

VULNERABILITY ASSESSMENT OF COASTAL ZONES USING GEOSPATIAL TECHNOLOGIES

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The 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 (200 nautical miles from the shoreline). These coastal 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. A national coastal erosion study conducted in 2008 reported that, 52% of the coastline in the east coast of Peninsular Malaysia is being eroded, 43% is stable, 1% is rebuilding and 4% undergoes changes according to the seasons. In the west coast, 50% of the coastline is being eroded, 30% is stable and 20% is rebuilding. It has been reported that mangrove forests which are mainly found on the marine alluvium along sheltered coasts and estuaries is valued for its protection and stabilization of low-lying coastal lands and hence prevent erosion in the coastal zone. Mangrove forests protect uplands from storm winds, waves, floods and erosion. Mangroves can help prevent erosion by stabilizing shorelines with their specialized root systems. The amount of protection afforded by mangroves among others depends on the width of the forest. Hence it is important to properly managed the mangrove forests which will indirectly prevent coastal erosion. Equally important is to have a proper integrated management plan of the coastal zones areas. As part of the management requirements, these coastal zones areas need proper monitoring in order to assess their vulnerability status. The use of geospatial technologies including remote sensing and geographic information system (GIS) is capable of analysing and predicting the vast coastal zones area at a landscape level. With the multi-temporal capability of the remote sensing data the vulnerability assessment can be carried out throughout a year with minimum field activities. The spatial information collected from the remote sensing data can be kept in a proper computer database format and integrated with GIS for future planning and prediction purposes. This paper highlights the use of geospatial technologies in the vulnerability assessment of coastal zones in Peninsular Malaysia.

Keywords: Coastal zones, mangrove forest, remote sensing, geospatial

DEVELOPMENT AND APPLICATION OF A GEOSPATIAL-BASED ENVIRONMENTAL VULNERABILITY INDEX FOR WATERSHEDS TO CLIMATE CHANGE IN THE PHILIPPINES

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Over the past two decades, several studies associated with global climate change have clearly manifested the increase of environmental problems in the international community. Evidences have shown that many of these problems have been observed in watershed areas where both resources and coping capacity are considerably limiting. Although watersheds are considered as vital ecosystems that play a significant role in abating the adverse effects of climate change, the insufficient information and knowledge on vulnerable regions could make management more difficult on these areas. These conditions may lead to deferment of a comprehensive mitigation and adaptation framework. Hence it is important to undertake vulnerability assessment studies in these areas to primarily aid the creation of an effective and efficient management plan as well as to optimize the use of available resources. This research is mainly focused on the development of a geospatial-based environmental vulnerability index for watersheds and other related ecosystems to climate change in the Philippines and its application to the Makiling Forest Reserve. The model is called the Geospatial-based Regional Environmental Vulnerability Index for Ecosystems and Watersheds or in short, the GeoREVIEW model. It involves 21 indicators that are classified under three different components namely, exposure, sensitivity and adaptive capacity. Each indicator can be categorized also as damage, resistance or hazard depending on their nature and inherent characteristics. For each indicator, a scale of 1 to 5 was used to emphasize the degree of vulnerability, 1 being the most resilient while 5 being the most vulnerable. The threshold levels in each scale were determined using statistical test and/or from existing spatial-based indices. Finally, an overall vulnerability point was calculated to provide the general evaluation of the landscape while a template was used to show key results of the entire assessment process. This geospatial-based approach was then applied to evaluate the vulnerability of the Makiling Forest Reserve, a potential carbon sink located around 65 km south of Metro Manila. The reserve was established in 1910 and its management was transferred to the University of the Philippines Los Baños in 1960 mainly for purposes of education and research. Based on the overall assessment, the vulnerability of the reserve was classified as “at risk” level. The results provide significant information that are imperative and indispensable in developing mitigation and adaptation strategies on climate change. And these can be utilized as well to facilitate policy formulation and advocacy pertinent to problems associated with such phenomenon.

Keywords: vulnerability assessment, geospatial-based approach, watersheds, climate change

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 concepts specifically analyzing the conditions that are stressing the environmental resources. 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. 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. The process of this exercise involved the production of a series of 'Opportunity Maps' with available data and with information gathered in the field studies. These maps were initially 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 were overlaid on 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 1st Opportunity Map, only the 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 working group for conservation oriented agencies, while finalizing the last Opportunity Map. 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 inclusion of climate change adaptation.

Keywords: vulnerability assessment, strategic environmental assessment, spatial analysis, climate change

VULNERABILITY ASSESSMENT FOR INTEGRATED DEVELOPMENT OF NATURAL RESOURCES ON WATERSHED BASIS IN DROUGHT PRONE AREAS OF ANDRA PRADESH, INDIA

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Watershed development projects 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. The crop failure led small and marginal farmers to even commit suicide. Keeping the above in view, Government of India proposed to treat 17450 micro watersheds covering 11.038 million hectares in a span of 18 years with a financial outlay of \$ 3.4 billions under Integrated watershed management programme (IWMP) in Andhra Pradesh from 2010-11 onwards. The drought vulnerability assessment study done in the above context analyzes drought frequency, trends, drivers & pressures, 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. The demographic, physiographic, hydro-meteorological, socio-economic, technological, environmental, and political indicators are studied through situational analysis, and depicted in tables and figures that include climate change Impact Matrix and Drought Vulnerability Assessment Matrix. Weightages are given to selected drought vulnerability indicators (poverty index, percentage of scheduled castes/scheduled tribes population, actual wages, percentage of small and marginal farmers, moisture index, area under rain-fed agriculture, drinking water availability, extent of degraded land, productivity potential of land, contiguity to ongoing watershed areas and cluster approach potential). On doing the above exercise, 281 watershed projects spreading over 1.21 million hectares of drought prone areas covering 1956 villages are identified for project proposal preparation. Systematic analysis of entire surface drainage area is done by using GIS and other data sets for demarcating hydro-geological units on 1:50000 integrated base maps showing drainage, village boundaries & forest areas at project level. Cadastral maps of 1:7920 scale were used for village level planning. Detailed project reports are prepared through village wise Participatory Net Planning (PNP) covering land, water, and bio-mass aspects. Drought adaptation initiatives comprising of land development, water use, appropriate agronomic practices and livelihoods (farm based and non-farm based) plans along with proper monitoring mechanisms are proposed for implementation in 5 years from 2010-11 onwards. Training and capacity building activities for stakeholders were also incorporated in the plans.

Keywords: Drought vulnerability indicators, adaptation initiatives, Watershed development

MODELLING DROUGHT HAZARD, VULNERABILITY AND RISK: A CASE STUDY OF BANGLADESH

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Bangladesh is one of the most disaster-prone countries in the world. Almost every year, the country experiences disasters of one kind or another, causing heavy loss of life and property and jeopardizing the development activities. In the last three decades, Bangladesh has suffered eleven droughts of major magnitude. In the context of global warming, most of the climatic models project a rise of temperature and more variability of rainfall in Bangladesh. This may cause an increase of drought severity and frequency in Bangladesh. Drought hazards, vulnerability, and risk assessment is therefore essential for implementing mitigation to reduce drought impact. Spatial and temporal characteristics of meteorological droughts in Bangladesh have been modelled by reconstructing historical occurrences of drought for multiple time steps and categories by employing standardized precipitation index approach in a geographical information system. A conceptual framework, which emphasizes the combined role of hazard and vulnerability in defining risk, is used to model the spatial pattern of drought risk. The key social and physical factors that define drought vulnerability in the context of Bangladesh are identified and corresponding thematic maps in district level are prepared. Drought vulnerability model is developed through the integration of those thematic maps. The risk is computed as the product of the hazard and vulnerability. The drought hazard model shows that north and north-western areas are most likely to suffer droughts. High variability of rainfall has made the region highly prone to droughts. The vulnerability model shows that the north and northwestern areas is also highly vulnerable to droughts from socio-economic and infrastructural point of view. Higher poverty rates, dependency on agriculture and irrigation have made these parts more vulnerable to droughts compared to other parts of the country. Projected changes in rainfall and temperature by climate models predicts more stress on water resources for irrigation in drought prone northwest Bangladesh due to climate change. Better water and crop management, augmentation of water supplies with other sources, increased public awareness and education, intensified watershed and local planning, and water conservation is necessary in the north and northwest Bangladesh for drought impact mitigation.

Keywords: Droughts, Vulnerability, Risk, Geographical Information System, Climate change.

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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Over the past half century, in particular in a couple of decades, rural communities in semi-arid area of Northern China, similar to the rest of rural China, have experienced fundamental changes, which are attributed to rural policy reform, human resource improvement, technological innovation, and investment on infrastructure. Some impacts have been considered as the positive to overall China's economic development, such as practice of rural household production system, rapid increase in rural income, massive migration of rural laborers to cities. However some are the negative, such as deterioration of natural ecosystem, widening gap between the rich and the poor, disintegration of rural organizations, which have been challenging China's further development. Rural development can be regarded as development of integrated system of nature, economy and society. Problems existing in rural China are essentially the vulnerability of the integrated system in the face of external interventions.

Concepts and assessment methods of vulnerability for science study are used for reference in our study and applied to the analysis of the integrated system. Taking communities in semi-arid area of Northern China as an example, this paper defines the concept of vulnerability of rural development according to the characteristics of rural community system. The vulnerability of rural development is the property of the integrated system of nature, economy and society, which is of poor stability, sensitive to external disturbance, easily harmed by external disturbance and difficult to recover. Referring to livelihood assets approach used for household vulnerability assessment, this paper develops an analyzing framework for assessment of vulnerability of rural development in semi-arid area of China. Community vulnerability is decided mainly by community's overall assets, including natural assets, physical assets, human assets, financial assets and social assets. Based on the analysis of vulnerability, we try to find indicators of community assets and measure the level of gross assets. Taking two villages in Ke'erqin (Horqin) Youyi Zhongqi of Inner Mongolia as example, we are trying to make overall assessment on vulnerability of rural community development. Based on the analytical framework and case study, some policy recommendations are provided for rural development intervention in semi-arid area in Northern China.

Keywords: rural development; vulnerability; social-ecological systems; community

AN ASSESSMENT OF STAND STRUCTURE AND CARBON STORAGE OF A MANGROVE FOREST IN THAILAND

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Mangrove ecosystems are vulnerable to climate change; particularly sea-level rise alters shore profile, soils, and salinity that lead to changes in mangrove structure and functions. However, some mangrove ecosystems have demonstrated different tolerances to previous sea-level fluctuations depending on mangrove types, species compositions and environmental conditions. Investigation of stand structure and productivity as well as carbon stocks of different mangrove communities in Thailand helps to understand their vulnerability or resilience to sea-level rise and related changes. 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 number of trees, saplings and seedlings were counted, the total height and diameter of trees and saplings were measured, and soil sampling was also undertaken. Leaf area index was undertaken and analyzed according to the hemispherical photography technique. Stand structure parameters e.g. relative density, relative abundance, importance value index (IVI) and diversity index were analyzed, while the total biomass and the carbon storage were also estimated using the allometry technique. Based on species composition and tree productivity, the mangrove community was also categorized using cluster analysis.

The occurrence of total 22 species in 12 genera and 10 families was observed, consisting of 22, 17 and 12 species of trees, saplings and seedlings, respectively. The species diversity and composition, regeneration potential and total biomass as well as the carbon storage varied remarkably among sites, between transects within site and/or among plots within transect, having the mean values of total biomass and carbon storage of 72.31-274.12 and 34.00-128.87 t/ha, respectively. In addition, 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. The *C. tagal* community had the greatest species diversity but the lowest productivity due to its small sizes of trees. On the other hand, *R. mucronata* community achieved not only greater species diversity but also the highest productivity and carbon stock. More importantly, the poor species richness, productivity and carbon storage as well as natural regeneration potential were observed in *A. marina* and *A. alba* communities, indicating the decline of these mangrove communities. Overall, the stand structure, in terms of species diversity and composition primarily contributed to the mangrove productivity and carbon stock as well as natural regeneration potential that may lead to variable vulnerability or resilience to the climate change of these mangrove stands.

Keywords: mangrove, stand structure, biomass, carbon storage, climate change

ADAPTATION RESPONSES TO COASTAL PERTURBATIONS: THE CASE OF PRIETO DIAZ AND BALER COASTAL DWELLERS IN THE PHILIPPINES

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An investigation in the highly vulnerable eastern seaboard of the Philippine islands fronting the Pacific Ocean was conducted to document the adaptation strategies and coping mechanisms of the mangrove dependent coastal dwellers to risks associated to coastal perturbations that include frequent typhoons, coastal flooding, extreme tidal fluctuations and sea level rise, among others. Sociological and anthropological techniques were employed to generate data that include interviews of household and key informants and focus group discussions (FGD). Non-parametric and descriptive statistics were applied to analyze data into qualitative form.

Result of the survey showed that sea level rise, coastal flooding and tidal fluctuation are the most prevalent among the coastal perturbations being experienced by the coastal households in Prieto Diaz province of Sorsogon. Similar experiences, however, prevail in Baler, Aurora province as well. Prevalence of coastal perturbations in these provinces are primarily attributed to its proximity to the vast Pacific Ocean and its being the highway of more than 20 typhoons per year. In the same vein, to lessen the impacts of coastal perturbations various protective barriers classified under hard structures were adopted that include building dikes, seawalls and putting sandbags and boulders. Mangrove stand protection and re-planting are carried out as well as a form of soft structure strategy to resist storm surges. Households that are directly affected by various perturbations employed retreat and accommodation strategies such as transfer to higher grounds, sell their properties and adjust dwelling elevations, among others. Despite the risks associated with living in the coastlines, some households opted to remain and bear the consequences brought about by ever changing coastal conditions especially during rainy months.

Other adaptation measures are identified in the paper highlighting its potentials to reduce the impacts of coastal perturbations that are further classified into protection, retreat and accommodation strategies.

Keywords: adaptation responses, coastal perturbations, coastal dwellers

CLIMATE CHANGE & FOOD SECURITY ASSESSMENT OF ATOLL ISLAND STATES OF FEDERATED STATES OF MICRONESIA (FSM)

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To fulfill the United Nations Framework Convention on Climate Change (UNFCCC) requirement 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. The FSM government through the office of their Climate Change Project, requested for assistance, both technical and financial from international and regional organizations, including the Secretariat of the Pacific Community (SPC), to assist in their Vulnerability Assessment work. A total of 8 teams covering the areas of Marine, Soils, Pests & Diseases, Forest, Trees & Vegetation, Agriculture & Land Use, Water, Disaster, and socio-economic was earmarked for this survey. SPC Land Resources Division (SPC LRD), through the Forests & Trees Team provided technical assistance in the vegetation survey component of the assessment, and this included the design of the survey/monitoring plots, co-ordination and the actual field survey of the 14 atoll islands. The recently developed design for Monitoring, Assessment, Reporting of Sustainable Forest Management (MAR - SFM) for atoll islands in the Pacific was used for this survey. Four strips of 100m x 10m were established and assessed on each of the atoll surveyed. The survey took a total of 22 days to complete.

Clearing for agriculture, infrastructure development, village expansion due to increase in population, burning, unsustainable harvesting, unnecessary clearing and the lack of appreciation or knowledge of the values of forest and trees have been identified as the main drivers of deforestation on the atolls. Some of the visible and possible impacts are coastal erosion, salt water intrusion, and food insecurity, loss of biodiversity, spreading of invasive species, increase carbon emissions, and extreme weather pattern. The recommended mitigation and adaptation measures include (1) Sustainable Management of Forest & Trees – conservation of sites and species, fire management, and replanting of crop trees such as coconut and breadfruit; (2) Coastal Forest Restoration and rehabilitation – restoration of Mangrove forest, replanting of *Calophyllum inophyllum*, *Casuarina equisetifolia* on shoreline; and (3) Sustainable Agriculture – strengthening of Agro Forestry systems, elevating of planting areas via mulching and de-composting, introduction of climate change resilient crops and the introduction of alternate crop varieties to supplement the local.

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 the eco-systems and therefore people to cope with extreme weather patterns, and to safeguard food security.

Keywords: atoll islands, sustainable forest management, mangrove, climate change

CLIMATE CHANGE ADAPTATION AND VULNERABILITY AT COMMUNITY LEVEL IN INDONESIA

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While scientists and elites discuss about climate change and its mitigation actions, the Indonesia rural communities talk about confusing climate variability. They do not know what and who to believe, and when to start planting or to go for a sailing. This climate variability affects the lives of the local communities. This paper pictures the adaptation and vulnerability of the local communities living around coastal mangrove areas to climate variability. These mangroves are classified into private mangrove forest, protection forest, and conservation forest or national park. Interview was done to the local communities, village and district governments, park manager, as well as local NGOs.

Communities living around mangrove forest have various sources of incomes but mostly from farming. Climate variability provides negative effect to the quantity and quality of their farm products, but the income of these farmers is not necessary affected. They take various adaptation strategies, reactive and anticipatory, planned and unplanned adaptations, ranging from income diversification with the assistant of the local NGO, changing farming strategies, and planting mangrove trees. Successful adaptation was found in the private mangrove forest by combining mitigation and adaptation strategies, planting trees in the coastal area and dike to protect their fish ponds. In contrast, local communities create more fish ponds in the protected mangrove forest area. The rural communities living in the conservation forests, on the other side, diversify their incomes by managing the forest for tourism with the support of the Park Manager.

The vulnerability of these communities is determined by resource availability; government, NGO and the Park development programs; and government policy on the access to the resources particularly the mangroves forest classified into the protection and conservation forest.

Keywords: climate variability, climate change, community, adaptation, vulnerability, private mangrove forest, protected mangrove forest, conservation forest.

EVALUATION OF WINDTHROW RISK DUE TO THINNING

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Computer simulation has predicted an increase in the magnitude and frequency of typhoons due to global warming. An average of 33,000 ha/yr of forest damage by strong winds and rain has been observed over the past 50 years in Japan. Windthrow has on occasion caused severe damage to forestry management and ecosystems. Recently, windthrow has been suggested as a possible cause of landslides due to soil disturbance and soil hardness reduction by the vibration of trees.

Thinning is necessary to manage forests suitable for timber production and it plays an important roles in environmental protection. In our experience, windthrow tends to occur within five years of thinning due to the new open space created by the cutting of trees. We are developing a method for evaluating the windthrow risk of thinning to enable appropriate forest management and to avoid forest damage caused by strong winds. The drag force of the wind on the trees can be basically estimated by multiplying the crown projection area to the vertical plane with the square of the wind speed. We calculated the drag force for every stand by estimating its crown projection area and wind profile. The crown projection area was estimated from the position of each stand and its height providing the average shape of the crown. The wind profile was estimated from the leaf layer volume of the windward stands. We determined the windthrow for each stand by comparing the turning moment with the given critical turning moment. We defined the risk as the stand density determined by windthrow.

We evaluated the risk for virtual stands in a scenario where the angle of inclination of the ground was 30 degrees, 3000 per ha of *Chamaecyparis obtusa* were planted, the tree growth and the mortality referred to the *Chamaecyparis obtusa* stand density management diagram and thinning was carried out by selection cutting. We assumed 96 combinations of parameters: Ry (yield index, the ratio of the present volume to the probable maximum volume), the thinning ratio, wind speed, thinning from below and above. The results showed high risk for higher Ry, which raised the slenderness ratio and lowered the critical turning moment. High risk was also estimated for a higher thinning ratio and thinning from upper story trees due to a reduction in protection by windward stands because of the larger open spaces.

Keywords : Windthrow, thinning, *Chamaecyparis obtuse*, yield index

SOIL ORGANIC CARBON LOSS THROUGH SOIL EROSION IN AGRO-ECOLOGICAL ZONES OF MEREK CATCHMENT, IRAN

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Land degradation is the loss in the productivity of land resources due to many factors, especially soil erosion. Soil organic carbon (SOC) loss is the main impact of erosion which not only causes declining crop yield, but also contributes to greenhouse gas (GHG) emission. The main objective of this study was to estimate the depletion of SOC due to soil erosion prevailing in the three agro-ecological zones within the Merek catchment, Iran. The erosion rate and SOC loss were estimated using Modified Pacific Southwest Inter Agency Committee (MPSIAC) model. The results showed that the most important soil erosion features in this catchment include inter-rill and gully erosion as well as landslide occurrence which in turn is promoted by deforestation and overgrazing. The erosion rate in the agriculture area, rangeland and forest is 10.61, 11.02 and 13.05 t ha⁻¹yr⁻¹, respectively, causing an annual SOC depletion by erosion of 142.24, 176.92 and 306.10 kg ha⁻¹yr⁻¹. The high loss of SOC in the forest zone is due to serious soil erosion, which is accelerated by sloping land. It is concluded that the MPSIAC model used in this study is able to satisfactorily predict soil erosion rate and SOC depletion at the catchment scale in the semi-arid region of Iran and maybe applicable to tropical region as well.

Keywords: soil organic carbon, greenhouse gas emission, erosion, MPSIAC model

SOIL EROSION AND LANDSLIDE VULNERABILITY ASSESSMENT OF MANANGA WATERSHED, CEBU, PHILIPPINES

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Mananga Watershed is a primary source of potable water for the people living in the uplands and the urban areas as well as it also supplies majority of the domestic, agricultural and industrial waters in Metro Cebu. However, it is constantly threatened by degradation due to natural and human-related activities. The project on the Vulnerability Assessment of Mananga Watershed is in support to the new research thrust of the Department. It aimed to identify the natural and man-made hazards; identify critical factors affecting the vulnerability of the watershed to soil erosion and landslide; determine and map-out the vulnerability levels; formulate specific mitigating measures; and formulate policy recommendations.

GIS-assisted models on soil erosion and landslide from previous research have been applied. The Universal Soil Loss Equation (USLE) was used and integrated in GIS as a tool in predicting soil erosion. The results showed that the predicted average soil loss of 152.38 tons ha⁻¹ yr⁻¹ under the existing landuse and cropping system is extremely higher than the tolerable soil loss. Soil erosion ranges from less than 1 to 1,316.11 tons ha⁻¹ yr⁻¹. However, when the model was applied using the proposed mitigating measures, the predicted average soil loss was reduced to 21.17 tons ha⁻¹ yr⁻¹ with a range of less than 1 to 287.9 tons ha⁻¹ yr⁻¹. Model simulation under the proposed mitigating measures showed that only about 25.79% or about 2,025.69 hectares have high to very high soil erosion. It implied that there was a decrease of 3,950.94 hectares from the original soil loss under these categories of 5,976.63 hectares under existing landuse. On the other hand, the areas with very low to low soil erosion have increased and it covered about 45.20% or 3,550.66 hectares. The areas with tolerable soil loss have increased from 1,648.95 hectares (28.75%) to 2,576.66 hectares (44.92%) or an additional area of 927.71 hectares.

The physical factors (L_p) affecting landslide are slope, rainfall amount, typhoon frequency, geological age, geologic formation, relative distance to the fault line, soil type, soil morphological classification, and landuse as expressed by this equation: $L_p = 0.3SI + 0.1R + 0.1T + 0.05Ga + 0.05Gf + 0.2F + 0.05So + 0.05Sc + 0.1Lu$. In computing for the overall landslide vulnerability (L_w), the model was also expanded to include the anthropogenic factors (L_a) and the final equation is $L_w = 0.9L_p + 0.1L_a$. Areas vulnerable to landslides are those located in steeper slopes, unstable geology and near fault lines. It was predicted that Barangay Buot Taup in Cebu City has the largest area with high landslide vulnerability having 238.80 hectares and followed by Pamutan and Sinsin in Cebu City and Camp 6 in Talisay City.

Keywords: soil erosion, landslide, GIS, vulnerability assessment, USLE

VULNERABILITY ASSESSMENT OF CUGMAN RIVER WATERSHED

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Cugman River Watershed is a seahorse-shaped catchment landscape which stretches from the northern portion of the province of Bukidnon toward the coastal area of the province of Misamis Oriental specifically within the City of Cagayan de Oro. It lies along 8°13'25" to 8°28'30" north latitude and 124°41'45" to 124°49'20" east longitude embracing ten (10) barangays of Libona, Bukidnon and three (3) barangays of Cagayan de Oro City covering a total area of 10,250 hectares.

Cugman River supports the domestic, industrial and commercial need 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, sedimentation which oftentimes causes flooding. The vulnerability assessment aims to generate 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, environmental conservation and guidelines for landuse zoning.

Using the GIS-assisted mapping and spatial analysis the five identified critical factors that influence landslide e.g. slope, rainfall, land use, soil type and geologic formation which were categorized into five different hazard ratings were overlaid. In addition, the critical factors attributed to human intervention such as farm practices and soil disturbance due to road construction were also considered of which the hazard value was determined as the average rating of the two factors. The final landslide hazard value was computed and the corresponding landslide hazard vulnerability map was generated. Out of the total area of 10,250 hectares, 1.95% or 199.5 hectares was zoned as highly vulnerable, 22.7% or 2,326.3 hectares was zoned as moderately vulnerable, 51.47% or 5,275.7 hectares was zoned as low vulnerability and 23.9% was zoned as very low vulnerability.

Using the model of the form; Soil Hazard Value (SEv) = f (rainfall, slope, soil type, land use), the soil erosion vulnerability hazard map was also generated. Likewise, the anthropogenic factors were also incorporated. The final soil erosion hazard vulnerability map was generated of which 250.26 hectares or 2.44% of the total watershed area was zoned as highly vulnerable, 33.12% was zoned as moderately vulnerable, 35.8% was zoned as low vulnerability and 28.64% was zoned as not vulnerable. Result of the delineation of floodplain areas within the watershed based from the highest water mark during the flood event specifically at the height of typhoon "Ondang" last 1994 which hit Cagayan de Oro City showed the flood prone areas mainly at the downstream portion particularly in the low-lying coastal barangays covering a total area of 203.09 hectares.

Keywords: soil erosion, landslide, GIS, vulnerability assessment, flooding

ASSESSMENT OF THE VULNERABILITY TO LANDSLIDE OF LOWER ALLAH VALLEY SUB-WATERSHED AT MINDANAO, PHILIPPINES

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The study was conducted to develop a vulnerability map and determine the physical and anthropogenic factors that significantly affect its vulnerability to landslide. The study area is geographically located between 124°30'00" – 141° 41'17" longitude and 6°10'10" – 6°26'33" latitude with an area of about 37,464.2 hectares. The terrain is very rugged with small area of floodplain. The factors effecting landslide were identified and those factors were given equivalent hazard categories. The 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 to the satellite image maps and sample location points with occurrences of landslide regardless of the degree were taken. The 37 location points identified were overlaid to the previously prepared single map reflecting all factors identified to get the data on percentage weight. The data were computed using weighted average for each factor. Then the factors were ranked in descending order with their corresponding weights.

The areas with occurrences of landslide were evaluated using the Qualitative Weighted Method. 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 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. The form of the model is $-\log [-\log (x)]$. A total of 5,726 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 inconsistent 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 were computed. 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 revealed that the vulnerability of the 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 57.18 % of the total watershed area falls under moderate category (3), 33.67 % falls under high category (4), 8.85 % falls under low (2) and only 0.30 % falls under very high category (5). Mitigating measures such as the rehabilitation of degraded areas to protect the soil from impact of rainfall particularly on steep slope, appropriate farming system, increase the land cover by planting permanent trees on road cut should be done.

Keywords: vulnerability assessment, landslide, watershed

ASSESSMENT OF FLOOD AND LANDSLIDE VULNERABILITY FOR WATERSHED MANAGEMENT PLAN AT GRINDULU WATERSHED, PACITAN DISTRICT, INDONESIA

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The numbers of critical watersheds in Indonesia continuously increased and their functions for environmental control were diminishing. This condition has increased substantially the frequency of flood and landslide hazard occurrences in the last decade. Unfortunately, there were no reliable maps for assessing vulnerable flood and landslide areas in most critical watershed area. Therefore watershed management could not be plan completely. A tool as formula for mapping of vulnerability level flood and landslide hazard areas at catchment level that meet district administrative boundary was developed, namely a book of "Rapid Investigation of Sub-watershed Degradation". Formula developed for assessment tools of vulnerabilities were distinguished between natural and manageable factors. Flood vulnerability was separated between area susceptible to flooded (flood area) and area that supply flood water (runoff) from a catchment. The formula for detecting runoff sources area differentiated into natural factors, i.e. maximum daily rainfall, watershed shape, river gradient, drainage density, average of watershed slope; and management factor was land use cover. The formula for detecting vulnerable flooded area were differentiated into natural factors, i.e., landform, land slope of riverside, meandering, and flow detention at branching river, and management factor was water control structures. The formula for detecting landslide vulnerability area were differentiated into natural factors, i.e., the maximum of cumulative consecutive three days daily rainfall, land slope, geology, fault, and regolith depth, and management factors were land use cover, slope cutting for road and houses, and population density at residential area. By using these formula, assessing and mapping of those vulnerability was conducted at Grindulu watershed (70,672 ha), Pacitan District, East Java Province, Indonesia for proposing treatment activities as the end part of watershed management planning process. The results indicate that the vicinity of Pacitan city where located nearly the estuary of Grindulu River was categorized as the highest vulnerable flooding area and covered about 2,255 hectares. The runoff sources contributed to flood from all sub-watersheds in Grindulu watershed were categorized as high vulnerable except from Tengi sub-watershed. The landslide vulnerability area at Grindulu watershed covered about 5,122 hectares and the level were categorized as very high, high, rather high, and low were respectively 7.21 %, 72.67 %, 20.01 %, and 0.11 %. The proposed treatments for each vulnerable areas were based on the weak factors that determined the vulnerability level of that area. Kind of proposed works also should be suited to the local resource availability. The detail formula for detecting and mapping vulnerable level of flood and landslide hazard area in a sub-watershed will be discussed later on the seminar.

Keywords: flood, landslide, vulnerability, map, hazard, Grindulu, watershed

LANDSLIDE AND FIRE VULNERABILITY ASSESSMENT OF BUED RIVER WATERSHED WITHIN THE PROVINCE OF BENGUET, PHILIPPINES

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Vulnerability assessment of the Bued River Watershed was conducted using GIS-assisted methodologies. Natural and man-made hazards found therein as well as the contributory factors related to it were determined. Mitigating measures to reduce damage in the area are recommended as policy directions and guide for its sustainable management. Activities composed of bio-physical and socio-economic assessment through watershed characterization to identify the factors to be analyzed. The ERDB-conceptualized formula was used to bring out weighted averages of natural and anthropogenic factors affecting hazards located therein which are then digitized and overlaid to bring out the levels of vulnerabilities of the watershed to hazards affecting it.

Results of the project showed the watershed as highly vulnerable to landslide and moderately vulnerable to forest/grassland fires. The major factors which led to high vulnerability are the soil types, the slope and terrain, the typhoon frequency and the ground disturbance by human activities. The strongest factors which led to the moderate vulnerability to fires are the frequent dry spell, proximity to fire-prone areas, accessibility (roads/trails), dry fuel materials, slope and terrain and type of vegetation, capital investment, policies, political institutions and technology. Mitigating measures to protect the watersheds from fire and from landslides have been recommended and will be presented to the Local Government Units for their information, guidance and reference in formulation of community plans like in other watersheds assessed.

Keywords: Vulnerability assessment, watershed characterization, geographic information systems, hazards, landslide, grassland/forest fire, biophysical factor, anthropogenic factor

DEVELOPMENT OF INDICATORS FOR ASSESSING SUSCEPTIBILITY OF DEGRADED PEATLAND AREAS TO FOREST FIRES IN PENINSULAR MALAYSIA

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Haze and forest fires had caused significant damage to property, vegetation, wildlife, environment and public health. Most of the forest fires reported in Malaysia occurred in degraded peatlands and logged-over peat swamp forests and is thus a major threat to the conservation of such ecosystem. The frequency of the occurrences increases during the drier El Nino period. Peat is semi decomposed vegetative matter accumulated over thousands of years, is globally significant as carbon storage. The destruction of peatlands through peat fires has greater impacts than the burning of surface vegetation. It releases greenhouse gases; sulphur and nitrous oxides; and particulate matter to the atmosphere, which are harmful to human health. Serious occurrences of forest fire are due to improper peat land management; slash and burn activities; and poor water regulation in cultivated peat lands. Most of the forest fires in Malaysia originate from sources outside the Permanent Reserve Forest, usually through preparation of farmlands by burning in small farms and plantations. Improper burning techniques and strong winds may cause the fire to spread to nearby secondary forests. Forest fires are reported to occur almost every year (some more than once) particularly in the highly degraded peatland areas. If this phenomena is allowed to go on, more and more peatlands will be degraded due to fires. It is thus very crucial that the issues related to this problem be addressed to protect the productivity of the land and the environment. In this regard, an initial step towards this direction is to have simple techniques to identify areas that susceptible or prone to forest fires. This study aims to develop susceptibility indicators to forest fires in such peatlands to assist site managers in being prepared and takes necessary mitigation measure to prevent the occurrence of the forest fires.

Key words: Risk map, fire prone, peat swamp forest, haze, mitigation measures

VULNERABILITY ASSESSMENT TO BIODIVERSITY LOSS: A CASE OF WESTERN HIMALAYA OF NEPAL

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The ecosystems of the Himalayan region of Nepal are as fragile as coastal zones due to climate change and other anthropogenic causes. This study was conducted in Jumla district of the remotest region of western Nepal. Data were collected and analyzed for vulnerability assessment in the upper watershed area of the Tila river system, which included socioeconomic status of rural households, ecological data for biodiversity assessment and meteorological data for temperature and climate change analysis. Socioeconomic data were collected using questionnaires and checklists, while biodiversity-related data were collected through direct field observation, plots establishment and measurement, and field experiments. Perception of local people on increased vulnerability to their livelihoods and state of knowledge about their adaptive measures of climate change were found out. Analysis of social benefits and costs of existing and future adaptive measures at local level was carried out to suggest coping strategies for the challenges of biodiversity loss and poverty alleviation programs in the Himalayan region.

Rising temperatures, glacial retreat and the changes in the availability and quality of water resources were found responsible for changes in natural biodiversity affecting a considerable number of globally important plant and wildlife species of the sub-alpine and alpine regions. Although the rate of green house gases emission in Nepal was negligible, there were clear indications of impacts of climate change such as high snow melting that caused tree line to shift up and the biodiversity to narrow down. The low level of water runoff in the glacial rivers from the Himalaya had caused low hydro-electricity generation. Being predominately an agrarian nation, impacts of biodiversity loss from climate change on livelihoods were found to be significant, affecting largely on agricultural crops production, livestock farming (low availability of grazing area and forage) and livelihood assets in the Himalayan region. Since, adaption has been considered as a major strategy to cope with present challenges of climate change in the developing countries like Nepal, the activities like altering the timing of planting of crops, changing crop types, controlling insect outbreaks, breeding new agricultural and forest species that could be better suited in the changing climatic conditions can be taken as good adaptive measures that confer resilience to the Himalayan ecosystems.

Key words: Climate change, biodiversity loss, vulnerability assessment, Tila River

CLIMATE VARIABILITY EFFECTS ON QUEENSLAND'S VEGETATION NET PRIMARY PRODUCTIVITY: AN ANALYSIS OF 2000-2006 MODIS SATELLITE IMAGERY

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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 compare the interannual variation of net primary productivity (NPP) between Queensland's major vegetation groups in relation to variability in annual rainfall, and to assess the potential effects of drought on the NPP of major vegetation groups. Using the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery products (MOD17A3), this study analysed 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 analysed and compared during moderately wet year (2000) and drought years (2002-2006).

Preliminary results have shown that there is a significant spatio-temporal variability of NPP over major vegetation groups in Queensland. For example, in the La Niña year of 2000, the mean NPP of rainforests and vine thickets was 18,780 gC/m²/yr⁻¹, in contrast to the low mean NPP of hummock grasslands (629 gC/m²/yr⁻¹). In the drought year of 2002, the mean NPP values range from 20,719 gC/m²/yr⁻¹ to 27 gC/m²/yr⁻¹. It shows that Queensland's grassland NPP has decreased by up to 96% in a drought year. In contrast, rainforest's NPP increased by 10% — an unexpected result. Some vegetation groups did not significantly change (e.g. Eucalypt open forests, Casuarina forest, etc.). Correlations between NPP and rainfall in the study area range from $r = 0.83$ to 0.93 . The results indicate that vegetation response to drought (as shown by NPP values) is related to vegetation's structural complexity. More work is being done to analyse other biophysical factors that may help in understanding NPP variability and the potential effects of climate.

Keywords: Net primary productivity, MODIS-NPP imagery, Climate variability, biomass, carbon

WOOD-BORING BEETLE COMMUNITIES IN KOREAN WHITE PINE FOREST AND ITS IMPLICATIONS 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 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 influence of climate change. Wood-boring beetle communities in a Korean white pine forest located in Gyeonggi-do and three Korean white pine forests in Chungcheongbuk-do were studied. The beetles were weekly collected by Malaise trap in each forest from May to September in 2007 and they were identified in species level. The number of identified species belonged to cerambycidae, curculionidae and scolytidae were 16, 25 and 9, respectively. Among the species identified, *Enaporrhinus granulatus* and *Balanobius roelofsi* were found only one forest, suggesting these species are vulnerable to decrease in the area of the white pine forest. An ambrosia beetle, *Xyleborus mutilatus* was the most dominant species in the white pine forests surveyed, suggesting 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.

Keywords: Cerambycidae; Curculionidae; Korean white pine forest; Scolytidae; Wood-boring beetle community

EFFECTS OF FAST-GROWING TREES ON POLLUTION LEVEL OF AN AREA AFFECTED BY ACID MINE DRAINAGE DISCHARGES FROM ABANDONED COAL MINE

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Mining industry without consideration for human health, harmony with nature, and proper measures of earth's resources, generally brings about huge environmental problems. There are 345 abandoned coal mines which include approximately more than 800 underground cavities and tunnels in Korea. Approximately 200 pitheads of the mines discharge 33,600 tons of AMD (Acid Mine Drainage) a day, and that is seriously influence on the primary water system such as Hangang river and Nakdonggang river in Korea. AMD is a kind of groundwater which is generated from the mines. It has pH 3-4 which is strongly acid and contains an amount of metallic ions such as Fe. It also shows high concentration of sulfate.

This study was carried out to monitor reducing pollution level of area where acid mine drainage discharged in an abandoned coal mine using fast-growing trees such as *Populus deltoids*, *Populus nigra* (Dorskamp clone) and *Salix alba* (131-27 clone). In order to build a purification belt nearby pollution sources, we installed study sites (Eoryong-Dongmyung coal mine) which is 300m² in San 47-1, Hwajeon 2-Dong, Taebaek City, Gangwon Province. We planted 60 seedlings including *Populus deltoids*, *Populus nigra* and *Salix alba* each 30 seedlings at intervals of the 2m nearby puddle and waterway at the mine-water outlet where *Alnus sibirica* has been dominant species. We took samples of soil, water, and *Alnus sibirica* to measure the pollution level nearby study sites in Sep. 2009.

Five sample trees were cut at 3, 6, 9, 12, and 15m from pollution sources and all sample trees were divided into three parts as leaf, branch, and stem. As a result of heavy metal analysis, heavy metal contents in tree components of *Alnus sibirica* decreased in the order of stem > branch > leaf and the contents of heavy metal element in each components were high in the order of Cu > Pb > As > Cd. Small amounts of Cd, Cu, As, Hg, and Pb were detected in soil and water samples taken from 0, 15, and 30m, it was below environmental standards established by Korean government. Continuous monitoring were planned to monitor pollution level of the area planted with *Populus deltoids*, *Populus nigra* and *Salix alba* to determine its phyto-remediation potential.

Keywords: Mine lands, water quality, purification, Phytoremediation, pollution

CLIMATE CHANGE VULNERABILITY AND HOUSEHOLD LEVEL ADAPTATION: A STUDY OF FOREST DEPENDENT COMMUNITIES IN DROUGHT PRONE AREA OF WEST BENGAL, INDIA

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The study of vulnerability assessment in the context of climate change is new area of research especially among developing countries like India. The adaptation process includes three essential stages i.e. 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 changes in climate. 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 per cent 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 as the vulnerable sector and constitute an integral part of social life of tribals and others living in and around forest areas and contribute substantially to the food supply of tribal populations in India. The 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 of climate change which helps to reduce vulnerability. This paper is an empirical study based on data collected through field survey. This study covers four villages- Rangakula, Khayarakura, Dhansimla and Bandhgaba, both are scheduled tribal based villages located in Sonamukhi forest area in the District of Bankura, one of the drought prone districts of West Bengal, consisting of 100 households in 2010. Socio-Economic Vulnerability Assessment for each village has been calculated. In this study, six factors i.e., occupation, sanitation, educational status; live stock 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 Three Categorized Ranking Method (TCR) assigning scores of 1 to 3, 1 being the least vulnerable. Besides, this paper has identified the households adaptation strategies like migration; microfinance through the formation of Self-help Group (SHGs), participation of women in forestry, water harvesting, accessibility of non-timber forest products. In addition, the paper describes vulnerability assessment using "Security Diagram" approach to measure drought vulnerability in India. This approach utilizes water stress and socio-economic susceptibility. In addition, this paper also tries to discuss Fuzzy Inference System to measure drought vulnerability. The Government of India has undertaken little policy action to reduce climate-related vulnerability particularly in the drought- prone regions of West Bengal. This paper has important policy implications for poverty, livelihood vulnerability and migration.

Key words: adaptation, security diagram, socio-economic vulnerability assessment, Fuzzy

Inference System, Migration, Water stress, socio-economic susceptibility

VULNERABILITY AND ADAPTATION CAPACITIES OF AGRICULTURE SYSTEMS TO THE CLIMATE CHANGE THREAT – A STUDY OF THE PERAK RIVER BASIN

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Agriculture system productivities and their activities are very much dependent on the state of the environment. The trend behavior of weather and climate parameters such as temperature, rainfall and sunshine for example dictates environmental conditions and their effects on water availability and temperature requirements in influencing crop productivity. The behavior of weather and climate also influences the operations of various work phases associated with a particular agriculture system. For example, in rice cultivation a number of work phases can be identified and each of these work phases is somehow very much related to the state of the weather and climate of a particular region during its operations. The paper discusses the potential threat of climate change on agriculture productivity and activity for agriculture systems in the Perak River Basin. The study begins with identifying and reclassification of agriculture systems and their susceptibility to the climate change based on levels of threat. The study then examines the potential impact of climate change on the productivity of each agriculture system and on their activities (work phases). The study also identifies and appraised the level of vulnerability and the inherent indicators of each agriculture system and their adaptive mechanisms practiced to address the climate change threat. This paper also discusses the future requirements of addressing the climate change threat based on the need for adaptive strategies identify the generic and specific vulnerability of agriculture systems.

Keywords: vulnerability, adaptation capacities, agriculture systems, climate change