted to a gamma probability distribution function:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \qquad for \quad x > 0 \tag{1}$$

Where, $\alpha > 0$ is a shape parameter, $\beta > 0$ is a scale parameter, $x > 0$ is the amount of precipitation, and $\Gamma(\alpha)$ defines the gamma function. The maximum likelihood solutions are used to optimally estimate the gamma distribution parameters, α and β for each station and for each time scale. This allows the rainfall distribution at the station to be effectively represented by a mathematical cumulative probability function as given by:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta}\, dx \tag{2}$$

Since the gamma function is undefined for $x = 0$ and a precipitation distribution may contain zeros, the cumulative probability becomes:

$$H(x) = q + (1-q)G(x) \tag{3}$$

Where, q is the probability of a zero. The cumulative probability $H(x)$ is then transformed to the standard normal distribution to yield the SPI. As the precipitation rate is fitted to a gamma distribution for different multiple time scales for each month of the year, the resulting function represents the cumulative probability of a rainfall event of a station for a given month of the dataset and at different multiple time scale of interest. This allows establishing a classification values for SPI to define severity of droughts (McKee *et al.* 1993).

To model the vulnerability of droughts, socio-economic system or physical assets that are susceptible to the impact of droughts are identified. Drought vulnerability is different for different individuals and nations and, therefore, selection of vulnerability indicators is directly relevant to the local study context and the particular hazard. After careful consideration of obtainable/quantifiable socio-economic and physical indicators, four individual socio-economic indicators: population density (PD), female to male ratio(FMR), percentage of people living below poverty level(PL), and percentage of people depending on agriculture (PA), and three physical/structural indicators: irrigated land (IL), soil moisture holding capacity (SM), and food production per unit area (FP) are identified to represent the vulnerability of various geographic populations to the impact of droughts in Bangladesh. For each of the above seven indicators, four classes were selected by using the natural break method. The composite drought vulnerability index (DVI) is calculated by using the following formula:

$$DVI = \frac{PD_r + FMR_r + PL_r + PA_r + IL_r + SM_r + FP_r}{Number\ of\ indicators} \quad (4)$$

Where r represents ratings assigned to each class of vulnerability indicators.
The Blaikie *et al.* (1994) approach in which risk is defined as the product of hazard and vulnerability has been used to model drought risk:

$$Drought\ Risk = Drought\ Hazard\ x\ Drought\ Vulerability(n) \quad (5)$$

Monthly rainfall data for the period of 1961–1999 from 18 rain-gauge stations of Bangladesh Meteorological Department (BMD) is used for the modeling of drought hazard. To model drought vulnerability, data of population density, percentage of people depending on agriculture, poverty, female to male ratio, irrigated land, and food production per land unit are obtained from Bangladesh Bureau of Statistics and the soil moisture holding capacity data is obtained from Soil Resources Development Institute of Bangladesh.

Result and Discussion

Drought hazard models were prepared based on the occurrences of moderate and severe droughts in Bangladesh at 6- and 12-month time steps. The spatial distribution of moderate droughts indicates that they tend to occur mostly in the central west part of Bangladesh. East and Northeast parts also experience moderate droughts but with lower frequencies. On the other hand, severe droughts tend to occur mostly in northwest Bangladesh. Some parts of southeast Bangladesh also experienced severe droughts at 6- and 12-month time steps, but the areal extent is not high compared to northwest Bangladesh. Overall, the drought hazard models of Bangladesh reveal that west part of Bangladesh is more prone to droughts and the prolonged droughts are mainly occurred in northwest Bangladesh. As the droughts mainly found to occur in the western part of Bangladesh, further research to model the drought vulnerability and risk were focused only on west Bangladesh.

All the vulnerability indicator maps were integrated using Equation 4 and the composite drought vulnerability map of west Bangladesh prepared as shown in Figure 2(a). From the pattern of vulnerability to drought, the western part of Bangladesh can be separated into low vulnerable southern part, moderate vulnerable central part and high vulnerable northern part. The highest vulnerabilities are concentrated in the northern and northwestern parts of the country where poverty rate is comparatively high. More than 70% of the people there depend on agriculture, and agriculture depends on irrigation.

Drought hazard and drought vulnerability maps were integrated using GIS to produce the drought risk maps at 6- and 12-month time steps. Figure 2(b) shows that 6-month droughts pose highest risk to some northwest districts of Bangladesh. Districts in the northern and central parts are exposed to moderate risk and the coastal districts face less risk to droughts of 6-month time step. The pattern of 12-month drought risk is more or less similar to 6-month drought as shown in Figure 2(c). The high risk zone of drought at 12-month time-step is also concentrated in the northwest Bangladesh.

The areas of highest hazard and risk correspond very well, in general, with the areas that are usually thought as drought prone and have records of high levels of agricultural damage due to droughts. Therefore, it can be assumed that the techniques used in the present study are appropriate for drought modeling of Bangladesh. Rainfall in Bangladesh has increase significantly at a rate of 5.25mm/year during the last 50 years (Shahid 2010). However, it has been found that the droughts in

Bangladesh have no relation with rainfall amount. Rather, it depends on inter-annual variability of rainfall which is directly related to ENSO index. Therefore, it can be concluded that increased rainfall due to climate change will not reduce the drought risk in Bangladesh. As it is still not clear about the effect of climate change on ENSO, it is not possible to come to conclusion about climate change impacts on droughts of Bangladesh.

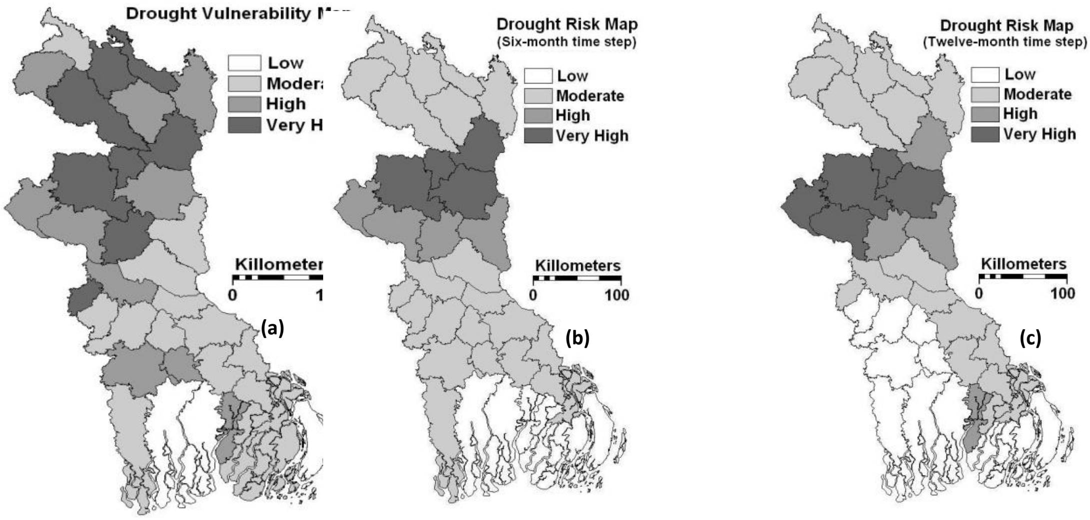

Figure 2. Spatial distribution of (a) drought vulnerability; and risk to (b) 6- and (c) 12-month time-steps droughts.

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Analytical Framework on the Vulnerability of Rural Development in Semi-Arid Area of Northern China: Assessment on the Scale of Community

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The semi-arid regions of the world are facing increasing challenges. Semi-arid area of Northern China, similar to the rest of world's semi-arid regions, is plagued by land degradation and desertification, and rural poverty. Ecologically fragile areas are often the home for the poor. It is of great significance to lower the vulnerability of rural community for the sustainable development in this area.

Vulnerability study is becoming one of the core problems in Sustainability Science (Kates *et al.* 2001). The vulnerability of development is not only a hot issue but also a challenging problem. This paper is trying to establish an analytical framework on the vulnerability of rural development in semi-arid area of Northern China on the scale of community. With a case study conducted on Beizifu Gacha (village), a community of Keyouzhongqi in Inner Mongolia, a general assessment of the vulnerability of rural development is discussed.

Methodology

Since the concept of vulnerability was first proposed by Timmerman (1981), it has been applied to many research areas, such as disaster management, natural environment, climate change, land use, sustainability science and poverty. Although there are differences about the nature and components of vulnerability, quite a few researchers consider that vulnerability is an important attribute of a system, which is of poor stability, sensitive to external disturbance, and hard to recover from external disturbances. Rural development can be regarded as the development of an integrated rural system, including natural, economic, social and other aspects. Therefore, vulnerability of rural development is the attribute of the integrated rural system of nature, economy and society, which is of poor stability, sensitive to external disturbances, and hard to recover from external disturbances.

Rural community has been chosen as the basic unit of vulnerability assessment in this study. Rural community is the cell of rural society and basic unit for enforcing rural development policies, and most, if not all, rural communities are experiencing profound changes and facing various challenges.

Internal attributes of rural community system are the main and direct reasons causing vulnerability, which are objects for assessment. Vulnerability of rural development can be regarded as the ability of community to withstand external disturbances, which is dependent on the overall community assets, including natural, physical, human, financial and social assets.

In view of the characteristics of semi-arid area in Northern China, and considering the availability and conciseness of indicators, an index system for assessing rural community assets was established as shown in Table 1. The lower the overall level of assets, the higher the vulnerability. The average of the corresponding indicators in Inner Mongolia had been normalized separately. Weights were assigned to each indicator according to expert advice, as in Table 1:

Total assets =0.3*natural assets +0.15* physical assets +0.2*human assets +0.15* financial assets +0.2* Social assets.

Table 1. Index system for assessing rural community assets.

Categories of assets	Index	Measurement	Symbol	Weight
Natural assets	Water resource	Average annual precipitation	N1	0.4
	Land resources	Cropland area per capita	N2	0.2
		Grassland area per capita	N3	0.2
	Vegetation coverage	Percentage of forest cover	N4	0.2
Physical assets	Irrigation infrastructure	Proportion of irrigated area	P1	0.3
	Productive fixed assets	Main PFA quantity per capita	P2	0.2
	Housing	Housing area per capita	P3	0.3
	Hard goods	Quantity per capita	P4	0.2
Human assets	Proportion of labor		H1	0.6
	Education level of adults		H2	0.4
Financial assets	Cash income	Net income per capita per year	F1	0.5
	Credit availability		F2	0.25
	Remittance availability		F3	0.25
Social assets	Participation in community organizations	Number of rural households in organizations	S1	0.5
	Social security system	Coverage of this system	S2	0.5

Case study: Assessing vulnerability of rural development of Beizifu Gacha, Keyouzhongqi in Inner Mongolia

Beizifu Gacha (village) is a typical semi-arid area located in the northeast of Inner Mongolia. It is a part of a National Nature Reserve – Nature Reserve of Horqin Wetland for Rare Birds. It has an average annual rainfall of about 380 mm, 75% of which concentrates in summer. Annual evaporation is 2390 mm, which is 6 times of the precipitation, and moisture is 0.3 to 0.4.

Using the above measurement system and survey data obtained in October 2010, the total level of assets in Beizifu were computed as shown in Table 2. The overall level of assets reflects the degree of vulnerability of community development. It indicated that the sustainable development of this community was hindered by a number of serious barriers, which leads to high level of vulnerability. Each category of assets is inadequate, especially physical, human and financial assets.

Table 2. Assets in Beizifu Gacha .

Categories of assets	Index	Measurement	Symbol	Weight	Value	Assets value
Natural assets	Water resource	Average annual precipitation	N1	0.4	0.51	0.52
	Land resources	Cropland area per capita	N2	0.2	0.85	
		Grassland area per capita	N3	0.2	0.40	
	Vegetation coverage	Percentage of forest cover	N4	0.2	0.32	
Physical assets	Irrigation infrastructure	Proportion of irrigated area	P1	0.3	0.25	0.40
	Productive fixed assets	Main PFA quantity per capita	P2	0.2	0.45	
	Housing	Housing area per capita	P3	0.3	0.55	
	Hard goods	Quantity per capita	P4	0.2	0.37	
Human assets	Proportion of labor		H1	0.6	0.49	0.41
	Education level of adults		H2	0.4	0.30	
Financial assets	Cash income	Net income per capita per year	F1	0.5	0.15	0.35
	Credit availability		F2	0.25	0.60	

Categories of assets	Index	Measurement	Symbol	Weight	Value	Assets value
	Remittance availability		F3	0.25	0.50	
Social assets	Participation in community organizations	Number of rural household in organizations	S1	0.5	0.80	0.60
	Social security system	Coverage of this system	S2	0.5	0.40	
Total						0.47

Conclusion

An analytical framework and index system for assessing vulnerability of rural development based on the scale of community was established to analyze the internal structure of rural community system by quantitative methods with a better understanding of rural community. Assessing vulnerability of rural development by the level of overall assets of rural community helps to indentify the components of vulnerability, providing policy implications for appropriate rural development intervention. This study is, however, still a preliminary one. Further testing and improvement of assessment methods, as well as comparison among different communities, would certainly improve the quality of the vulnerability assessment.

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An Assessment of Stand Structure and Carbon Storage of a Mangrove Forest in Thailand

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Global climate change, specifically changes in temperature, CO_2, precipitation, and sea-level, have potential impacts on mangroves and these changes combined with anthropogenic threats will threaten their resilience. Mangrove ecosystems are vulnerable to climate change where sea-level rise is the greatest threat. Global sea-level has risen since 1961 at an average rate of 1.8 mm/yr (1.3 to 2.3) mm/yr and since 1993 at 3.1 (2.4 to 3.8) mm/yr and is projected to rise up to 0.58 mm/yr for 2090–2099 due primarily to thermal expansion of the ocean and melting of glacial ice (IPCC 2007). Generally, sea-level rise altering shore profile, soils, and salinity affects individual mangrove species and mangrove zones that can lead to changes in mangrove stand structure and functions. However, some mangrove ecosystems have demonstrated different responses to previous sea-level fluctuations depending on mangrove types, species compositions and environmental conditions. Mangroves on low relief islands, lacked of rivers or blocked by coastal development are more vulnerable compared with those in deep sediments on high islands or surrounded by flourishing dense mangrove forest or riverine mangroves. For instance, mangroves of the Pacific Islands region have been reported to be vulnerable to small increases in sea-level (Gilman *et al*. 2006).

In Thailand, mangrove forests are located on the edge of the coastline in brackish water or where seawater floods over. The total area of the mangrove forest had been decreased from 0.37 million ha in 1961 to 0.24 million ha in 2004 due primarily to the conversion to shrimp farms. At present, the mangrove forest distributes largely along the west coast (73.1%) of southern Thailand followed by those found along the east coast (11.4%) of southern Thailand, in the eastern part (11.0%) and in the central part (4.5%), respectively (Faculty of Forestry 2007). However, these mangrove forests vary largely in terms of stand structure (species diversity and composition) and productivity depending on location and environmental conditions that may lead to variation in their responses to sea-level rise. An assessment of stand structure and production as well as carbon stocks of different mangrove communities in Thailand helps to understand their vulnerability to sea-level rise and related changes in order to build resilience into mangrove conservation and restoration plan. This study was, therefore, aimed at investigating stand structure, biomass and carbon storage and determining stand characteristics that were vulnerable to climate change.

Methodology

This study was carried out in 11 provinces, representing primary and secondary mangrove stands throughout Thailand. In each province, three 20 x 50 m sampling plots were established randomly in two transects perpendicular to the sea shore. The main plot was divided into 10 subplots (10 m x 10 m) and 4 m x 4 m and 1 m x 1 m nesting plots were also established within 10 m x 10 m subplots. All trees (over 4.5 cm diameter at breast height, DBH), saplings (less than 4.5 cm DBH but over 1.30 m total height) and seedlings (less than 4.5 cm DBH and 1.30 m total height) were identified in all 10 m x 10 m, 4 m x 4 m and 1 m x 1 m subplots, respectively; and the total height and diameter of trees and saplings were measured. In each subplot, three soil samples and a hemispherical photograph were taken; and leaf area index was then analyzed using Gap Light Analyzer (GLA) Version 2.0 (Frazer *et. al.* 1999). Stand structure parameters: relative density, relative abundance, importance value index (IVI) and Shannon-Weiner index were analyzed (Ludwig & Reynolds 1988). The total biomass of trees and saplings was estimated following the allometric relationship derived from Komiyama *et al.* (1987) and the total biomass was then converted to the carbon storage using the carbon content of mangrove trees reported by Faculty of Forestry (2009). Based on species composition and the carbon storage, the mangrove community was categorized using a cluster analysis with the Jaccard Index, while the stand structure parameters and the carbon storage of each community were then statistically compared.

Results, Discussion and Recommendations

A total of 22 species in 12 genera and 10 families was observed, consisting of 22, 17 and 12 species of trees, saplings and seedlings, respectively. There were 14 species, 8 of which belonged to the family Rhizophoraceae, observed in all tree, sapling and seedling stages. On the other hand, 8 species were not found in either sapling or seedling stage. The result indicated the greater natural regeneration potential of the former. Specifically, *Rhizophora apiculata* and R. *mucronata* were of greater importance than the other tree species of the family Rhizophoraceae.

The species diversity and composition, natural regeneration potential, canopy structure, and total biomass as well as the carbon storage varied remarkably among sites, between transects within site and/or among study plots within transect due primarily to stand structure, location and/or soil conditions. The mean values of diversity index, total biomass, carbon storage and leaf area index varied largely between 0–1.80, 72.31–274.12 t/ha, 34.00–128.87 t/ha and 0.98–3.34, respectively. Most of the study plots observed in the central part, which were generally degraded or restored mangrove forests, had poor species diversity, total biomass and carbon storage. In contrast, the study plots investigated in the eastern and southern parts, which were mostly primary forests, had greater species richness, forest production and/or natural regeneration potential. Particularly, higher species diversity and forest production as well as natural regeneration potential were commonly found in a mangrove forest along the west coast of southern Thailand, consistent with the study by Faculty of forestry (2007).

The interpretation of a cluster analysis allowed the following five mangrove communities to be categorized: *Avicennia marina*, *A. alba*, *Rhizophora mucronata*, *R. apiculata* and *Ceriops tagal* communities. Most parameters including stand structure, growth, biomass and carbon storage were significantly different among the five communities ($p<0.05$) except seedling density ($p=0.41$) as shown in Table 1.

Table 1 Comparison of stand structure, growth, biomass and carbon storage of five mangrove communities in 11 provinces of Thailand

Parameters	Community: *Avicennia marina*	*Avicennia alba*	*Rhizophora mucronata*	*Rhizophora apiculata*	*Ceriops tagal*	p-value
Number of species						
Tree	2^{a}	3^{a}	3^{a}	5^{b}	6^{b}	<0.01**
Sapling	2^{a}	2^{a}	1^{a}	3^{b}	4^{b}	<0.01**
Seedling	1^{a}	1^{a}	1^{a}	2^{b}	2^{b}	<0.01**
Leaf area index	1.98^{ab}	2.06^{b}	2.49^{b}	1.90^{ab}	1.63^{a}	<0.01**
Tree density (trees/ha)						
Tree	260^{ab}	147^{a}	334^{b}	295^{ab}	230^{ab}	<0.01**
Sapling	67^{a}	48^{a}	32^{a}	54^{a}	170^{b}	<0.01**
Seedling	51^{a}	102^{a}	27^{a}	60^{a}	84^{a}	0.41
Diversity index	0.166^{a}	0.346^{a}	0.324^{a}	0.841^{b}	0.960^{b}	<0.01**
Diameter at breast height (cm)						
Tree	8.07^{a}	12.18^{b}	8.43^{a}	10.64^{b}	6.53^{a}	<0.01**
Sapling	2.57^{b}	2.04^{a}	1.52^{a}	2.23^{ab}	2.38^{b}	<0.05*
Height (m)						
Tree	7.45^{ab}	9.28^{ab}	10.90^{b}	10.72^{b}	6.13^{a}	<0.01**
Sapling	3.48^{b}	2.47^{ab}	2.15^{a}	3.22^{ab}	3.85^{b}	<0.01**
Total biomass (t/ha)						
Tree	79.81^{a}	137.19^{ab}	176.88^{b}	190.25^{b}	58.88^{a}	<0.01**
Sapling	0.94^{a}	0.44^{a}	0.75^{a}	0.69^{a}	3.06^{a}	<0.01**
Total	80.75^{a}	137.63^{ab}	177.63^{b}	190.94^{b}	61.94^{a}	<0.01**
Carbon storage (t/ha)						

Tree	37.52[a]	64.47[ab]	83.13[b]	89.41[b]	27.68[a]	<0.01**
Sapling	0.44[a]	0.20[a]	0.35[a]	0.33[a]	1.43[b]	<0.01**
Total	37.96[a]	64.67[ab]	83.48[b]	89.74[b]	29.11[a]	<0.01**

The *C. tagal* community, mostly found in infertile soil conditions, had the greatest species diversity but the lowest forest biomass and carbon storage due to its small sizes. The *R. mucronata* community, mostly man-made forest after logging, had greater forest biomass and carbon storage but less species diversity and natural regeneration potential. On the other hand, the *R. apiculata* community, primary forest where environmental conditions were suitable for a mangrove forest, achieved not only greater species diversity but also the highest forest biomass and carbon stock. Similarly, greatly higher stand production of *R. apiculata* community in Thailand, compared with other communities e.g. *Brugueira* and *Sonneratia* communities, was also reported by Komiyama *et al*. (2008). More importantly, poor species richness, forest production and carbon storage as well as natural regeneration potential were mostly observed in *A. marina* and *A. alba* communities in the central part where the mangrove forest was degraded and/or restored after conversion to shrimp farms. Of the two communities, the *A. marina* community had lower species diversity and smaller trees and sapling which, in turn, achieved lower forest biomass and carbon storage. The findings indicated the decline mangrove community of the former.

Overall, the stand structure, in terms of species diversity and composition, contributed primarily to the mangrove production and carbon stock as well as natural regeneration potential that may lead to variable vulnerability. However, monitoring of gradual changes of mangrove margins and site-specific assessment of mangrove vulnerability are, therefore, needed to increase mangrove resilience to the climate change of these mangrove stands.

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Adaptation Responses to Coastal Perturbations: The Case of Prieto Diaz and Baler Coastal Dwellers in the Philippines

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Sea level rise, storm surge, coastal flooding, and tsunami among others constitute coastal perturbations triggered by climate change. The effects of such perturbations pose a variety of risks to both human and environmental coastal systems. The estimated sea-level rise would inundate low-lying areas and drown coastal marshes and wetlands among others (Lal *et al.* 2010).

There are about 634 million people living in coastal low elevation areas (Greenfieldboyce 2008). Humans gravitate in areas near water due to increasing population, urbanization and weak land use planning and enforcement (Cruz *et al*. 2007). If such migration pattern continues, it is inevitable that humans are at risks. Humans have been adapting to the changing climatic conditions for centuries (UN, 2007), but the adaptation or coping mechanism practices may differ due to the coastal geographical location and human peculiarities. Thus, it is important that these adaptation or coping mechanisms be documented to know how the affected people deal with the various risks associated with coastal perturbations. The objectives of the research are: to determine the households' awareness of, and effects of the change in the coastal environment; to identify the households' coping mechanisms/adaptation strategies to coastal perturbations; and to identify the catalysts in the adaptation of coping mechanisms to coastal perturbations.

Methodology

This research applied both the sociological and anthropological approaches in the collection of primary data, such as the participatory rural appraisal-type interview schedule, focus group discussion and key informant interview. Likewise, secondary sources such as the comprehensive land use plan, socioeconomic development plan and barangay profile, if and when available were retrieved to serve as additional references to validate information obtained from the household-respondents. In the collection of primary data, a semi-structured interview schedule was used in the interview of both the male and female household-respondents. A total of 50 households were interviewed. Qualitative approach was used in the analysis of the collected primary data. Household interviews were held in Prieto Diaz, Sorsogon and Baler, Aurora. Both provinces face the east board side of the Pacific Ocean.

The municipality of Prieto Diaz is situated at the northeastern tip of Sorsogon Province with coordinates of $13^0$13"N and $124^0$12"E. It is bounded in the north by the Pacific coast, in the west by the municipality of Bacon, in the south by municipality of Gubat and the Philippine Sea in the northern and eastern sides. Its irregular coastline is more than 10 km long; and 19 of its 23 barangays are located along the coast stretching upward the hilly part of the municipality. Vast mangroves sprawl from the tip of the Poblacion to Prieto Diaz-Gubat boundary.

The municipality of Baler is located in the mid-eastern part of Luzon at coordinates between $15^0$47'36" and $16^0$09'05"N latitudes and $121^0$26'52" and $121^0$47'32"E longitudes. It is bounded by the municipalities of Dipaculao and Maria Aurora in the northwest, San Luis in the southwest, Baler Bay in the north, and the Pacific Ocean in the east.

Results and discussion

Coping Strategy
A. Prieto Diaz, Sorsogon

Households believed the coastal ecosystem is changing. Changes that have been observed are sea-level rise, unpredictable tidal fluctuations, erosion and sedimentation, frequent occurrence of typhoon, and coastal flooding (Tables 1 and 2). Causes of such incidents are attributed to various factors. In the case of sea-level rise and tidal fluctuations, households associate such events to erosion and sedimentation. Soils that eroded are perceived to have stockpiled in the sea causing level to rise; whereas tidal waves had become unpredictable and presumably influenced by the lunar cycle. As regards to flooding, it is the households' opinion that storm surge and overflow of rivers in the upland during typhoon trigger the inundation of the shoreline. Households are aware of the likelihood of a tsunami to happen but they also know that Prieto Diaz has a three to five kilometer break water as buffer zone.

To cope with the changes in coastal environment, strategies for adaptation is gradually being institutionalized specifically in Barangay Diamante (Doma, per.comm. 2009). These adaptation strategies are categorized as *Protect* and *Retreat.*

Under *Protect,* the technologies for adaptation strategies include the planting of different mangrove species and putting up of sea wall and sandbags fronting the open sea. Of these technologies, the planting of mangroves delivered the most significant impact as far as protection against coastal perturbations is concerned.

As regards to *Retreat*, evacuation and transfer of residence become the most conventional strategy adapted by households to minimize the impacts of coastal perturbations. Whenever the community is at the centre or eye of the typhoon, local officials inform all households in the community to prepare themselves and transfer to the designated evacuation centres setup in public schools and sometimes churches as early as possible.

B. Baler, Aurora

Households recalled that way back in the 1990s, the sea water was some distance away from the current shoreline. They surmised that the sea-level had risen and came closer due to an earthquake that hit Luzon on 16 July1990. The tectonic plate was supposed to have triggered the rise of sea-level. As to the recurring tidal movements, households attribute such occurrence to the geographical location of the province as the province is located on the eastern seaboard facing the vast Pacific Ocean. Incidents of coastal flooding, however, are perceived to be associated with typhoons that often led to erosion in the uplands bringing along sediments and soil materials cascading into the sea.

Restoration using mangrove plants is one of the strategies strongly enforced in the municipality by the coastal stakeholders to minimize, if not totally control, the effects brought about by coastal perturbations (Costa, per.comm. 2010). Households disclosed that with the presence of mangroves, the municipality had been spared from getting inundated. Further, they claimed that mangroves effectively served as a buffer and windbreaker especially when the typhoon is accompanied by gusty wind leading to strong storm surges (Milan, per.comm. 2010).

Households deemed *gasang* as an effective way to break the impacts of gusty wind and storm surge (Table 3). *Gasang* are boulders that formed naturally along the shoreline and it is only found in Sitio Munting Gasang. With both mangroves and *gasang* buffering the community households, impacts of the typhoon and other forms of coastal perturbations have been significantly reduced. However, in times when mangrove stand and *gasang* could not contain the storm surges, households usually flee to higher grounds like the Ermita Hill which is very close to the centre of built up areas.

Recommendations

With the lessons learned from the two coastal communities with regards to impacts of coastal perturbations brought about by extreme climatic events, the following suggestions are made:

- Massive sustain initiatives on Information Education Communication (IEC) regarding climate change and the potential dangers/impacts of climate variability to households and environment;
- Encourage wider participation of households to ensure adaptation of strategies/practices of relevance to coastal perturbations and climate change/variability;
- Mainstream developmental plans and programmes to municipal ordinances and policies addressing climate change and variables;
- Implement and institutionalize the rules on easement/salvage zone to discourage establishment of settlement area along coast/shoreline; and
- Institutionalize early warning systems in all vulnerable areas

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Federated States of Micronesia Atoll Islands Climate Change and Food Security Vulnerability Assessment

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Federated States of Micronesia (FSM) being a small island state is at great risk from projected impacts of climate changes particularly sea-level rise. The projected climatic changes by the years 2050 and 2100 are: (i) a temperature increase of about 1^{o} C by 2050 and 2^{o} C by 2100; (ii) a 10% reduction in rainfall by 2050 and a 20% reduction by 2100; and (iii) an increase in sea-level of between 19.77 cm to 23.85 cm by 2050 and 48.87 cm to 60.25 cm by 2100. The atolls in the FSM are rarely exceeding 3–4 m above present mean sea-level and most of the settlements, economic activities, infrastructure, and services, are located at or near the coast. It is estimated that with a 1 m sea-level rise, a substantial area of atolls in FSM would be lost. This figure will be much more with storm surges superimposed on the 1 m sea-level rise (Halavatau 2009).

To fulfill the United Nations Framework Convention on Climate Change (UNFCCC) requirements for the preparation of national communications from non-Annex I Parties, the FSM Government took the initiative of carrying out a Climate Change/Food Security Vulnerability Assessment on 14 atoll islands in the states of Pohnpei, Chuuk and Yap.

Methodology

The recently developed design for Monitoring, Assessment and Reporting of Sustainable Forest Management (MAR – SFM) for atoll islands in the Pacific was used for this survey. With the absence of reliable maps and satellite images, four strips of 100 m x 10 m were established and assessed on each of the 14 atolls surveyed. Strips were evenly distributed within each island. The four strips make up a plot.

Figure 1. Plot layout

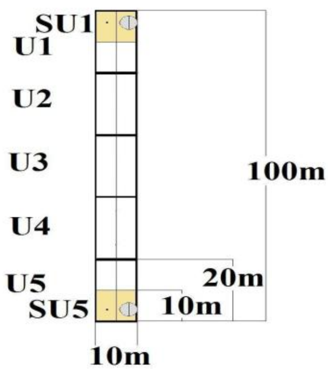

Figure 2. Strip Design

Parameters for measuring trees, deadwoods and regenerations were as listed in Table 1 below.

Table 1. Parameters and recording levels

Recording Units	**Recording level**
All Sub plot units (U1-U5: 20m x 10m)	≥ 25 cm DBH ≥ 25 cm DBH Standing Deadwood ≥ 25 cm diameter Lying Deadwood
Sub plot sub unit level 1 (SU1 & SU5: 10m x 10m)	≥ 10 cm ≤ 24 cm DBH ≥ 10 cm ≤ 24 cm DBH Standing Deadwood ≥ 10 cm ≤ 24 cm diameter Lying Deadwood
Sub plot Level 2 (Circular Plot – 2m radius)	≥1.3 m height and ≤ 9cm DBH ≥1.3 m height and ≤ 9cm DBH Standing

Results

Table 2. Field assessment results.

Forest Characteristics	**Observations**
▪ *Diversity* – observations in terms of indicator and endangered species	Names of atoll vegetation types may vary somewhat but could be distinguished in the following five main littoral plant communities; Herbaceous strand, Littoral Shrub land, Pandanus Scub, Littoral Forest, and Mangrove Forest. Dominant species in Herbaceous Strand are herbaceous creeping vines like *Ipomoea pes-carprae* (beach morning-glory), *Vigna marina* (beach pea), *Canavalia rosea* and grasses like *Thuarea involuta* and *Lepturus repens.* Herbaceous vegetation on rock substrates is dominated by grasses and sedges *Cyperus stoloniferus, Paspalum vaginatum* and *Fimbristylis cymosa*. Vines listed above also occur on rock substrate. *Scaevola taccada* and *Wollastonia biflora* are the two most characteristic species of littoral shrubland. Pandanus Scrub is a scrubby vegetation dominated by *Pandanus tectorius* (screwpine) typically occurring on rocky shores. This community or zone is often absent on coasts, but when present it may integrate into the herbaceous strand on its seaward side, and the littoral forest on its inland side. Littoral Forest is the most common and characteristic type of vegetation occurring on tropical shores. It consists of dense forest and is often dominated by a single tree species. The most characteristic trees are *Barringtonia asiatica*, *Pisonia grandis*, *Hernandia nymphaeifolia, Casuarina equisetifolia, Guettarda speciosa* and *Terminalia spp*. *Rhizophora stylosa* is the most common species in the mangrove forest of the FSM. A similar species found in the Micronesia is the *Rhizophora apiculata*.

Forest Characteristics	Observations
▪ *Disturbances* – by fires, cyclones, insects, invasive species, livestock	Disturbances were noticed in the form of fires, cyclones, tidal waves, livestock, invasive species, and agriculture clearing.
▪ *Forest functions* – Protection of soil, water, conservation of biodiversity, social and cultural services	In the atoll situation, forest and trees are mostly for food, protection of soil and water, carbon sink, social and cultural services and the maintenance and conservation of biodiversity
▪ *Forest extend* – Forest, wooded land, Agro forestry, Coconut forest and plantation	In all the islands surveyed, the extend of forest cover is basically limited to agro-forestry, coconut forest and plantation and breadfruit patches within and near the villages
▪ *Forest Characteristics* – Primary, Secondary with natural regeneration, enrichment planting, plantations	All the islands are covered with secondary vegetation, natural regeneration, coconut and breadfruit plantations
▪ *Land ownership* – State, Private, Customary	All the islands are customary owned
▪ *Vegetation* – species present	On atoll situations, it is hard to delineate boundaries of coastal and inland plants. Some plants found on the coast are inland species planted on the shore.
▪ *Food Security*	Of all the islands surveyed, breadfruit and coconut were in abundance whilst banana was only found in patches around the villages. Most of the taro patches visited has problems with salination. This happened after king tides hit the islands. Breadfruits were not in season at the time of the survey.

Drivers of Deforestation in the Atolls

It was observed and confirmed that the main drivers of forest and tree clearing in the atolls were clearing for agriculture, clearing for infrastructure development, clearing for village expansion due to increase in population, burning, unsustainable harvesting and unnecessary clearing, and the lack of appreciation or knowledge of the values of forest and trees.

Recommendations

Table 3. Adaptation and mitigating measures

Critical Vulnerable Sectors/ Systems	Impacts	Adaptation/ Mitigation Option I	Adaptation/ Mitigation Option II	Adaptation/ Mitigation Option III
Forest and Tree Resources	- Change in Species composition - Coastal erosion, salt spray - Salt water intrusion, salination - Food insecurity - Loss of Biodiversity, genetic resources - Forest and tree health and Invasive species - Carbon Emissions - Extreme weather patterns	**Sustainable Management of Forest and Tree resources:** *Fire Management* –Reduce/Stop burning of trees *Forest & tree Conservation* – Stop unnecessary cutting of trees – Replant breadfruit and coconut trees	**Forest restoration and rehabilitation:** Restoration of Mangrove forest Rehabilitation of coastal forest and trees, e.g. planting of *Calophyllum inophyllum, Casuarina equisetifolia*	**Sustainable agriculture systems:** Agro – Forestry Raising of planting areas by de-composting and mulching Introduce other variety of breadfruits that may fruit at different times as the local variety. Introduce climate change resilient crops (CePaCT)

Re – assessment could be done every 3 – 5 years to monitor the status of the forest and tree resources.

Mitigation & Adaptation Needs

For the FSM to be able to carry out the recommended Adaptation and Mitigation measures, the following will be needed:

- Reliable information on forest resources
- Sound forestry policies and programmes for climate change mitigation and adaptation consistent with forestry and sustainable development objectives
- Capacity and resources for implementing SFM
- Ability to address inter-sectoral issues
- Education and Awareness

Conclusion

Forests and planted trees can help local communities adapt to climate change through livelihood diversification and provision of ecosystems services. Sustainable Management of Forest and Tree resources increases the resilience of people and eco-systems to cope with extreme weather patterns, and therefore safeguarding food security.

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Picturing Climate Change Adaptation and Vulnerability
At Community Level in Indonesia

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As an island country located in the tropics, Indonesia is quite vulnerable to the changes in climate. This country is reported to have disasters related to climate change every year such as flood, landslide, drought, forest fire, etc. The disasters affect the local communities, whose livelihoods depend on the surrounding environment, including the ones living in the coastal areas. Many of these people are fishermen or practise sylvofishery - rearing fish in ponds dug within the mangrove forests.

With existing climate condition, these local communities have to be able to adapt in order for them to survive. Their efforts are challenged with the existing policies applied in the mangrove forests that affect their access to the resources. These mangrove forests found in nearly all provinces in Indonesia and located in the forest and non forest areas and are managed for economic purposes, environmental services, or biodiversity conservation. The Ministry of Forestry is responsible for managing the conservation forests, and Perhutani (the state government) and the Regional Forest Government are responsible for the protection forests.

This study aims to gain a better understanding of the adaptation strategy and the vulnerability of the local communities living in the coastal area, particularly the ones living in and around the mangroves classified into conservation, protection and private mangrove forests. It is assumed that the policies applied at each forest management type will also affect the vulnerability of these people.

Methodology

The research is conducted in the villages located in the coastal areas that have strong interaction with the mangroves forests. Two villages were selected in each mangrove forest management type. These villages are Mojo and Nyamplungsari (Central Java Province) for private mangrove forests, Muara and Langensari (West Java Province) for protection forests, and Gilimanuk and Sumber Klampok (Bali Province) in conservation forests.

Around 10% of the households at each village were interviewed. Data related to their understanding about climate change, adaptation strategies and vulnerability of the local communities were collected. These data were analyzed using multivariate analysis to determine the vulnerability of the local communities, and tested with T-test to find out whether the three mangrove forest management systems are significantly different in terms of the vulnerability of the local communities.

Results, discussion and/or recommendations

Community understanding on Climate Change

Local communities do not understand climate change but they observe that the there is an unpredictable change in seasons. Their observations are usually about the changes in wet and dry seasons for they will affect their planting and their farm production. Some of the changes they observe are presented in Table1.

The farmers decide the time to plant based on their observation on the weather and their own judgement on rainfall. They do not get any information concerning the weather conditions from the extension workers. Consequently, this affects their decisions on farming.

Table 1. The changes of season.

Season	Month												Impact
	1	2	3	4	5	6	7	8	9	10	11	12	
Rainy season													
• 2005	xxx	xxx	xx	x							x	xx	
• 2008	xxx	xxx	xx	x								x	
• 2010	X	x	x	x	xx	x	x	x	x	x	xxx		
Flood													
• 2005	xxx	xxx									xxx	xxx	Rice field and fishpond with low dikes will be flooded
• 2010													No flood
Fishpond													
• 2005	X	x	x	x	x	x	x	x	x	x	x	x	There is always fish caught in the fish trap all year long
• 2010	X	x									x	x	No planting in month 1,2,11,12

Note: x: low xx: medium xxx: heavy
Source: Langensari villagers, West Java

Community Adaptation Strategy

The communities living in/around the private mangrove forests and the protection forests practise sylvofishery, but in different styles. The ones in the private forest plant the mangrove trees along the dikes, not only to strengthen the dikes but also to give shade to the dikes. In the protection forests, the Perum Perhutani allows the local communities to make use of the mangroves for sylvofishery with some restrictions: maintaining 60% to 80% of the mangroves in the centre of the fish ponds, allow to clear 20% to a maximum of 40% for fish or shrimp farming. Besides, they have to pay Rp 120,000 per household per ha per year to the Perum Perhutani. These communities do not always follow the restrictions. All the communities in the study areas receive development programmes and they form groups to facilitate the implementation of the programmes.

Climate change has different impacts to the local communities. The ones living in the private mangrove forests observe that the sea water level has risen about an inch. The local communities responded by making their dikes higher and planting mangrove trees to strengthen the dikes. To keep the dikes, they do not drain the fish pond but use a net to harvest the fish. These communities also received government development programmes to establish village nurseries, supplying mangrove tree seedlings to plant in their coastal area.

The rain that happens all year round this year affects the water salinity and this reduces harvest and lower the quality of the milk fish. The communities reported that the 6-month old milk fish used to weigh around 3 ounce each. With the continuous rain it weighs only around 2 to 2.5 ounce each. In order to improve the local village economy, with assistance of (OISCA) - an NGO, they switch to rearing the soft-shell crab. This project is successful and they are now looking for buyers. The OISCA also works intensively to make local communities realize the importance of protecting and improving the mangrove forests.

In the protection forests, the local communities observe that they have less milk fish harvest due to the pest in their fish ponds. They also observe that their shrimps are mostly stressed out and die after 40 days. These people apply pesticides to improve the harvest and keep opening new fish ponds.

In the National Park, the local communities are not allowed to fish. These people can develop ecotourism. The Park Manager provides various assistances to these people enabling them to earn income from tourism. They also train them to be tourist guides. The Park Manager also conducts intensive awareness programmes to make local communities understand the importance of mangrove forests and educate them to protect the forests.

Vulnerability of the Community

The analysis shows that the number of vulnerable villagers differs significantly in those three forest management types (Table 2).

Table 2. The vulnerability of the respondents living in/around classified into private, protection and conservation forests.

LOCATION		AVERAGE	PERCENTAGE OF
District	**Villages**	**SCORE**	**VULNERABLE PEOPLE**
Pemalang, Central Java	Mojo	7.74	37%
(Private Forest)	Nyamplungsari	7.71	30%
Pamanukan-Subang , West	Muara	4.14	57%
Java (Protection Forest)	Langensari	5.22	82%
West Bali National Park, Bali	Gilimanuk	6.03	58%
(Conservation Forest)	Sumber Klampok	8.00	55%

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Soil Organic Carbon Loss through Soil Erosion in the Agro-Ecological Zones in Merek Catchment, Iran

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Soil erosion not only causes declining crop yields, but also induces off-site impacts such as eutrophication and CO_2 emission. Strong action of soil erosion leads to removal of the fine soil particles which contain Soil Organic Carbon (SOC). Soil disturbance (erosion included) negatively affects the role of SOC on crop productivity. Miralles et al. (2009) found significant correlation between high soil quality level and SOC in semi-arid regions. Soil erosion in this region is widespread, caused mainly by deforestation, overgrazing and improper agricultural activities, resulting in the decline of plant nutrients and SOC reserve; and it is higher in the hilly and mountainous areas because of shallower soil depth. Global emissions of carbon (C) through land use change and soil cultivation are estimated at 136±55 Pg, regarded as the second largest source of emitted C into the atmosphere (after fossil fuel) and depleted SOC pool have contributed 78 ±12 Pg of C to the atmosphere (Lal 2004). Most cultivated soils have lost between 30 and 50% of their original SOC pool, whereas severely eroded soils may have lost 70–80% (Lal 2001). The study of Bilgo et al. (2006) has shown that 770 kg C ha^{-1} yr^{-1} was lost by erosion in the cultivated soils.

Quantitative assessment of land degradation, especially soil erosion and loss of SOC should be carried out at the catchment scale for effective evaluation (Morsli et al. 2006). A catchment is a heterogeneous area due to its natural characteristics and variety of land use activities. As such, the Modified Pacific Southwest Interagency Committee (MPSIAC) model can be used as a suitable tool for estimating the rate of erosion at the catchments in the semi-arid region. This model comprises erodibility and erosivity factors that include topography, climate, run-off, lithology, soil characteristics (K factor of RUSEL), vegetation, land use, upland erosion and gully erosion. These factors and their indices are calculated by summation of all scores for fairly accurate and reliable estimation of erosion and specific sediment yield (Vente et al. 2004). The objectives of this study are : (i) to determine the dominant erosion features in the Merek catchment, Iran; (ii) to determine the spatial distribution of organic carbon in the soils; and (iii) to estimate the SOC depletion through soil erosion using MPSIAC model.

Methodology

This study was conducted at the Merek catchment, located about 35 km southeast of Kermanshah, Iran. It is the upper catchment of the Karkheh River basin (KRB) located in the Zagros Mountain chains (west of Iran) with an area of 23, 038 ha (Figure 1). The mean annual precipitation and temperature are 481 mm and 17.7°C, respectively. The soils are mostly clayey and silty in nature. Land degradation in this catchment is mainly due to soil erosion caused by deforestation, overgrazing and improper tillage activities. In this study, a geomorphological facies map was prepared by overlapping the maps of geology, topography (slope steepness, slope aspect and elevation), erosion features and land use type using satellite image (land-sat 2002) and GIS (Ilwis version 3.5). Soil sampling and field verification were carried out in these facieses as the homogenous area. Soil physico-chemical characteristics were determined in the laboratory including soil texture, bulk density and SOC. The data were statistically analyzed using SAS version 6.12. Soil erosion intensity and SOC depletion were estimated using MPSIAC model after validation. The nine factors of this model were estimated and scored for each geomorphological facies. This is more reliable because scoring for a homogeneous unit is more applicable and easier than for heterogeneous area (Nikkami 2003, Ownagh & Nohtani 2004, Hesadi et al. 2007).

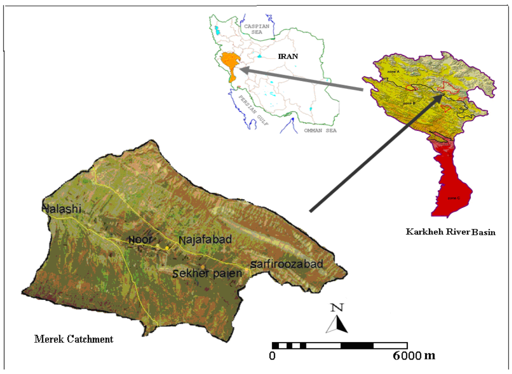

Figure 1: A map showing the location of the Merek catchment

Results and Discussion

Dominant erosion features

Main soil erosion features found were inter-rill, rill, gully and landslides. Most of the gullies are formed on the fine grained geological materials such as marls, shale and sandstone of Eocene age (Kashkan Formation). Improper agricultural activities, especially heavy tillage without fallow and rotation period, and vegetation clearance, lead to concentrated run-off and soil erosion (Parkner et al. 2007). Landslide occurs frequently in the forest which is dominated by marl and shale with smectite clay mineral. Most of the landslides occurring in this catchment are initiated by piping and cracking. Piping (tunneling) erosion is common in arid and semi-arid regions that change the geomorphic and hydrologic characteristics of affected areas (Blanco & Lal 2008).

Soil erosion Intensity

An annual erosion intensity value within each geomorphological facies was converted to mass weight (t $ha^{-1}yr^{-1}$) using bulk density value. The weighted average erosion rates in the agriculture area, rangeland and forest are 10.61, 11.02 and 13.05 t $ha^{-1}yr^{-1}$, respectively. The annual soil erosion at catchment scale for the study area is approximately 192, 951.55 t. High erosion intensity is observed in the forest and in some parts of the rain-fed agriculture areas where landslide, piping and gully erosion occur. Moderate erosion intensity is found mainly in the agriculture area and rangeland, coinciding with the occurrence of snow, inter-rill and rill erosion.

SOC levels

Mean SOC values in the agriculture area, rangeland and forest, are 1.35%, 1.56% and 2.14%, respectively. Statistical analysis showed that their means are significantly different from each other. Higher level of SOC in the forest compared to that of the other zones is related to high biomass production by oak (*Quercus persica*). However, burning of crop residues and improper tillage practices, especially in the hilly lands, may reduce organic carbon in the soils of the agriculture zone. The former should be discouraged and curtailed to reduce CO_2 emission into the atmosphere. Field observations showed that most of the farmers in the catchment burn wheat and barley residues during August and early September for subsequent cultivation of their crops (without fallow) in early autumn. It is estimated that annually 259 Gg of CO_2 is emitted into the atmosphere by burning of crop residues in Iran (Environment Organization of Iran 2003). Improper tillage practices strongly accelerate soil erosion processes by destroying SOC and soil structure (Rosa et al. 2009). Low SOC in the most parts of rangelands is affected by overgrazing. An investigation by Li et al. (2008) showed that heavy sheep grazing decreased about 16.5% of SOC.

Although SOC in the forest zone is significantly higher than that of the other zones, the erosion rate is higher because of the lower land quality, especially steep slope (20–40 %), fine grained parent materials (marl and shale) and smectite clay mineral content. Furthermore, the erosion is made worse by the illegal grazing of livestock in the area. Field observations showed that piping and landslides occurred frequently in the recently cleared forest and roadsides contributing to soil erosion and SOC loss. In contrast, SOC depletion in the moderately sloping land (<10% slope) is probably due to heavy soil texture, improper tillage practices and burning of crop residues.

SOC Depletion through Soil Erosion

The annual SOC loss through soil erosion in the agriculture area, rangeland and forest is 147.24, 176.92 and 306.10 kg $ha^{-1}yr^{-1}$, respectively (155.10 kg $ha^{-1}yr^{-1}$ for the whole catchment). The annual soil erosion and SOC depletion in this catchment area are 245 570.5 and 3679.5 t, respectively (Table 1). The rate of SOC loss in the forest zone is higher compared to the others because of higher erosion rate in that zone. The rate of SOC loss for the forest zone is higher compared to the others because of higher erosion in that zone. Usually, the SOC transported by soil erosion is exposed to the atmosphere, promoting emission of CO_2, another GHG. This is yet another important aspect of human-induced global warming. It means that soil erosion should be curtailed at any cost.

Table 1. Rates of SOC depletion through soil erosion in the agro-ecological zones in the Merek catchment

Agro-ecological Zone	Soil Erosion Intensity (t/ha/yr)	SOC loss through Soil Erosion (kg/ha/yr)	Annual Soil Erosion (tone) *	Annual SOC Depletion (tone) **
Agriculture	10.61	147.24	157134.1	2015.4
Rangeland ***	11.02	176.92	67607.7	1185.8
Forest	13.05	306.10	20828.7	478.3
Catchment	8.56	155.10	245570.5	3679.5

*Annual soil erosion in facies (t) = Area (ha) × t ha-1yr-1

** Annual nutrients decline and OC loss in facies = facies area (ha) × sum of nutrients losses (kg ha -1 yr -1)

*** The area of rangeland except facies 2 and 4 where are rocky and cliff

Field surveys revealed that improper tillage such as cultivation up and down the slope in hilly lands with slope of 10–20 % do occur. These areas can be regarded as the critical areas for soil erosion and hence higher SOC loss. A study by Quinton et al. (2006) showed that this cultivation system led to greater carbon loss than cultivation across the slope. SOC in the rangeland and forest zones is more prone to erosion as compared to that of agriculture area because of steep slope in the former. The eroded SOC in the hill slope is more than that of other areas. A study by Nael et al. (2004) showed that disturbance factors such as grazing and tillage practices resulted in 60% reduction of SOC. The MPSIAC model can satisfactorily be used to determine soil erosion rate and predict the loss of SOC at the catchment scale of the semi-arid region of Iran.

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Soil Erosion and Landslide Vulnerability of Mananga Watershed, Cebu, Philippines

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Mananga Watershed is an important watershed that comprises the largest protected cluster of watersheds and natural parks in Metro Cebu. Located 15 km west of Cebu City in the mid upland portion of Cebu Province, it has been classified as the Central Cebu Protected Landscape (CCPL) pursuant to Republic Act No. 9486. It covers wholly or partially 15 barangays in Cebu City, six barangays in Talisay City and three barangays in Minglanilla, Cebu; with an approximate area of 7 876.87 ha. It supplies majority of the domestic, agricultural and industrial water in Metro Cebu. However, it is constantly threatened by degradation and rising vulnerability levels due to natural and human-related activities. Thus, this research aimed to assess the vulnerability specifically on soil erosion and landslide; identify the critical factors affecting the vulnerability; determine and map-out the vulnerability levels; formulate specific mitigating measures; and formulate policy recommendations.

Methodology

Soil erosion and landslide vulnerability were studied in Mananga Watershed. Secondary and primary data were gathered. For soil erosion, the Universal Soil Loss Equation (USLE) was integrated in GIS and the critical factors were based on the empirical formula developed by Wischmeir and Smith (1978) with some modifications. It computes soil loss as a product of six major factors, whose values are expressed as, A = RKLSCP; where A is the soil loss (t ha^{-1} yr^{-1}), R is rainfall erosivity, K is soil erodibility, LS is the topographic factor, C is the cover factor, and P is the erosion control factor. The GIS-assisted methodology was adopted from Lanuza (2007) that involved data transformation of spatial and temporal data to vector GIS format and subsequent data conversion to raster format. Soil erosion vulnerability map was computed using GIS and classified into five soil erosion vulnerability classes.

Landslide vulnerability involved the identification and analysis of physical and anthropogenic factors that served as key inputs by assigning hazard values and relative weights on their contributions to landslide occurrence. The GIS-assisted procedure was adopted and applied where each factor map with geo-relational data was converted to grid format using the hazard ratings (Lanuza, 2007). Landslide vulnerability map due to physical factors was calculated as the sum of weighted product of individual factors as shown:

$$Lp = 0.3Sl + [0.1Cl(r) + 0.1Cl(t)] + [0.05G(f) + 0.05G(a) + 0.2G(fl)] + [0.05S(t) + 0.05S(mc)] + 0.1Lu,$$

Where: Lp is landslide vulnerability due to physical factors
Sl is the slope factor;
Cl is the climatic factor with *r* as rainfall amount and *t* as typhoon frequency;
G is the geology with *f* as formation, *a* as age, and *fl* as relative distance to the faultline;
S is the soil factor with *t* as soil type and *mc* as morphological classification; and
Lu is the landuse.

The anthropogenic factor was computed as the average of the hazard values of the three identified factors (farming systems, ground disturbance, and occupancy and habitation). The overall watershed vulnerability to landslide was then calculated by incorporating the physical and anthropogenic factors, with relative weights of 0.90 and 0.10, respectively as shown:

$$Lw = 0.9Lp + 0.1La,$$

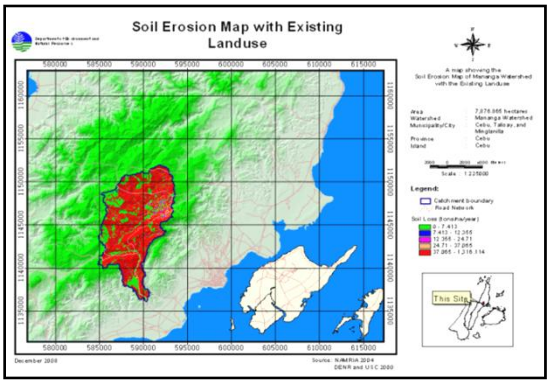
Where Lw is the overall landslide vulnerability,
Lp and La are the landslide vulnerability due to physical and anthropogenic factor, respectively.

Based on generated map of vulnerable areas to soil erosion and landslide, mitigation measures were formulated to reduce and control the negative impacts.

Results, Discussion and/or Recommendations

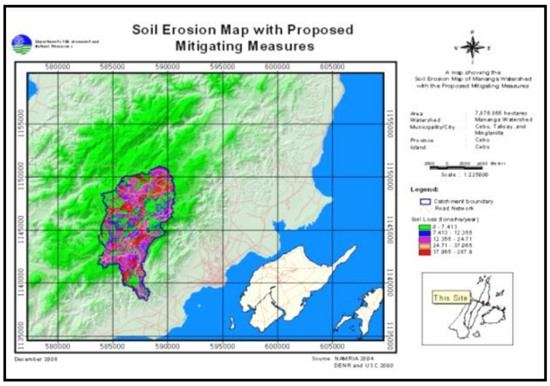
Vulnerability assessment is a rapid tool in identifying and determining areas vulnerable to natural and man-made hazards. Zielinski (2002) stressed that it also analyzes and explains those factors that make the hazard a threat to the community like soil erosion and landslide. Indeed, soil erosion has been considered a major threat to sustainable agriculture and the environment (Colacicco et al. 1989). It occurs due to the complex interactions of many environmental processes (Bradford & Huang 1996). Comparably, landslides are more threatening because of the massive movement of earth mass that results to damage of properties and lives. Varnes (1985) stated that identifying the conditions and processes promoting past instability makes it possible to use these factors to estimate future landslides.

Along with the complexity, the GIS-assisted approach in managing and analyzing the information has been developed. GIS is a systematic means of geographically referencing a number of "layers" of information to facilitate the overlaying, quantification, synthesis and analysis of data to aid in decision making (Burrough & McDonnell 1998). GIS-assisted models on soil erosion and landslide from previous research have been applied. USLE was used and integrated in GIS as a tool in predicting soil erosion. The results showed that the predicted average potential soil loss of 152.38 t ha^{-1} yr^{-1} under the existing land use and cropping system is extremely higher than the tolerable soil loss. Soil erosion ranges from less than 1 to 1316.11 t ha^{-1} yr^{-1}. Areas vulnerable to soil erosion are in steep slopes with poor vegetative cover and insufficient erosion control (Figure 1). However, when the model was applied using the proposed mitigating measures such as adoption of natural resource management (NRM) strategies and environment-friendly technologies leading to increase the soil cover as well as improving the hillland farming systems within the watershed, the predicted average soil loss was reduced to 21.17 t ha^{-1} yr^{-1} with a range of less than 1 to 287.9 t ha^{-1} yr^{-1} (Figure 2).



Soil Loss (t/ha/yr)	Area (ha)	Distribution (%)
Very Low	1,648.95	20.97
Low	65.21	0.83
Moderate	173.08	2.20
High	240.37	3.06
Severe	5,736.26	72.94

Figure 1. Extent of soil loss and location of areas vulnerable to soil erosion within Mananga Watershed, Cebu, Philippines under existing landuse and erosion control measures in 3-D view generated through GIS.



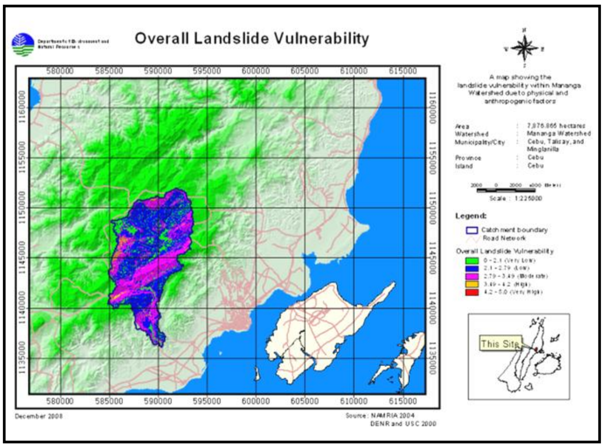
Soil Loss (t/ha/yr)	Area (ha)	Distribution (%)
Very Low	2,576.66	32.80
Low	974.00	12.40
Moderate	2,279.77	29.02
High	907.04	11.55
Severe	1,118.65	14.24

Figure 2. Extent of soil loss and location of areas vulnerable to soil erosion within Mananga Watershed, Cebu, Philippines under the recommended mitigating measures in 3-D view generated through GIS.

Model simulation under the proposed mitigating measures showed that only about 25.79% or about 2025.69 ha have high to very high soil erosion. It implied that there was a decrease of 3950.94 ha from the original soil loss of 5976.63 ha under existing land use. On the other hand, the areas with very low to low soil erosion have increased and it covered about 45.20% or 3550.66 ha. The areas with tolerable soil loss have increased from 1648.95 ha (28.75%) to 2576.66 ha (44.92%) or an additional area of 927.71 ha. Other researchers have tried predicting soil erosion using USLE with GIS (Ogawa *et al*. 1997, Mongkolsawat *et al*. 1994). Though, these researchers have applied various approaches, it has been observed that the application of a GIS-assisted approach is feasible. Definitely, it simplified complex operations because it can integrate the spatial and analytical functionality for spatially distributed data.

The physical factors affecting landslide are slope, amount of rainfall , typhoon frequency, geological age, geologic formation, relative distance to the fault line, soil type, soil morphological classification, and land use. In computing for the overall landslide vulnerability (Lw), the model was also expanded to include the anthropogenic factors (La) and the final equation is Lw = 0.9Lp + 0.1La. Areas vulnerable to landslides are those located in steeper slopes, unstable geology and near fault lines (Figure 3). It was predicted that Barangay Buot Taup in Cebu City has the largest area with high landslide vulnerability having 238.80 ha followed by Pamutan and Sinsin in Cebu City and Camp 6 in Talisay City.

Based on the results, the recommended strategies and policies must focus on addressing the low soil fertility and productivity by adopting sound and environment-friendly technologies as well as avoidance to landslide-prone areas to prevent and avoid damage or loss of human lives and properties.



Vulnerability Class	Area (ha)	Distribution (%)
Very Low	748.37	9.52
Low	2,497.23	31.78
Moderate	3,864.63	49.18
High	747.69	9.52
Very High	0	0

Figure 3. Overall landslide vulnerability map of Mananga Watershed, Cebu, Philippines generated through GIS.

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Vulnerability Assessment of Cugman River Watershed

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The Cugman River Watershed is a seahorse-shaped catchment landscape which stretches from the northern portion of the province of Bukidnon towards the coastal area of the province of Misamis Oriental, specifically within the City of Cagayan de Oro. It lies along 8º13'25" to 8º28'30" N latitude and 124º41'45" to 124º49'20" E longitude embracing 10 barangays of the Municipality of Libona, Bukidnon; and 3 barangays of Cagayan de Oro City, covering a total area of 10,250 ha.

The Cugman River supports the domestic, industrial, and commercial needs for water by the local communities, especially the highly urbanized barangays of Cagayan de Oro City. However, the sustainability of the streamflow including its water quality is being threatened by soil erosion, which also induces heavy sedimentation that causes flooding. As such, the Cugman watershed was characterized and subjected to assessment of its vulnerability to apparent hazards such as landslide, soil erosion and flooding. The vulnerability assessment aims to generate a vulnerability map out of the different maps of critical factors that shall be used as guidance in the preparation of Integrated Watershed Management Plan, as basis for policy issuances preferably for disaster preparedness and environmental conservation, as well as guidelines for land use zoning.

Methodology

Vulnerability assessment comprises the identification of different hazards threatening the integrity of the watershed, identification of natural and anthropogenic factors that triggers the occurrences of such hazards, and mapping of said factors using GIS-assisted mapping and spatial analysis techniques. The identified natural critical factors were mapped and categorized according to the ratings as shown in Table 1.

Table 1. Rating of critical physical factors.

Vulnerability Class	Rating	Critical Physical Factors				
		Slope (%)	Rainfall (Annual – mm)	Vegetative Cover	Soil Type	Geologic Formation
Not Vulnerable	1	0 – 8	<1743	Secondary forest	Adtuyon clay	Ultramafic/ Indahag limestone
Low Vulnerability	2	8.1 – 18	1743 – 1834	Reforestation/ orchard	Adtuyon clay	Schist
Moderately Vulnerable	3	18.1 – 30	1835 – 1925	Grassland/ brushland	Alimodian clay	Bukidnon formation
High Vulnerable	4	30.1 – 50	1926 – 2016	Industrial agri-plantation	Bolinao clay	Himalyan formation
Very highly Vulnerable	5	>50	>2016	Domestic agri-crops	Bolinao clay	Quarternary alluvium/ Cagayn terrace deposits

The categorized maps of critical natural factors were then overlayed using the GIS-assisted mapping and spatial analysis techniques to get the hazard value which is the sum of the weighted product of the vulnerability ratings of each categorized map.

In the case of anthropogenic factor which covers only soil disturbance due to road construction and farming practices, relative distance from the road was also adopted to categorize the maps into different levels of vulnerability. The two categorized anthropogenic maps were then overlaid and the hazard value of each polygon formed by such overlaying is the average of the hazard rating of farming practices and road disturbance.

The vulnerability hazard maps due to physical or natural factors and anthropogenic factors were finally overlaid to get the vulnerability map of the watershed. The hazard value is the sum of the hazard values for natural and anthropogenic factors at 90% and 10%, respectively. The final hazard value of both the natural and anthropogenic factors is referred to the guide manual to determine the final vulnerability of the watershed. The same methodology was used for the landslide and soil erosion hazards except that the weightages of critical factors were different.

For flooding hazard, actual field verifications were conducted and using local key informants to pinpoint the actual level of flood in the locality. The elevations and coordinates of the exact location of highest watermarks were taken using GPS. The data gathered were used to delineate the flood prone areas of the watershed.

Results, discussion and/or recommendations

Using the GIS-assisted mapping and spatial analysis the five identified critical factors that influence landslide: slope, rainfall, land use, soil type and geologic formation, were mapped and categorized into five different hazard ratings. The categorized maps were overlaid following the model of the form:

Landslide Hazard Value (Lv)
= slope (40%) + rainfall (30%) + soil type (15%) + vegetative cover/land use (10%) + geology (5%)

In addition, the critical factors attributed to human interventions such as farm practices, and soil disturbances due to road construction, were also considered of which the hazard value is determined as the average rating of the two factors. The final landslide hazard value at a ratio of 90% physical factor and 10% anthropogenic factor was computed and the corresponding landslide hazard vulnerability map was generated. Out of the total area of 10 250 ha, 1.95% or 199.54 ha was zoned as highly vulnerable, 22.7% or 2326.31 ha was zoned as moderately vulnerable, 51.47% or 5275.7 ha was zoned as low vulnerability and 23.9% or 2448.98 ha was zoned as none or very low vulnerability.

Using the model of the form:
Soil Erosion Hazard Value (SEv)
= rainfall (40%) + slope (20%) + soil type (15%) + land use (20%) and geology (5%)

the soil erosion vulnerability hazard map was also generated. Likewise, the anthropogenic factors were also incorporated at the same 90% and 10% ratio for physical and anthropogenic factors respectively. Hence, the final soil erosion hazard vulnerability map was generated of which 250.26 ha or 2.44% of the total watershed area was zoned as highly vulnerable, 3393.29 ha or 33.12% was zoned as moderately vulnerable, 3670.18 ha or 35.8% was zoned as low vulnerability and 2935.99 ha or 28.64% was zoned as very low vulnerability or not vulnerable.

Result on the delineation of floodplain areas within the watershed based on the highest water mark during flood event, specifically at the height of typhoon “Ondang” in 1994 which hit Cagayan de Oro City, showed that the flood prone areas are mainly at the downstream portion, particularly in the low-lying coastal barangays, covering a total area of 203.09 ha.

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Assessment of the Vulnerability to Landslide of Lower Allah Valley Sub-watershed at Mindanao, Philippines

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The study entitled "Assessment of the Vulnerability to Landslide of Lower Allah Valley Sub-Watershed at Mindanao, Philippines" was conducted from 2006–2007 to develop a vulnerability map and a model for vulnerability to landslide, and also to determine the physical and anthropogenic factors that significantly affect its vulnerability to landslide, and recommend appropriate mitigating measures. The study area is geographically located between 124°30'00"–141°41'17" E longitude and 6°10'10"–6°26'33" N latitude. It has an area of about 37,464.2 ha based on topographic divide. The terrain is very rugged with small area of floodplain. It has two rivers which drain to Allah River.

Allah Valley Watershed has been the focus of development, protection and management by the National Irrigation Administration and the Forest Management Bureau. These efforts have been aimed at sustaining its economic significance. Among the major activities conducted to achieve these objectives are the protection of the remaining forested areas and the rehabilitation of the open and denuded portions. There are great concerns for Allah Valley Watershed to sustain the domestic and irrigation needs of the surrounding communities due to the presence of upland farmers within the watershed. The hazard that this watershed poses cannot be discounted. Records show that soil erosion, flash floods, and landslides have been taking place for quite some time. Sediments that were deposited in the low lying areas are proofs of these occurrences. The assessment of Allah Valley Watershed to determine its susceptibility or vulnerability to different hazards, like flooding, soil erosion and landslide in particular, would provide information necessary in the formulation of policies and programmes to safeguard lives, properties and economy of the surrounding communities. Moreover, this vulnerability assessment is a pre-requisite in the preparation of the Integrated Watershed Management Plan (IWMP) for Allah Valley Watershed.

Methodology

Data used were derived from thematic and hazard maps of the watershed. The factors affecting landslide were identified: soil type, rainfall distribution, slope, geologic, land cover, farming system, occupancy and habitation, distance to road, and distance to fault line. The factors were given equivalent hazard categories as follows: 1– Very Low, 2 – Low, 3 – Moderate, 4 – High, and 5 – Very High. These hazard maps were overlaid to create a single map with intersection of areas. Each area or polygon has its own characteristics of hazard categories. The data on areas susceptible to landslide and landslide susceptibility map were used, and were overlaid on to the satellite image map, to create sample location points with occurrences of landslide regardless of the degree. The 37 location points identified were overlaid on to the previously prepared single map reflecting all identified factors to get the data on percentage weight. The data were computed using weighted average for each factor.

The areas with occurrences of landslide were evaluated using the Qualitative Weighted Method (Van Westen 1993). The nine maps developed containing important variables in the occurrence of landslide were given weights then a combination formula was used to integrate all the weights to develop a final landslide vulnerability map. The model developed is shown below:

Landslide Vulnerability = [(24.3%)* Soil Type + (16%) *Rainfall Distribution + (11.9%)*Slope + (10.8%)*Geologic
+ (9.8%)*Land Cover + (9.8%)*Farming System + (7.0%)*Occupancy and Habitation
+ (5.5%)*Distance to Road + (4.9%)*Distance to Fault line].

The landslide vulnerability map was assessed as to its validity using ordinal regression analysis. Out of the five link functions available to construct the model, the negative log-log function was used because it best fits the model. A total of 5726 cases were used in the study. The predictive value of the model was also determined and the result was significant. Furthermore, the model was subjected to goodness of fit in order to determine if the data observed are consistent with the fitted model. The Chi-Square Based Fit revealed that the data and model predictions are similar hence the model is good. To determine the coefficient of determination of the ordinal regression model, the R^2 approximations are computed using the methods such as Cox and Snell's R^2; Nagelkerke's R^2; and Mc Fadden's R^2. The resulting pseudo R^2 revealed that Nagelkerke method had the highest significant pseudo R^2 value of 0.753 which means that 75.3% of the variation in the vulnerability of the area to landslide can be accounted by the model and the rest is attributed to other factors.

Results and discussion

Results revealed that the vulnerability of the Lower Allah Valley Sub-Watershed to landslide is significantly affected by the following factors: soil, rainfall, slope, geologic, land cover, farming system, settlement, distance to road, and distance to fault line. The percentage of contribution of each factor is reflected in the model. About 25.5% of the total area in hectare falls under low hazard category (low vulnerability), 68.6% of the total watershed area falls under moderately hazard category (moderate vulnerability), 5.9% falls under high hazard category (high vulnerability), and only 0.004% falls under very high hazard category (very high vulnerability). The physical factors contributed 77.70% and anthropogenic factors contributed 22.30% in the vulnerability of the sub-watershed to landslide. Among the barangays within the Lower Allah Valley Sub-watershed, it was predicted that Barangay Upper Sepaka followed by Barangay Colongulo both located in the Municipality of Surallah Province of South Cotabato have the largest area with high vulnerability to landslide which covers 692.71 ha and 452.11 ha, respectively. However, minimal areas with very high vulnerability was noted within the sub-watershed located at Barangay Talahik and Colongulo, both located in the Municipality of Surallah Province of South Cotabato, with areas of 1.16 ha and 0.16 ha, respectively. Areas vulnerable to landslide are those located in moderately steep to steep slope, unstable geology, agricultural crops specifically corn planted on hilly areas and near fault line. This may be triggered further by high rainfall that cause the saturation of soil and some ground disturbance like road construction and settlements which may lead to landslide. Very high to high vulnerability to landslide is located mostly on the north-eastern part of the sub-watershed while low vulnerability to landslide areas are mostly located on the south-western part of the watershed. Although the south-western part has steep slope, the area is still covered with closed canopy forest with stable geologic rocks that contribute to low vulnerability to landslide.

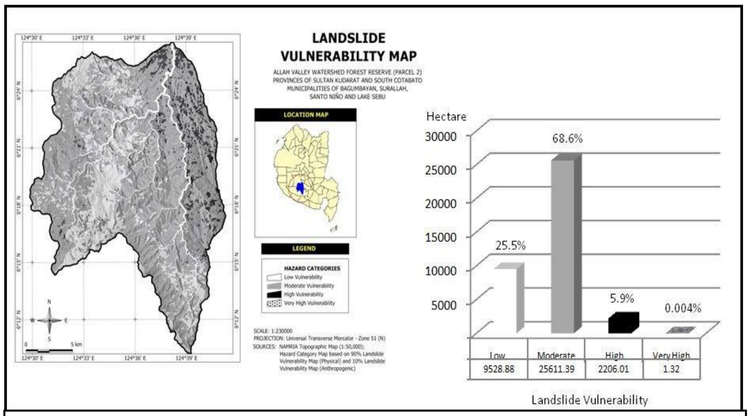

Figure 1. Landslide Vulnerability Map of Lower Allah Valley

Having chosen the model with the negative log-log link, interpretations based on the parameter estimates were done as follows:

Distance to fault line – As the area moves away from the fault line it tends to have low vulnerability to landslide since there is a low risk of allowing infiltration and accumulation of ground water from the faults that may trigger landslide.

Soil – In general, the soil of Lower Allah Valley sub-watershed is characterized as mountain and recent soils which are generally relatively shallow and are often poorly anchored, hence, it tends to have high vulnerability on landslide.

Geology – As the age of the rock increases it means less vulnerable to landslide.

Rainfall Distribution – The Lower Allah Valley Sub-watershed is located in typhoon-free area hence less rainfall accumulated which means low vulnerability on landslide. Moreover, the rainfall is distributed evenly during the year with an average of 2600 mm per year which is found in the southeastern part while the northeastern part has no very pronounced season of about one to three months. In majority of cases, the main triggering factor of landslides is heavy or prolonged rainfall because the rainfall drives an increase in pore water pressures within the soil which makes it vulnerable to landslide.

Distance to Road – Low vulnerability on landslide will occur if the area is far from the road since the area or ground is not disturbed by human activities particularly in those sloping areas where roads are constructed. Most landslide occurrences are observed as the distance from the road decreases.

Occupancy and Habitation – Low vulnerability to landslide will occur if the area is far from the settlements since the land is less disturbed from human activities.

Slope – Flat slope have low vulnerability to landslide because of stable or constant gravitational pull while steep slope is subjected to unstable gravitational pull.

Land Cover – If the area is covered with primary forest and tree cover, less or no landslide will occur because canopy reduces the impact of raindrops to soil and the root systems of trees help bond the soil thus preventing occurrences of landslides.

Farming System – Generally, agricultural crops such as irrigated rice field are planted on lower elevation while corn is planted on the 0 to 30% slope. Most landslide occurrences are observed on grassland, brush land and degraded forest which covers 28% of the total area of Lower Allah Valley Sub-watershed located mostly on 8% to 50% slope. Tree mono-crop and coconut mono-crop farming systems within the watershed area resulted to low vulnerability to landslide.

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Assessment of Flood and Landslide Vulnerability for Watershed Management Plan of Grindulu, Pacitan District, Indonesia

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During the last decade, flood and landslide disasters occurred very often in Indonesia, including the Grindulu watershed. As part of mitigation measure, assessment and mapping of the vulnerability were conducted at the Grindulu watershed (70,672 ha), Pacitan Regency, East Java Province, Indonesia.

Methodology

A tool for assessing vulnerability of flood and landslide hazard areas in catchment area was developed and published as the "Rapid Investigation of Sub-watershed Degradation" (Paimin et al. 2006). Assessment tools of vulnerabilities were distinguished between natural and manageable factors. Flood vulnerability was separately assessed for area susceptible to flood (flood area) and area that supply flood water (runoff) from a catchment. For runoff sources area, the following factors were measured: maximum daily rainfall, watershed shape, river gradient, drainage density, average of watershed slope, and management factor of land use/cover. For vulnerable flooded area, the following factors were measured: landform, land slope of riverside, meandering, and flow detention at branching river, and management factor consisted of water control structures. To assess landslide vulnerability the following factors were evaluated: maximum of cumulative consecutive three-day daily rainfall, land slope, geology, fault, and regolith depth, and land use/cover, slope cutting for road and houses, and population density at residential area. Each factor was weighted based on its role and was also scored into five classes: very low (1), low (2), medium (3), high (4), very high (5). The value of vulnerability was determined by the product of weight and score divided by 100. Then, the value was classified into five categories: very low (<1.70), low (1.7–2.5), medium (2.6–3.4), high (3.5–4.3), and very high (>4.3). The data analysis and mapping process of the flood vulnerability were conducted by applying a geographic information system (GIS) of Arc View 3.2. By using these procedures, assessing and mapping of vulnerability were conducted at Grindulu watershed (70 996 ha), Pacitan District, East Java Province, Indonesia, to propose mitigation activities as watershed management planning process.

Result and discussion

Grindulu watershed covers area of 70 996 ha which was divided into three sub-watersheds, namely: (1) Asem Gondok (16,23 ha), (2) Upper Grindulu (40 000 ha), and (3) Lower Grindulu (14 173 ha). Upper Grindulu sub-watershed was split into five sub-sub watersheds of: (a) Malikan, (b) Ngepoh, (c) Pronggo, (d)Tengi, and (e) Pronggi. Asem Gondok sub-watershed distinguished into sub-sub watersheds of: (a) Bungkah, and (b) Pacitan; whereas Lower Grindulu sub watershed was separated into sub-sub watersheds of: (a) Lower Grindulu 1, (b) Lower Grindulu 2, (c) Lower Grindulu 3, and (d) Lower Grindulu 4.

Areas highly susceptible to be flooded covered about 2736 ha (high and very high vulnerability categories) and were located at the lower part of the watershed. Flood occurence does not just depend on the vulnerability of flooded area but also depend on the supply of flood water from the catchment area. The whole watershed contributed high runoff that supplied flood water categorized as high vulnerability (value >3.5), except the small sub-watershed of Tengi. Area vulnerable to landslide included 5122 ha that spread over the upper part of watershed. Proposed mitigation treatment for vulnerable area was based on those factors that determined the vulnerability of the area, and should be adapted to the local resource availability.

The distribution of flooded area was mapped (Figure 1). The largest vulnerability of flooded area occurred at Lower Grindulu 4 sub-sub watershed (1345 ha), followed by Lower Grindulu 3 (654 ha), and Bungkah (230 ha) sub-sub watersheds. The area that is vulnerable to flooding starts from the confluence area between Malikan and Ngepoh rivers, then, down to the Lower Grindulu sub-watershed up to the estuary of Grindulu River. The alluvial plain and alluvial valley indicated that the areas were naturally easy to be submerged. Part of the area susceptible to flood is protected by earth embankment on the riverside. The other area that consisted of farm land was mostly flooded during the rainy season. According to the Regency Public Work Service, the flood occurred on 9 November 2000 covered an area of 2093 ha. Based on rainfall data observed in the period of 1976 – 2003, maximum daily rainfall that produced flood had a cycle of five years (GGWRM 2004). Therefore, little failure on management of flooded areas will lead to a big disaster.

Degree of landslide vulnerability in the Grindulu watershed was mapped (Figure 2). The areas that are most vulnerable (high and very high categories) to landslide in Grindulu watershed covered 5286 ha with the largest area located at Malikan (2303 ha) and Ngepoh (1342 ha) sub-sub watersheds, followed by Pacitan sub-sub watershed (849 ha).

The upper catchment area of sub-sub watersheds of Malikan and Ngepoh are highly vulnerable landslide areas bordering at the stream bank (Figure 2). Therefore, this area needs priority landslide control measures; besides, the area is also close to residency and other public infrastructures.

Based on the last decade’s experiences in Indonesia, areas vulnerable to landslide situated at the stream bank and at the upper part of the catchment area will cause flash flood as a result of a combination of landslide and flood. Starting with landslide at the stream bank, mass movement will plug up stream flow; therefore, surface runoff will be accumulated at the upper area like a reservoir. With increasing rainfall and surface runoff, accumulated water will flow over the earth plug. Finally, when the plug collapse, sudden flow or pouring out of stored water will flood the area.

Through watershed management, problem of the catchment area and lower watershed area could be integrated holistically, and the role of involved institutions could be identified clearly (Gunawan 2005). The problem of catchment area was related to surface runoff as source of flood and landslide. Principally, reducing flood vulnerability is by increasing river dimension; whereas, on the catchment area by reducing surface runoff with soil and water conservation practices and by establishing surface water retention. Mass movement of landslide was not only damaging heap up area (on site) but also sedimentation on the lower area (off site). Mitigating landslide with tree planting measures on deep-seated slide (>3 m) is less effective since it is determined rather by geology and climate (Bruijnzeel 2004)

Basically, techniques to control supply of flood water from the catchment area are based on soil and water conservation principles.: (1) increase infiltration of rainfall into the soil, and (2) increase surface and subsurface storage. Modifying river dimension or size could be accomplished by having structures of earth embankment (dike), flood diversion (floodway), and control sedimentation.

Conclusion

Vulnerability of flooded area covered about 2736 ha mostly located at the lower watershed area. Proper management of this area is critically needed since the supply of flood water from the whole catchment area indicated high potency, except Tengi sub-sub watershed. The areas that are most vulnerable (high and very high categories) to landslide in Grindulu watershed covered 5286 ha where the largest areas are located at Malikan (2303 ha) and Ngepoh (1342 ha) sub-sub watersheds, followed by Pacitan sub-sub watershed (849 ha).

Assessment of the flood and landslide vulnerability could be applied to determine degree of watershed problem that should be solved through management, especially for planning purposes. Vulnerability map could be utilized as guidance in selecting priority activities with socio-economic and bio-physical condition considerations; whereas the degree and quantity (areas) of vulnerability could be used for selecting appropriate treatment design and estimation of budget required.

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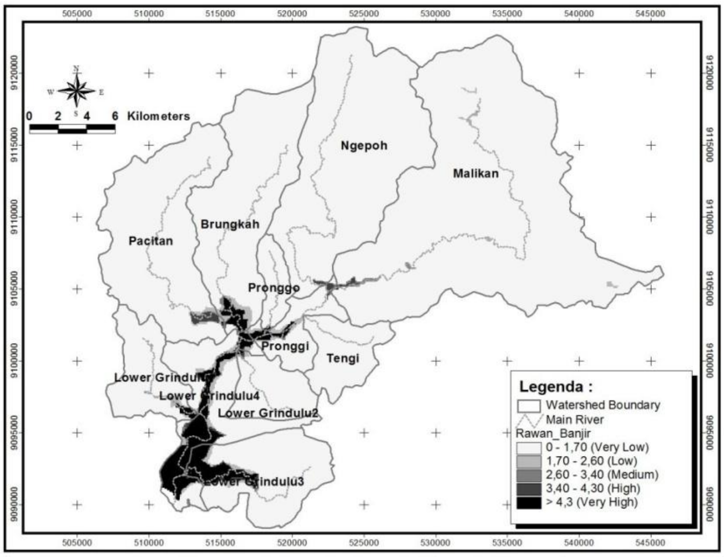

Figure 1. Map of flooded area vulnerability at Grindulu Watershed.

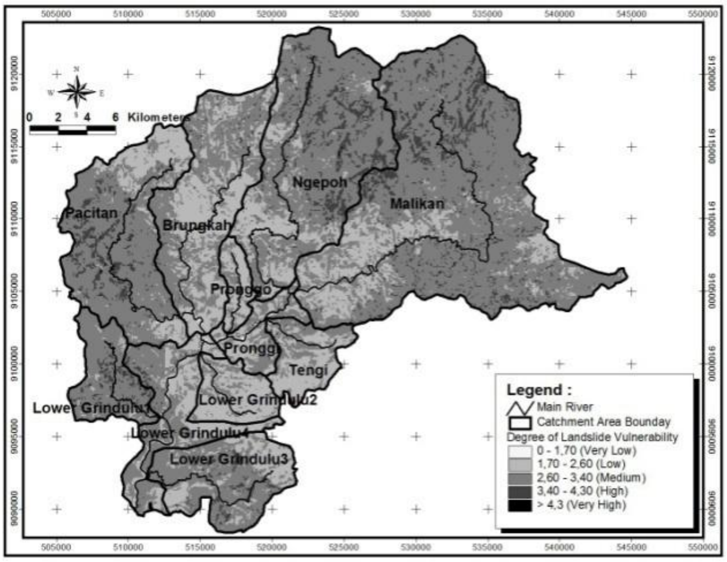

Figure 2. Map of landslide vulnerability at Grindulu Watershed

Landslide and Fire Vulnerability Assessment of Bued River Watershed within the Province of Benguet, Philippines

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The Bued River Watershed drains towards Rosario in La Union, Sison, San Fabian, San Jacinto and Mangaldan in Pangasinan. The historic and scenic Kennon Road, Mt. Sto. Tomas communication facilities, Camp John Hay, Philippine Military Academy, Philippine Economic Zone and other eco-tourism areas of aesthetic and climatic value are located in this watershed. During heavy rainfall oradverse weather conditions, Bued River contributes high volume of flood waters to low lying areas endangering lives and properties. Such was the case when typhoons Ondoy and Peping hit Northern Luzon.

Vulnerability assessment is necessary for the sustainable development of watersheds and natural resources. It identifies the hazards in the watershed, and its vulnerability, thus providing decision makers with information as to what, where and when interventions should be introduced to reduce/prevent damage and/or enhance the coping capacity of an ecosystem.

Methodology

The assessment was conducted through the creation of a multi-disciplinary team coming from various sectors/services of DENR-CAR, and participation in a series of workshops. Primary data collection includes sample collection and laboratory analysis, and interviews and focus group discussions.

Processing and analysis of data was done through GIS. The GIS-assisted methodology formulated by the ERDB Vulnerability Team was followed wherein natural forces and anthropogenic factors were recognized as factors affecting the vulnerability of the watersheds to hazards (Figure 1). Identification of critical factors related to various hazards and assigning of classes and weights to these factors are done in workshops. These classes and weights are then factored in to the watershed digital maps and through GIS, the data factored in are processed resulting in maps which when overlaid show what and where the hazards in the watershed are and the highest vulnerabilities of the watershed. A crucial element in reducing vulnerability to natural hazards is the analysis of human settlements and infrastructures.

Results and discussion

The Bued River Watershed covers about 14 302 ha. Geographically, it lies between 16º14’00” to 16º24’30” N and 120º30’45” to 120º38’50” E. It includes 25 barangays in the southern portion of Baguio City (2077 ha), six barangays of Tuba, Benguet (11 912 ha) and a small portion of Itogon, Benguet (313 ha). Watershed assessment showed that the Bued River is highly vulnerable to landslide and moderately vulnerable to fire.

Hazard Identification

Watershed characterization data, as well as focus group discussion with occupants in the watershed, revealed two major hazards with serious effects in the area. These are landslide and forest/grass fire. Landslides were observed along steep road cuts during the field survey as well as in steep areas. Forest/grass fires were also observed to have occurred as shown by scorched/dead wildlings and scarred barks of Benguet pine trees in the area.

1. Landslide Assessment

Data was collected as per the following parameters: biophysical (watershed morphology – area, elevation, slope, drainage pattern/density; geology and soils – geologic materials, fault lines, soil physical and chemical properties; climate – rainfall, typhoon occurrence and frequency, etc.; land-

use/vegetation – vegetation and extent of area; hydrology – streamflow, water quality, flood and drought occurrence); and socio-economic (socio-demographic – sex, age, income, education, etc.; attitudes of the people towards the watershed; awareness of the people of watershed concerns; and perceptions of watershed occupants).
In assessing landslide vulnerability, the biophysical factors were assigned numerical scores based on weights or their relative importance in influencing landslide.

In assessing landslide vulnerability due to some anthropogenic factors, the following were considered to have an influence on landslide: farming systems, ground disturbance by human activities and occupancy and habitations. These were then assigned hazard classes and weights.

GIS - Approach Landslide Vulnerability Analysis
The mathematical model applied to derive the landslide vulnerability map is:

Landslide Vulnerability Map
= [(Rated Slope Map*0.25)+(Rated Soil type/Morphological Classification Map*0.10)
+(Rated Rainfall*0.15)+(Typhoon frequency Map*0.15)
+(Rated Geologic Formation/Age Map*0.10)+(Rated Land Use/Cover Map*0.15)
+(Rated Rock Fracturing/fault line*0.10)]

The derived GIS-assisted approach to landslide assessment due to biophysical factors was applied to Bued River Watershed together with the anthropogenic factors to form the model:

Landslide vulnerability= [0.90 (biophysical factors) + (0.10 anthropogenic factors)]

The anthropogenic factor was determined by taking the mean of factors considered to contribute to the vulnerability of the watershed to landslide.

Considering the biophysical and anthropogenic factors, the overall vulnerability of the watershed to landslide is 3.60 which is highly vulnerable. About 39.6% of the area is highly to very highly vulnerable to landslide and 27.9% is moderately vulnerable. Combination of rainfall characteristics, slope, soil characteristics and soil disturbance brought about by cultivation contributed greatly to the vulnerability of said areas to landslide.

2. Forest/Grass Fire Assessment
Data was collected as per the following parameters: biophysical (slope and terrain; dry fuel materials present in the area; vegetation; aspect in relation to wind exposure; wind velocity and direction; dry spell; fire breaks; natural barriers; proximity to fire-prone areas; accessibility and infrastructure) and anthropogenic (socio-cultural – access to property rights, social knit, leadership and incendiarism; psycho-sociological – awareness/knowledge, beliefs, perceptions and attitudes; economic/technology factors – household/community economy, market and prices, capital investment and technology; political and Institutional -institutions and policies).

The derived GIS-assisted approach to fire assessment due to biophysical factors was applied to Bued River Watershed together with the anthropogenic factors to form the model:

Fire vulnerability = [0.40 (biophysical factors) + (0.60 anthropogenic factors)]

The anthropogenic factor was determined by taking the mean of factors considered to contribute to the vulnerability of the watershed to landslide.

As a result of the overall computation for vulnerability to forest fire, a mean general average hazard value of 3.00 was obtained which shows that the Bued River Watershed area is moderately vulnerable to forest fires. The value seemed reasonable and realistic as evidenced by the seasonal occurrence of forest fire in the area. However, forested areas near cultivated farms should be given due attention in terms of forest fire protection.

Formulation of Mitigating Measures
Focus group discussions and workshops by the technical team with key persons were conducted to come up with appropriate mitigating measures. The mitigating measures focused on interventions that may reduce the effects of the identified hazards or improve the adaptation of the watershed to the identified hazard(s).

Review, Analysis and Policy Recommendations
Existing policies gathered during the conduct of watershed characterization were reviewed and analyzed. Series of in-house workshops were initiated by the Team to come up with the needed policy recommendations to address the identified problems and minimized damage due to the identified hazards.

Conclusions and recommendations
The vulnerability assessment of the Bued River Watershed showed that the area is highly vulnerable to landslides and moderately vulnerable to forest/grassland fires. Through the geographic and spatial results, location of potential landslide areas and potential fire-prone areas were pinpointed and mitigation measures as well as policy directions and changes that can be adopted by LGUs were recommended. Some recommendations of utmost importance are:

1. Watershed Management Planning should consider vulnerability assessment results by focusing on developing interventions/projects in identified hazard-prone areas;
2. Result of vulnerability assessment should be incorporated in the community and municipal comprehensive land use plan (CLUPs). This would ensure saving of lives, properties and government money;
3. Infrastructures and settlements must be avoided in areas with moderate to high landslide vulnerability (steep slopes, unstable geology and near fault lines) specifically within the stretch of barangays Camp 4 and Twin Peaks. Upper slopes of roads constructed in steeper slopes must be supported with ripraps; and LGUs and other government agencies (DPWH, DENR) must install warning signs on the hazard-prone areas to warn prospective developers and investors;
4. Intensive IEC campaign must be done through "barangay pulong-pulong". GIS maps of landslide-prone areas should be displayed in the municipal and barangay halls to inform stakeholders of the dangers and possible occurrence of landslides in the areas and a simple rainfall monitoring devise be installed and once threshold of amount of rainfall is reached, warning should be given to residents living near slide-prone areas;
5. Planting of fire-resistant species in fire-prone areas and planting of perennial crops or tree-vegetable combinations should be encouraged to forest occupants;
6. Use of indigenous or adaptable/compatible forest tree species (i.e tuai, Ficus sp., alibangbang, akleng parang) in reforesting highly vulnerable areas.

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Development of Indicators for Assessing Susceptibility of Degraded Peatland Areas to Forest Fires in Peninsular Malaysia

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The occurrence of forest fires is not new in the ASEAN region but it is still an important issue (Ismail *et al.* 2008). The devastation seems to be critical in drier periods of *El-Niño* episodes. In Malaysia, forest fires pose a major threat to the management and conservation of peatlands which has been very much reduced in extent and quality. Forest fires have not only directly destroyed the flora and fauna of the peatland ecosystem, but their resulting haze is also detrimental to health and contributes to the accumulation of green house gases in the atmosphere. They also affect many related economic activities such as air transportation, sports, outdoor recreation and tourism. It was estimated that the aggregate incremental cost of the haze damage due to forest fires in 1997/1998 in Malaysia amounted to about USD270 million (Mohd. Shahwahid & Jamal,1999). It is also apparent that some of these forest fires recur periodically and some affect the same areas resulting in almost irreversible impacts. Such areas will be devoid of any tree vegetation and permanently colonized by *Imperata* sp. (Ismail *et al.* 2006). It is thus important to understand the underlying causes of forest fires, so that appropriate mitigating measures could be formulated and affected areas rehabilitated.

In Malaysia incidences of forest fires mainly occurred in degraded peat swamp forests, forest plantations and logged-over forests (Ismail et al. 2008). The fires that affected the forest plantations and some secondary forests are mainly surface fires, which burn combustibles such as fallen litter, grasses and shrubs. Nevertheless, those occurred in the degraded peat swamp forests are more serious as it involved the surface and below surface fires (Mohd Suhaimi et al. 2005). Some of the major reasons for the cause of fire are:

- Land preparations in agricultural plantations establishment
- Land preparations by farmers
- Traditional slash and burn agricultural practices
- Recreational activities such as camping and picnicking
- Hunting
- Snapped electric cable
- Natural causes– lightning, spontaneous combustion, etc.

The main objective of this study was to develop a map showing susceptibility classes to forest fires based on matrices of indicators developed for degraded peatlands in Peninsular Malaysia.

Methodology

- Peatland areas such as Northern Selangor, Kuala Langat and Southeastern Pahang, that have been regularly burnt by fires were identified. Record of weather patterns for a period of at least 20 years was used in determining suitable study sites. Selection of suitable sites was also based on historical data being kept at the state forestry departments.
- Data on peat depth, stand density, bulk density, moisture content, dryness index, water table and species composition were collected and analyzed. Data on water table, moisture content, bulk density and dryness index were collected every three months. These physical data formed major indicators that need to be quantified and ascertained regularly in conjunction with fluctuations in weather patterns within the study areas.
- The frequency of the data collection reflected the weather patterns within the study areas. Quantified data on physical environment provided an input to a matrix of indicators and ultimately an appropriate index was calculated and assigned to indicate the degree of susceptibility to forest fires.
- Similar data were collected from peatland areas not prone to forest fire.
- Based on the index that had been developed and tested, bigger area of degraded peatlands was assessed for its susceptibility to forest fires.

Results, discussion and recommendations

Map of fire susceptibility classes for peatland areas in Peninsular Malaysia were developed as shown in Figure 1. The fire susceptibility classes were based on outcomes from each main peatland area in Southeastern Pahang (Figure 2), Northern Selangor (Figure 3) and Kuala Langat (Figure 4). Nevertheless, the fire susceptibility classes have to be updated from time to time to reflect the current situation on the sites. The fire susceptibility classes developed can be used as a tool to minimize forest fire in Peninsular Malaysia through proper planning and implementing mitigation measures by appropriate authorities.

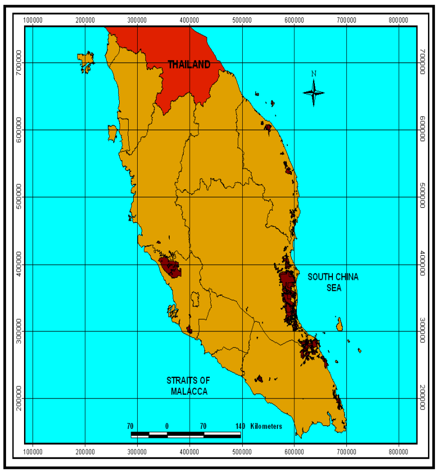

Figure 1. Map of fire susceptibility classes for peatlands in Peninsular Malaysia.

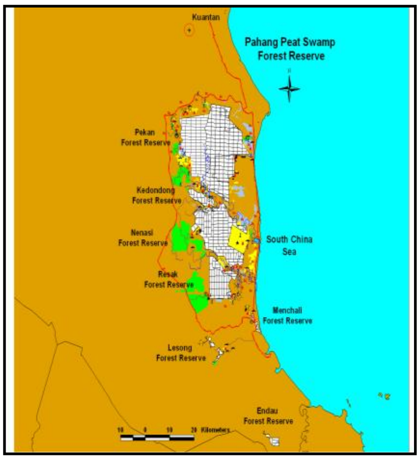

Figure 2. Map of fire susceptibility classes for South East Pahang peatlands.

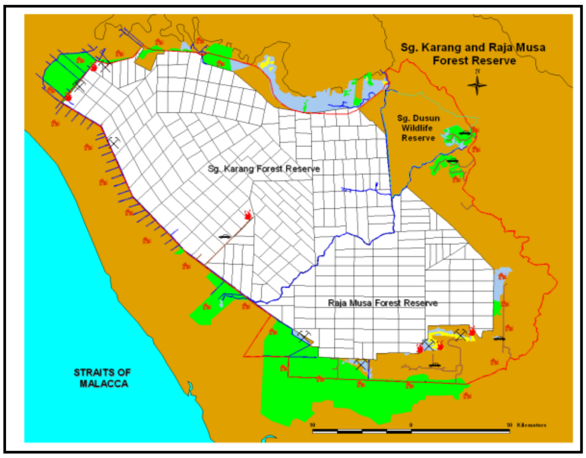

Figure 3. Map of fire susceptibility classes of North Selangor peatlands

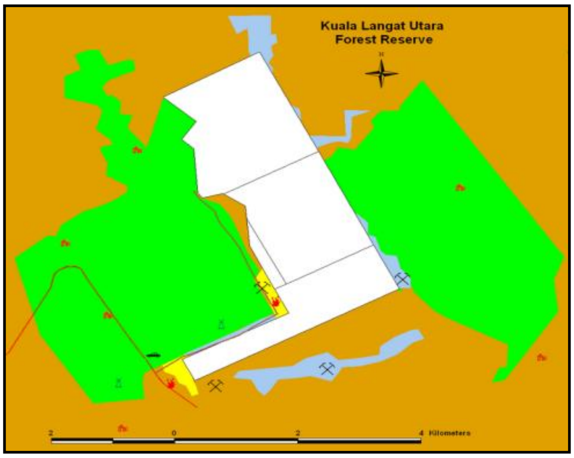

Figure 4. Map of fire susceptibility classes for Kuala Langat peatlands.

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Vulnerability Assessment to Biodiversity Loss: A Case of Western Himalaya, Nepal

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About 30% of the world's surface and 29% of Nepal's total area are covered by forests. Wise management could allow utilizing forest resources while maintaining biodiversity, ecosystem services and benefits for local and global communities. Biodiversity also provide essential services for many local communities such as non-timber forest products, traditional medicines and other needs for subsistence (CBD, 2003). Nepal comprises only 0.09% of global land area but possesses disproportionately large diversity of flora and fauna at genetic, species and ecosystem levels (MoFSC, 2002). It incorporates the Palaearctic and Indo-Malayan bio-geographical realms, and major floristic provinces of Asia. Nepal's rich biodiversity is a reflection of this unique geographic position as well as its altitudinal and climatic variations. Considering the unique biodiversity and endemism in the Himalaya (Table 1), it has been identified as one of the global biodiversity hotspots (Bhuju et al., 2007).

The ecosystems of the Himalayan region of Nepal are fragile. Due to climate change and other anthropogenic causes, indications of vulnerability to forest biodiversity loss have been reported (MoFSC, 2009). Mean annual temperature of the country was estimated to have increased by 0.06°C between 1977 and 1994, and is projected to increase by another 1.2°C by 2030 (ADB, 2009). According to MA (2005), "Biodiversity is declining rapidly due to land use change, climate change, invasive species, overexploitation,…",). Groom et al. (2005) pointed out the anthropogenic climate change as a major cause of biodiversity loss. While these drivers may vary in their importance among ecosystems and regions, current trends indicate a continuing loss of biodiversity.

Climate change has been observed to affect forest ecosystems through the timing of seasonal events (e.g. flowering), rates of growth and reproduction, distribution of species, species interaction (e.g., predation, parasitism, competition, and symbiosis), migration of forests, changes in composition, and extinction of species (Regmi et al., 2009). Rising temperatures, glacial retreat, flood and erosion, erratic monsoons, water shortages and drought events all have posed threats to Nepal's globally important biodiversity (IPCC, 2002). Although more emphasis has recently been placed on adaptation, there is less knowledge on what adaptation options have to be considered to conserve and sustainably use biodiversity (UNFCCC, 2002). The current rate of biodiversity loss suggests that biodiversity will not be able to continue to cope with the multitudes of pressures (Biringer et al., 2005).

Ecosystems vulnerability refer to the potential loss of natural habitat or ecosystem function (Jonas & Rouget, 2006), which is determined at specific spatial and temporal scale and is a dynamic process as it changes with local conditions (CBD, 2005). Therefore, vulnerability assessment is crucially important in national planning for biodiversity conservation and sustainable development.

Table 1. Diversity and Endemism in the Himalaya

Taxonomic Group	Species	Endemic Species	Percent Endemism
Plants	10,000	3,160	31.6
Mammals	300	12	4.0
Birds	977	15	1.5
Reptiles	176	48	27.3
Amphibians	105	42	40.0
Freshwater Fishes	269	33	12.3

Methodology

This study was conducted in the upper watershed area of the Tila River system of Jumla District in northwestern Nepal, which has an elevation of 2370 m to 4680 m (Figure1). Vulnerability assessment to forest biodiversity loss was carried out in terms of forest degradation, uphill shift of forest cover, rarity of fauna, invasion/colonization by one or few species, and reduced number of medicinal and aromatic plants (MAP) as used in various reports (CBD, 2003; Lim et al., 2005; Jonas & Rouget, 2006). Primary data collection included case studies, participatory mapping, transect walks, field visits and sample plot measurements in the study area. Household survey to collect people's perception on vulnerability to biodiversity and economy of the rural households was conducted using different sets of semi-structured questionnaires, vulnerability matrices (Downing & Doherty, 2004) and checklists. Ecological data for biodiversity assessment and meteorological data for temperature trend analysis were collected from secondary sources such as databases and reports available from the concerned sector organizations. Biodiversity-related data were collected through direct field observations, plots establishment and measurements, and timeline analysis. A consultation workshop was also organized involving different research organizations, local experts, farmers and community-based organizations as suggested by Regmi et al. (2009). Since CBD (2003) stated some steps suitable for vulnerability assessment, the methods suggested by Lim et al. (2005) including brainstorming, checklist, econometric techniques, scenario development, and expert judgment were widely used for assessing present vulnerability.

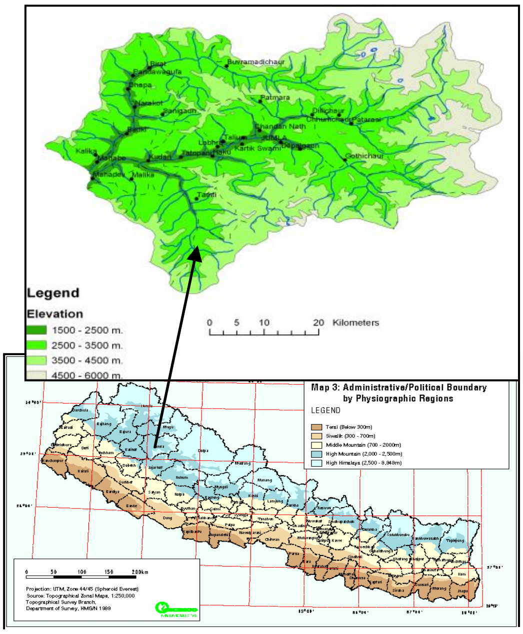

Figure 1. Study area – Jumla district, Nepal

Results and discussion

Perception of local people revealed that there was increased vulnerability to their livelihoods from forest biodiversity loss, especially MAP species due to climate change. Their state of knowledge about adaptive measures was sufficient but practices were unsystematic. Rising temperatures, glacial retreat and the changes in the availability of water resources were found responsible for changes in natural biodiversity affecting a considerable number of globally important plant and wildlife species of the region. According to local residents, days and nights were becoming warmer and rainfall patterns were irregular and random. There were clear indications of impacts of climate change such as high snow melting that caused tree line to shift uphill slope and the biodiversity to narrow down. Like the findings from Jonas & Rouget (2006), the degradation of forest was one of the major threats to biodiversity loss. Being a predominately agrarian nation, impacts of biodiversity loss from climate change on livelihoods were found to be significant, largely affecting availability of forest products including MAPs, livestock farming (low availability of palatable forage) and other livelihood assets in the Himalayan region. Econometric technique (Lim et al., 2005) showed that social costs had highly surpassed the social benefits from reduced forest resources and fewer alternatives at local level. It was carried out to suggest coping strategies for the challenges of biodiversity loss and poverty alleviation programmes in the region. Local adaptation to cope with present challenges of climate change includes activities like altering the timing of planting of crops, changing crop types, controlling insect outbreaks, and breeding new agricultural species that could be better suited in the changing climatic conditions. Precipitation extremes showed an increasing trend in intense precipitation events.

Figure 2. Observed vulnerability to biodiversity loss from climate change.

Intensive rainfall events, increase in frequency and intensity of floods, and changes in monsoon patterns were found triggering physical loss of fertile soil and aggravated sedimentation problems; socioeconomic condition changed and people more dependent on medicinal plants. Analysis of current vulnerability by developing scenarios and timelines with the involvement of stakeholders (Downing & Doherty, 2004) showed the vulnerability context such as unprecedented flooding from snow melting, invasion by one or few species and uphill migration of subalpine pine tree species (Figure 2). Southern aspects were drier than northern due to more solar radiation and therefore had no or less vegetation in the same altitude. There was more likelihood of increasing risk of invasive species, for which early detection and management were crucial to maintain its biodiversity. The riparian areas were found facing the threat of invasion from some native species, especially shrubs. Although unobserved during this study, forest fires that occurred intentionally or accidentally were also frequently causing significant damages to pine trees, shrubs and wild animals in the summer. It also had direct impacts on wildlife species which have low dispersal capacity and narrow home range such as soil fauna, non-flying insects, snow leopard, musk deer, etc. It was also found that the distribution and composition of species in the forest and rangeland were becoming more homogenous over the area, which has been observed since the past few years.

Recommendations

Since Nepal is preparing the National Adaptation Programme of Action (NAPA), it should develop and include the appropriate methodologies to assess the vulnerability to biodiversity loss particularly in the sensitive Himalayan region of the country. Institutional and technological strengthening is necessary to precisely assess both direct and indirect changes spatially and temporally. Initiatives are required to mainstream adaptive measures into national policies and actions to address the adverse impacts of climate change, reduce vulnerability to biodiversity and confer resilience to the Himalayan ecosystems. Particular attention should be paid to utilize existing local knowledge, practices and innovations, including good practices on biodiversity management. However, the ecosystem behaviours may not remain the same in the future.

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Drought Effects on Queensland's Vegetation Net Primary Productivity: An Analysis of 2000–2006 MODIS Satellite Imagery

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Droughts have always been a part of the Australian environment. Over the past decades, droughts caused significant damage to people, property, animals, and the environment signifying Australia's vulnerability to climate variability (Bureau of Meteorology, 2009). With the threat of climate change, the impacts of droughts in Australia may exacerbate in the future. Mpelasoka et al. (2007) showed that by 2030, the frequency of droughts will increase by 20–40% over eastern Australia. This would have major negative consequences for agriculture, natural resource management, drought relief payments, river systems and water resources, bushfire frequency, and biodiversity conservation (McAlpine et al., 2009).

In Australia, drought is defined as a condition when the rainfall, over a three-month period, belongs to the lowest decile (i.e. lowest 10%) of what has been recorded for that region in the past (Bureau of Meteorology, 2008). Severe droughts often bring significant damage to plant and animal life, as well as to non-living components of a region (e.g. Lind et al., 2006). For Australian vegetation, drought can affect plant's physiological processes and other attributes such as: a) transpiration rate of certain Eucalypt species (Eberbach & Burrows, 2006); b) patterns of flowering phenology for some trees (Law et al., 2000); c) incidence and severity of diseases in Eucalypts (Old, 2000); and d) primary productivity (Leuning et al., 2005).

Queensland's flora is diverse, reflecting a wide range of temperate, tropical, sub-tropical, monsoonal, marine and arid environments prevailing in the State. Based on the National Land and Water Resources Audit (NLWRA, 2001), about 1 425 064 km^2 of Queensland are classified into 23 major vegetation groups (MVGs). About 75% of which is covered by the eucalypt woodlands, tussock grasslands, eucalypt open woodlands, acacia shrublands, hummock grasslands and acacia forests and woodlands (NLWRA, 2001). Approximately 18% (30.4 million ha) of Queensland's native vegetation has been cleared — one of the largest areas of cleared land in Australia.

Net primary productivity (NPP) represents the net amount of carbon added to plant biomass per unit of space and time. Over a region with varying climatic types and forest ecosystems, the spatial and temporal variability of NPP can be enormous. The objectives of this study were to: a) characterize and compare the inter-annual variations of net primary productivity (NPP) between Queensland's major vegetation groups (e.g. *rainforests, eucalypt open forests, eucalypt woodlands, acacia forests, tussock grasslands,* etc.) in relation to variability in annual rainfall; and b) assess the potential effects of drought on the NPP of major vegetation groups.

Methodology

The study area covers the State of Queensland – Australia's second largest state (1 852 642 km^2). Occupying the northeastern corner of the Australian continent, Queensland has significant variations in climate given its vast area. It has low rainfall and hot summers in the inland west, a monsoonal wet season in the north, and warm temperate conditions along the coastal strip (Bureau of Meteorology, 2008). In the State capital of Brisbane, the annual mean temperature ranges from 14°C to 26°C, while the mean annual rainfall is 1,061 mm. In the tropical north, Cairns' annual temperature ranges from 20°C to 29°C, with mean annual rainfall of 2,223 mm. Using the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery products (MOD17A3), this study analyzed multi-temporal (2000–2006) images covering the entire state of Queensland. Ten major vegetation groups (MVGs) of different structural complexity (e.g. rainforests and vine thickets, eucalypt open forests and woodlands, acacia forests and woodlands, callitris forests and woodlands, melaleuca forests and woodlands, tussock grasslands, etc.), were sampled from the MODIS-NPP imagery. Their NPP values were analyzed and compared during moderately wet year (2000) and drought years (2002–2006).

Results, iscussion and onclusion

Results have shown that there is a significant spatio-temporal variability of NPP over major vegetation groups in Queensland (Table 1). For example, in the La Niña year of 2000, the mean NPP of rainforests and vine thickets was 18 780 $gC/m^2/yr^{-1}$, in contrast to the low mean NPP of hummock grasslands (629 $gC/m^2/yr^{-1}$). In the drought year of 2002, the mean NPP values range from 20 719 $gC/m^2/yr^{-1}$ to 27 $gC/m^2/yr^{-1}$. It shows that Queensland's grassland NPP has decreased by up to 96% in a drought year. This result is expected – the lack of water during the 2002 drought year hindered plant growth and productivity. This highlights the vulnerability of these areas to drought events which can impact the ecological and agricultural systems dependent on these grassland regions.

Table 1 Comparison of stand structure, growth, biomass and carbon storage of five mangrove communities in 11 provinces of Thailand

Parameters	Community					p-value
	Avicennia marina	*Avicennia alba*	*Rhizophora mucronata*	*Rhizophora apiculata*	*Ceriops tagal*	
Number of species						
Tree	2^{a}	3^{a}	3^{a}	5^{b}	6^{b}	<0.01**
Sapling	2^{a}	2^{a}	1^{a}	3^{b}	4^{b}	<0.01**
Seedling	1^{a}	1^{a}	1^{a}	2^{b}	2^{b}	<0.01**
Leaf area index	1.98^{ab}	2.06^{b}	2.49^{b}	1.90^{ab}	1.63^{a}	<0.01**
Tree density (trees/ha)						
Tree	260^{ab}	147^{a}	334^{b}	295^{ab}	230^{ab}	<0.01**
Sapling	67^{a}	48^{a}	32^{a}	54^{a}	170^{b}	<0.01**
Seedling	51^{a}	102^{a}	27^{a}	60^{a}	84^{a}	0.41
Diversity index	0.166^{a}	0.346^{a}	0.324^{a}	0.841^{b}	0.960^{b}	<0.01**
Diameter at breast height (cm)						
Tree	8.07^{a}	12.18^{b}	8.43^{a}	10.64^{b}	6.53^{a}	<0.01**
Sapling	2.57^{b}	2.04^{a}	1.52^{a}	2.23^{ab}	2.38^{b}	<0.05*
Height (m)						
Tree	7.45^{ab}	9.28^{ab}	10.90^{b}	10.72^{b}	6.13^{a}	<0.01**
Sapling	3.48^{b}	2.47^{ab}	2.15^{a}	3.22^{ab}	3.85^{b}	<0.01**
Total biomass (t/ha)						
Tree	79.81^{a}	137.19^{ab}	176.88^{b}	190.25^{b}	58.88^{a}	<0.01**
Sapling	0.94^{a}	0.44^{a}	0.75^{a}	0.69^{a}	3.06^{a}	<0.01**
Total	80.75^{a}	137.63^{ab}	177.63^{b}	190.94^{b}	61.94^{a}	<0.01**
Carbon storage (t/ha)						
Tree	37.52^{a}	64.47^{ab}	83.13^{b}	89.41^{b}	27.68^{a}	<0.01**
Sapling	0.44^{a}	0.20^{a}	0.35^{a}	0.33^{a}	1.43^{b}	<0.01**
Total	37.96^{a}	64.67^{ab}	83.48^{b}	89.74^{b}	29.11^{a}	<0.01**

Some vegetation groups did not significantly change (e.g. Eucalypt open forests, Casuarina forest, etc.). In contrast, rainforest's NPP increased by 10%. This agrees with the results of a study of the Amazon rainforests during the 2005 drought (Saleska et al., 2007). It showed that the forest canopy "greenness" (measured by MODIS Enhanced Vegetation Index) was dominated by a significant increase and not a decline. However, more recent study refuted this result: Samanta et al. (2010) contested that there was no co-relation between drought severity and greenness changes, which is contrary to the idea of drought-induced greening. Thus, they concluded that the Amazon forests did not green-up during the 2005 drought. With these contradictory findings, it suggests that more research should be done to better understand rainforests' vulnerability to drought events.

The results indicate that vegetation response to drought (as shown by NPP values) is related to vegetation's structural complexity. MODIS imagery demonstrated its usefulness for this type of study.

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Wood-boring Beetle Communities in Korean White Pine Forest and its Implication to Ecosystem Vulnerability Under the Influence of Climate Change

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Wood-boring beetles such as bark and ambrosia beetles can be one of the most serious threats to forest health under the influence of climate change although they are one of the important sources for biological diversity in forests. Korean white pine, *Pinus koraiensis*, is one of the dominant conifer species in Korea and it is expected that area of the white pine forest decreased because it is suitable for cooler region. Under the influence of climate change, biodiversity of the wood-boring beetle in Korean white pine forest can be reduced due to loss of habitat. Simultaneously the wood boring beetles can be sources for mass mortality of the white pine. This research was conducted to elucidate biological diversity of the wood-boring beetles in Korean white pine forest and its implication to ecosystem vulnerability under the influence of climate change.

Methodology

The study was conducted in the Korean white pine forests of Gunpo-si, Gyeonggi-do; and Cheongju-si, Cheongwon-gun, and Boeun-gun, Chungcheongbuk-do; as part of a nation-wide wood-boring beetle monitoring research in 2007. The location and information of collection sites were shown in Table 1. The wood-boring beetles were collected weekly by Malaise trap in each forest from May to September in 2007. In Gyeonggi-do, three Malaise traps were setup in Gunpo-si; whereas one trap was setup in Cheongju-si, Cheongwon-gun and Boeun-gun in Chungcheongbuk-do, respectively. The collected bark beetles were identified to species level.

Table 1. Information on location of study area and characteristics of forests surveyed.

Area code	Area	Latitude; Longitude	Altitude (m)	DBH[1] (cm)	Degree of vegetation	Thinning history
GP	Gunpo-si	N37°; E126°	100	15	1	2 years
CJ	Cheongju-si	N36°; E127°	200	20	1	-
CW	Cheongwon-gun	N36°; E127°	400	16	1	-
BE	Boeun-gun	N36°; E127°	300	20	3	1 year

Results and discussion

Abundance and species diversities of cerambycidae, curculionidae and scolytidae were variable to month surveyed. Generally, abundance of wood-boring beetle in spring was highest and diversities were almost equal both in spring and autumn (Figure 1).

The number of identified species belonged to cerambycidae, curculionidae and scolytidae were 16, 25 and 9, respectively. Although the collections were conducted in the Korean white pine forest, common species between Gyeonggi-do and Chungcheongbuk-do were only three species in each family. This result suggested that wood-boring beetle communities were identical in response to local environment. Abundances and diversities increased with increase in altitude and diameter at breast height (DBH). Abundances and diversities are highest one year after thinning then it dramatically decreased (Figure 2)

Among the species identified, *Enaptorrhinus granulatus* and *Balanobius roelofsi* were found only in one forest, suggesting that these species are vulnerable to decrease in the white pine forest. An ambrosia beetle, *Xyleborus mutilatus,* was the most dominant species in the white pine forests surveyed, suggesting that it has potential to outbreak in the white pine forests. Our results showed that the wood- boring beetle communities were key stone in both aspect of prevention loss of biodiversity in the forest and reduction in vulnerability of the white pine forest under the influence of climate change.

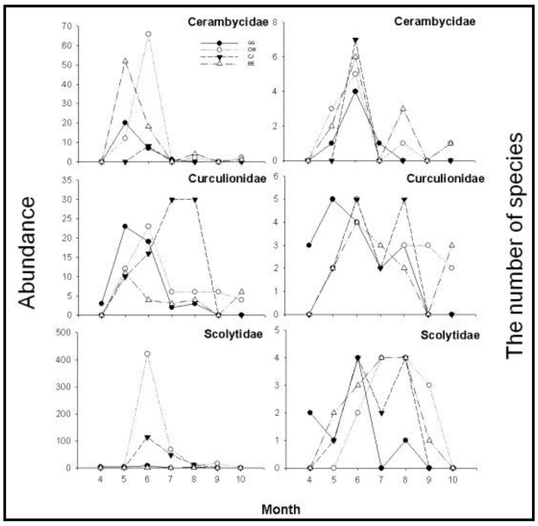

Figure 1. Monthly changes in abundance and the number of species that belonged to Cerambycidae, Circulionidae and Scolytidae in 2007.

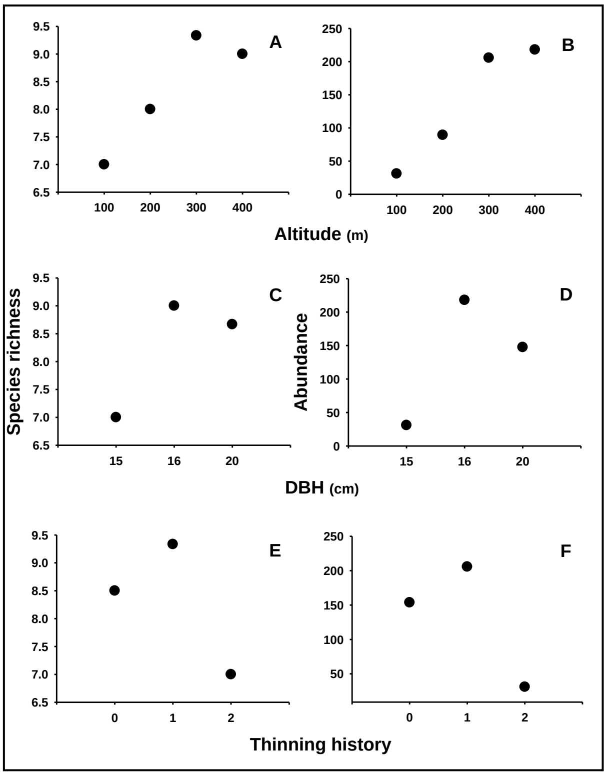

Figure 2. Influence of altitude, diameter at breast height (DBH) and the year after thinning on species richness and abundance.

Monitoring of Pollution Level of Area Where Acid Mine Drainage Discharges in an Abandoned Coal Mine Using Fast Growing Trees

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Mine Reclamation Corp. (2008) reported that there are 1,548 varioussized abandoned mines scattered throughout South Korea. Mine waste, including debris and acid mine drainage, is expected to have negative influence on agricultural lands and water systems continuously. Only 32 abandoned coal mines out of 338 have acid mine drainage treatment facilities. Ecosystem restoration projects are enhanced only on 48 closed metal mines out of 936. Thus, not enough efforts are being distributed on identifying the scale of the mine waste effects and restoring ecosystems. Therefore, it is urgent to prepare a long-term plan to prevent more damage on ecosystems around the abandoned mines, since the scale of damage caused by acid mine drainage from mine waste is anticipated to be large.

Phyto-remediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. There are several different types of phyto-remediation mechanisms. In the study, we use phyto-extraction and phyto-stabilisation types using fast growing trees among five phyto-remediation types. Generally, trees differ in their ability to translocate heavy metals from the root to the shoot. Drew et al. (1987) grew poplar clones in sludge-amended soil and found Zn and Cd concentrations to be the highest in foliage. McGregor et al. (1996) analyzed tissue of sycamore, birch and willow trees which had naturally established on sites contaminated by waste from an explosives factory and a chromium processing works. Chromium, Pb and Cu were found to have accumulated mainly in the root, and Zn concentrations were highest in the bark.

This study was carried out to monitor reducing pollution level of an area where acid mine drainage discharged in an abandoned metal mine using fast-growing trees such as *Salix koreensis*, *Populus euramericana*, *Populus tomentiglandulosa*, and *Liriodendron tulipifera.*

Methodology

This study was carried out in an abandoned mine (N 37°13'12.11", E 126°55'46.37") near Hwasung City, Gyunggi Province. The biome of this area is mixed broad-leaved forests with coniferous forests in the northern part of the warm-temperate zone and soils were classified as brown forest soils developed on granite gneiss. Average annual precipitation in the sites is 1,319 mm and annual mean temperature is 11.7ºC.

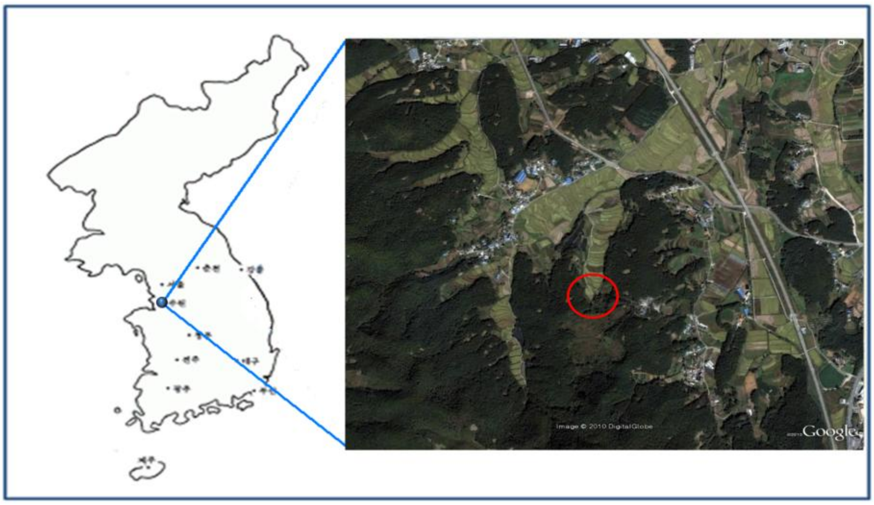

Figure 1. Location of the study site (O) in Hwasung City, Gyunggi Province.

Vegetation belt was established to purify pollutant using fast growing trees such as *Salix koreensis*, *Populus euramericana*, *Populus tomentiglandulosa*, and *Liriodendron tulipifera* to nearby puddle (about 1,200 ㎡) in April 2010.

There were 50 *Salix koreensis*, 50 *Populus euramericana*, 45 *Populus tomentiglandulosa*, and 45 *Liriodendron tulipifera* planted at intervals of 1.5m nearby puddle and waterway at the mine-water outlet where *Populus tomentiglandulosa* and *Robinia pseudoacacia* are the dominant species. Samples of soil, water, and study species were collected to measure the pollution level in nearby study sites., Survival rates, mean height of seedling, and mean diameter of seedling by species were collected in October 2010.

Results

Table 1. Physical and chemical properties of abandoned mine land in Hwasung City, Gyunggi Province, Korea.

Depth	Particle distribution (%)				Three phase (%)			Bulk density (g/㎤)
	Sand	Silt	Clay	Soil texture	Liquid	Solid	Gaseous	
0–15㎝	71.7	19.3	9.0	Sandy Loam	13.7	56.0	30.3	1.56
15–30㎝	74.1	23.0	2.9	Loamy Sand	14.6	59.8	25.6	1.71

Depth	pH	O.M. (%)	T.N. (%)	Avail. P_2O_5 (mg/kg)	CEC	K^+	Na^+	Ca^{2+}	Mg^{2+}
					(me/100g)				
0–15㎝	5.92	0.36	0.024	0.16	15.40	0.08	0.11	1.07	0.23
15–30㎝	6.20	0.20	0.018	1.80	11.44	0.07	0.10	0.69	0.20

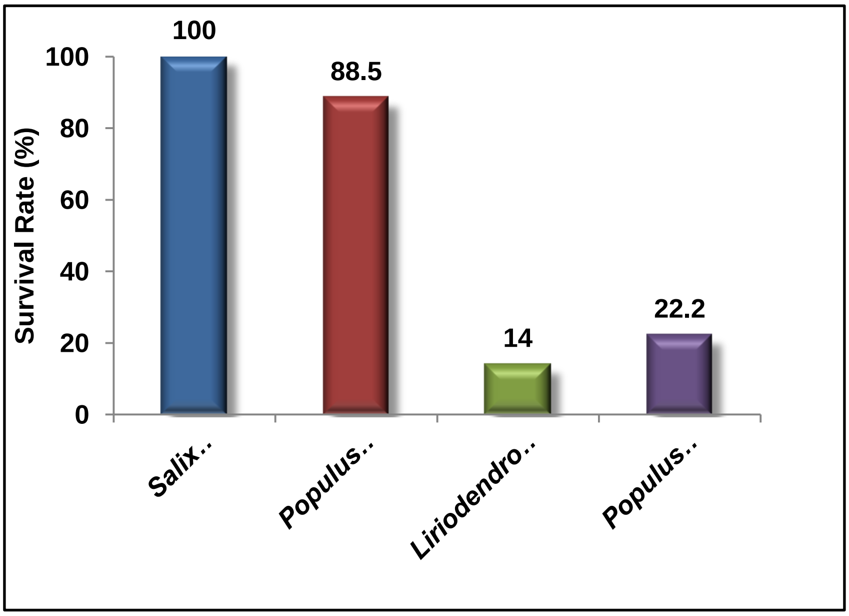

Figure 2. Survival rates of *Salix koreensis*, *Populus euramericana*, *Populus tomentiglandulosa*, and *Liriodendron tulipifera* seedlings after five months.

Discussion

As a result of heavy metal analysis in soil and water in the study site, the concentrations of all heavy metals exceeded the standard of soil and water pollution. The concentrations of heavy metal element in soils were high in the order of Al > Fe > Mn > Zn and the concentrations of heavy metal element in water were high in the order of Mn > Zn > Al > Fe. Generally, the concentrations of Al, Mn, and Zn in water decreased farther apart from the pollution source

The concentration of Al was higher in *Liriodendron tulipifera* than in the other species, generally the highest in *Salix alba*. The heavy metal concentration in tree components of all tree species decreased in the order of stem > branch > foliage.

As a result of heavy metal analysis in herbaceous plants such as *Equisetum arvense*, *Typha orientalis*, *Scirpus tabernaemontani*, and *Miscanthus sinensis* var. *purpurascens*, they have high concentration of heavy metal similar to woody plants.

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Climate Change Vulnerability and Household Level Adaptation
A Study on Forest Dependent Communities in Drought Prone Area of West Bengal, India

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Vulnerability assessment in the context of climate change is a new area of research especially among developing countries like India. The adaptation process includes three essential stages: vulnerability assessment, capacity building and implementation of adaptation measures. The fundamental goal of adaptation strategies is the reduction of the vulnerabilities to climate-induced change. Given the lack of resources, and access to technology and finances, developing countries such as India have limited capacity to develop and adopt strategies to reduce their vulnerability to climate change. In India, nearly two thirds of the population is rural, whose dependence on climate-sensitive natural resources is very high. Its rural populations depend largely on the agriculture sector, followed by forests and fisheries for their livelihood. Indian agriculture is monsoon dependent, with over 60% of the crop area under rain-fed agriculture that is highly vulnerable to climate variability and change. The paper focuses on understanding and quantifying the vulnerability of forest dependent communities in West Bengal, India. Forest is a vulnerable sector and constitutes an integral part of social life of tribes living in and around forest areas, and contributes substantially to the food supply of tribal populations in India. Besides, during droughts and in times of scarcity, the dependence on forests for food has found to increase.

Given this backdrop, the paper attempts to measure quantitative vulnerability assessment for the forest dependent communities where drought hazards are prevalent and to examine household adaptation strategies to reduce vulnerability due to climate change. Secondly, it also examines the development policies of the Government of India to enhance the resilience to climate change to reduce vulnerability.

Methodology

This study was conducted in four villages: Bandhgaba, Dhansimla, Rangakula, and Khayarakura. All four are tribal-based villages located in Sonamukhi forest area in the District of Bankura, one of the drought prone districts of West Bengal. Twenty-five households from each village have been selected on the basis of random sampling.

Analysis and Results

Six factors: occupation, sanitation, educational status, livestock assets, food sufficiency from agriculture, and awareness to climate change, have been incorporated for socioeconomic vulnerability assessment of each village. Vulnerability Indices have been calculated using the Three Categorized Ranking Method (TCR), assigning scores of 1 to 3 (1 being the least vulnerable). The basic assumptions are:

1. Lower level of educational facilities is associated with higher vulnerability;
2. Lower level of sanitation is associated with higher vulnerability;
3. Higher level of livestock assets is associated with lower vulnerability;
4. Lower level of awareness to climate change is associated with higher vulnerability;
5. Higher food sufficiency is associated with higher vulnerability;
6.People with diversified occupation are considered less vulnerable and people involved only in agriculture are considered highly vulnerable.

The socio-economic vulnerability identified Bandhgava village as moderately vulnerable among the four villages because of its weak adaptive capacity including highest illiteracy percentage (92%). Almost 100% of village respondents had less than three-months of food sufficiency to sustain their livelihood (Table 1).

Table 1. Vulnerability assessment for four villages.

Village	Education	Sanitation	Livestock assets	Climate awareness	Food sufficiency < 3 months	Occupation	Combined	Vulnerability
Bandhgaba	3	3	1	1	3	1	2	M
Dhansimla	3	2	1	1	3	1	1.84	L
Rangakula	2	3	1	1	2	2	1.84	L
Khairakura	2	3	1	1	2	2	1.84	L

Note: M stands for medium and L stands for low.

Adaptation strategy

The use of non-timber forest products (NTFP), water harvesting by means of digging and drilling for drinking water, distress migration, and formation of Self-help Group (SHG) in the micro finance programme, are the mostly mentioned adaptation strategies (Table 2). The distress migration is acute in the village Bandhgaba. It is also found that the adaptation capacity of the village Bandhgaba is low due to no formation of SHG and the occurrence of maximum migration in that village.

Table 2. Adaptation strategy by the households in the four villages of the District Bankura

Adaptation strategy	Bandhgaba Village (% of household responses (Yes)	Dhansimla Village (% of household responses (Yes)	Rangakula Village (% of household responses (Yes)	Khairakura Village (% of household responses (Yes)
Water harvesting	100	20	100	100
Distress migration	76	56	4	8
Collection and sale of NTFP	84	92	76	84
Formation of Self-Help Groups	4	8	24	24

The Security Diagram has three components: environmental stress, state susceptibility and crisis probability curves. The Security Diagram is used to measure vulnerability. It depends on both water stress and socio-economic susceptibility. The assumption behind the Security Diagram is that the higher the water stress, the higher the likelihood of crises. At the same time, the higher the socio-economic susceptibility (i.e. the lower the adaptive capacity), the lower the stress required to cause a crisis. Within the framework of the Security Diagram, vulnerability is expressed in the functional form as $z = f(x, y)$ where z are some measurable indicators of the level of vulnerability which has a function of two explanatory variables – socio-economic susceptibility (x) and water stress (y). The contour line of the Security Diagram is shown in Figure 1. The assumption of contour lines is that the higher the contour lines are away from the origin, the higher vulnerability and vice versa.

The contour lines ***z***1, ***z***2 and ***z***3 are the different levels of vulnerability at varying combinations of socio-economic susceptibility x and water stress y. Correspondingly, vulnerability is quite low at z1 and high at z3. The Security Diagrams assume that crisis is likely to occur at say, points between *z*2 and z3, where the levels of socio-economic susceptibility are highest or, in other words, the adaptive capacity to impacts of water stress are lowest. These contour lines are treated as "crisis probability curves". The low crisis probability curve (CPCL) and high crisis probability curve (CPCH) correspond to *z*2 and z3 in Figure 1b, respectively. The probability curves are a convenient yardstick for measuring the degree of vulnerability of the state over time.

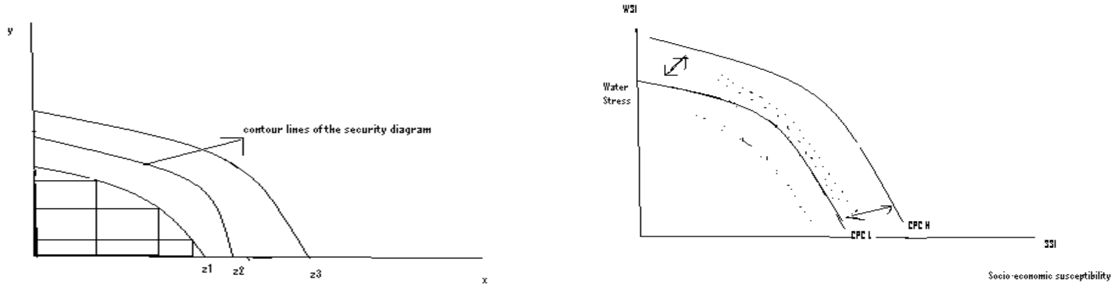

Figure 1. Contour lines of the Security Diagram (a) and Crisis Probability Curves (b) (Source: Acosta- Michlik et al., 2005)

Fuzzy Inference System

The socio-economic susceptibility is applicable when there is the availability of time series data on the selected variables. Fuzzy Inference System is more appropriate in case of non-availability of time series data. Fuzzy Inference System is used to measure drought vulnerability (Bhattacharya & Das, 2007; Acosta-Michlik et al., 2005). Fuzzy set theory is useful in translating linguistic statements such as ‘high’ or ‘low’ into numerical values. This involves translation of propositions into quantitative values using membership functions.

Conclusions and Governmental Policy

The paper has made an attempt to assess vulnerability to climate change such as drought in order to get insight into the determinants of vulnerability. In terms of the socio-economic vulnerability, Bandhgava village has been identified as having medium vulnerability among the four villages. Identified household’s adaptation strategies include migration; formation of SHG, water harvesting and accessibility of NTFP. Developmental efforts by the Government of India help build adaptive capacity through two levels of interventions. First, climate specific interventions such as drought proofing, rainwater harvesting, campaigning awareness about available drought-resistant varieties, better access to medium- / long-range weather forecasts, and possibly early warning networks. Secondly, to building up broader capacity through education, access to agricultural credit, health care, and infrastructure, etc.

For developing countries like India, adaptation requires assisting the vulnerable population during adverse climate conditions and empowering them to cope with climate risks in the long-run for better living. The Government of India implements a series of centrally sponsored schemes under different ministries and departments for achieving social and economic development. At present, while none of the schemes is explicitly referred to as adaptation schemes; many contain elements (objectives and targets) that clearly relate to risks from climate variability. A recent initiative by the Department of International Development (DFID) and the World Bank in India seeks to identify how to integrate adaptation and risk reduction into their portfolio of programmes.

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Vulnerability and Adaptation of Agriculture Systems to the Climate Change Threat – A Study of the Perak River Basin

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Trend changes of temperature and rainfall (increasing or decreasing values, and associated variability/anomalies associated with trend changes) would have direct adverse impacts on agricultural systems sustenance now and in the future through their influences on the plant/crop physiological processes, disruptions on human activities and practices, and crop productivity. Following this, disruptions to agricultural systems sustenance would have severe impacts on many critical sectors in a developing country such as Malaysia. These impacts could include the potential contribution of the agriculture sectors on the country's Gross Domestic Product (GDP) and associated human activities with the sector. More important are the lower income populations associated with many rural agricultural practices especially predominant in the highland interiors, coastal zones and rural low lying floodplains of Malaysia. These would be severely affected as agriculture activities are governed by situations of the environment. Most of these populations hover near the poverty threshold values and any disturbance to their economic well-being would affect their ability to stay above the poverty line. In most cases these populations contribute significantly to the supply of local produce and horticultural products that could affect, to a lesser extent, the food security in Malaysia.

Methodology

The paper presents part of the findings of a research that examines the impacts of temporal and spatial trend changes of temperature and rainfall within three river basins in Peninsular Malaysia on a number of selected high income economic systems (hydro-electric power generation, industries and agricultural systems). The paper attempts to discuss the formulation of an agriculture vulnerability to climate change model based on a critical appraisal and review of existing vulnerability models. Vulnerability models that were assessed include those explored in studies by Pielke (1998), IPCC TAR (2001, 2007), Kasperson (2002), Fussel & Klein (2006), Adger et.al. (2004), Smit &Wandel (2006), Brooks et al. (2004), and Fussel (2007). This generic model provides the framework of analyses for agricultural systems within a defined administrative boundary such as country, state or district; or those defined by morphogenetic classification, such as a drainage basin; or for different types of agricultural systems, such as padi cultivation.

The Perak River Basin (PRB) was selected as the study region as agriculture contributes significantly to Perak's GDP (Perak State Economic Report, 2010) and also the existence of agricultural systems, such as padi cultivation, which are very sensitive to environmental change attributed to trend changes of temperature and rainfall (Department of Agriculture, 2010). In addition to these factors, Perak River Basin temperature and rainfall data are available from the Department of Meteorology, and Department of Drainage and Irrigation Climate Stations, to provide information of trend change behaviour of temperature and rainfall which are, as mentioned earlier, critical factors that could affect agricultural systems sustenance.

Three major components were identified from the vulnerability model for agricultural systems. These are (1) climate change threat behaviour, (2) external and internal vulnerability indicators, and (3) the inherent adaptive capacities and the adaptation needs.

The agricultural systems examined in the Perak River Basin, would focus on (1) agricultural systems in general, and (2) the most sensitive and highly at risk to climate change threat, which, in this study, padi cultivation systems were chosen.

Temperature and Rainfall Data

Temperature and rainfall records were derived from eight Department of Meteorology Malaysia stations located within the Perak River Basin. Temperature and rainfall records were analyzed from 1951 to 2007. Temperature and rainfall records were also derived from 44 stations operated by the Department of Drainage and Irrigation Malaysia to further enhance the temperature and rainfall records of the Department of Meteorology. The latter temperature and rainfall records were for the period of 1935 to 2007. The time series and trend surface analysis were based on monthly data for the period mentioned. Hydro-meteorological regions and its temporal and spatial trends and patterns were distinguished from the study. Identification of these hydro-meteorological regions, thus, describes the potential risk regions to climate change induced stresses within the Perak River Basin.

Vulnerability Indicators

External Vulnerability Indicators

External vulnerabilities refer to the level of accessibility of the agricultural system(s) to resources that could influence the sustenance of the agricultural activities. These include accessibility to water resources for irrigation, transportation systems, and land for the development and expansion of agriculture.

Internal Vulnerability Indicators

Internal vulnerabilities describe the internal characteristics of the agricultural system(s). These include types of crops that are cultivated, the associated agricultural practices, human capacities, infrastructural availability and accessibility to innovation methods and technologies.

Vulnerability indicators were derived by means of ground observations, published documents including maps, and questionnaire surveys. Vulnerability indicators would be classified and weighted, where five classes are usually chosen. In this study, a 5 denotes very high risk and 1 denotes very low risk.

Strengthening Resilience

Adaptive capacities describe the inherent capacities of a system to absorb the impact of particular threat behaviour. The state of a system's adaptive capacity would describe its level of resilience and of its vulnerability. Inherent practices such as the use of high strain species in padi cultivation would determine whether padi yield would decline or at least be sustained for a specific time period when exposed to increasing temperature or floods. The availability of water storage systems in a farm, for example would strengthened a farming system when exposed to short episodes of dry weather.

Adaptation refers to the needs and ability of an agricultural system to sustain its productivity and activities under impending climate change threat. Adaptation is basically a process of sustainable development of the agricultural system. In order to achieve this, agricultural systems need to examine the state of their vulnerability as determined by the internal and external vulnerabilities. Adaptation would generally covers the immediate needs, short term needs and long term needs to improve the state of the vulnerability indicators. Improving the state of the vulnerability indicators also meant improving the state of resilience of the system.

Results

Temperature and Rainfall Trend Changes

Temporal

The percent change of temperature and rainfall in the PRB is very small. The temperature percent change in the PRB is -0.09 to 0.14 %. This shows the evidence of intra percent change in temperature, and the average percent change in temperature is 0.05% for the period 1968 to 2008 (~30 years of record). The continuing trend change in temperature would have significant effect on hydrological and weather process and would have an impact on crop physiology and cultivation activities. The percent change of rainfall in PRB is small too. The range of percent change is -1.90 to 1.28% for the period 1951 to 2007 (~60 years of record). The average percent change is – 0.08%.

Spatial

The small variation of temperature and rainfall describes local influences at the district and at the *mukim* level. These intra variations in temperature and rainfall would create stresses on crop productivity and cultivation activities in the PRB.

Agricultural Systems Vulnerability

Agricultural systems vulnerability can be assessed at two levels of enquiry – agriculture as a total system in the PRB and at the scale of each agricultural system within the PRB.

The external and internal vulnerability indicators would be different at the two levels identified. For example, at the higher level of agriculture as a total system, the following external indicators would be important consideration in the agriculture vulnerability model such as the modes of linkages that describe inflow and outflow of goods in the PRB. Another indicator is the susceptibility of the PRB to the effects of the transboundary environmental issues, and the availability of human capital movement into the PRB. The internal vulnerability indicators are diverse and many, and the following are considered important factors in the development of the vulnerability model: percentage of tree crops compared to non-tree crops, percentage of irrigated lands, types of irrigation practices, percentage of large scale farms or commercial agriculture as compared to subsistence agriculture, level and type of technology use, quality of human capital, quality of farm infrastructure, application of fertilizers and other crop quality enrichment practices, and density of transportation systems.

There is a slight difference when vulnerability indicators are examined at the level of types of agricultural systems. For example in the present study, padi cultivation was examined as it is very sensitive to environmental change. Thus external factors such as distance to threat sources (such as river, steep slopes, storm surges and coastal inundation) would determine susceptibility of the system to potential risks from flooding, soil erosion and tidal inundation. In addition to these factors that describe proximity to threats, there are also other indicators that were used in the vulnerability model such as accessibility to marketing outlets; whilst internal indicators included that of crop species used, frequency of cultivation, farm machineries, application of fertilizer, and types of farming practices.

Strengthening Resilience of Agriculture Systems

The vulnerability model identifies the state of vulnerability of the system at risk as mentioned earlier at the two levels of study – agriculture as a total system and the individual types of agricultural system (padi cultivation was examined as it is very sensitive to environmental change).It also shows that in order to increase the resilience of the system against risk, the state of the vulnerability indicators (internal and external indicators) have to be improved and strengthened. However, what is also important here is that by understanding the nature of vulnerability, the system's inherent capacity to adapt would also be examined following which system's adaptation would follow different time phases of immediate, short-term and long-term needs for adaptation.

Discussions

Agricultural systems vulnerability in the PRB can be examined at two levels. Each level looks at vulnerability as consisting of three major components: (1) threat behaviour, (2) system's vulnerability, and (3) system's sustainability. However, the parameters used to characterize the three components are quite different. These two levels of assessment can be modeled as shown in Figure 1 and fine-tuned accordingly at the scale of the basin system and at specific agricultural system type. These models can be used to assess vulnerability for other river basins and other types of agricultural systems.

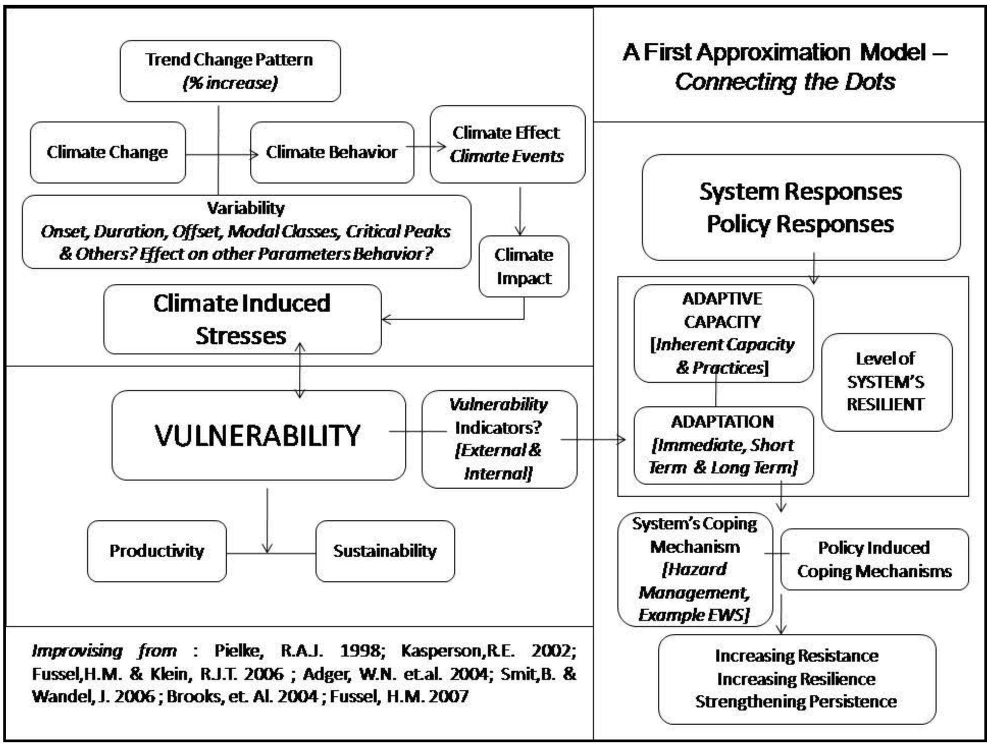

Figure 1. Modeling the assessments of vulnerabilities of agricultural systems

Conclusions

Agricultural systems are highly at risk to climate change. Vulnerability models provide useful tools in accessing the relationship between threat behaviour, system's vulnerability and system's sustainability. Vulnerability models are applicable for different types of river basins assessment and different types of agriculture systems.

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Recommendations

The following recommendations were forwarded by participants at the end of the symposium.

Recommendation 1

Recognizing the relevance of vulnerability assessment to climate change, the Symposium should be organized regularly to help address the new environment challenges of the region and elsewhere.

Recommendation 2

The interaction with fellow participants and organizers was extremely helpful. Most of the presentations were qualitative and useful for their current work. The poster exhibits were also informative.

It is recommended to have a follow up symposium in other countries prone to natural hazards like Bangladesh, China or India; and learn other VA perspectives such as drought, earthquake and floods. Possible hands-on site visit in tackling those VA in respective sites/countries would be extremely beneficial.

Recommendation 3

Lectures were very helpful to get knowledge about the nature of disasters and related activities in different countries of the Asia-Pacific region. However, there was no presentation from many highly disaster-prone countries in Asia like Pakistan, Myanmar, etc. This symposium should be organized regularly with greater participation from highly disaster-prone and climate change vulnerable countries.

Recommendation 4

The participants recommended launching a joint research programme on vulnerability assessment considering the similarity of problems occurring in their respective countries. The programme will also systematize the approach in the conduct of vulnerability assessment. The symposium however enables the participants to learn the similarity and differences of approaches in vulnerability assessment.

Recommendation 5

Papers on vulnerability assessment of coastal areas are limited and no paper was presented on tsunami and coastal erosion. Countries with experience on such hazards like Sri Lanka and Indonesia should be invited in the next symposium.

Appendix I

Programme

Day 1 7 December 2010

08:00 – 12:00	*Arrival/Registration of Participants*
12:00 – 14:00	*Lunch*
14:00 – 15:15	*Opening Programme* • Welcome Remarks by Marcial Amaro, Jr., ERDB Director • Message by Sim Heok-Choh, APAFRI Secretariat • Message by Im-Kyun Lee, KFRI • Keynote Message by Manuel Gerochi, DENR Undersecretary • Opening of Exhibition
15:15 – 15:30	*Coffee Break*
16:00 – 16:20	*Overview of the Symposium – Antonio Daño*
16:20 – 17:30	*Plenary Papers* • Watershed based V&A assessment for Forestry/Biodiversity Sector – Rex *Victor Cruz* • Vulnerability Assessment of Coastal Zones Using Geospatial Technologies – *Khali Aziz Hamzah*
18:30 – 21:00	*Dinner*

Day 2 8 December 2010

08:00 – 08:15	*Symposium Mechanics – Angelito Exconde*
08:15 – 10:15	***Theme 1: Applications and Models*** • Development and Application of a Geospatial-based Environmental Vulnerability Index for Watersheds to Climate Change in the Philippines – *Cristino Tiburan, Jr.* • Incorporating Vulnerability Assessment Principles into the Integrated Strategic Environmental Assessment of the Northern Province of Sri Lanka – *Anura de Silva* • Vulnerability Assessment for Integrated Development of Natural Resources on Watershed Basis in Drought Prone Areas of Andhra Pradesh, India – *Suvarna Chandrappagari* • Modelling Drought Hazard, Vulnerability and Risk: A Case Study of Bangladesh – *Shamsuddin Shahid* • Analytical Framework on the Vulnerability of Rural Development in Semi-arid Area of Northern China: Assessment on the Scale of Community – *Zhang Qiaoyun*
10:15 – 10:35	*Coffee Break*
10:35 – 11:35	***Theme 2: Vulnerability Assessment of Coastal Zones*** • An Assessment of Stand Structure and Carbon Storage of a Mangrove Forest in Thailand – *Sapit Diloksumpun* • Adaptation Responses to Coastal Perturbations: The Case of Prieto Diaz and Baler Coastal Dwellers in the Philippines – *Honorato Palis*
11:35 – 11:50	*Briefing for afternoon activities*
11:50 – 13:30	*Lunch*
13:30 – 18:00	*Field Trip*
18:30 – 21:30	*Dinner/Cultural Night*

Day 3 9 December 2010

08:00 – 08:15	*Wrap-up of Day 2 – Aida B. Lapis*
08:15 – 08:55	• Federated States of Micronesia Atoll Islands Climate Change & Food Security Vulnerability Assessment – *Jalesi Mateboto* • Picturing climate change adaptation and vulnerability at community level in Indonesia– *Niken Sakuntaladewi*
09:00 – 10:35	***Theme 3: Vulnerability Assessment of Watersheds*** ***A. Soil erosion/landslide/flood/fire*** • Soil Organic Carbon Loss Through Soil Erosion in Agro-ecological Zones of Merek Catchment, Iran – *Mosayeb Heshmati* • Soil Erosion and Landslide Vulnerability Assessment of Mananga Watershed, Cebu, Philippines – *Reynaldo L. Lanuza* • Vulnerability Assessment of Cugman River Watershed – *Manolito Pasco* • Assessment of the Vulnerability to Landslide of Lower Allah Valley Sub-watershed at Mindanao, Philippines – *Ma. Cristina Micosa*
10:35 – 10:55	*Coffee Break*
10:55 – 11:55	• Assessment of flood and landslide vulnerability for watershed management plan of Grindulu, Pacitan District, Indonesia – *Paimin* • Landslide and Fire Vulnerability Assessment of Bued River Watershed Within the Province of Benguet, Philippines – *Anthony Victor Lopez* • Development of Indicators for Assessing Susceptibility of Degraded Peatland Areas to Forest Fires in Peninsular Malaysia – *Ismail Parlan*
12:15 – 13:15	*Lunch*
13:15 – 16:30	***B. Biodiversity loss/pollution*** • Vulnerability Assessment to Biodiversity Loss: A Case of Western Himalaya of Nepal – *Dhananjaya Lamichhane* • Drought Effects on Queensland's Vegetation Net Primary Productivity: An Analysis of 2000-2006 MODIS Satellite Imagery – *Armando Apan* • Wood-boring Beetle Communities in Korea White Pine Forests and its Implications to Ecosystem Vulnerability under the Influence of Climate Change – *Won Il Choi* • Monitoring of pollution level of area where acid mine drainage discharges in an abandoned coal mine using fast growing trees – *Im Kyun Lee* • Climate Change Vulnerability and Household Level Adaptation: A Study on Forest Dependent Communities in Drought Prone Area in West Bengal, India – *Jyotish Prakash Basu* • Vulnerability and Adaptation Capacities of Agricultural Systems to the Climate Change Threat – A Study of the Perak River Basin – *Osman Salleh Khairulmaini*
16:30 – 18:00	*Closing Programme*
18:30 – 21:00	*Farewell Dinner*

Appendix II.

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