

Assessing Climate Change Impacts, Vulnerability and Adaptation

The Case of Pantabangan-Carranglan Watershed



Rodel D. Lasco
Rex Victor O. Cruz
Juan M. Pulhin
Florencia B. Pulhin

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World Agroforestry Centre
College of Forestry and Natural Resources,
University of the Philippines Los Baños
Philippines, 2010

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World Agroforestry Centre
2/F Khush Hall, IRRI, Los Baños, Laguna, Philippines
Telephone: +63 49 5362701 ext 2860 & 2544
Telefax: +63 49 5362925
Email: ICRAF-Philippines@cgiar.org

College of Forestry and Natural Resources
University of the Philippines Los Baños
College, Los Baños, Laguna
Telephone: (049) 536-3996
Telefax: (049) 536-3206
Email: cfnr@uplb.edu.ph

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List of Acronyms / Abbreviations

A & D	alienable and disposable
AIACC	Assessments of Impacts and Adaptations to Climate Change
CAI	current annual increment
CLSU	Central Luzon State University
CLUE-S	Conversion of Land Use and its Effects at Small
CV & E	climate variability & extreme
DA	Department of Agriculture
DAR	Department of Agrarian Reform
dbh	diameter at breast height
DENR	Department of Environment and Natural Resources
DMPMC	Development Management Plan of the Municipality of Carranglan
ENSO	El Niño Southern Oscillation
FGD	focus group discussion
GCM	general circulation model
GIS	geographic information system
GHG	greenhouse gas
IA	irrigators' association
IEC	information, education and communication
IPCC	Intergovernmental Panel on Climate Change
LGU	local government unit
MAO	municipal agriculture officer
masl	meters above sea level
MAB	mean annual biotemperature
MAT	mean annual temperature
NDCC	National Disaster Coordinating Council
NIA	National Irrigation Authority
NIA-UPRIIS	Natioanal Irrigation Authority- Upper Pampanga River Integrated Irrigation System
NPC	National Power Corporation
NPP	net primary productivity
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PCW	Pantabangan-Carranglan Watershed
PET	potential evapotranspiration
PINC	Philippines Initial National Communication
PMP	Pantabangan Master Plan
PREC	precipitation in the growing season
ROC	Relative Operating Characteristic
SWIP	small water impounding projects/programs
TA	technical assistance
TAR	Third Assessment Report
UPRIIS	Upper Pampanga River Integrated Irrigation System
VIC	Variable Infiltration Capacity

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Preface

Climate change is one of the defining issues of our day. As I write this, world leaders are in Copenhagen grappling with how to deal with this seemingly intractable issue. While scientists are almost one in pointing out the dangers of climate change, global response is still fragmented.

The Philippines is one of the most vulnerable countries to climate risks both current and future. Annually, the country experiences the havoc caused by tropical cyclones. Every few years, the ENSO phenomenon adds another layer of confusion to the weather patterns. As a result, small farmers in the country have developed ways of adapting to such seemingly capricious climate.

This book arose out of pioneering research in one of the most important watersheds in the country. When it started in 2002, there was hardly any information on the impacts of climate change on Philippine watersheds and their natural and social systems. Through this research, we were able to explore how climate change could affect our forests, water resources and local communities.

The methodologies, key findings and lessons learned from this research are now compiled in this book. It is our hope that these be useful to researchers, students, policy makers and development workers interested on the impacts of climate change as well as how we can cope with it.

We would like to express our gratitude to the global project Assessment of Impacts and Adaptation to Climate Change (AIACC) of START and UNEP of which we had been a part. Special thanks go to Dr. Neal Leary who was the global coordinator of AIACC. But most of all, we are indebted to the small farmers and institutional partners in the Pantabangan-Carranglan Watershed who gave their time and resources in the conduct of this research.

Rodel D. Lasco
Country Coordinator
World Agroforestry Centre (ICRAF)
Philippines

1.0 Climate Change and Watersheds

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report concludes that climate change is becoming a present reality as warming of the climate system has become unequivocal (IPCC 2007). All general circulation models (GCMs) predict an enhanced hydrological cycle and an increase in area-averaged annual mean rainfall in Asia. This is expected to exacerbate pressure on the region's natural resources that are already under severe stress from rising population. Developing countries will be most vulnerable, as they have limited resources and capacity to adapt to the effects of climate change.

Apart from intraseasonal and interannual variability in climate, extreme weather events such as cyclones, prolonged dry spells, and intense rainfall are known to cause adverse effects such as droughts and floods in tropical Asia. Generally, what is observed in many parts of Asia is the increase in frequency of intense rainfall events that has caused severe flooding, landslides, and debris and mud flows (IPCC 2007).

Climate change poses varying threats, direct or indirect, both to natural and human systems. Scientific studies show that human health, ecosystems, and socioeconomic sectors (e.g., hydrology and water resources, food and fiber production, coastal systems and human settlements), all of which are vital to sustainable development, are sensitive to changes in climate. These will be affected by both the magnitude and rate of climate change, as well as the changes in climate variability (IPCC 2001 and 1996).

While many regions are likely to experience the adverse impacts of climate change, of which some are potentially irreversible, some effects of climate change are likely to be beneficial. For instance, crop production in the mid and high latitudes is projected to increase at a local mean temperature increase of 1-3 °C (IPCC 2007). Clearly, it is important to understand the nature of climate change risks, where natural and human ecosystems are likely to be most vulnerable, and what may be achieved by adaptive responses.

In Southeast Asia the key concerns include the impacts of climate change on ecosystem vulnerability (e.g., biodiversity loss) and water resources. The IPCC Third Assessment Report (TAR) highlights the scarce information available on these concerns. Specifically lacking are integrated assessments of impacts, adaptation, and vulnerability (IPCC 2001).

Watersheds are critical to economic development and environmental protection in Southeast Asia and are likely to be affected by future climate change. In the Philippines watershed areas are believed to be among those to be adversely affected by climate change. Watersheds are critical to the economic development and environmental protection and are, therefore, key to the pursuit of sustainable development. More than 70% of the country's total land area lie within watersheds. Much of the remaining natural

forests that provide a host of environmental services are located in these areas. Also, it is estimated that no less than 1.5 million hectares of agricultural lands currently derive irrigation water from watersheds. Moreover, around 20 to 24 million people, nearly one-third of the country's total population, inhabit the uplands of many watersheds, majority of whom depend on watershed resources for survival. However, scientists working on climate change in Southeast Asia have limited experience in impacts and vulnerability assessment. Lack of research support from internal sources has stifled development of research capacity. Aside from resource constraints, strategic partnerships with scientists from developed countries are also required.

The lack of research is reflected in the absence of articles from the Southeast Asian region in peer-reviewed literature. The result is under-representation of cases from the region in the IPCC assessment reports.

The Assessments of Impacts and Adaptations to Climate Change (AIACC), a global study designed to address the lack of scientific research on climate change impacts, adaptation, and vulnerability of watershed resources and local communities, was launched in 2002. One of AIACC's regional studies focused on the Philippines, Indonesia and Indo-China. This project assessed the impacts of climate change and associated land use and cover change on water resources, forest ecosystems, and social systems of watersheds in Southeast Asia. The project leaders conducted studies in selected watersheds in the region and provided training and technical assistance to scientists from Indo-China on research methods to be implemented in their respective watersheds. Future climate scenarios were developed and downscaled, and the results were used in conjunction with a climate-vegetation model to predict future land use and cover change. The impacts of climate and land use/cover change were assessed with measures of change in biodiversity, carbon and water budgets, livelihood, health, demographic shifts, and changes in social structure resulting from climate and land use/cover change. The project team conducted an integrated vulnerability assessment of natural and social systems in the watershed. It also developed and evaluated adaptation strategies. Research findings and policy implications were presented to policy makers and development workers. In the Philippines the study was conducted in Pantabangan-Carranglan Watershed (PCW) in Nueva Ecija province.

1.1 Overview of Pantabangan-Carranglan Watershed

1.1.1 Biophysical environment

Geographic location and importance

The PCW lies between 15°44' to 16°88' north latitude and 120°36' to 122°00' east longitude (Figure 1.1). The watershed is

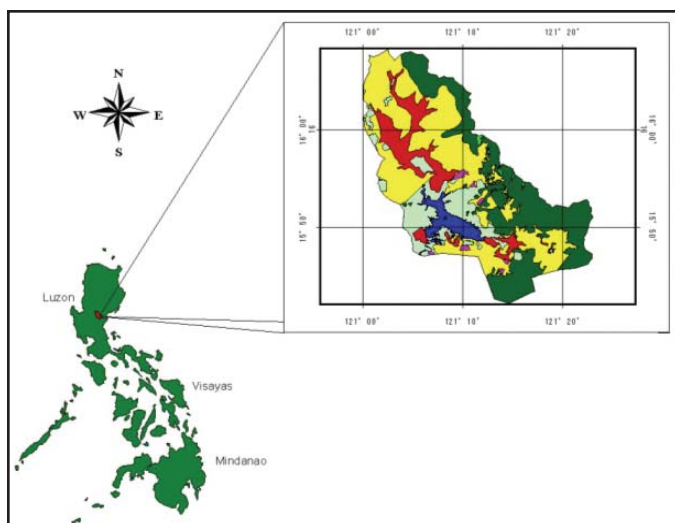


Figure 1.1. PCW location map. Sources: Landuse maps [1:50,000] from College of Forestry and Natural Resources, UPLB and Provincial Environment and Natural Resources Office, Nueva Ecija.

bounded on the north, northwest and northeast by the Caraballo Mountain Ranges and on the south, southeast and southwest by the Sierra Madre Ranges. It is located in the Municipalities of Pantabangan and Carranglan in the Province of Nueva Ecija, Municipalities of Alfonso Castañeda and Dupax del Sur in the Province of Nueva Vizcaya, and Municipality of Maria Aurora in the Province of Aurora. The watershed is approximately 176 km away from Manila (Saplaco et al. 2001).

PCW has a total area of 97,318 ha of which 4,023 ha comprise the water reservoir (1999 Land Use Map). It is considered as a 'critical watershed' under the government's classification since it supports a multi-purpose dam for irrigation and hydroelectric generation. The watershed also provides water for domestic and industrial uses and serves to tame the flood waters which for years damaged the farm crops in Central Luzon (NPC 1997).

The completion of the Pantabangan Dam in 1974 has greatly eased the water supply requirement of about 8,000 hectares of farmlands in the floodplains (NPC 1997). Currently, PCW supplies the irrigation requirements of 24 municipalities in Nueva Ecija, Bulacan, and Pampanga. It has a total service area of 102,532.21 ha which is divided into four districts. A total of 369 irrigators' associations (IAs) consisting of 62,039 farmers depend on PCW for their farm irrigation needs (NIA-UPRIIS 2004).

The construction of the Pantabangan Dam has also addressed the country's need for electricity. It generates 100,000 kilowatts of hydroelectric power which supplies electricity to Central Luzon and adjacent regions (NPC 1997).

Climate

PCW area largely falls under the Philippine Climatic Type I with two pronounced seasons, namely, dry from December to April and wet the rest of the year. A small portion of the watershed,

especially that at the boundary of Aurora, falls under Climatic Type II, characterized by no dry season and very pronounced maximum rainfall from November to January. Its annual average rainfall is 1,766.5 mm (Saplaco et al. 2001, NPC 1995 and 1997).

Minimum monthly temperature is recorded at 23.21 °C and 33.71 °C for the maximum monthly temperature. The lowest temperature occurs during December through March while the highest temperature occurs from April through November with an average of 33 °C (NPC 1995 and 1997).

The average annual relative humidity is 83.37%. The lowest relative humidity occurs during May with 76.6% and the highest during September with 86.67% (NPC 1995 and 1997).

Topography and soil

The topography of PCW is characterized by complex land configuration and mountainous rugged terrain. It ranges from nearly level, undulating and sloping to steep hilly landscapes. The highest mountain peaks in the area are Mount Susong Dalaga, with an elevation of 1,650 masl, and Mount Nedumular, with an elevation of 1,410 masl. Among the other mountains that can be seen in the area are Mount Amok, Kaanducian, Pulog Mabilog, Carranglan, and Maluyan. Strong, undulating, hilly terrain dissected by narrow, flat-bottom valleys formed by streams characterize the foot of these mountains. The headwaters of the streams originate from the mountains (Saplaco et al. 2001).

Soils at PCW originate mostly from weathered products of meta-volcanic activities and diorite. Surface soil textures are silty clay loam, clay loam, and clay. There are four types of soils in the watershed, namely: Annam, Bunga, Guimbaloan, and Mahipon (Saplaco et al. 2001). The Annam soil type is primarily a mountain soil which comes from weathered igneous rocks. It is moderately deep ranging from 50-130 cm and dominantly brown and clayey in color. This soil type is recommended for trees and forest crops. Guimbaloan soil is usually found on moderately sloping or undulating areas and on hilly and mountainous relief. Derived from basalt and meta-volcanic materials, this soil type is predominantly clayey, about 50 cm deep and well drained. The Bunga soil type, on the other hand, is present in level to nearly collu-alluvial landscapes. The dominant color is dark, grayish brown with strong brown and light gray matter. It is clayey in texture, with a depth of 147-155 cm and is moderately well drained. Mahipon usually occurs on level to nearly level collu-alluvial landscapes. This soil type is derived from quaternary alluvial/talus deposits and terrace gravels. It also has a clayey texture but has a restricted internal drainage. It is moderately acidic which makes it useful for the cultivation of agricultural crops.

Land use

The major land use types found in PCW are forests, open grasslands, and reforestation sites (Figure 1.2). Vegetation in the watershed is predominantly second growth. Since the logging boom in 1960s, primary forests in the watershed have greatly declined, though remnants of dipterocarp forest can still be found

(Saplaco et al. 2001). Nevertheless, of significant occurrence is the increase in the area of reforested sites, although these sites are now under intense pressure from increasing population. Residential and barangay sites, as well as cultivated areas, are included in the alienable and disposable (A & D) areas.

Rice, vegetables, corn, onion, and other agricultural crops are grown on cultivated lands. Rice, onion, and vegetables are the primary crops raised on the lowland areas of Carranglan. Within the watershed divide, most of the areas devoted for rice production are rain-fed. Water pumped from wells and run-of-the-river irrigate some areas for rice production. With this current cultivation practice, rice growing cannot maximize the best use of the land. Hence, other primary crops are produced like yellow corn and onion. Secondary crops are also planted which include vegetables, like

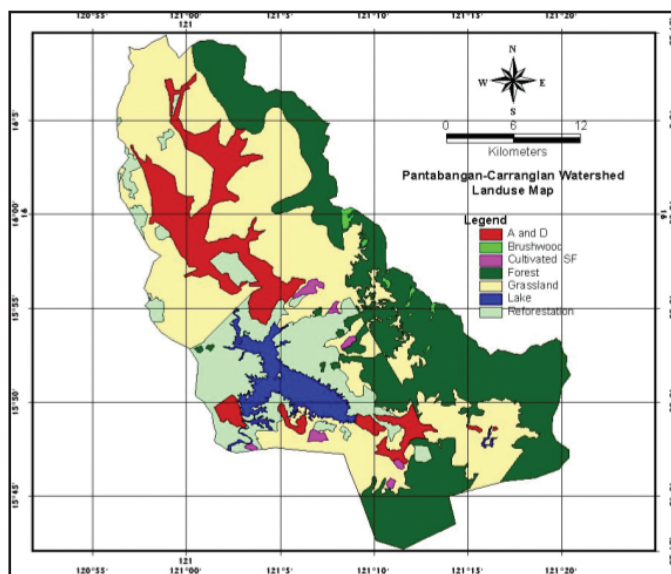


Figure 1.2. 1999 Land use map of PCW with municipal boundary.

eggplant, tomatoes, bitter gourd, and squash (Saplaco et al. 2001, Toquero 2003).

The most popular crop during the dry season is onion. Second cropping is practiced by farmers in irrigated rice lands and sometimes in rain-fed areas depending on the frequency of rain during the year (Toquero 2003). In *kaingin* (slash-and-burn) farms crops like banana, cassava, sweet potatoes, and corn are normally grown. Meanwhile, only one pastureland was recorded in the area. This is found in Pantabangan where only limited areas are devoted for agriculture (Saplaco et al. 2001).

1.1.2 Demographic characteristics

There are a total of 36 barangays found in PCW, of which 17 are found in Carranglan, 14 in Pantabangan, three in Alfonso Castañeda, and two in Ma. Aurora. As of year 2000 about 60,824 people reside in PCW which comprise 12,398 households (Census 2000).

Three ethnic groups inhabited PCW long before the Spanish occupation. These are the Aetas, Irol-les and the Italengs. They were soon joined by several groups of migrants, among them were Pangasinensis, Ibaloi, Ifugao, Waray, Bicolano, Pampango, Kalinga, Kankanaï, Ibanag, Cebuano, and Ilongot. However, the construction of the Pantabangan Dam in 3 March 1971 has led to relocation of the residents of the town which resulted to waves of out-migration from the period of 1970s to 1980s. Today, residents in PCW are predominantly Tagalog and Ilocano. Other groups present in the area are Pangasinensis, Pampango, Waray, Bicol, Ifugao, and Ibaloi (Saplaco et al. 2001).

1.1.3 Socioeconomic characteristics

The largest portion of PCW is located in Pantabangan and Carranglan in Nueva Ecija. The major source of livelihood of these municipalities comes from agricultural activities. In Pantabangan 13% of the total land area which accounts for about 5,406 ha are devoted to agriculture. Meanwhile, a total of 19,704 ha or 28% is allotted for farming in Carranglan. Among the major crops produced are rice, corn, onion, and vegetables. However, even if the Pantabangan reservoir is located in these areas, it only acts as a host for irrigation water to the Central Luzon area. Farmlands are unirrigated because of topography, hence, farmers are dependent on rain (Master Plan of the Municipality of Pantabangan [MPMP] 1998-2000, Development Management Plan of the Municipality of Carranglan [DMPMC] 2003-2007).

Fishing is the second largest industry in these areas, specifically in Pantabangan. This is because the area houses the dam reservoir which is one of the biggest fishing reservoirs in Asia. Carranglan, on the other hand, depends on large fishponds for its fish production. Other sources of income of residents are cottage and business activities which include wood and rattan craft, animal dispersal, and small stores (MPMP 1998-2000, DMPMC 2003-2007).

More than half of the productive population of Pantabangan and Carranglan are in the labor force. However, unemployment is still a problem due to limited employment opportunities in these areas (MPMP 1998-2000, DMPMC 2003-2007). Hence, many residents depend on the goods and services provided by the watershed for their livelihood. Commonly practiced in these areas are *kaingin* and charcoal-making.

Construction of Pantabangan Dam begun on March 1971 and was completed on August 1974. The man-made lake that forms part of the dam reservoir has submerged the old Pantabangan town and seven outlying barrios, namely: Liberty, San Juan, Cadaclan, Napon-Napon, Marikit, Villarica, and Conversion (Saplaco et al. 2001). All the residents of the old town were resettled to the upper portion of Pantabangan. This resettlement process, which was a joint responsibility of the National Irrigation Administration (NIA) and Department of Agrarian Reform (DAR), started in May 1973 and was completed in August 1974. NIA was in charge of most of the infrastructure development. DAR took care of land distribution for the settlers (Toquero 2003). The families affected received land grants in place of their submerged lands and were subsidized by the government for five years to include free water supply and lower electricity rate. Since the submergence of the town, the government has poured in livelihood projects to help

1.0 Climate Change and Watersheds

residents recover from the loss of their properties and to make the place productive (MPMP 1998-2000).

Since the dam's construction, the area has continually received support from various agencies and institutions in the form of projects or programs. Uplifting the economic conditions of the relocated settlers was a prime concern of the government. DAR was the leading agency that took care of this mission. Even before the resettlement of the affected families, the agency started to conduct trainings on livelihood programs. This was followed by livestock dispersal (pig, goats, and cattle) and fish production projects. The Department of Agriculture (DA) took over the enhancement of the economic welfare of the residents in the mid-1980s. Livestock production was improved by the dispersal of bull and breeders in 1985-1998, and cattle carabao, goat, swine, and chicken in 1993-1998. Rice and corn production was also boosted in the same period through the distribution of certified seeds, organic fertilizers, use of small farm machineries, and a limited number of post harvest facilities (Toquero 2003).

One of the most prominent projects implemented in the watershed was the RP-Japan Reforestation Project which was launched in partnership with the Department of Environment and Natural Resources (DENR). This Japan International Cooperation Agency-funded project commenced in 1976 and ended in 1992. It aimed to reforest the open and denuded areas of PCW and provide technical support through the establishment of the Afforestation Technical Cooperation Center and the Training Center for Forest Conservation. The project has not only rehabilitated the denuded parts of the watershed but also created jobs for the local residents. Moreover, more than 600 Filipino forestry personnel were trained through this project who are now actively working in environment departments (Yoshida 2000).

Aside from the joint project with the Japan government, the DENR launched several reforestation programs, particularly in Pantabangan. These are the Regular Reforestation Program covering a total area of 823 ha and the Integrated Social Forestry Program which reforested 856 ha. The department has also engaged in Contract Reforestation Program with NIA in 1989-1990. In this program the DENR contracted NIA to reforest a total of 900 ha in PCW (MPMP 1998-2000).

The National Power Corporation (NPC) and NIA also have their share of projects implemented in the watershed area. Aside from training and extension services, NPC conducts yearly reforestation and extension projects in the three sectors under its jurisdiction. The reforestation projects cover an average of 30-40 ha a year.

Meanwhile, the biggest project implemented by NIA in PCW is the Watershed Management and Erosion Control Project which lasted from 1980-1988. This project was funded by World Bank and aimed to control soil erosion and minimize sedimentation and siltation in the reservoir. It has four components: reforestation, feasibility study of an integrated development, waste management and smallholder agroforestry pilot project, and integrated forest protection pilot program. Among the activities undertaken in this project were reforestation with agroforestry and timber

crops of a 24,522-ha area in the watershed and construction of several plantation access roads and facilities. Due to the project's labor-intensive activities such as nursery operations, plantation establishment and development, and forest protection and fire prevention, it has provided employment for some 3,800 residents in Pantabangan in 1982. Aside from this, the project also provided revenue and profit share to the communities in the watershed in the form of facilities, such as domestic water supply, school building, and road improvements (NIA n.d.).

The Casecanan Multipurpose and Irrigation Project is a recent project implemented in PCW. It was constructed in November 1995 and began its operation on 11 December 2001. The project was designed to collect a portion of the waters of the Casecanan and Taan Rivers in Nueva Vizcaya and transport it to the Pantabangan reservoir. It is designed to benefit the irrigation requirement of 35,000 new hectares of agricultural lands and stabilize the water supply of the current areas serviced by PCW. Moreover, it will generate approximately 150 megawatts of hydroelectric capacity to the important Luzon grid.

As already mentioned, the above projects have significantly helped the residents in PCW through the provision of jobs, livelihood programs, and various forms of assistance. But despite the three-decade development effort of the government (amounting to PHP 1.5 billion), there is still widespread poverty in the resettlement as shown by a high percentage of families with income below the poverty threshold of PHP 7,377. The residents also perceived the services provided by the government organizations as unsatisfactory. This implies the failure of the government in providing an economically-viable resettlement area for the residents. A point of concern that could have contributed to this failure is the lack of participation of the residents in the planning and monitoring of the development projects or programs. Some residents were not used to the livelihood activities introduced, hence, they were forced to open kaingin in the critical watershed (Toquero 2003).

Moreover, these development projects and programs may have also resulted to dependency of some people to these forms of assistance

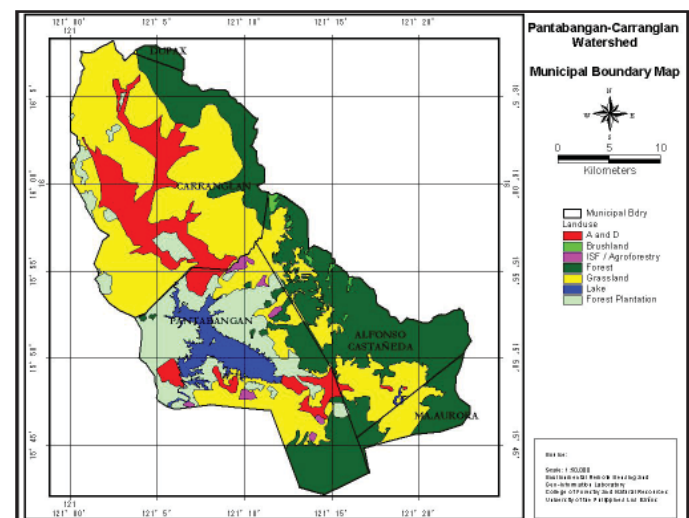


Figure 1.3. Land use map of PCW with municipal boundary.

and even to the goods and services provided by the watershed for their source of living. With the recent completion of these development projects and programs, the local settlers resort to charcoal-making which destroys the areas that they reforested. What aggravates the situation is that this type of livelihood is practiced by more than 50% of the residents in the watershed (Toquero pers. comm.)

Irrigation service

The PCW supplies the irrigation requirements of 24 municipalities in Nueva Ecija, Bulacan, and Pampanga (Figure 1.3) through the Upper Pampanga River Integrated Irrigation System (UPRIIS) which is operated by NIA. As shown in Table 1.1, it has a total service area of 102,532.21 ha which is divided into four districts. A total of 369 IA's consisting of 62,039 farmers depend on PCW for their farm irrigation needs (NIA-UPRIIS 2004).

Table 1.1. PCW service area

Province / Municipalities	Mu-	District 1	District 2	District 3	District 4
NUEVA ECIJIA					
1. San Jose		5,727.72			
2. Muñoz		4,032.62			
3. Sto. Domingo		5,547.04			
4. Quezon		3,670.56			
5. Licab		2,404.67			
6. Llanera		1,140.39	4,899.85		
7. Talavera		2,439.00	5,751.79		
8. Rizal			4,664.24		

Table 1.1. PCW service area (continued)

Province / Municipalities	District 1	District 2	District 3	District 4
8. Rizal		4,664.24		
9. Gen. Natividad		6,608.75	254.75	
10. Aliaga		1,686.12	2,969.45	
11. Cabanatuan City		302.17	6,002.13	
12. Sta. Rosa			5,481.45	
13. San Leonardo			2,893.04	
14. Jaen			5,069.98	
15. Zaragoza			2,404.00	
16. San Antonio			4,437.31	
17. Peñaranda			334.18	379.00
18. Gapan				5,259.63
19. San Isidro				3,448.82
20. Cabiao				4,573.91
BULACAN				
1. San Miguel				4856.85
2. San Ildefonso				517.88
PAMPANGA				
1. Arayat				1462.78
2. Candaba				3312.13
Sub-Total	24,962.00	23,912.92	29,846.29	23,811.00
GRAND TOTAL				102,532.21

Box 1. Institutions involved in watershed management

Spearheading the management of PCW are national government agencies, namely, the DENR, NIA, and NPC. Each institution has specific areas within the watershed that is under its jurisdiction. This institutional arrangement comes from the need to sustainably manage the watershed so that there will be sufficient amount of water in the reservoir for irrigation and hydroelectric power generation. Supporting these institutions in the performance of their functions are the local government units (LGUs) present in the area.

The DENR is the primary government agency responsible for the conservation, management, development, and proper use of the country's environment and natural resources, including those in reservations, watershed areas, and lands of the public domain. It is also responsible for the licensing and regulation of all natural resources utilization as may be provided by law in order to ensure equitable sharing of the benefits derived for the welfare of the present and future generations of Filipinos. Since PCW is located in Central Luzon, it falls under the jurisdiction of DENR Region III. Two Provincial Environment and Natural Resources Offices and Community Environment and Natural Resources Offices located in Aurora and Nueva Ecija manage the watershed.

NIA is a government-owned and controlled corporation tasked with the development and operation of irrigation systems all over the country. Through Letter of Instruction 1002 dated 20 March 1980, NIA was authorized to manage, protect, develop, and rehabilitate certain portions of PCW Reservation. Meanwhile, Republic Act 3601, as amended by Presidential Decrees 552 and 1072, empowered NIA to acquire real and personal properties and all appurtenant rights, easements, concessions and privileges, whether the same are already devoted to private or public use in connection with the development of its projects (Saplaco et al. 2001). Under the jurisdiction of NIA are the areas of Ma. Aurora in Aurora, Alfonso-Castañeda in Nueva Vizcaya, and Carranglan and Pantabangan in Nueva Ecija (NIA 2003).

Meanwhile, NPC is the agency engaged in power generation and transmission all over the country. Among its functions is the development of electric power generation facilities including hydroelectric power and construction and operation of dams, reservoirs, and diversion facilities required for this purpose. A memorandum of agreement signed on 1 April 1997 turned over to NPC a total of 14,166 hectares of PCW. The areas under the jurisdiction of NPC are Daldalayap, Bunga, and Carranglan of Sector I; Burgos, Carranglan of Sector II; and Conversion, Pantabangan of Sector III (NPC 1997).

Finally, the LGUs constitute the provincial, municipal, and barangay political units in the Philippines. They can engage in development programs, economic activities, law enforcement, and legislation, among others. Through the process of devolution instituted under the 1991 Local Government Code, the LGUs are given the responsibility to conserve, manage and protect the natural resources.

2.0 Methodologies

This chapter presents the methods and simulation models used in the AIACC study. This will be useful to students and other researchers who want to engage in climate change research. Further details of the methods and models are given in the references.

Climate change impacts on Philippines forest ecosystems are simulated using Holdridge Life Zones and geographic information system (GIS). The CO2Fix Model is used to quantify carbon stocks and fluxes of various land cover types in PCW. The CLUE-S (Conversion of Land Use and its Effects at Small) Model is used to predict land use change and land use in PCW. Impact assessment on water resources is done using SEA/BASINS Integrated Modeling System and the BROOKS Hydrologic Models. Meanwhile, the socioeconomic component of the study uses a combination of qualitative and quantitative methods in order to arrive at a multi-level indicator of vulnerability of communities living in PCW.

2.1 Simulating climate change impacts on forest ecosystems using Holdridge Life Zones and GIS

Generally, the study follows the approach of using scenarios to predict forest cover that is used by Somaratne and Dhanapala (1996) in Sri Lanka and is given as an example in the Adaptation Policy Framework of the United Nations Development Programme (Jones and Boer 2003).

The Holdridge Life Zone system is an ecological classification system based on three climatic factors, i.e. precipitation, heat (biotemperature) and humidity (potential evapotranspiration ratio (Holdridge 1967). Holdridge (1967) defined a life zone as a group of associations related through the effects of these three major climatic factors. Figure 2.1 shows the most common life zones on the Earth. All Philippine forests can be classified under the tropical belt because biotemperature is always greater than 24 °C. Thus, the main determinant of life zone classification is precipitation. The value used for precipitation is the mean annual total of water in millimeters that falls from the atmosphere either as rain, snow, hail, or sleet. In the case of the Philippines, this is the mean annual rainfall.

$$\text{Precipitation} = \text{annual rainfall (mm)}$$

The mean annual biotemperature is the measure of heat that is utilized in the life zone chart. The biotemperature mean is the average of the Celsius temperatures at which vegetative growth takes place relative to the annual period. The range of temperatures within which vegetative growth occurs is estimated to lie between 0 °C as a minimum and 30 °C as a maximum. The positive temperatures within this range must be averaged out over the whole year period in order to make it possible to effectively compare a given site with any other on the earth. The equation for biotemperature is as follows:

$$\text{Mean annual biotemperature (MAB)} = \Sigma (0 < T < 30) / 12 \text{ months}$$

or

$$\text{Mean annual biotemperature} = \Sigma (0 < T < 30) / 365 \text{ days}$$

The third climatic factor that determines the boundaries of life zones is humidity, best described by the potential evapotranspiration (PET) ratio. PET is the theoretical quantity of water that would be given up to the atmosphere within a zonal climate and upon a zonal soil by the natural vegetation of the area throughout the growing season. Since both evaporation and transpiration are directly correlated with temperature, other factors being equal, the mean annual potential evapotranspiration in mm at any site may be determined by multiplying the mean annual biotemperature by the factor 58.93.

The PET ratio is determined by dividing the value of the mean annual potential evapotranspiration by the value of the mean annual precipitation, both in millimeters. Since potential evapotranspiration is the total water that could potentially be utilized by the normal quantity of water available for potential use in transpiration by the vegetation or evaporation, potential evapotranspiration ratio is a measure of humidity that may be utilized for comparing distinct sites. In equation:

$$\text{Mean Annual PET} = (\text{MAB}) (58.93)$$

$$\text{PET ratio} = \text{Mean Annual PET} / \text{Mean Annual P}$$

The Holdridge Life Zone chart (Figure 2.1) is a graphical classification of some of the most common lifezones on earth for the purpose of showing relationships of mountain vegetation to that of lowlands, working only with annual precipitation and temperature values to develop this chart (Holdridge 1967). The Holdridge forest types utilized in this model are rough estimates of the potential forest types that will thrive for a given precipitation and temperature.

Based on the three parameters, Holdridge life zones for the Philippines are identified using ArcView 3.2. Changes in the distribution of forest types in response to synthetic climate change scenarios are determined (Table 2.1). These precipitation and temperature scenarios are within the limits of GCM projections in the country (Philippines Initial National Communication [PINCC] 1999). ArcGIS 8.1 is used to process the maps needed for the Holdridge life zone model.

Rainfall map is based on the data collected by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). Average rainfall (1961-1990) in the Philippines ranges from 1000–4000 mm. Temperature data is also gathered from PAGASA. A Thiessen map is created from the 55 stations all over the Philippines. Average temperature (1949-2002) in the country ranges from 19.3–28.2 °C.

The land use map is based on a 1993 map prepared by the Presidential Task Force on Water Resources Development and Management. There are only about six million hectares of forests left (excluding brushland and man-made forest), a mere 20% of the country’s total land use. Of these, 1.6 million hectares are non-production forests and less than 1 million hectares are old growth forests. This land use map served as the boundary of Philippine forests and used as an overlay on the calculated Holdridge life zone in the Thiessen map.

2.2 Forest carbon budget

2.2.1 Field sampling, biomass calculation, and carbon analysis

For natural forests the point-centered quarter method is used. It is a plotless method of sampling that is designed to determine the number of trees per unit area that can be calculated from the average distance between the trees. Four parallel lines are randomly laid out. Each parallel line comprises five sampling points with a 50 meter distance from each other. In each point two lines form a cross. One of the lines is the compass direction and the other is the line perpendicular to it and passes through the sampling point. The distance to the midpoint of the nearest tree inside each quadrat with a diameter at breast height (dbh) of ≥ 10 cm is measured. The tree species is then identified and its dbh measured.

For brushlands, 10 plots measuring 10 m x 10 m are established. In each plot all trees with > 10 cm dbh are identified and their dbh measured. For tree plantations, two 5 m x 40 m plots are established in each plantation type. If trees with dbh > 50 cm are present whether they are included in the sample plots or not, an additional sample of 20 m x 100 m is established. In plots measuring 5 m x 40 m, all trees with dbh of > 5 cm are measured and identified. In 20 m x 100 m plots only trees with a diameter > 30 cm are measured. For understory vegetation, four frames measuring 1 m x 1 m are randomly laid out near the sampling

Table 2.1 Synthetic climate change scenarios used in the study

Increase in rainfall (% relative to present)	Increase in temperature (°C)		
	1	1.5	2.0
25	Scenario 1a	Scenario 1b	Scenario 1c
50	Scenario 2a	Scenario 2b	Scenario 2c
100	Scenario 3a	Scenario 3b	Scenario 3c

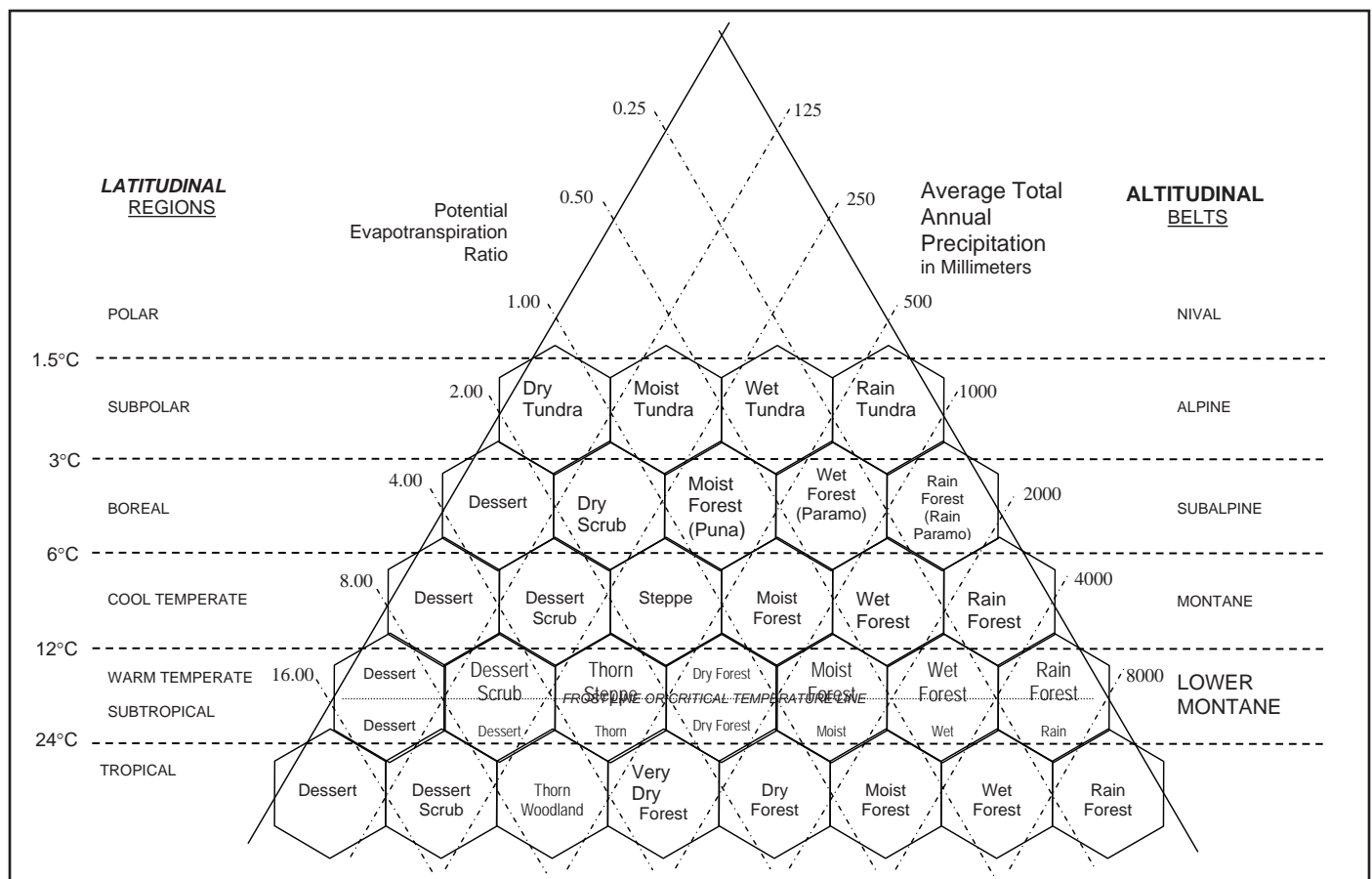


Figure 2.1. The Holdridge System of vegetative cover classification (Holdridge 1967).

points. All herbaceous and woody vegetation (< 5 cm dbh) inside the frame are collected. Sample fresh weight is determined and then samples are oven dried. Inside the same sampling frames used for measuring understorey and herbaceous vegetation, a 0.5 m x 0.5 m transect is established for litter collection. Total fresh weight of all the samples are taken after which about 300 grams are reserved for air drying and oven drying. Samples are dried inside the oven with a temperature of $\pm 102\text{ }^{\circ}\text{C}$ for at least 48 hours or until weights of the samples become constant. Coarse litter is collected in the 0.5 m x 0.5 m quadrat within the understorey sample plot. Similar to the understorey, a sub-sample of about 300 g is taken for oven drying and carbon content analysis.

In grasslands ten 1 m x 1 m sampling frames are laid on the ground. Grasses inside the sampling frames are harvested for biomass determination. Similar to understorey and litter, fresh samples are weighed and a sample of 300 grams is set aside for oven drying.

Soil samples are collected within the sample plots of second growth brushland and grassland areas at 30 cm depth. Samples are air dried and are taken to the Soils Laboratory of the Soil Science Department of the College of Agriculture, University of the Philippines Los Baños for analysis. For bulk density determination, samples are collected using a ring metal with height of 10 cm and diameter of 3 cm at 20-30 cm depth.

Tree biomass is calculated using the following allometric equation (Brown 1997):

$$Y (kg) = EXP(-2.134 + 2.53 * LN(D))$$

Biomass values for litter, understorey and grasses are calculated using the following formula:

$$ODW_t = \frac{TFW - (TFW * (SFW - SODW))}{SFW}$$

where: ODW = total oven dry weight
TFW = total fresh weight
SFW = sample fresh weight
SODW = sample oven-dry weight

Carbon density is calculated using the following formula:

$$C \text{ density } (Mg \text{ ha}^{-1}) = \text{Biomass density } (Mg \text{ ha}^{-1}) * 0.45$$

For more details of field sampling of carbon stocks and sequestration, please refer to IPCC GPG (2003), Pearson et al. (2005), and the 2006 IPCC GHG inventory guidelines.

2.2.2 The CO2Fix Model

Total carbon budget of the various land cover in PCW is computed using the CO2Fix model. It is a tool which quantifies the C stocks and fluxes in the forest, soil organic matter compartment

and the resulting wood products at the hectare scale. Version 2.0 of the model includes the following features:

- Simulate multi-species and unevenly-aged stands in multiple cohorts (defined as group of individual trees or group of species which are assumed to exhibit similar growth and which maybe treated as single entities within the model);
- Parameterize the growth by stand density;
- Deal with intercohort competition;
- Allocation, processing lines, and end-of-life disposal of harvested wood;
- Soil dynamics;
- Handle a wider variety of forest types including agroforestry systems, selective logging systems and post harvesting mortality; and
- Output viewing charts.

In modeling the growth of the stand, two basic approaches are considered:

- tree growth as a function of tree or stand age; and
- tree growth as a function of tree size or stand basal area, volume, or biomass.

Biomass components

The model is parameterized to PCW conditions. Where the age of the stand is known, biomass growth is in the form of current annual increment (CAI) of stemwood volume, in $\text{m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$. Moreover, biomass of other stand components such as branches, foliage, and roots are also calculated as an additional fraction to the growth rate of the tree biomass. Carbon content of the wood components and wood density of the sample species are also important inputs.

Turnover rate

Data on the annual rate of mortality (turnover) of the biomass components is estimated using the default value while the stem turnover rate is a function of the mortality rate of the stand. The mortality of each species is described as the mortality due to senescence or old age and density-related competition and the mortality caused during and after logging operations. It is assumed that all trees have a maximum age and the annual mortality increases when the age of the stand approaches the maximum age, thus, in this model mortality is parameterized as a percentage of the standing biomass.

Interactions (competitions)

Growth of trees in a stand is affected by the presence of other trees. There are two ways of parameterizing competition:

- Competition relative to the total biomass in the stand (e.g., in a *Eucalyptus* stand only); and
- Competition relative to each cohort (e.g., *Eucalyptus* and *Acacia* plantation).

A default value of '1' is used for no competition at all.

Management interventions (harvesting)

The inputs necessary to determine the management interventions

are: the age at which the harvesting takes place, intensity of harvesting done (fraction of cohort biomass removed), and allocation of the biomass removed to different 'raw material' classes as slash, logwood, and pulpwood.

Parameterizing the soil

The model requires inputs like the mean annual temperature (MAT) of the soil ($^{\circ}\text{C}$), precipitation in the growing season (PREC, mm) and PET in the growing season (PET, mm) for the study site. PREC and MAT data can be found at <http://www.worldclimate.com> or mean monthly temperatures can be computed using 'PET.xls' file installed in CO2FIX. Values of litter in the soil are also needed.

Parameterizing wood products

The end of this module is to track carbon from harvesting to final decay. This is because carbon is released to the atmosphere when either by-products are set aside in the manufacturing phase, firewood is burned, or products in landfills decompose. The model allocates harvested biomass like the fraction of the logwood to be used for sawn wood, boards and panels, pulp and paper, and firewood. The fraction of pulpwood to be used for boards and panels, pulp and paper, and firewood are also allocated.

Information on processing losses is also necessary like the fraction of sawn wood lost and reprocessed as boards, pulp and paper, wood fuel, or wood dumped at the mill site.

Moreover, in the end-products stage the allocation of the commodities to different categories will be specified into long-term, medium and short-term use. The life span of the products in use describe the share of remaining products disposed each year.

Sources of errors in using the model are measurement errors in the data and the lack of data used for model construction. This study tries to collect all the necessary inputs needed by the model in the field in order to arrive at accurate projections and results. However, in nature variability occurs such as growth variation between years due to weather circumstances, intraspecies genetic differences and site quality variation and other management irregularities and risks caused by storm and fire. These variations are not captured by the model because it relies on fixed input data from perfectly managed stands.

2.3 Land use and cover change: Clue-S Model

This section describes in general the CLUE-S Model for land use and land cover change based on Verburg (2002). Details of how the model is used in PCW are described in Chapter 6.0.

Model structure

The model is subdivided into two distinct modules: a non-spatial demand module and a spatially explicit allocation procedure (Figure 2.2). The non-spatial module calculates the area change for all land use types at the aggregate level. Within the second part of the model these demands are translated into land use changes at different locations within the study region using a raster-based system.

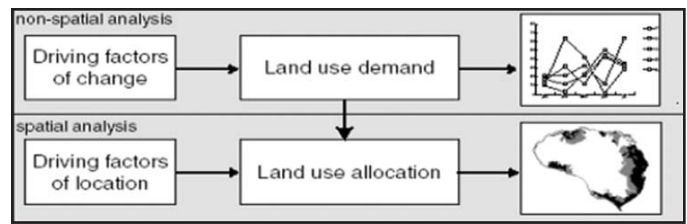


Figure 2.2. Overview of the CLUE-S modeling process.

For the land use demand module different alternative model specifications are possible ranging from simple trend extrapolations to complex economic models. The choice for a specific model is very much dependent on the nature of the most important land use conversions taking place within the study area and the scenarios that need to be considered. The results from the demand module need to specify, on a yearly basis, the area covered by the different land use types, which is a direct input for the allocation module. The rest of this discussion focuses on the procedure to allocate these demands to land use conversions at specific locations within the study area.

The allocation is based upon a combination of empirical, spatial analysis, and dynamic modeling. Figure 2.3 gives an overview of the procedure. The relations between driving forces and the spatial distribution of land use are determined by an empirical analysis of actual land use patterns. The results of this empirical analysis are used within the model when simulating the competition between land use types for a specific location. In addition, a set of decision rules is specified by the user to restrict the conversions that can actually take place based on the actual land use pattern. The different components of the procedure are now discussed in more detail.

Spatial analysis

The pattern of land use, as it can be observed from an aeroplane window or through remotely sensed images, reveals the spatial organization of land use in relation to the underlying biophysical and socioeconomic conditions. These observations can be formalized by overlaying this land use pattern with maps depicting the variability in biophysical and socioeconomic conditions. GIS is used to process all spatial data and convert these into a regular grid. Apart from land use, data are gathered that represent the assumed driving forces of land use in the study area. Data can originate from remote sensing (e.g., land use), secondary statistics (e.g., population distribution), maps (e.g., soil) and other sources. To allow a straightforward analysis, the data are converted into a grid-based system with a resolution that depends on the resolution of the available data. This often involves the aggregation of one or more of the thematic data. For instance, it does not make sense to use a 30 meter resolution if that is available for land use data only, while the digital elevation model has a resolution of 500 meter. Therefore, all data are aggregated to the same resolution that best represents the quality and resolution of the data. The relations between land use and its driving factors are thereafter evaluated using stepwise logistic regression. Logistic regression is an often used methodology in land use change research (Geoghegan et al.

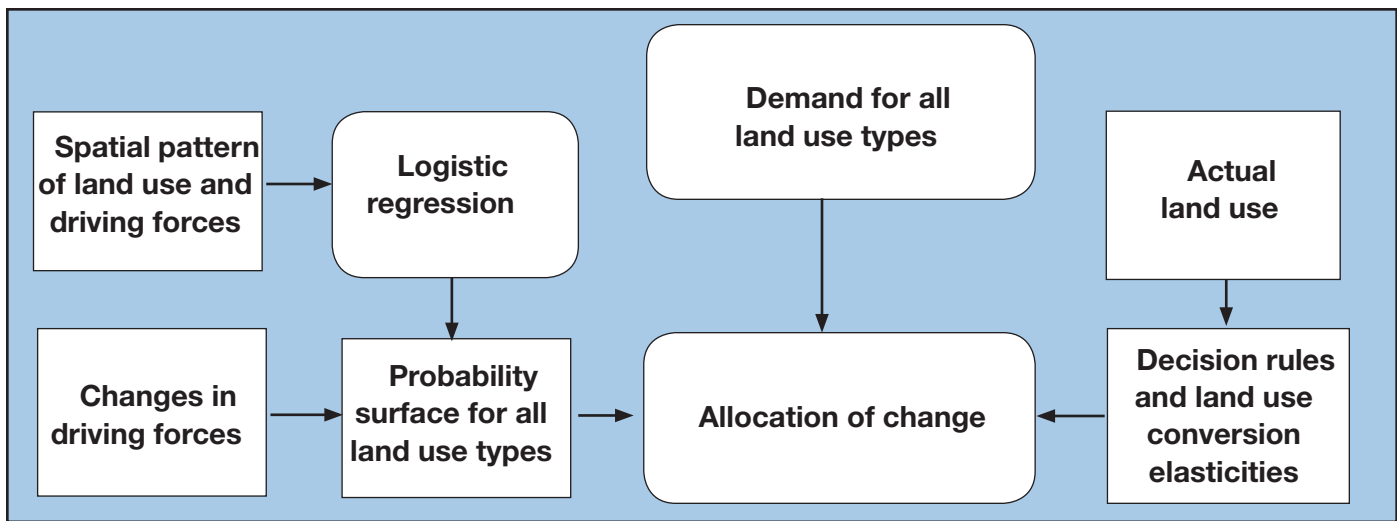


Figure 2.3. Schematic representation of the procedure to allocate changes in land use to a raster-based map.

2001, Serneels and Lambin 2001). In this study logistic regression is used to indicate the probability of a certain grid cell to be devoted to a land use type given a set of driving factors following the equation:

$$\text{Log} (P/1-P) = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \beta_n X_{n,i}$$

where P_i is the probability of a grid cell for the occurrence of the considered land use type and the X s are the driving factors. The stepwise procedure is used to help select the relevant driving factors from a larger set of factors that is assumed to influence the land use pattern. Variables that have no significant contribution to the explanation of the land use pattern are excluded from the final regression equation. The goodness of fit can be evaluated for all equations with the Relative Operating Characteristic (ROC) Method (Pontius and Schneider 2000, Swets 1986) which evaluates the predicted probabilities over the whole domain instead of only evaluating the percentage of correctly classified observations at a fixed cut-off value. This is an appropriate methodology for the application. A wide range of probabilities will be used within the model calculations which only makes the quality of the regression model over a wide range more interesting. The influence of spatial autocorrelation on the regression results can be minimized by performing the regression only on a sample of pixels that are selected at more or less equidistant from one another. Such a selection method is adopted in order to maximize the distance between the selected pixels to attenuate the problem associated with spatial autocorrelation.

Based upon the regression results a probability map can be calculated for each land use type. A new probability map is calculated every year with updated values for the driving factors that are projected to change in time, for instance, the population distribution.

Decision rules

Land use type or location specific decision rules can be specified by the user. Location specific decision rules include the delineation of protected areas such as nature reserves. If a protected area is

specified, then no changes are allowed within this area. Land use type specific decision rules determine the conditions under which a land use type is allowed to change in the next time step. These decision rules are implemented to give certain land use types a certain resistance to change in order to generate the stability in the land use structure that is typical for many landscapes. Three different situations can be distinguished and for each land use type the user should specify which situation is most relevant for that land use type.

For some land use types it is very unlikely that they are converted into another land use type after their first conversion. For instance, as soon as an agricultural area is urbanized it is not expected to return to agriculture or to be converted into forest cover. Unless a decrease in area demand for this land use type occurs the areas covered by this land use are no longer evaluated for potential land use changes. If this situation is selected it also holds that if the demand for this land use type decreases, there is no possibility for expansion in other areas. In other words, when this setting is applied to forest cover and deforestation needs to be allocated, it is impossible to reforest other areas at the same time. Other land use types are converted more easily. A swidden agriculture system is most likely to be converted into another land use type soon after its initial conversion. When this situation is selected for a land use type, no restrictions to change are considered in the allocation module. There are also a number of land use types that operate in between these two extremes. Permanent agriculture and plantations request an investment for their establishment. It is, therefore, not very likely that they are converted very soon after into another land use type. However, in the end, when another land use type becomes more profitable it is well possible that there is a conversion. This situation is dealt with by defining relative elasticities for change (ELASu) for the land use type considered ranging between 0 (similar to situation 2) and 1 (similar to situation 1). The higher the defined elasticity, the more difficult it gets to convert this land use type. The elasticity should be defined based on the user's knowledge of the situation, but can also be tuned during the calibration of the model.

Competition and actual allocation of change

Given the probability maps, the decision rules in combination with the actual land use map and the demand for the different land use types, the actual allocation of land use change is made in an iterative procedure (Figure 2.4). The following steps are followed in the calculation:

1. The first step includes the determination of all grid cells that are allowed to change. Grid cells that are either part of a protected area or under a land use type that is not allowed to change (situation 1 above) are excluded from further calculation.

2. For each grid cell i the total probability ($TPROP_{i,u}$) is calculated for each of the land use types u according to: $u u u i u i ITER ELAS P TPROP$, where $ITER_u$ is an iteration variable that is specific to the land use. $ELAS_u$ is the relative elasticity for change specified in the decision rules (situation 3 described above) and is only given a value if grid-cell i is already under land use type u in the year considered. $ELAS_u$ equals zero if all changes are allowed (situation 2).

3. A preliminary allocation is made with an equal value of the iteration variable ($ITER_u$) for all land use types by allocating the land use types with the highest total probability for the considered grid cell. This will cause a change in land use for a number of grid cells.

4. The total allocated area for each land use is now compared to the demand. For land use types where the allocated area is smaller than the demanded area the value of the iteration variable is increased. The value is decreased for land use types for which too much is allocated.

5. Steps 2 to 4 are repeated as long as the demands are not correctly allocated. When allocation equals demand the final map is saved and the calculations can continue for the next yearly timestep.

Multi-scale characteristics

One of the requirements for land use change models are multi-scale characteristics. The above described model structure incorporates different types of scale interactions. Within the iterative procedure there is a continuous linkage between macro-scale demands and local land use suitability. When the demand changes, the iterative procedure will ensure that the land use types for which demand increased have a higher competitive capacity (higher value for $ITER_u$) to ensure enough allocation of this land use type. Instead of only being determined by the local conditions, captured by the logistic regressions, it is also the regional demand that affects the actually allocated changes. This allows the model to 'overrule' the local suitability, it is not always the land use type with the highest probability according to the logistic regression equation that the grid cell is allocated to.

Apart from these two distinct levels of analysis there are also driving forces that operate over a certain distance instead of being locally important. Applying a neighbourhood function that is able

to represent the regional influence of the data incorporates this type of variables (Figure 2.6). Population pressure is an example of such a variable: often the influence of population acts over a certain distance. Therefore the actual location of the settlements of the people is inappropriate to describe the land use pattern. The surface created by a neighbourhood function is much more capable to represent this driving factor. Instead of using these variables generated by neighbourhood analysis it is also possible to use the

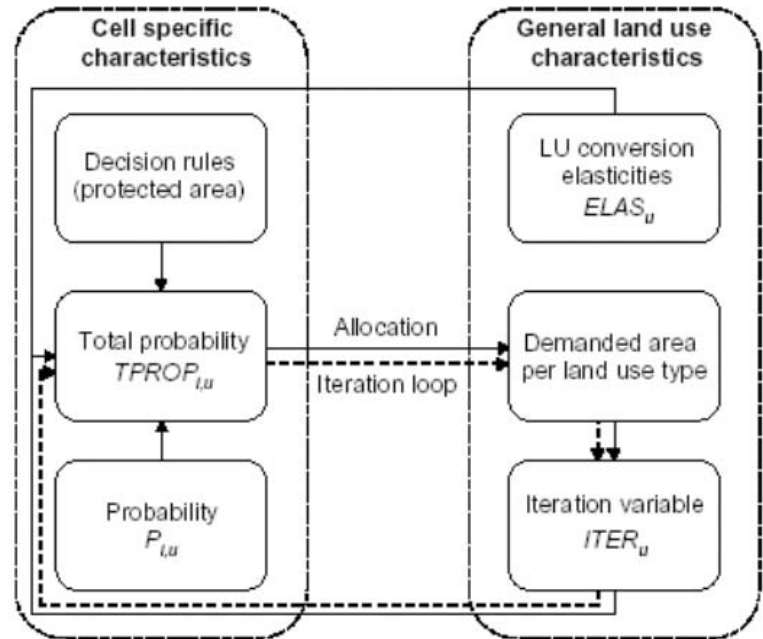


Figure 2.4. Representation of the iterative procedure for land use change allocation.

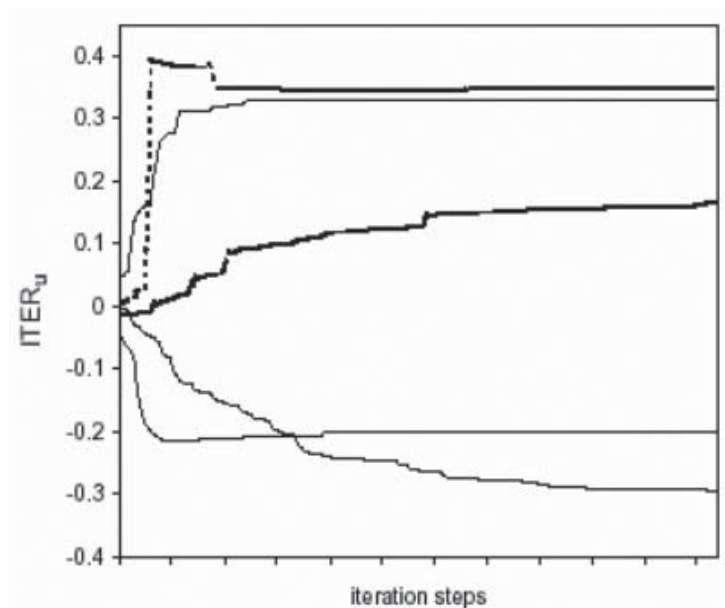


Figure 2.5. Change in the iteration parameter ($ITER_u$) during the simulation with one time step. The different lines represent the iteration parameter for different land use types. The parameter is changed for all land use types synchronously until the allotted land use equals the demand.

more advanced technique of multi-level statistics (Goldstein 1995) which enable to include higher-level variables in a straightforward manner within the regression equation (Polsky and Easterling III 2001).

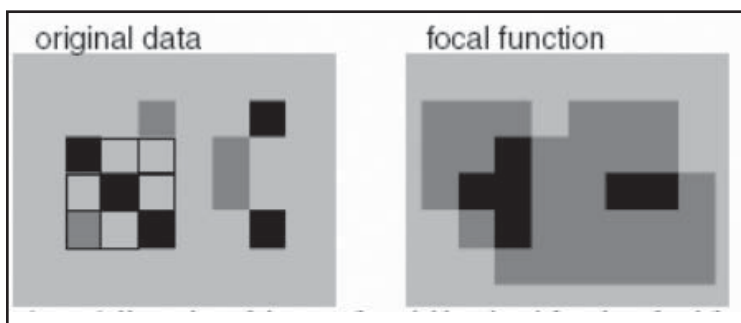


Figure 2.6. Illustration of the use of a neighbourhood function (focal function) to create a variable surface to represent the higher level influence of the variable.

2.4 Simulating impacts on water resources using SEA/BASINS and BROOKS Hydrologic Models

Water is one of the most valued resources in a watershed. It is used for a wide variety of purposes and is often referred to as one of the basic resources that drive development. However, in many watersheds water resources are now in various stages of degradation. Many rivers invariably exhibit extreme low and peak flows that make water resources management a difficult task. As commonly believed, the degradation of water resources is largely attributed to the deterioration of the watershed in general and of the land in particular brought about by improper management of land use and land use practices. Climate change and variability, specifically that of rainfall and temperature, aggravates the adverse impacts of land use. Water resource is also one of the most difficult to manage owing to the influence of factors such as climate that is beyond the direct influence of management. Further, water is also highly influenced by land use and land use practices that in many watersheds are often impossible to limit, more so to prohibit.

Impact assessment of water resources is done by using SEA/BASINS Integrated Modeling System and BROOK Hydrologic Models as discussed below.

2.4.1. SEA/BASINS

SEA/BASINS Integrated Hydrological Modeling System is developed by Southeast START Research Center (SEA START RC). It uses the Variable Infiltration Capacity (VIC) Model developed by Liang et al. (1994), and the Dynamic Routing Model developed by Lohmann et al. (1996). The VIC Model (vertical) calculates the water balance at each individual grid cell while Dynamic Routing Model (horizontal) routes the runoff generated by each grid cell downstream. These two separate models have a number of advantages. It separates the ‘indirect

water routing’ and ‘direct water diversions.’ The former, which include impacts of land use change and climate change, expresses them mainly through the ‘vertical’ model, that is, the water balance at the grid cell level. The latter, including increased withdrawals and diversions for agricultural, industrial, and domestic use, impacts mainly on the ‘horizontal’ model, which represents flow routing. The separation into the grid cell and channel components also allows for an easy interface to treat non-point source and in-channel chemical processes separately. The data requirements for these two models are enumerated in Table 2.2. Pre-processing and process flow for these models are described below and illustrated in

Table 2.2. Data needed for the VIC and Dynamic Routing Models

Data for VIC Model	Data for Dynamic Routing Model
Forcing Data Precipitation (mm) Maximum temperature (°C) Minimum temperature (°C) Windspeed (m s ⁻¹)	Elevation Stream network Discharge data
Template Data Soil property Land cover Elevation	

Figures 2.12– 2.13.

In the pre-processing stage watershed boundary, stream networks, contour lines, soil and vegetation maps are processed and converted into grid maps using ArcView and are then converted to ASCII files using ArcInfo. Daily precipitation, daily wind speed, maximum and minimum temperature from three stations will be interpolated using SURFER program and GSMAC.

After pre-processing and parameterization, VIC Model will be executed to create runoff data and will be routed using Dynamic Routing Model to simulate discharge values. To make routed discharge cohere with observed discharge, simulated discharge will be calibrated by editing fraction of runoff and baseflow.

VIC Model

The VIC Model is a semi-distributed, grid-based hydrological model which parameterizes the dominant hydrometeorological processes taking place at the land surface–atmosphere interface. A mosaic representation of land surface cover, subgrid parameterizations for infiltration, and the spatial variability of precipitation account for subgrid scale heterogeneities in key hydrological processes.

The model uses two soil layers and one vegetation layer with energy and moisture fluxes exchanged between the layers (Figure 2.7). The VIC hydrology model will be coupled to a water management model to predict the effect of water withdrawal, irrigation, and reservoir operation decisions on downstream flows.

The VIC Model represents surface and subsurface hydrologic

processes on a spatially-distributed (grid cell) basis. In typical SEA/BASINS applications, grid cells of 1 km have been used. Although each grid cell may contain different vegetation classes, for example, 33% with tall coniferous trees and 36% with grassland each represented by a different vegetation parameter set (e.g., leaf area index, surface roughness), in normal SEA/BASINS operation homogenous grids are used. Grid cell subsurface processes are represented using average soil characteristics for the entire cell. Water balance terms are computed independently for each coverage class (vegetation and bare soil) present in the model. Energy balance is excluded from normal SEA/BASINS runs.

Vegetation and soil characteristics associated with each grid cell are reflected in sets of vegetation and soil parameters. Parameters for vegetation types are specified in a user defined library of vegetation classes (usually derived from standard, national classification schemes) while the distribution over the gridded land surface area is specified in a vegetation parameter file. Soil characteristics (e.g., sand and clay percents, bulk density) are represented as two vertical soil layers (VIC-2L). The sources of data and specification for each vegetation and soil parameter are described in greater detail in the links following from the VIC Model operations web page.

Processes governing the flux and storage of water in each cell-sized system of vegetation and soil structure include evaporation from the upper soil layers, evapotranspiration, canopy interception, evaporation, infiltration, percolation, runoff and baseflow. A full discussion of the algorithms relating to these processes may be found at <http://www.hydro.washington.edu/Lettenmaier/Models/VIC/VIChome.html>, particularly Liang et al. (1994), Liang et al. (1998) and Cherkauer et al. (1998).

Features of interest include the eponymous variable infiltration curve, shown to the right of the soil and vegetation column schematic (Figure 2.7), which scales the maximum infiltration by a non-linear function of fractional grid cell area to enable runoff calculations for sub grid-scale areas (such as what arises from the use of multiple vegetation classes). Another feature is the specification of baseflow as a function of soil moisture in the lowest soil layer. This relationship is non-linear at high soil moisture contents, producing rapid baseflow response in wet conditions. Below a user-specified value of soil moisture, the function becomes linear, thereby reducing the responsiveness of baseflow in dry conditions. As well as for many other processes in the VIC-2L model, the parameters that define both the infiltration curve and the baseflow curves are user-specified, affording the model user a good deal of control over these processes.

The model is run one grid cell at a time over a desired period (any subset of the period spanned by the model forcing data), to produce time series of runoff, baseflow, evaporation, and other physical variables for each grid cell.

Dynamic Routing Model

The routing model was developed by Dag Lohmann. The model transports grid cell surface runoff and baseflow produced by VIC

Model within each grid cell to the outlet of that grid cell then into the river system. In this model, it is assumed that water of each grid can flow to one of eight directions depending on elevation gradient (Figure 2.8). It will follow the steepest gradient downstream. The Dynamic Routing Model sums runoff from each grid to water station by taking into consideration distance and time, and exits a

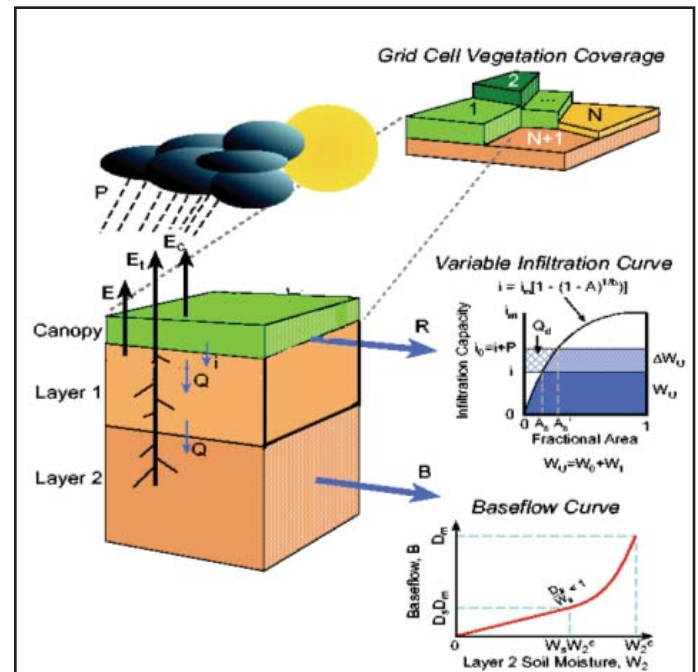


Figure 2.7. VIC Model's representation of surface and subsurface hydrologic processes based on a grid.

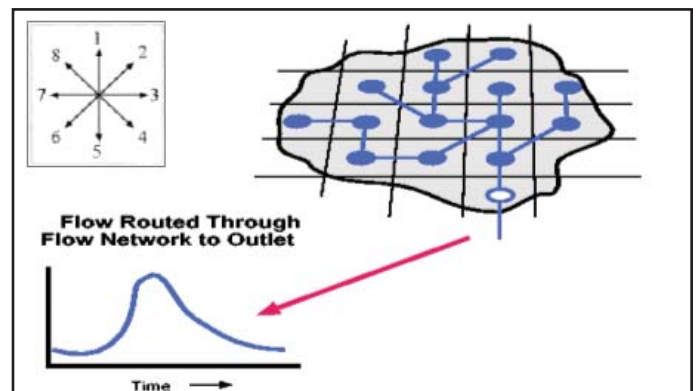


Figure 2.8. Illustration of how the Dynamic Routing Model routes runoff following the steepest gradient.

2.4.2 Pre-processing for SEA/BASINS System

Data preparation

Preparation for running the VIC Model consists of several pre-processing steps. These steps are the following:

1. Delineate watershed boundary using ArcView. The coverage is converted to ASCII file (*mask.asc*) using ArcInfo.

2. Interpolate observed daily precipitation, wind speed, maximum temperature and minimum temperature from local stations using SURFER program with two GS Scripts developed by SEA START RC (*G_W.BAS* and *N_X.BAS*). This produces four directories of text files for the four forcing parameters (GPCP, WIND, MAX and MIN).

3. Prepare gridded integrated elevation file that contains elevation of watershed boundary (line), stream network and contour lines. ArcView is used to convert these three objects from line to grid, use *eleva.aml* script in ArcInfo to merge these three grid coverages, and export to *eleva.asc* file.

4. Develop gridded routing network, gridded flow accumulation (*flowaccu*) and grid identification coverages (*id*) from gridded integrated elevation file using *routing.aml* script of ArcInfo. The *id* coverage will be used to locate the hydrological stations for calibration/verification. The *routing.aml* script will also export these ascii files necessary for routing model step; i.e., *velo.asc*, *diffu.asc*, *xmask.asc*, *flowdirec.asc*, and *frac.asc*.

5. Prepare soil parameter file from local soil texture (%sand and %clay) data for 0–30 cm and 30–100 cm layers. Use ArcView to convert polygon into grid. Use *soil.aml* script in ArcInfo to convert these grid coverages into *sand30.asc*, *sand100.asc*, *clay30.asc*, and *clay100.asc* files.

6. Convert vegetation (land cover) classification into UMD classification (13 classes) system and converting vegetation polygon to grid coverage using ArcView. Using *veg.aml* of ArcInfo to convert the gridded vegetation into *veg_mask.asc*.

Parameterization for SEA/BASINS execution

7. Set up location of forcing related files by specifying the locations of forcing data files (Step 2) and create daily forcing for each grid cell. Specify the beginning and end dates for the run.

8. Create *soilfile* by specifying the name and location of soil data file (Step 5). Soil parameter can also be adjusted manually in the soil parameter calibration menu so that the calculated soil moisture agrees with the observed data at the same location. The program will also automatically call *elevation.asc* (Step 3), and *mask.asc* (Step 1) files. The file *id.asc* will also be created in this step.

9. Create vegfile from *veg_mask.asc* (Step 6), *id.asc* (Step 4) and vegetation index (*veg_inde.asc*) which is supplied with the program (for UMD classification).

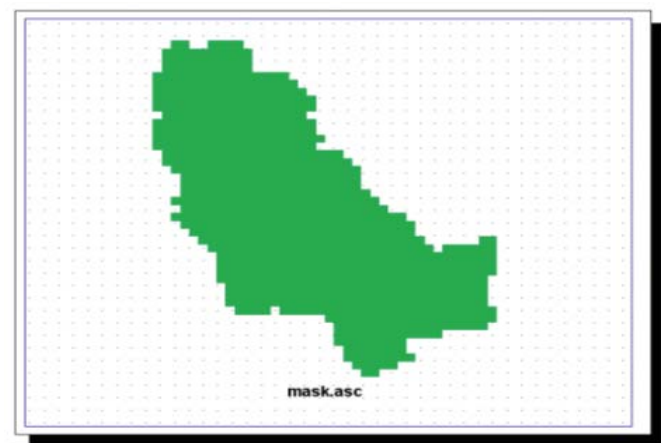


Figure 2.9. Snapshot of *mask.asc* file.

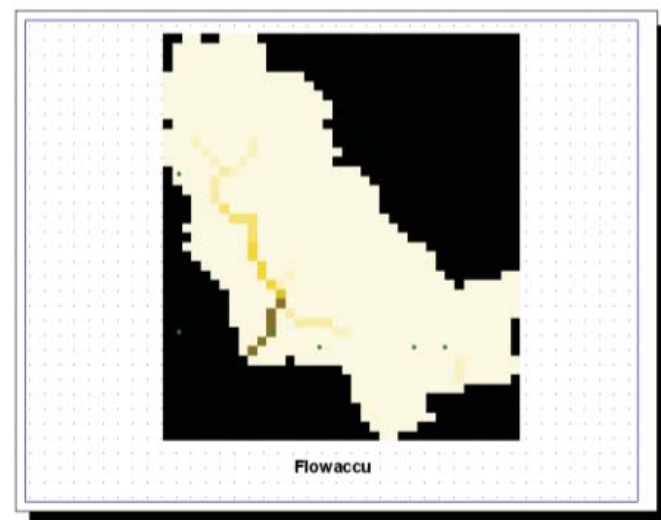


Figure 2.10. Snapshot of *flowaccu* file.

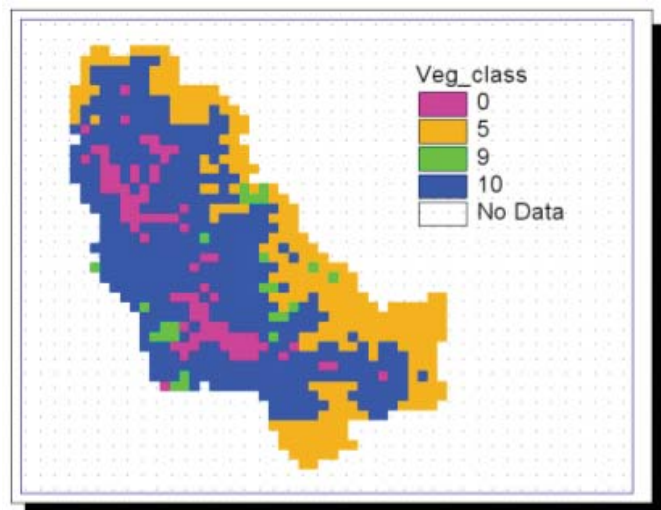


Figure 2.11. Snapshot of vegetative cover in grid format.

10. Specify the starting day, month, year and ending day, month, year that VIC-2L will be run.

2.4.3 Execution of VIC Model

1. Run VIC-2L using forcing (Step 7), *soilfile* (Step 8), *vegfile* (Step 9) and vegetation library (*veg_lib*) which is supplied with the program (for UMD classification).

2. Further refining VIC run, if desired, can be done by editing *soilfile* for these variables: variable infiltration curve parameter (infiltr), or fraction of maximum velocity of baseflow where non-linear baseflow begins (Ds), maximum velocity of baseflow (Dsmax), or fraction of maximum soil moisture where non-linear baseflow occurs (Ws), or average soil temperature (avg_T), or soil thermal damping depth (dp), or fractional soil moisture content at the critical point (Wcr_FRACT), or fractional soil moisture at the wilting point (Wpwp_FRACT), surface roughness of baresoil (rough), or surface roughness of snow pact (snow_rough), or average annual precipitation (annual_prec).

2.4.4 Execution of flow routing model

1. Locate the identification number (ID) of the grid cell that flow will be routed to from its latitude and longitude using ArcView and gridded flow accumulation coverage (Step 4). Put the name of the station and its gridded ID in the appropriate boxes in the Routing Model window.

2. For model calibration, enter the time period when that observed daily discharge data is available at that station in appropriate boxes. Calibration can be done by adjusting the fractions of runoff and of baseflow to be routed into channels until the routed discharge agrees with observed discharge at that observation station.

Once the optimum fractions of runoff and baseflow to be routed are obtained, use these fraction to calculate discharge for other time periods as long as forcing data are available.

2.4.5 BROOK Hydrologic Models

The BROOK Hydrologic Models simulate the water budget on a unit land area at a daily time step. It is applicable to the land phase of the precipitation-evaporation-streamflow part of the hydrologic cycle for a point or for a small, uniform (lumped parameter) watershed. The BROOK 90 uses Penman-Monteith equation to compute for the potential evapotranspiration while BROOK 5 uses the Hamon method (Federer 1995). Tables 2.3 and 2.4 enumerate the data needed to run the BROOK 90 and BROOK 5 models, respectively.

Table 2.3. Data needed to run the BROOK 90 Model

Parameter	Unit
Area	ha
Latitude	
Daily rainfall (years of record)	mm
Daily maximum & minimum temperature	°C
Daily solar radiation	MJ m ⁻²
Daily average vapor pressure	Kpa
Daily average wind speed	m s ⁻¹
Streamflow	

Table 2.4. Data needed to run the BROOK 5 Model

Parameter	Unit
Area	ha
Latitude	
Highest elevation	m
Lowest elevation	m
Basin length	m
Direction of streamflow	
Land use	
% of Forest	
% of Crops & pasture	
% of Bldg/roads	
% of Bodies of water	
Water table depth	m
Daily mean temperature (years of record)	
Daily rainfall and (years of record)	
Soil texture	
Drift deposits	

2.5 Multi-level vulnerability indicator of local communities in PCW

Local communities living within watersheds are subject to major natural occurrences that reflect climate variability and climate change over the last few decades. Usually, communities are composed of different socioeconomic groups with varying degrees of vulnerability. Within the watersheds, too, can be found different user-institutions which may exert socioeconomic influence over the vulnerability of local communities in relation to climate variability and extremes. This part of the study discusses methods drawn from the Philippine experience that could help advance the current state of knowledge and policies relevant to the vulnerability of local communities and institutions to climate variability and extremes.

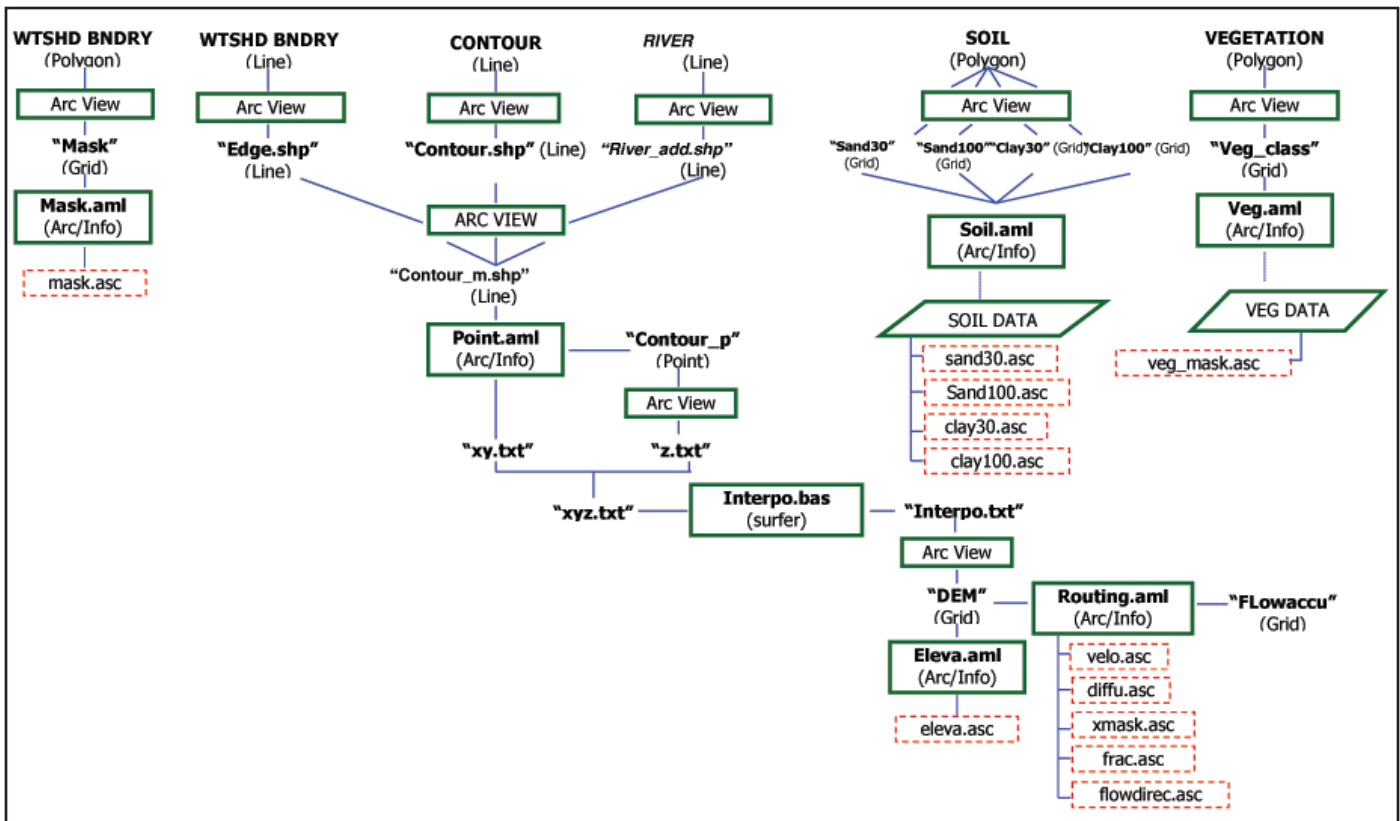


Figure 2.12. Pre-processing of data for SEA/BASINS Modeling System.

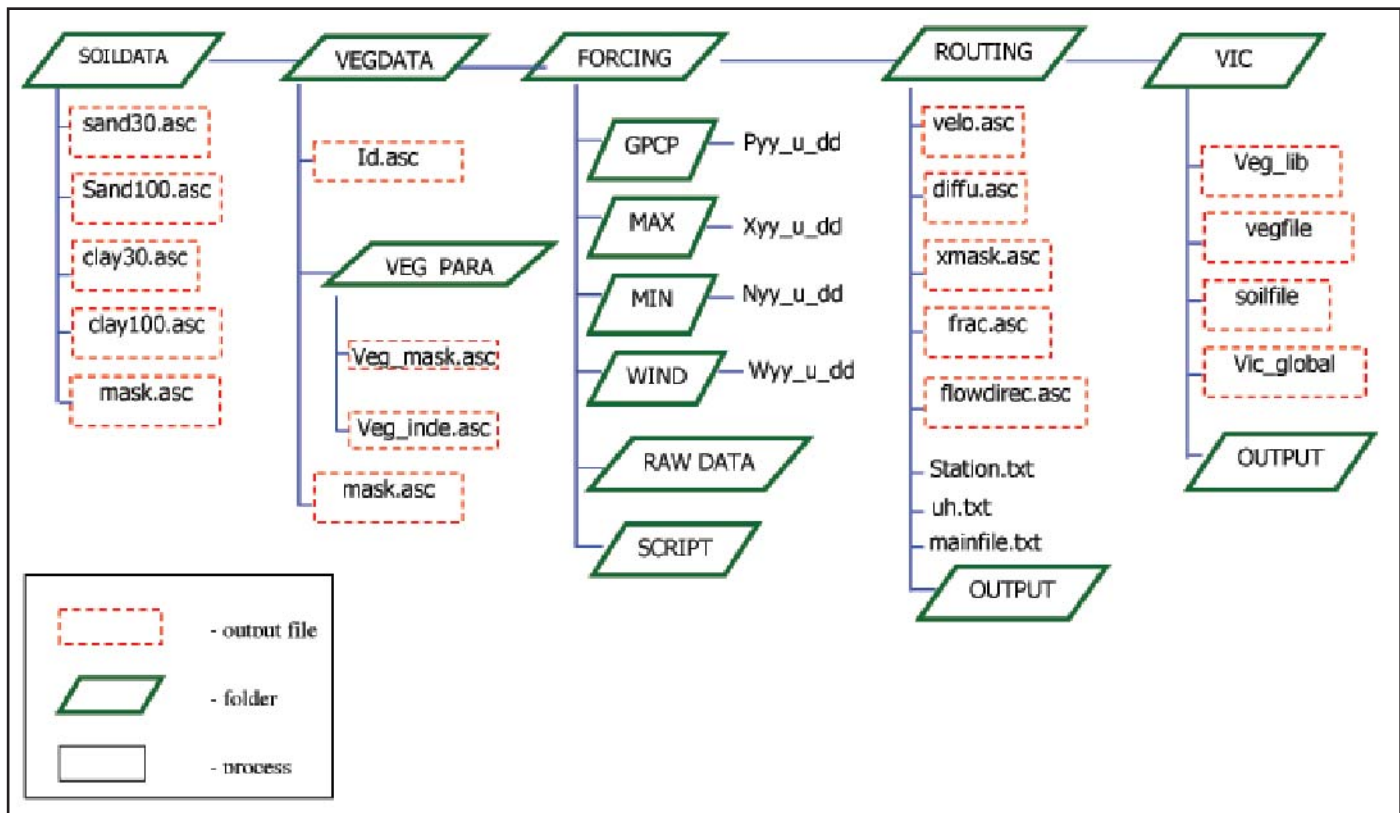


Figure 2.13. Process flow of SEA/BASINS Modeling System (VIC Model and Dynamic Routing Model).

2.5.1 Data collection

The study employs a combination of data collection methods: secondary data gathering, household survey, use of participatory rural appraisal techniques, direct field observation, and GPS readings of identified vulnerable areas. The following sections briefly discuss these methods.

Secondary data gathering

Available secondary information on the biophysical and socioeconomic aspects of the watershed are gathered from relevant agencies to understand the local and regional context of the watershed communities. Sources of information include municipal and provincial development plans, sociodemographic statistics from the National Statistics Office, atlas and other maps from various sources, project documents, and other pertinent information from different institutional stakeholders of PCW.

Meanwhile, climatic data like rainfall, temperature, El Niño and La Niña episodes, and other natural calamities that occurred in PCW are obtained from PAGASA and the weather station near the watershed. These data are gathered on a historical basis.

Household survey

Household survey is conducted to determine the vulnerability of households to climate variability and extremes and the socioeconomic factors influencing their vulnerability. It makes use of a pre-tested interview schedule that contains the following information: (1) socioeconomic profile of the respondent; (2) household's use and benefits from PCW; (3) climate variability and extremes experienced in the last few decades and their impacts; (4) household's vulnerability in terms of food availability, water supply, livelihood, and health; and (5) adaptation strategies.

The survey covers the four municipalities of the three different provinces encompassing the watershed. These are Pantabangan and Carranglan in Nueva Ecija, Alfonso-Castañeda in Nueva Vizcaya, and Ma. Aurora in Aurora. Twenty-six of the 36 barangays within the watershed area are covered. Ten of 36 barangays are excluded since a very small portion of their respective areas is within the watershed boundary, hence, very few people live in these areas. A total of 375 respondents are randomly selected using the barangay records. This sampling technique employed is adopted from Chua (1999) which allows a 0.05 permissible error and 95% confidence interval level.

PRA techniques

Focus groups discussions (FGDs) are done in 21 barangays to complement the household survey and determine the vulnerability of various socioeconomic groups at the community level. The FGDs employed a combination of participatory rural appraisal (PRA) techniques such as time line analysis, stakeholder analysis, participatory vulnerability assessment, and community mapping. The choice of these techniques was guided by the different research questions, the explicit objective of the study to engage the local stakeholders in the process of assessing their current vulnerability, and the literacy level of the local communities (see Pulhin 2002 for discussions on these techniques).

Field observations and GPS readings

Direct field observation is also conducted to validate information gathered through household survey and focus group discussions. In addition, GPS readings of vulnerable areas identified by the local communities are also collected for purposes of mapping these areas.

2.5.2 Data analysis

The study employs a combination of qualitative and quantitative approaches to analyze the information gathered through the abovementioned methods. Qualitatively, the degree of present vulnerability of the different socioeconomic groups is assessed by aggregating and analyzing the results of FGDs. At the household level, a more quantitative technique using correlation and regression analyses are employed to determine the factors influencing the household's vulnerability based on the vulnerability index developed. In addition, vulnerable areas are identified using GIS to complement the participatory vulnerability mapping conducted by the local communities.

Qualitative analysis

Results from FGDs conducted in 21 barangays are combined and synthesized to identify the climate variability and extremes experienced by the local communities in the last few decades, to determine the more vulnerable groups and their location in the watershed, and to assess the nature and extent and of their vulnerability. This qualitative analysis centers on the vulnerability situation of major socioeconomic groups in the watershed as identified by the community members themselves during the FGDs. The emphasis on socioeconomic groups provides a broader perspective of community vulnerability and complements the more micro and quantitative analysis done at the household level.

Development of vulnerability index

Results from the household survey are used to develop a vulnerability index. The index consisted of four major component indicators: food, water, livelihood, and health. The indicators are further divided into subcategories, each of which are given corresponding weights. Drawing from the framework of Moss et al. (1999), the subcategories comprises relevant variables that involve certain characteristics of the component indicators in relation to climate variability and extremes (representing the household's sensitivity in relation to these components) and the presence or absence of adaptation strategies (representing the household's coping capacity).

Two types of weights are considered in the development of the index: researchers' weights representing the experts' view, and that of the watershed communities' representing the local stakeholders' view. The first iteration for the vulnerability index computation is based on the researchers' judgment that makes use of composite weighing where all the four major components (food, water, livelihood, and health) are given equal weights (25 points each) with a grand total of 100 points. The subcategories under each major component are also given corresponding weights with each level of the subcategories given equal points.

Other than the researchers' judgement, the local communities' perspective is also taken into account in the development of the index. Using the same set of indicators developed by the researchers, two separate FGDs are conducted in two clusters of barangays in the municipalities of Pantabagan and Carranglan where participants are asked to provide their own weights for the index. Consensus is sought from the participants during the FGDs on specific weights that they should assign for each component indicators at various levels.

Table 2.5 presents the vulnerability index developed using the researchers' judgment and that of the local communities'.

Correlation and regression analysis

The computed final vulnerability index, food index, water index, livelihood index and health index are correlated with the factors hypothesized to influence vulnerability using Spearman Correlation. These include a combination of demographic, socioeconomic, and geographic factors including the number of coping mechanisms practiced by each household. Moreover, to determine the combined effects of the different hypothesized factors on households' vulnerability, regression analysis is done using SPSS ver. 10 for Windows. Both the correlation and regression analysis used a 0.01 to 0.05 level of significance.

Mapping of vulnerable areas

The vulnerability of PCW to climate variability and extremes is assessed using an arbitrary set of rules (Table 2.6) related to five key parameters, namely: slope, elevation, distance from the road, distance from the river and distance from the community center. With the aid of GIS, the degree of vulnerability by land use type is determined for the entire watershed using the category of low, medium, and high vulnerability. A single vulnerability map is developed by overlaying all the individual maps produced for each of the five parameters.

On the other hand, GPS readings are made for all the vulnerable places identified by the local communities themselves during the FGDs conducted in the different barangays using the participatory vulnerability mapping technique. The GPS readings of the vulnerable places are plotted in the vulnerability map of the watershed developed through GIS. The idea is to determine whether there will be congruence between vulnerable areas identified using biophysical parameters through GIS with what the stakeholders see as vulnerable places.

Table 2.5. Multi-level indicator of vulnerability of PCW households to climate variability and extremes (CV & E) using varying weights

Vulnerability index	Weights by researchers	Weights by local communities		
		P	C	P & C
A. Food	25	25	40	32.5
a.1 Seed availability	12.5	20	15	17.5
a.1.1 Availability of planting materials	4.17	8	7	7.5
i. Available any-time of the year	0	3	2	2.5
ii. Seasonal or hard to find	4.17	5	5	5
a.1.2 Is it affected by CV & E?	4.17	9	5	7
i. Yes	4.17	9	4	6.5
ii. No	0	0	1	0.5
a.1.3 Adaptation strategies	4.17	3	3	3
i. With adaptation	0	2	1	1.5
ii. Without adaptation	4.17	1	2	1.5
a.2 Crop Yield	12.5	5	25	15
a.2.1 Percent lost in rice production	4.17	1.5	10	5.75
a.2.2 Is it affected by CV & E?	4.17	2	10	6
i. Yes	4.17	2	7	4.5
ii. No	0	0	3	1.5
a.2.3 Adaptation strategies	4.17	1.5	5	3.25
i. With adaptation	0	0.5	2	1.25
ii. Without adaptation	4.17	1	3	2
B. Water	25	40	40	40
b.1. Domestic water	12.5	33	15	24

Legend: (P) Pantabagan; (C) Carranglan; (P & C) Pantabagan and Carranglan

Table 2.5. Multi-level indicator of vulnerability of PCW households to climate variability and extremes (CV & E) using varying weights (continued)

Vulnerability index	Weights by researchers	Weights by local communities		
		P	C	P & C
b.1.1 Sources of domestic water	2.5	11	7	9
i. Natural sources	2.5	8	6	7
ii. Through agencies	1.25	3	1	2
b.2.1 Distance of house to sources of water	2.5	5	2	3.5
i. 0– 250 m	0.62	0.4	0.2	0.3
ii. 251 – 500 m	1.25	1	0.3	0.65
iii. 501 – 1000 m	1.88	1.5	0.5	1
iv. > 1000 m	2.5	2.1	1	1.55
b.1.3 Observation for the supply of domestic water	2.5	7	2	4.5
i. Declining supply	2.5	3	1	2
ii. Increasing supply	0	2	0.5	1.25
iii. No change	1.25	1	0.5	0.75
b.1.4 Is domestic water supply affected by CV & E?	2.5	5	2	3.5
i. Yes	2.5	3	1.5	2.25
ii. No	0	2	0.5	1.25
b.1.5 Adaptation strategies	2.5	5	2	3.5
i. With adaptation	0	1	0.5	1.25
ii. Without adaptation	2.5	4	1.5	2.75
b.2 Irrigation water	12.5	7	25	16
b.2.1 Regularity / problem with supply?	4.17	3	10	6.5
i. Problem with supply	0	1	3	2
ii. No problem with supply	4.17	2	7	4.5
b.2.2 Effects of scarcity	4.17	2	10	6
i. Decrease in production /income	2.78	1	7	4

Legend: (P) Pantabangan; (C) Carranglan; (P & C) Pantabangan and Carranglan

Table 2.5. Multi-level indicator of vulnerability of PCW households to climate variability and extremes (CV & E) using varying weights (continued)

Vulnerability index	Weights by researchers	Weights by local communities		
		P	C	P & C
ii. No (zero) production / income	4.17	0.5	1	0.75
iii. Delayed harvest	1.39	0.5	2	1.25
b.2.3 Adaptation strategies	4.17	2	5	3.5
i. With adaptation	0	0.56	2	1.28
ii. Without adaptation	4.17	1.44	3	2.22
C. Livelihood	25	15	10	12.5
c.1 Seek sources of income in cases of CV&E?	8.33	6	2	4
i. Yes	0	4	0.5	2.25
ii. No	8.33	2	1.5	1.75
c.2 Is income from other sources sufficient?	8.33	6	6	6
i. Sufficient	0	2	2	2
ii. Not sufficient	8.33	4	4	4
c.3 Adaptation strategies	8.33	3	2	2.5
i. With adaptation	0	2	0.5	1.25
ii. Without adaptation	8.33	1	1.5	1.25
D. Health	25	20	10	15
d.1 Experienced health problems during CV&E?	6.25	6	2	4
i. Yes, experience health problems	6.25	4	1.5	2.75
ii. No	0	2	0.5	1.25
d.2 Kinds of health problems experienced during CV&E	6.25	7	4	5.5
i. Diarrhea, amoebiasis, dehydration, dysentery”	4.17	3	2	2.5
ii. Dengue, typhoid, malaria	6.25	2	1	1.5

Legend: (P) Pantabangan; (C) Carranglan; (P & C) Pantabangan and Carranglan

Table 2.6. Criteria used for the assessment of vulnerability of PCW to climate change

Landuse	Slope			Elevation (m)			Distance from road (m)			Distance from river (m)			Distance from community (km)		
	Low	Mod	High	Low	Mod	High	Low	Mod	High	Low	Mod	High	Low	Mod	High
Grass/ Brush	0-50	-	>50	100-250	250-500	>500	>500	200-500	<200	>1000	500-1000	<500	>1000	500-1000	<500
Agriculture	<8	8-18	>18	100-250	250-500	>500	<500	500-1000	>1000	<500	500-1000	>1000	<500	500-1000	>1000
Forests	<18	18-50	>50	100-250	250-500	>500	>1000	500-1000	<500	>1000	500-1000	<500	>1000	500-1000	<500

Table 2.7. Data requirements for the socioeconomic component of the study

Data Category	Time Scale					Time Resolution			Spatial resolution/level			
	Historical	Present	2020	2050	2100	Multi-decadal	Annual	Seasonal	Farm/household	Community	Watershed	National
<i>Demographic trends</i>												
Population trend	X	X	X	X	X	X				X	X	X
No. and size of households	X	X	X	X	X	X				X	X	X
Population density	X	X	X	X	X	X				X	X	X
Annual growth rate	X	X	X	X	X	X	X			X	X	X
Migration pattern	X	X	X	X	X	X				X	X	X
Age and sex composition	X	X	X	X	X	X				X	X	X
Fertility and mortality rate	X	X	X	X	X	X				X	X	X
Ethnic groups	X	X	X	X	X	X				X	X	X
<i>Socioeconomic trends/characteristics</i>												
Sources of livelihood		X	X	X	X		X	X	X	X	X	X
Income and expenditures		X	X	X	X		X	X	X	X	X	X
Educational attainment		X	X	X	X		X	X	X	X	X	X

Table 2.7. Data requirements for the socioeconomic component of the study (continued)

Data Category	Time Scale					Time Resolution			Spatial resolution/level			
	Historical	Present	2020	2050	2100	Multi-decadal	Annual	Seasonal	Farm/household	Community	Watershed	National
Employment/unemployment	X	X	X	X	X		X	X	X	X	X	X
Literacy rate	X	X	X	X	X		X	X	X	X	X	X
Labor supply	X	X	X	X	X		X	X	X	X	X	X
Land ownership	X	X	X	X	X		X	X	X	X	X	X
Food consumption	X	X	X	X	X		X	X	X	X	X	X
Demand for water	X	X	X	X	X		X	X	X	X	X	X
Demand for fuelwood	X	X	X	X	X		X	X	X	X	X	X
Demand for timber and other forest products	X	X	X	X	X		X	X	X	X	X	X
Demand for settlement and agricultural land	X	X	X	X	X		X	X	X	X	X	X
Agricultural production	X	X	X	X	X		X	X	X	X	X	X
Cultural practices/beliefs related to forests	X	X	X	X	X	X	X			X	X	X
Socio-economic groupings	X	X	X	X	X	X				X	X	
Geographic factors												
Distance from farm	X	X	X	X	X	X				X	X	
Distance from road	X	X	X	X	X	X				X	X	
Distance from market	X	X	X	X	X	X				X	X	
Governance structure	X											
Forest policy	X	X				X				X	X	X
Institutional arrangements		X				X				X	X	X
Government support and services		X				X				X	X	X

Table 2.8. Research questions and research techniques used in the socioeconomic component of the study

Research questions	Research method/PRA technique	Remarks
What are the natural occurrences in the area that reflect climate variability and extremes over the last 50 years or so?	Participatory Time Line Analysis of climate-related events Household interviews	Focus Group Discussions of different socioeconomic groups are conducted in the study barangays
What are the impacts of these natural occurrences on the socioeconomic well-being of the local communities?	Participatory Impact-Analysis of climate related events Household interviews	Impacts of climate variability and extremes to local communities may include impacts on water supply, crops production, livelihood, lost of lives, and properties, etc.
What are the different socioeconomic groups and institutions/agencies in the area that are affected by climate variability and extremes?	Stakeholder analysis of socioeconomic groups dependent on the watershed. Institutional analysis of different agencies concerned on watershed management	The different socioeconomic groupings of local communities are identified as well as the different government, private, and non-government institutions working in the area
Who are the vulnerable sectors in the community?	Stakeholder Analysis/Focus Group Discussions Identification of vulnerability index Household interviews	Identification of vulnerable socioeconomic groups probably based on livelihood, e.g., crop farmers tilling their own land, tenants, people whose livelihood are at risk, etc. Vulnerability index is also be developed based on literature and in consultation with the community members. Such index could include among others, household size, total income, total expenditure, crop sales price in bad year, crop land, road access, livestock holdings, social capital, household assets, etc.
What makes the different socioeconomic groups vulnerable to climate change/variability and extremes?	Household interviews, Focus Group Discussions	Identification of causal factors that influence present vulnerability
In which part of the watershed are the vulnerable groups/areas located?	Community mapping of vulnerable areas	Vulnerable areas in selected barangays are identified using participatory mapping technique with the aid of existing topographic and administrative maps with delineated barangay boundary. Vulnerable areas may be located in head waters, main tributary, downstream, etc.
What are the communities' current coping mechanisms/strategies and capacities to climate variability and extremes?	Focus Group Discussions Household interviews	Various forms of coping mechanism may include out-migration, selling of productive assets, resorting to adaptive coping strategies (e.g., curtailing consumption of some items, etc.), normal income generating pattern, etc.
What lessons can be gleaned from current vulnerability and coping capacities for adapting to future climate change?	Focus Group Discussions Household interviews	Recommendations to promote appropriate adaptation strategies to future climate change are generated from the local communities.