AIACC Final Reports

An Integrated Assessment of Climate Change Impacts, Adaptations and Vulnerability in Watershed Areas and Communities in Southeast Asia

A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AS 21

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About AIACC

Assessments of Impacts and Adaptations to Climate Change (AIACC) enhances capabilities in the developing world for responding to climate change by building scientific and technical capacity, advancing scientific knowledge, and linking scientific and policy communities. These activities are supporting the work of the United Nations Framework Convention on Climate Change (UNFCCC) by adding to the knowledge and expertise that are needed for national communications of parties to the Convention.

Twenty-four regional assessments have been conducted under AIACC in Africa, Asia, Latin America and small island states of the Caribbean, Indian and Pacific Oceans. The regional assessments include investigations of climate change risks and adaptation options for agriculture, grazing lands, water resources, ecological systems, biodiversity, coastal settlements, food security, livelihoods, and human health.

The regional assessments were executed over the period 2002-2005 by multidisciplinary, multi-institutional regional teams of investigators. The teams, selected through merit review of submitted proposals, were supported by the AIACC project with funding, technical assistance, mentoring and training. The network of AIACC regional teams also assisted each other through collaborations to share methods, data, climate change scenarios and expertise. More than 340 scientists, experts and students from 150 institutions in 50 developing and 12 developed countries participated in the project.

The findings, methods and recommendations of the regional assessments are documented in the *AIACC Final Reports* series, as well as in numerous peer-reviewed and other publications. This report is one report in the series.

AIACC, a project of the Global Environment Facility (GEF), is implemented by the United Nations Environment Programme (UNEP) and managed by the Global Change SysTem for Analysis, Research and Training (START) and the Third World Academy of Sciences (TWAS). The project concept and proposal was developed in collaboration with the Intergovernmental Panel on Climate Change (IPCC), which chairs the project steering committee. The primary funding for the project is provided by a grant from the GEF. In addition, AIACC receives funding from the Canadian International Development Agency, the U.S. Agency for International Development, the U.S. Environmental Protection Agency, and the Rockefeller Foundation. The developing country institutions that executed the regional assessments provided substantial in-kind support.

For more information about the AIACC project, and to obtain electronic copies of AIACC Final Reports and other AIACC publications, please visit our website at www.aiaccproject.org.

Summary Project Information

Regional Assessment Project Title and AIACC Project No.

An Integrated Assessment of Climate Change Impacts, Adaptations, and Vulnerability in Watershed Areas and Communities in Southeast (AS 21)

Abstract

Watersheds are critical to economic development and environmental protection in Southeast Asia, and are likely to be affected by future climate change. 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 of Philippines and Indonesia, respectively, and provided training and technical assistance to scientists from Indo-China on research methods to be implemented in their 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, and developed and evaluated adaptation strategies. Research findings and policy implications were presented to policy makers and development workers.

Location of the study on 'Integrated Assessment of Climate Change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities' in Indonesia is focused in Citarum Watershed. Citarum watershed is an important watershed in West Java, Indonesia. Water supply from this watershed is used for many purposes, e.g., electricity generation, domestic consumption, irrigation water, flushing the canal. It can supply about 7,650 MCM (million cubic meters per year) where about 5,750 MCM come from Citarum dams (Saguling, Cirata and Jatiluhur) and about 1950 MCM come from other rivers (Perum Jasa Tirta II 2003). At present about 78% of the water is used for irrigation, 14% for industrial activities and electricity generation, and 8% for domestic consumption. The study assesses the impact of climate and land use changes on stream flow and hydrology balance of the watershed in the future, and community perception on climate change as well as the willingness of downstream community to support and to assist upstream community in protecting forest as part of actions to mitigate the impact of climate change in the future. The study found that most of districts within the watershed will face serious water shortage problem in the future. Downstream community who have good knowledge and understanding on role of forest in regulating water balance and water conservation and also electricity companies are willing to pay compensation or to give reward to upstream community who protect and increase forest cover. Further studies on institutional system for distributing the reward and methods for determining the amount of the compensation is required.

Administering Institution

Environmental Forestry Programme (ENFOR), College of Forestry and Natural Resources, University of the Philippines Los Baños College, Laguna, Philippines 4031 and Bogor Agricultural University, Kampus IPB Darmaga, Bogor, Indonesia

Participating Stakeholder Institutions

Department of Environment and Natural Resources, Visayas Avenue, Diliman, Quezon City, Philippines; National Irrigation Administration, Diliman Quezon City, Quezon City, Philippines; National Power Corporation, Cor. Agham Road and Quezon Avenue, Diliman Quezon City, Philippines; International Centre for Research on Agroforestry, College of Forestry and Natural Resources, University of the Philippines Los Banos; Local Government Units, NGOs, and People's Organizations; International Centre for Research on Agroforestry, Indonesia; Dinas Pertanian Kabupaten Bandung (Bandung Agriculture Office), Indonesia; PDAM Purwakarta and Jakarta (Drinking Water Local State Company), Indonesia; Ministry of Environment, Indonesia; Local NGOs: WPL (Warga Peduli Citarum), FPC (Forum Peduli Citarum), DPKLTS (Forum Pemerhati Kelestarian Lingkungan Tatar Sunda) and ARCATE (Applied Research on Climate and Technology), Indonesia; Indonesian Power Company, Indonesia.

Countries of Primary Focus

Philippines and Indonesia

Case Study Areas

Philippines, Indonesia, Laos, Cambodia, and Vietnam

Systems Studied

Philippines: Ecosystems (Forest), land use/land cover, biodiversity, and human settlements; and Indonesia: Food security, land use/land cover

Sectors Studied

Philippines: Forestry, water resources and agriculture (crop production); and Indonesia: Crop production, water resources, and climate resources

Groups Studied

Philippines: Livelihood (subsistence and commercial farmers), Demographic (rural poor), Resource Managers, others (power and irrigation agencies); and Indonesia: Subsistence farmers, hydropower company, and drinking water company

Sources of Stress and Change

Philippines: Climate change, climate variability, land use change, population growth and land degradation; and Indonesia: Changes in seasonal climate, land use change, land degradation, population growth, and economic growth.

Project Funding and In-kind Support

AIACC: US$ 150,000 grant; ARCATE: US$ 1,000 in-kind contribution; ICRAF US$ 500 in-kind contribution; Local NGOs: US$ 250 in-kind contribution; and Indonesian Power: US$ 500 in-kind contribution.

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Key Partners

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Executive Summary

Research problem and objectives

The IPCC Third Assessment Report (TAR) states that the continued rise in greenhouse gasses (GHG) is likely to lead to significant changes in mean climate and its variability in the Asian Region (IPCC Working Group II, 2001). All 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.

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

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 therefore key to the pursuit of sustainable development. More than 70% of the country's total land area lies 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 presently derive irrigation water from watersheds. Moreover, around 20 to 24 million people –close to one-third of the country's total population – inhabit the uplands of many watersheds majority of who depend on its resources for survival. However scientists working on climate change in Southeast Asia have limited experience in impacts and vulnerability assessment.

Only one national level study has been completed thus far on vulnerability assessment and adaptation and none are on-going or planned (The Philippines Initial National Communication on Climate Change, 1999). Initial results of a preliminary vulnerability assessment for a watershed area in the country suggest that changes in precipitation will result in a –12% to 32% change in runoff depending on the GCM used (Jose *et al*., 1996). The 1999 National Communication also highlighted the need for vulnerability assessment of major reservoirs and rivers in the country as well as impacts on major water users. Completely lacking is information on the impact of climate change on local communities inhabiting watershed areas. Similarly, impacts on natural forest ecosystems have also not been quantified.

In Indonesia, based on study on regional water balance using 1995 data, it was found that most of watersheds in Java are already at critical stage. The ratio between water demand and supply in some of watersheds are already close to one. Moreover, in a few watersheds the ratio is already more than one (e.g. in Brantas watershed it is 1.12). Watersheds outside Java have mostly less than 0.76 (SME, 1998). This indicates that some watersheds, in particular in Java, are vulnerable to climate change. In the last ten years it was shown that during El-Nino years, most of rice growing area in Java and some in South Sumatra (e.g. Lampung) suffered from severe drought due to significant decrease in water supply from reservoirs (Las *et al.*, 1999). On the other hand, during La-Nina years flood commonly occurs in some regions (Jazis *et al.*, 1999). Similar to the Philippines, studies on the impact of climate change, in particular on water resources and forest ecosystem are still lacking.

The impact of doubling CO_2 on Indonesia's rainfall, forest productivity and crop production has also been evaluated (Boer *et al.*, 2000a; Boer and Team 2000; Amien *et al.*, 1996). It was shown that under doubling CO_2, annual rainfall in southern part of Indonesia (Java and eastern part of Indonesia and part of Sumatra) might increase while in the northern part of Indonesia (Kalimantan, Sulawesi) it would decrease, and this is consistent with historical data. Similarly, forest and crops productivity may also change depending on location.

Scientists working on climate change in the Philippines and Indonesia have limited experience in impacts, adaptation 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 SE Asian region in peer-reviewed literature. The result is under-representation of cases from the region in the IPCC assessment reports.

This study was designed to address the lack of scientific research on climate change impacts, adaptation and vulnerability of watershed resources and local communities in the Philippines, Indonesia and Indo-China.

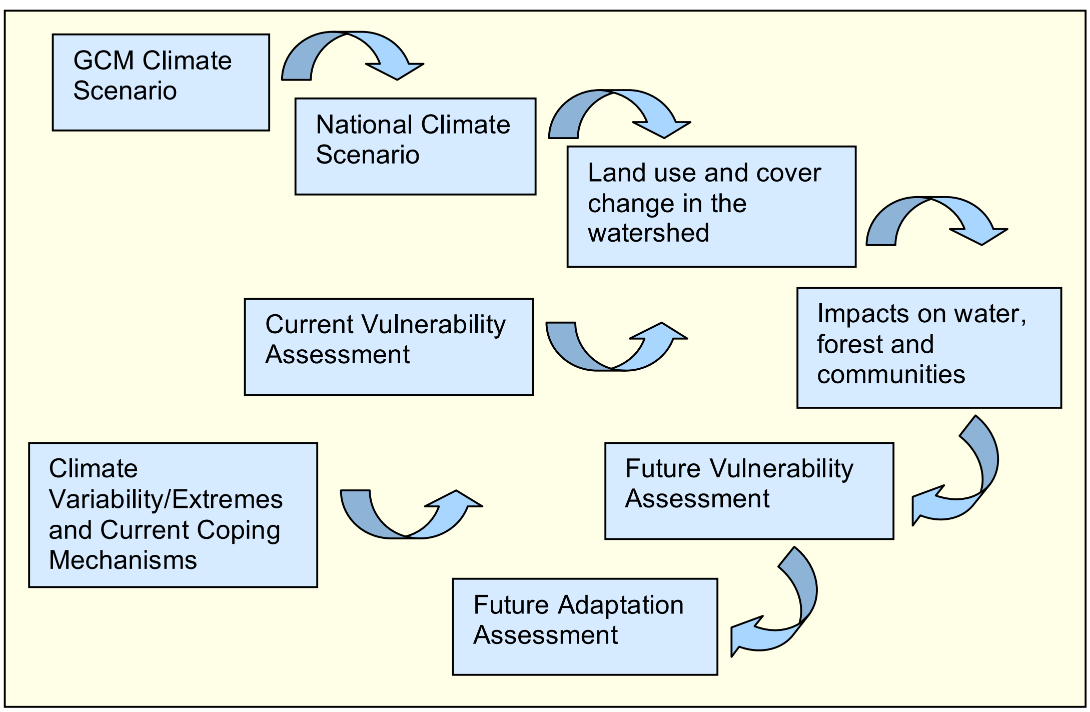
The main objectives of the study were to:

- Assess the impacts of climate change to water resources, forest ecosystems, and social systems of the watersheds;
- Conduct integrated vulnerability assessment of natural and social systems in the watershed areas;
- Develop adaptation strategies for natural water resources, forests ecosystems and social systems;
- Promote stakeholder participation in the research process;
- Contribute to peer reviewed literature; and
- Help build capacity of local scientists to conduct integrated assessment studies.

In the Philippines, the study was conducted in Pantabangan-Carranglan Watershed (PCW) in Nueva Ecijia Province while in Indonesia, the study was conducted in Citarum Watershed in West Java.

Approach

The general framework of the study is shown in Figure. The study used climate change scenarios generated by GCMs as well as current climate coping mechanisms as starting points. An integrated assessment of impacts, adaptation and vulnerability of natural and social systems was conducted.



General Framework of the study.

The study also characterized the recent and future trends in rainfall and temperature along with land use and land cover and the associated patterns of streamflow. Description of recent trends was made using primarily available records of observed climatology and hydrology. To characterize future trends in climate, downscaling of regional GCM results was undertaken. CLUE-S model was used to project the likely land use scenarios while SEA-BASIN model was used to predict the future changes in streamflow resulting from changes in climate and land use and land cover.

The study assess climate change impacts on Philippine forests ecosystems, the study used GIS and the Holdridge Life Zones to simulate vegetation changes. Synthetic scenarios of precipitation and air temperature were used in the study within the limits of GCM projections for the country.

Furthermore, the study was also conducted through desk study (simulation modeling), survey and interview with a number of stakeholders (local government, electricity companies, water drinking state company and local community).

Scientific findings

The study revealed that in Pantabangan-Carranglan Watershed in 2080 rainfall is projected to increase by as much as 12.7 % and temperature to increase by more than 5% of the average observed daily values between 1960 and 1990. This change in climate could translate to about 17% increase in wet season streamflow and a decrease of around 35% in dry season streamflow of PCW. The increase in streamflow could lead to higher likelihood of floods in the service areas of Upper Pampanga River Integrated Irrigation System (UPRIIS) than it is at the present. Likewise, the projected decrease in streamflow of PCW during the dry season will likely increase the incidence of water shortage which could be aggravated by the increasing water demand due to increasing temperature. The projected changes in climate and the associated changes in streamflow patterns of PCW will likely have more serious impacts on the lowland farmers in view of the absence of deliberate program to reduce the vulnerability of the lowland farmers to floods and water shortages.

Furthermore, assessment of vulnerability of the watershed by land use with the aid of Geographical Information System (GIS) revealed that more than 65% of the entire PCW is moderately vulnerable to climate extremes and change while more than 25% is highly vulnerable. Most of the areas that are highly vulnerable are forests, grasslands and brushlands by virtue mainly of their location in steep and highly elevated areas and proximity to roads. Areas that are moderately vulnerable are largely grasslands, brushlands and forests.

Among the vulnerable places in PCW identified by the local communities themselves during Focus Group Discussions (FGD) include low-lying flood-prone settlement areas, agricultural areas prone to floods and droughts, dying streams/rivers, farmlands at the tail-end of irrigation canal, highly erodible areas (in steep slopes) along riverbanks, unstable areas with steep slope that support infrastructure, and grasslands and forested areas/plantations near roads and settlements susceptible to fire.

Using the Holdridge life system, simulation of future climate change, showed that dry forests in the Philippines (more than 1 M ha) are the most vulnerable to climate change. They will be eliminated even with a 50% increase in rainfall. If rainfall doubles, even the moist forests (3.5 M ha) will be totally replaced. On the positive side, the wet and rain forest life zones will significantly expand as dry and moist forests become wetter. Thus, overall, it is expected that the total area of forest in the Philippines will not decline.

In Indonesia, the study showed that Citarum watershed is very vulnerable to climate change. Risk of drought and flood may increase in the future if deforestation can not be stopped and if there are no significant efforts to increase forest cover. Based on simulation studies, it was found that minimum forest cover of about 25% is required to minimize the impact of climate change in the future.

Active participation of local community in Citarum Watershed in protecting and increasing forest cover is very important to ensure the successful of reforestation activities. However, the study suggests that upstream communities may continue to do deforestation if they can not find alternative livelihoods to sustain their everyday needs. Developing reward system for supporting upstream community to increase forest cover and to avoid deforestation has been found to be one of the effective ways to reduce rate of deforestation. Deforestation can be avoided if the community can increase land use intensity or find suitable alternative activities to get additional income such as raising livestock and trading.

Development of reward system for environmental services provided by the upstream community is possible since the downstream community is willing to support activities or program for maintaining and increasing forest cover of the upstream watershed by increasing price of drinking water from the current price. In addition, electricity company (Indonesian Power) is also willing to support community to do reforestation activities through community development program. With the activities, it is expected that the minimum forest cover of 25% could be achieved and this is expected to ensure the continuous supply of water during dry season and extreme drought years.

Capacity building outcomes and remaining needs

The limited capacity of developing country scientists in the Asia-Pacific region to conduct vulnerability assessment and adaptation planning is well recognized (Zakri *et al*., 2000). Thus, a key feature of this project is the enhancement of capacity of local researchers to conduct climate change impact and vulnerability assessment. By working with developed country scientists from its key partners, (ICRAF and GCTE) there were transfer of skills and know-how in modeling and assessment tools. Aside from the researchers, other stakeholders within each the Philippines and Indonesia benefited as they participate in the research process. These include staff of government agencies, NGOs and even people's organizations. Training courses and technical assistance for scientists from Indo-China (Laos, Vietnam and Cambodia) were also implemented by the project as part of its capacity building efforts in the region. Furthermore, several graduate and undergraduates students had participated actively during the implementation of the project.

Project key members of the research team were also involved in various capacities during the first national communication of the Philippines. As expected, their involvement greatly contributed. The research team initially presented the project and its objectives through workshops to Department of Environment and Natural Resources (DENR), Local Government Units (LGUs), National Irrigation Administration (NIA), National Power Corporation (NPC), Non-government Organizations (NGOs), and People's Organizations (POs) to ensure that they are aware of the project. Trainings in different methods in assessing climate change impacts were held to capacitate local scientists and stakeholders. Also, the project is in regular contact with the Philippine Interagency Committee on Climate Change secretariat. The project updates the stakeholders and participating agencies through presentations and workshops every time the project has initial results so that they are always keep informed. In addition, members of the research team were invited to several conferences and workshops to serve as resource person and to present results of the project.

During the study, a number of public awareness capacity building activities have been conducted in Indonesia. The public awareness activities were conducted through seminar and dialogues with local government, local NGOs and local communities. Trainings on the use of simulation modeling approach to assess climate change impact were conducted at regional and national level. The participants of the trainings were scientist from least developed countries and national research agencies and universities. Further training is required particularly in developing socio-economic scenarios in climate change studies. Institutional studies (regulations and local institutions system) for the development of reward system for communities who provide environmental services is also required.

National communications, science-policy linkages and stakeholder engagement

The AIACC-AS21 project is well-positioned to contribute to the Philippines 2nd National Communication. One of the members of the research team, Ms. Joycelline Goco heads the preparation of the 2nd National Communication as chair of the Philippine Inter-agency Committee on Climate Change. Project staff was able to participate in the initial consultations leading to the preparation of the 2nd National Communication. Many of the findings of our AIACC-AS21 project will feed directly to the 2nd National Communication being pioneering studies on climate change impacts and adaptation in natural ecosystems, water, and local communities. Some of these are climate projection the project team generated for the project area and the adaptation strategies used and developed by the local communities in mitigating impacts of climate change. These will be used in the disaster preparedness in the national communication. Furthermore, the project team in cooperation with the Philippines Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) will be doing climate projection for the entire Philippines. This will also be included in the national communication.

Climate change is hardly being considered at all in the planning process of the government. There is a need for bottom-up assessment and planning to address vulnerability and enhance adaptive livelihood at the local and national level. Participatory action research engaging the different stakeholders should be pursued to minimize vulnerability of the poor and enhance adaptive capacity at the local level. Policies and development programs should aim at empowering the local communities to broaden their range of choices of appropriate strategies rather than making them dependent on external support.

The result of the study has been communicated to climate change focal point. Now, Indonesia government is in the process of preparing second national communication. The principal investigator has been invited by the Ministry of Environment to assist in preparing and designing project activities for the second national communication. The focus of the second national communication will be on adaptation aspect. This aspect was not accommodated in the first national communication due to lack of understanding and studies on the issues.

Policy implications and future directions

There is a need for bottom-up assessment and planning to address vulnerability and enhance adaptive livelihood at the local and national level. Participatory action research engaging the different stakeholders should be pursued to minimize the vulnerability of the poor and enhance the adaptive capacity at the local level. Policies and development programs should aim at empowering the local communities to broaden their range of choices of appropriate strategies rather than making them dependent on external support. However, this should not preclude questioning the large scale cause of vulnerability such as poverty, inequity, institutional and economic barriers to development including the issue of power and conflicts (Brook, 2003).

The specific policy recommendations that arise our study are the following:

- Integrate climate-related risks in watershed planning and management
- Integrate climate-related risks in community-based programs

In order to streamline action plan of adaptation to climate change issues into national development program, further awareness rising is required either through science-policy forum or national working group on climate. Due to devastating impact of ENSO phenomena on many sectors, Indonesia government developed a number of national working groups to work on the issues and provide inputs in policy makers in actions or in steps required in anticipating the events. The direction of research in the future should be focused on how to institutionalize climate information and how to encourage and to engage local communities in protecting and improving environmental quality in sustainable ways.

PART I: PHILIPPINES

1 Introduction

Pantabangan-Carranglan Watershed (PCW) is found in the heart Luzon, the largest island of the Philippines. It is located between 15^{O} 44′ to 16^{O} 88′ north latitude and 120^{O} 36′ to 122^{O} 00′ east longitude (Figure 1.1). The watershed is bounded on the north by the Caraballo Mountain Ranges and on the south by the Sierra Madre Mountain Ranges. It is approximately 175 km from Manila and is found within the provinces of Nueva Ecija, Nueva Vizcaya and Aurora. There are 5 municipalities that encompass the watershed. The largest portion of the watershed is located within the towns of Pantabangan and Carranglan, Nueva Ecija. About 20% of the watershed is found in the towns of Alfonso Castañeda and Dupax del Sur of Nueva Vizcaya and the rest of the watershed is located in Ma. Aurora, Aurora. There are 36 barangays in the watershed of which 17 are found in Carranglan, 14 in Pantabangan, 3 in Alfonso Castañeda and 2 in Ma. Aurora. (Pantabangan History; NPC 1997).

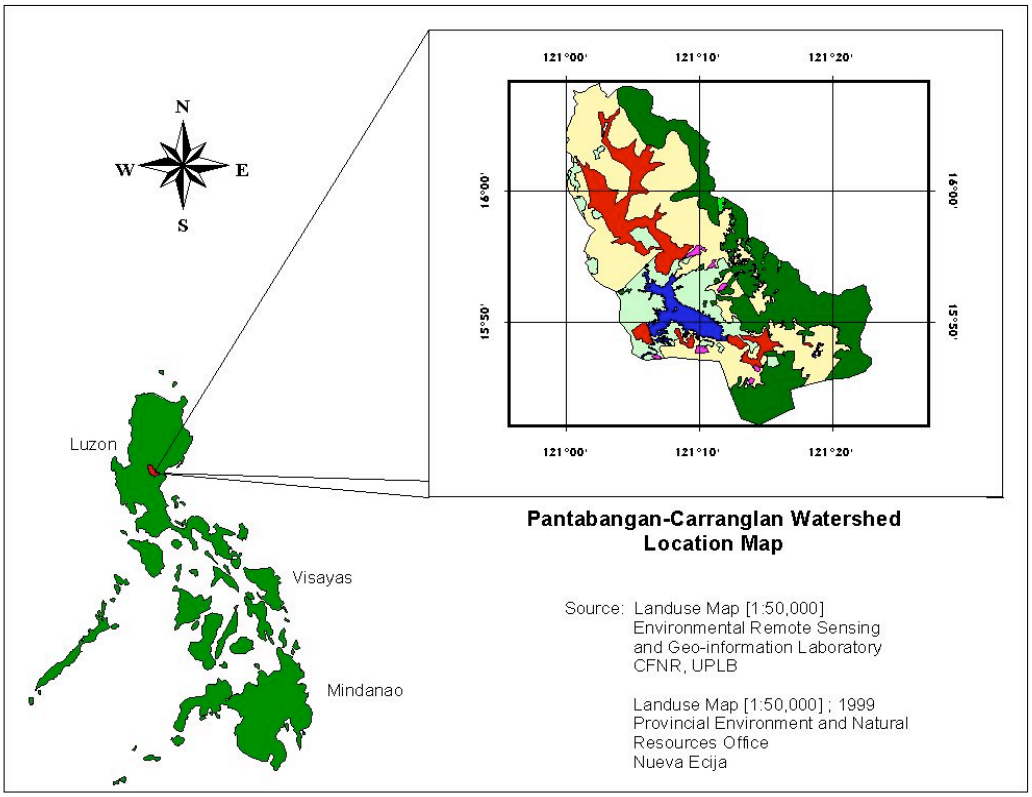


Fig. 1.1: Location of Pantabangan-Carranglan watershed.

The PCW has a total area of 97,318 ha of which 4,023 ha comprise the water reservoir (1999 Land use Map). The major land use types in the Pantabangan-Carranglan Watershed are forestlands, open grasslands, and cultivated lands (Figure 1.2). Natural vegetation in the watershed is predominantly second growth forests. Remnants of dipterocarp forests can still be found within the watershed. Primary forests in the area have significantly declined as early as the logging boom in the 1960s. Grazing and reforestation activities are found in open and grassland areas which are dominated by cogon (*Imperata cylindrica*). Residential and barangay sites are also common in these areas.

The Pantabangan-Carranglan Watershed largely falls under the Climatic Type I of the Corona Classification System. It has two pronounced seasons; dry from November to April and wet during the rest of the year. A small portion of the watershed falls under Type II characterized by very pronounced wet season from November to January and evenly wet the rest of the year. Based on rainfall data collected from 4 rainfall stations, the annual rainfall in the watershed ranges from 1,776.5 mm to 2,270.9 mm.

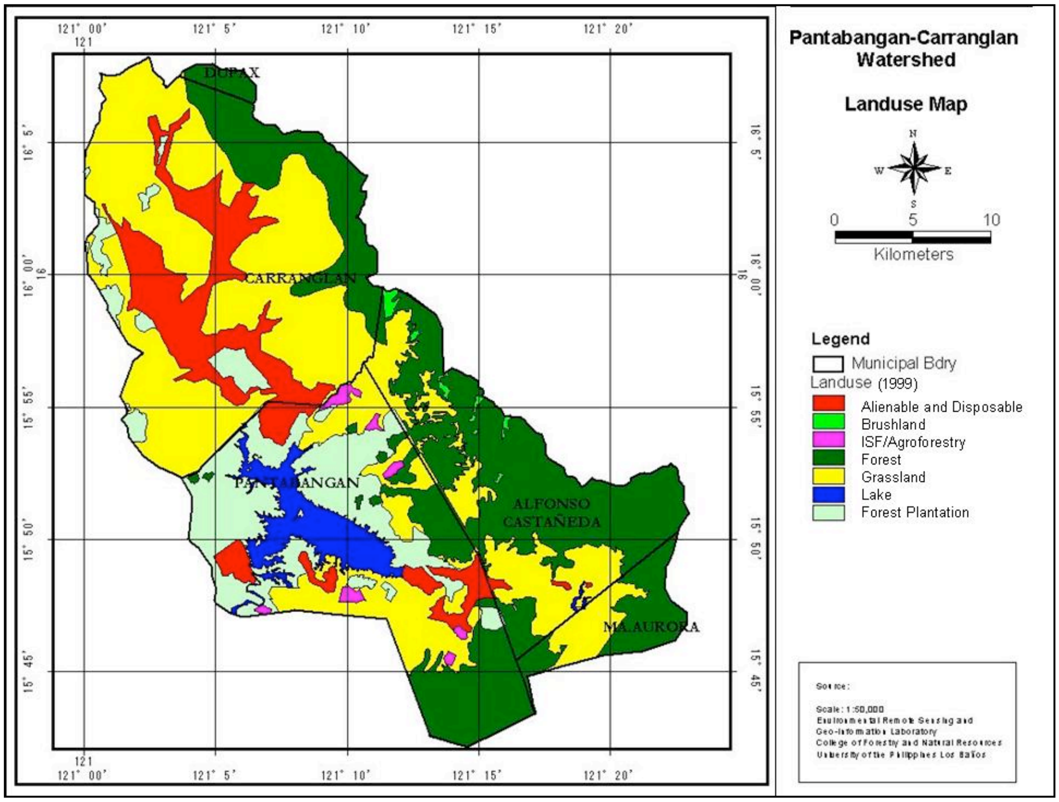


Fig. 1.2: Land use (1999) in Pantabangan-Carranglan watershed.

Rice, vegetables, corn, cassava, onion, and other agricultural crops are grown on cultivated lands. Rice, onions and vegetables are the primary crops raised on the lowland areas of the municipality of Carranglan. Most of the areas devoted for rice production are rain fed. Water pumped from well and runoff irrigates some areas for rice production. Other crops like banana, cassava, sweet potato and corn are normally grown on kaingin farms.

The Pantabangan-Carranglan Watershed 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. Administratively, the PCW is under three national government agencies, namely: the National Irrigation Administration (NIA), the National Power Corporation (NPC) and the Department of Environment and Natural Resources (DENR). The NIA takes care of the watershed areas immediately surrounding the Pantabangan reservoir. Watershed areas within the Carranglan headwaters are under the jurisdiction of the NPC. The remainder of the PCW is under the jurisdiction of the DENR. This institutional arrangement in PCW is rooted in the need to sustainably manage the watershed so that sufficient amount of watershed is captured and stored in the reservoir for irrigation as well as hydroelectric power generation (Pantabangan History; NPC 1997).

The average annual streamflow at the Pantabangan dam site was highest (1,577.50 MCM) in 1971 to 1980, followed by 1946 to 1970 (1,363.30 MCM) and 1981 to 1986 (1,152.60 MCM).

The completion of the Pantabangan-Carrangalan dam in 1974 has greatly eased the water supply requirement of about 8,000 hectares of farmlands in the floodplains (NPC 1997). At present, the PCW supplies the irrigation requirements of 24 municipalities in the provinces of 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 consisting of 62,039 farmers depend on the PCW for their farm irrigation needs (NIA-UPRIIS 2004).

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 therefore key to the pursuit of sustainable development. More than 70% of the country's total land area lies 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 presently derive irrigation water from watersheds. Moreover, around 20 to 24 million people –close to one-third of the country's total population – inhabit the uplands of many watersheds majority of who depend on its resources for survival. However scientists working on climate change in Southeast Asia have limited experience in impacts and vulnerability assessment.

Completely lacking is information on the impact of climate change on local communities inhabiting watershed areas. Similarly, impacts on natural forest ecosystems have also not been quantified. Thus this study was aimed to:

- Assess the impacts of climate change to water resources, forest ecosystems, and social systems of the watersheds;
- Conduct integrated vulnerability assessment of natural and social systems in the watershed areas;
- Develop adaptation strategies for natural water resources, forests ecosystems and social systems;
- Promote stakeholder participation in the research process;
- Contribute to peer reviewed literature; and
- Help build capacity of local scientists to conduct integrated assessment studies.

1.1 General Framework.

Figure 1.3 shows the relations between global climate change and the local human or ecological impact via changes in watershed functions. At each step in the causal change, the relationship between global climate and local impact can be modified by local or regional factors and adaptive responses.

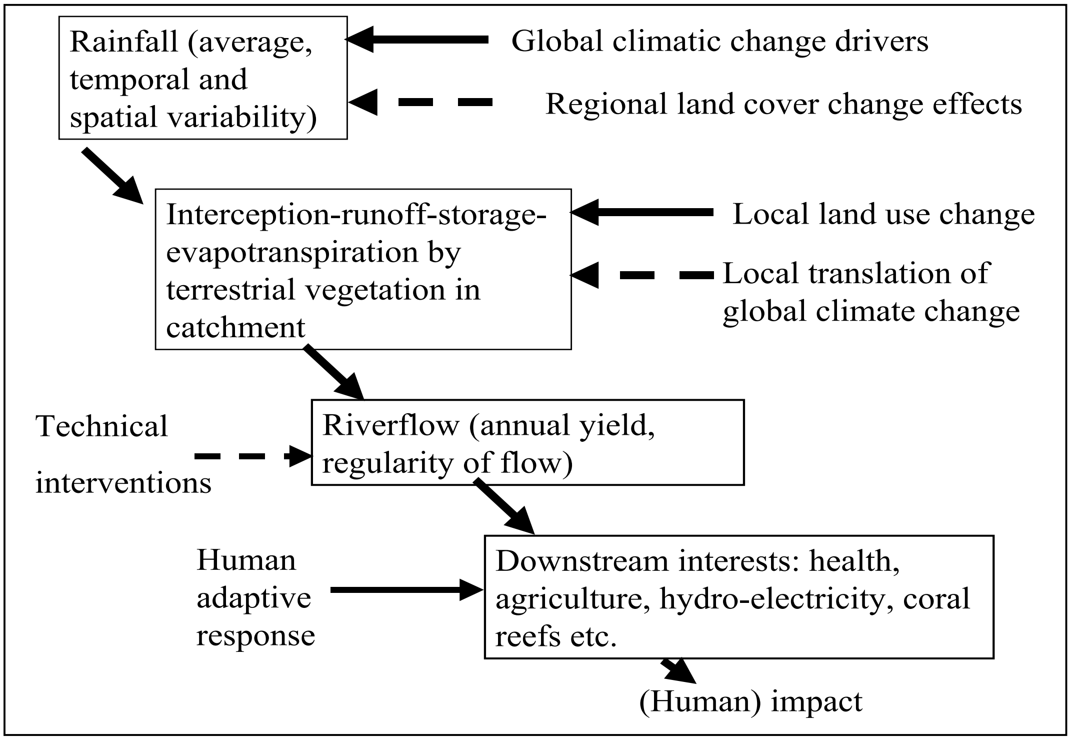


Fig. 1.3: Relation of climate change, watershed functions and local impact.

The general framework of the study is shown in Figure 1.4. The study used climate change scenarios generated by GCMs as well as current climate coping mechanisms as starting points. An integrated assessment of impacts, adaptation and vulnerability of natural and social systems was conducted.

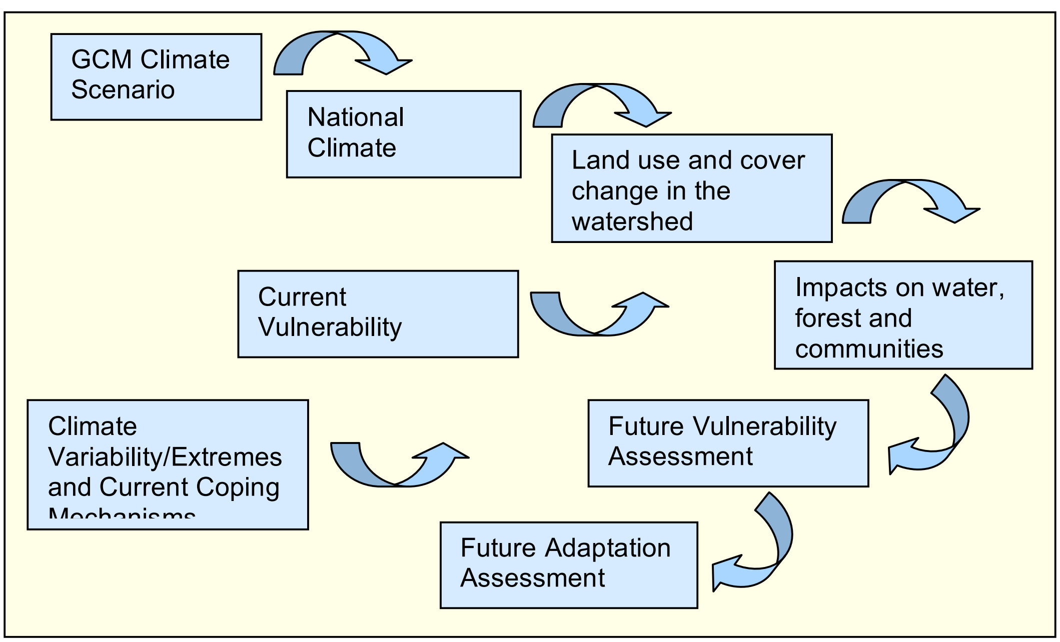


Fig. 1.4: General framework of the study.

1.1.1 Prediction of landuse and cover change resulting from climate change scenarios

MAGIC-SCENGEN was used to develop climate change scenarios. MAGICC (Model for the Assessment of GHG Induced Climate Change) is not a GCM, but it uses a series of reduced-form models to emulate the behavior of fully three dimensional, dynamic GCMs. SCENGEN (Scenario Generator) is a simple database that contains the results of a large number of GCMs experiments. It manipulates data sets based on the information about the rate and magnitude of global warming supplied by MAGICC.

MAGICC includes six IS92 scenarios, i.e. IS92a up to IS92f, and four SRES scenarios, i.e. SRESA1, SRESA2, SRESB1 and SRESB2. In this study, emission scenario SRESA2 and SRESB1 were used. These two scenarios reflect current understanding and knowledge about underlying uncertainties in the emissions. SRESA2 describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slow. SRESB1 describes a convergent world with the same global population that peaks in mid-century and declines thereafter, rapid change in economic structures toward a service and information economy, with reduction in material intensity, and the introduction of clean and resource-efficient technology (IPCC, 2000). With these characteristics, the SRESA2 will lead to higher future GHG emissions while SRESB1 leads to lower future GHG emissions. Thus SRESB1 was defined as policy scenario, while SRESA2 as reference scenario.

Outputs from MAGICC-SCENGEN have a resolution of 0.5x0.5 minutes. In order to have better resolution, the outputs were downscaled using interpolation technique, such as Kriging. Impact of climate change on land use and cover was evaluated using simple model inter-linking present-day vegetation with climate, and then using the outputs of GCMs based climate projections to derive potential shift in vegetation boundaries (Ravindranath and Deshingkar, 1997). In this analysis all vegetation categories that are primarily anthropogenic in origin, such as monoculture plantations, cultivation or completely transformed vegetation, were excluded.

The CLUE-S model was used to generate the future land use scenarios in the watershed. The model is sub-divided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure. 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.

1.1.2 Climate change impact assessment

The impacts of the climate change scenarios on the natural and social systems within the watersheds were assessed. Sectoral assessments were conducted on the following: forest ecosystems (biodiversity, carbon budgets), water resources, and socio-economic conditions of the people.

Impacts on water resources emphasize on the water budget of selected watershed using SEA-BASINS Integrated Modeling System developed by SEA START RC that has the capability to integrate the change in land use. Special attention was focused on the impacts on stream flow volume, regime and quality in relation to the sufficiency of water to supply the demands for domestic, agricultural and industrial uses. Water supply was assessed through estimating the impacts of climate change on the river runoff using SEA-BASINS hydrologic model.

Socio-economic impacts of climate change on the lives of watershed communities were assessed in four areas: livelihood, health, demographic shifts and change on social structure. Potential changes in livelihood sources and income, labor demand, as well as change in the required social services in the uplands to support livelihood activities were analyzed. Potential health problems associated with climate change were examined. Demographic shifts resulting from population movements brought about by climate change were also assessed. The baseline information on socio-economic condition of the watershed communities was determined through the gathering and analysis of secondary and primary information.

1.1.3 Assessment of adaptation strategies

Adaptation strategies refer to all those responses and adjustments to climate change that may be used to reduce vulnerability and strengthen resilience (UNEP/IES, 1996). It also refers to actions that taken to benefit from opportunities that may arise from climate change. On the basis of the potential impacts, adaptation strategies were developed with the participation of the various stakeholders.

Following the IPCC Guidelines, the key steps used in assessing the adaptation options are discussed below.

- *Defining objectives*: reduction of watershed vulnerability and promotion of sustainable development.
- *Identification of climate impacts of importance*: This was taken from the results of the previous activity (impact assessment).
- *Identifying the adaptation options*: This involved compiling the list of possible adaptive responses to the impacts of climate change to the selected watershed. Aside from literature review, consultations with other experts and stakeholders were conducted. Specific adaptation measures include: modifying existing and constructing new infrastructure, introducing water-saving technologies, upgrading efficiency of irrigation systems, and introducing low water-use crops.

At the broader policy level, appropriate policy options at the watershed level were identified and analyzed based on economic, social and environmental criteria. Some of these options include provision of tenurial security, livelihood support, strengthening social capital, and provision of other social services to reduce local communities' vulnerability and increase their resilience to climate change.

1.1.4 Vulnerability assessment

Vulnerability refers to the degree to which a natural or social system is susceptible to, or unable to cope with the effects of climate change (Working Group II, 2001). In essence, vulnerability is a function of impacts minus adaptation (i.e. Vulnerability = Impacts- Adaptation). The study assessed the ability of natural and social systems in the watershed areas to cope with climate change. The analysis was carried out using analog and modeling approaches. This involves a two-stage process: (a) assessment of present vulnerability and (b) assessment of future vulnerability.

Vulnerability of the watershed communities was assessed by building on the outputs of the impact assessments through linking climate-associated impacts (or outcomes) to multiple physical, social and political-economic causal agents and processes. By doing so, vulnerability analysis provides a sound basis for policy, since it is through responding to its causes that vulnerability can be redressed (Ribot *et. al.*, 1996).

1.1.5 Integrated assessment

The study seek to integrate vertically (science-policy) and horizontally (across disciplines) through the use of modeling exercises and non-modeling approaches (UNEP/IES, 1996). Multi-stakeholder workshops were also used as a tool in capturing the views of the various sectors of society including watershed communities.

The integrated assessment was aided by the use of Participatory Rural Techniques such as household survey and Focus Group Discussions (page 270).

The study is divided into three major components: Forests ecosystems, Social systems, and Water resources. In each component, an integrated assessment of climate change impacts, adaptation, and vulnerability was done. Following this Introduction is Chapter 2: Characterization of Current Climate and Scenarios of Future Climate Change in Pantabangan-Carranglan Watershed. Chapter 3 reveals the key findings in the assessment of impacts and vulnerability of the three components. Chapter 4 presents adaptation strategies identified to mitigate climate change impacts. National Forestry assessment is shown in Chapter 5. The study concludes by pointing out key research and policy measures that could help advance the body of knowledge and improve policy to reduce the vulnerability of watershed communities, institutions, as well as other vulnerable groups to climate variability and extremes.

2 Characterization of Current Rainfall, Temperature and Streamflow and Scenarios of Future Rainfall, Temperature and Streamflow in Pantabangan-Carranglan Watershed

2.1 Activities conducted

The following activities were conducted to characterize current climate and scenarios of future climate change in Pantabangan-Carranglan Watershed:

1. Assessed current and future rainfall and temperature changes;
2. Downscaled climate change scenarios for HADCM3_A2a, HADCM3_B2a, CCCma_A2a, CCCma_B2a, CSIRO_A2a and CSIRO_B2a under two emission scenarios; and
3. Assessed current and future streamflow changes.

2.2 Description of Scientific Methods and Data

2.2.1 Characterization of future climate

The future climate scenarios (2020, 2050 and 2080) for the watershed were generated using the method described by Hewitson (2003). GCM values at four grid points closest to the study watershed were obtained from Hadley Centre. Climate change scenarios for HADCM3_A2a, HADCM3_B2a, CCCma_A2a, CCCma_B2a, CSIRO_A2a and CSIRO_B2a were downscaled by perturbing the GCM values with historical climate data in two weather monitoring stations closest to the study area. For each GCM scenario four grid point values were used to determine the corresponding values for the two weather stations in the watershed by Kriging. The interpolated values for each GCM were then perturbed with the historical climate data from the two weather stations closest to the watershed.

2.2.2 Future land use and land cover

The CLUE-S model was used to generate the future land use scenarios in the watershed. The model is sub-divided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure (Figure 2.1). 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.

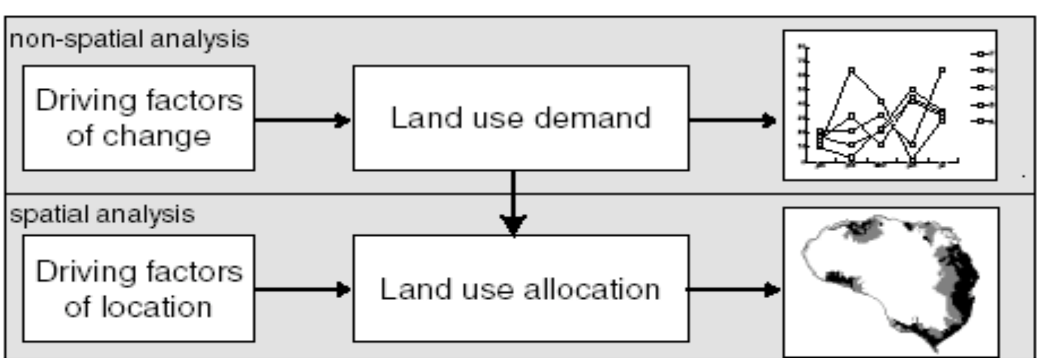


Fig. 2.1: Structure of CLUE-S model.

2.2.3 Future streamflows

SEA-BASINS Integrated Modeling System developed by SEA START RC was used to predict the future streamflow pattern. The SEA-BASINS consist of two models, the Variable Infiltration Capacity (VIC) model and the Dynamic Routing Model (Figures 2.2a and 2.2b). VIC Model (vertical) is a precipitation-runoff model which calculates the water balance at each individual grid cell, while Dynamic Routing Model (horizontal) routes the runoff generated by each grid cell to the outlet of the watershed. The data requirements of the models are summarized in Table 2.1.

In the pre-processing phase, watershed boundary, stream networks, contour lines, soil and vegetation maps were processed and converted into grid maps using Arc View and then converted to ASCII files using ArcInfo. Daily precipitations, daily wind speed, maximum and minimum temperature from 3 stations were interpolated using SURFER program and GSMAC.

After pre-processing and parameterization, VIC model was executed to create runoff data and routed using dynamic routing model to simulate discharge values. To make routed discharge cohere with observed discharge, simulated discharge was calibrated by editing fraction of run-off and baseflow. Results of calibrating SEA-BASIN in PCW are shown in Figure 2.3 and Table 2.2. The calibrated model shows the ability to satisfactorily simulate the streamflow hydrograph of PCW. The results of t-test also reveal that the streamflow estimated using the calibrated model does not significantly vary from the observed streamflow of PCW.

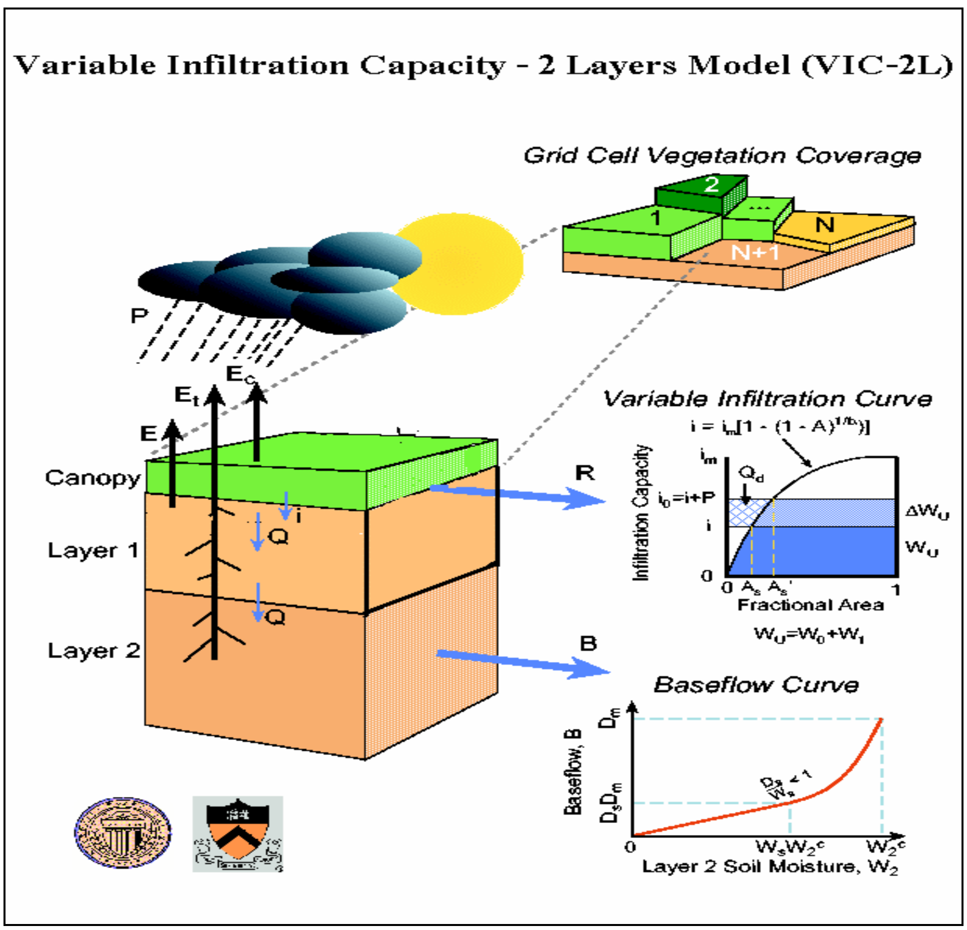


Fig. 2.2a: Variable infiltration capacity model of SEA-BASIN (Liang et al. (1994).

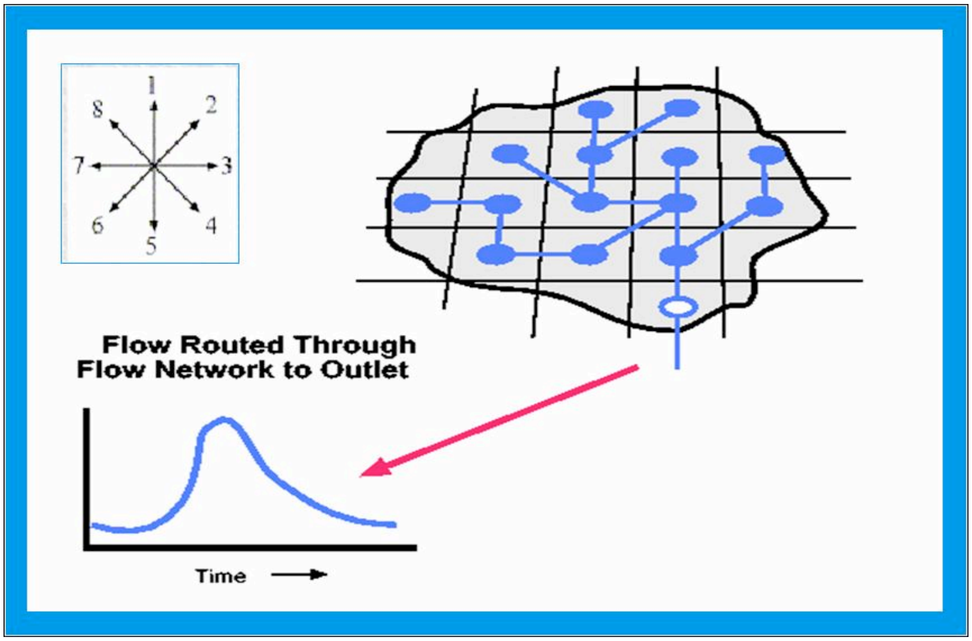


Fig. 2.2b: Illustration of the routing model of SEA-BASIN (Lohmann et al. *(1996).*

Data for VIC Model	Data for Routing Model
Forcing Data • Precipitation (mm) • Maximum temperature (^{0}C) • Minimum temperature (^{0}C) • Wind speed (m/sec)	• Elevation • Stream network • Discharge data
Template Data • Soil property • Land cover • Elevation	

Table 2.1: Data needed to run the VIC and Routing Models.

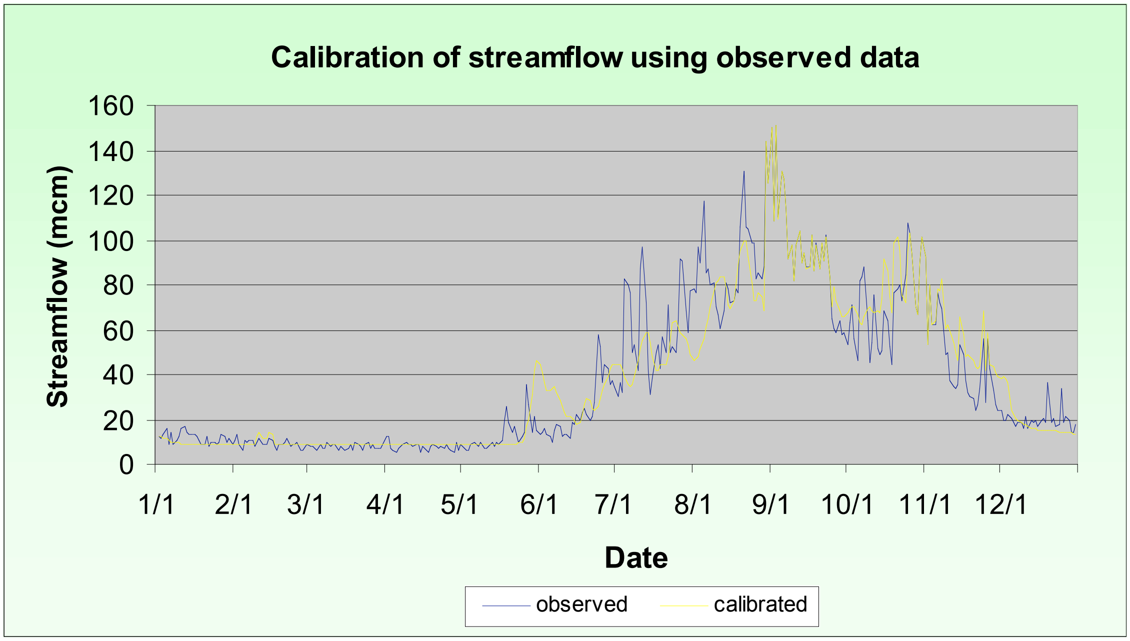


Fig. 2.3: Comparison of observed and estimated streamflows after calibration for Pantabangan-Carranglan watershed (1997).

t-Test: Paired Two Sample for Means Observed vs. Calibration Model I		
	Observed	*Calibrated*
Mean	37.8873472	38.1693826
Variance	1176.9262	1080.53527
Observations	365	365
Pearson Correlation	0.93360021	
Hypothesized Mean Difference	0	
df	364	
t Stat	-0.43731039	
P(T<=t) one-tail	0.3310728	
t Critical one-tail	1.64905055	
P(T<=t) two-tail	0.6621456	
t Critical two-tail	1.9665025	

Table 2.2: Results of t-test for SEA-BASIN calibration.

2.3 Results and discussion

2.3.1 Trends in observed rainfall

Based on records from two synoptic stations of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the annual rainfall in the PCW ranges between less than 1,200 mm to more than 2,500 (Figure 2.4a). In general, the annual rainfall appears to be stable as far as records from 1960 to 2001 is concerned. Over the last decade however, a slightly decreasing trend in the annual rainfall is noted from the Cabanatuan station and a slightly increasing trend noted in the CLSU station (Figures 2.4b and 2.4c).

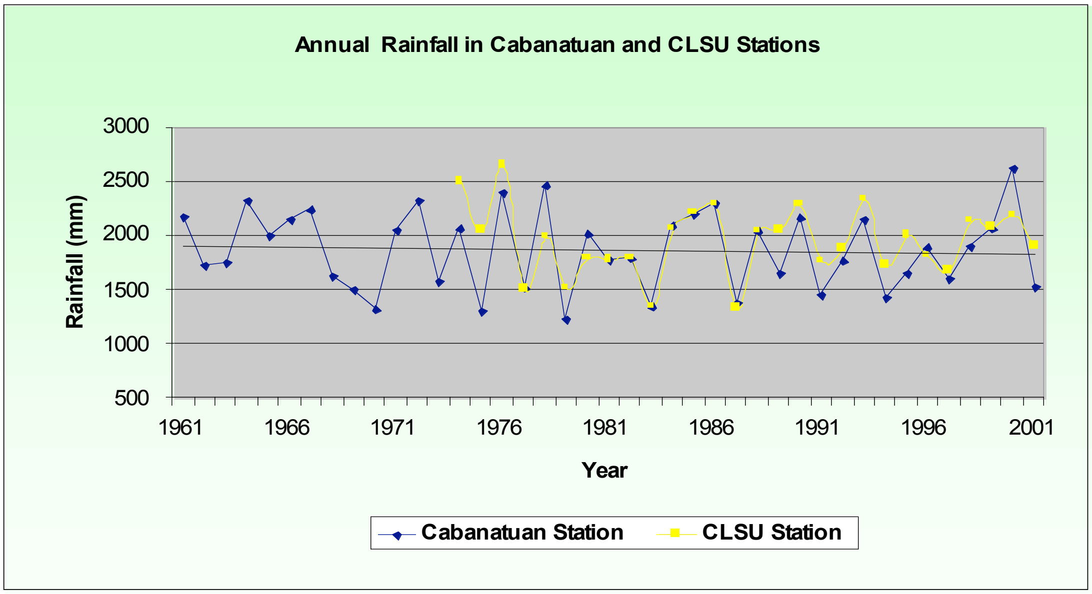


Fig. 2.4a: Comparison of annual rainfall in Cabanatuan and CLSU stations

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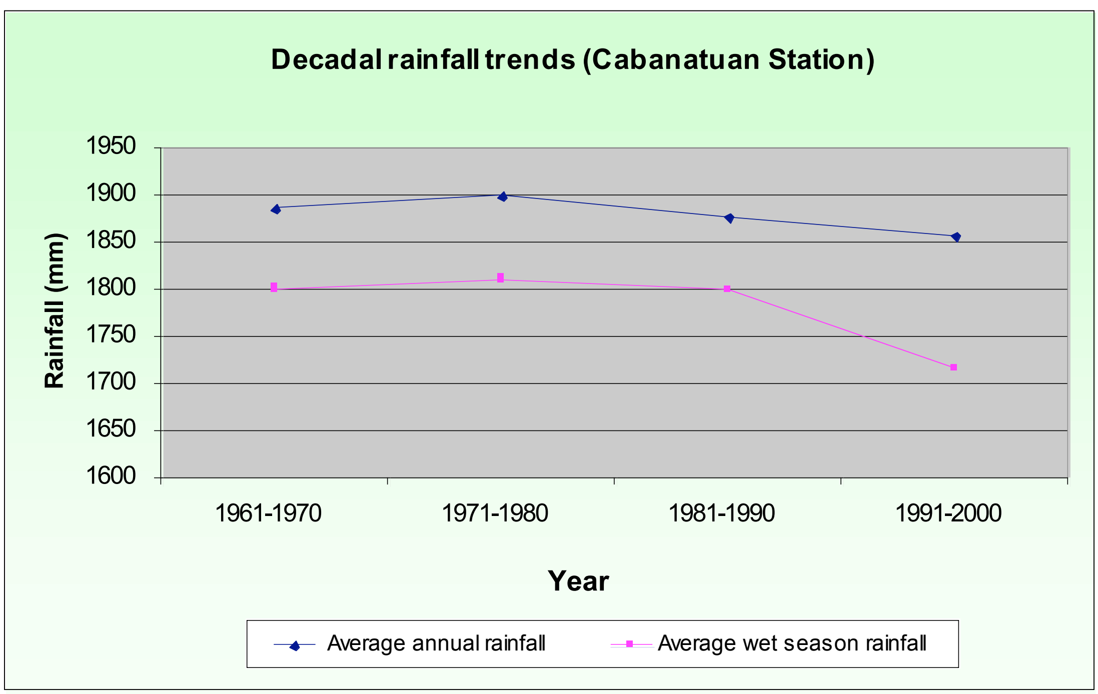


Fig. 2.4b: Decadal rainfall trends in Cabanatuan station.

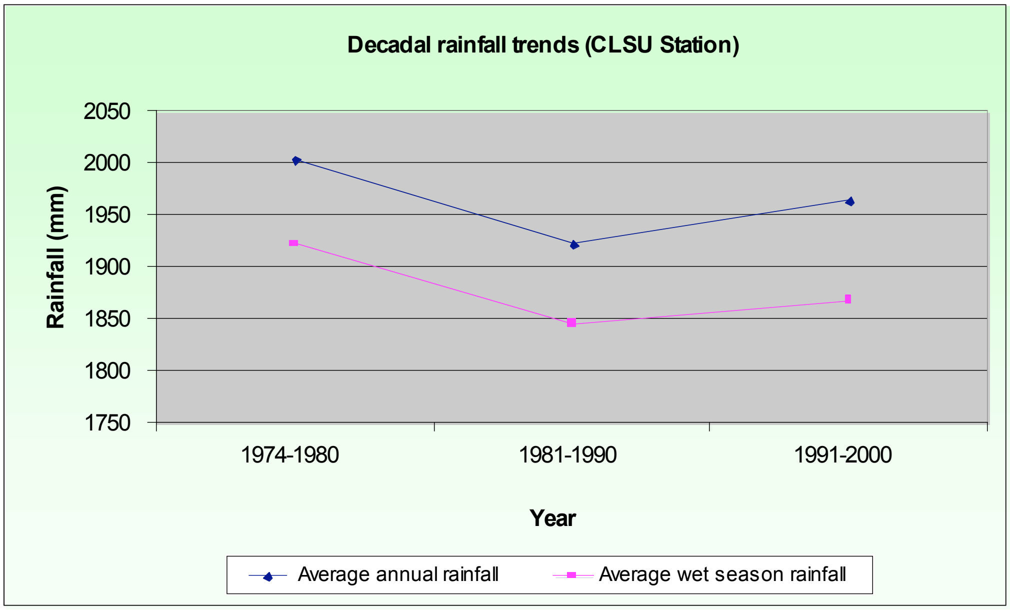


Fig. 2.4c: Decadal rainfall trends in CLSU station.

The number of rainy days seems to be increasing especially starting in the late 90's onto the new millennium (Figure 2.4d) even as no significant perceptible change in the trend of the number of consecutive rainy days was noted (Figure 2.4e). As for the maximum rainfall events a decreasing trend after 1981 is noticeable although it is uncertain if such trend is due to climate change or change in the mode and circumstance of monitoring rainfall (Figure 2.4f). The onset of rainy season falls usually between May and June which is normal for the kind of climate in the PCW. There is however a slight tendency for the onset of the rainy season to come earlier than May toward the end of the century (Figure 2.4g). Again it is yet too early to pronounce if this constitutes a change in the pattern of arrival of the rainy season that will persist over the long term or merely a short term variability pattern.

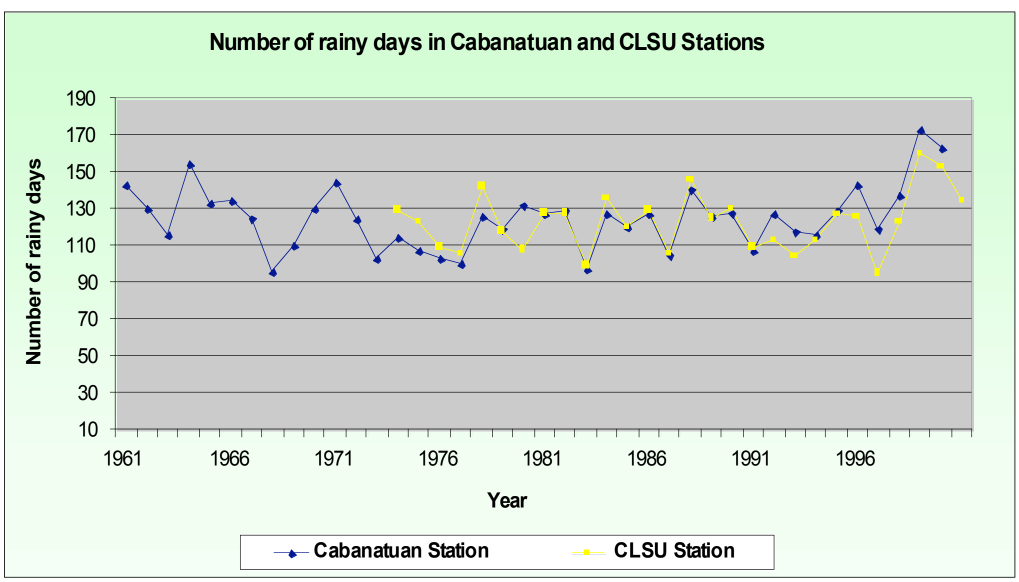


Fig. 2.4d: Number of rainy days in Cabanatuan and CLSU stations.

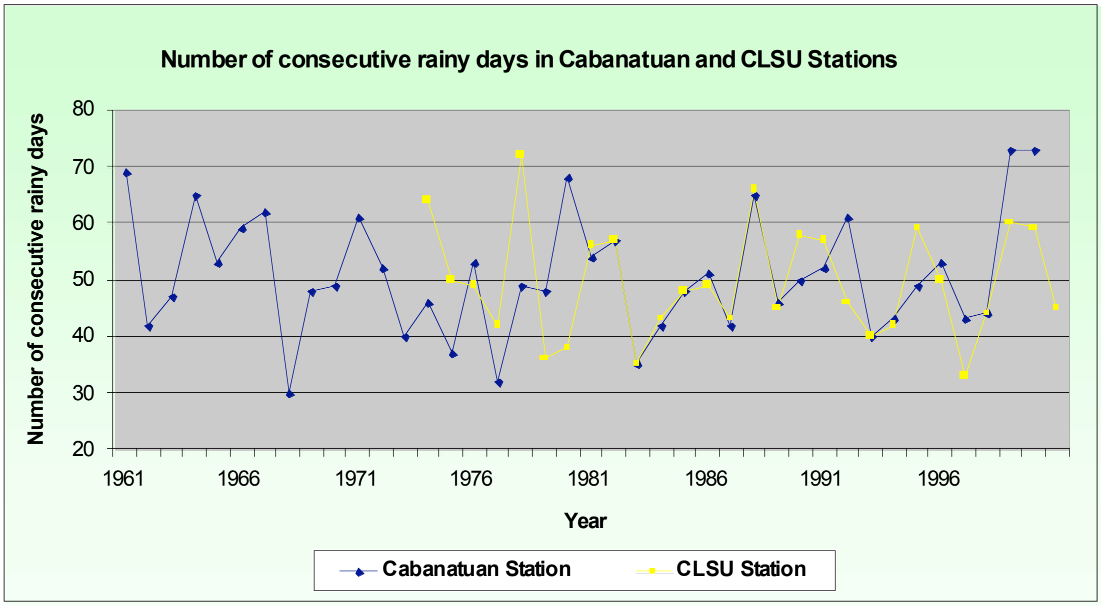


Fig. 2.4e: Number of consecutive rainy days in Cabanatuan and CLSU stations.

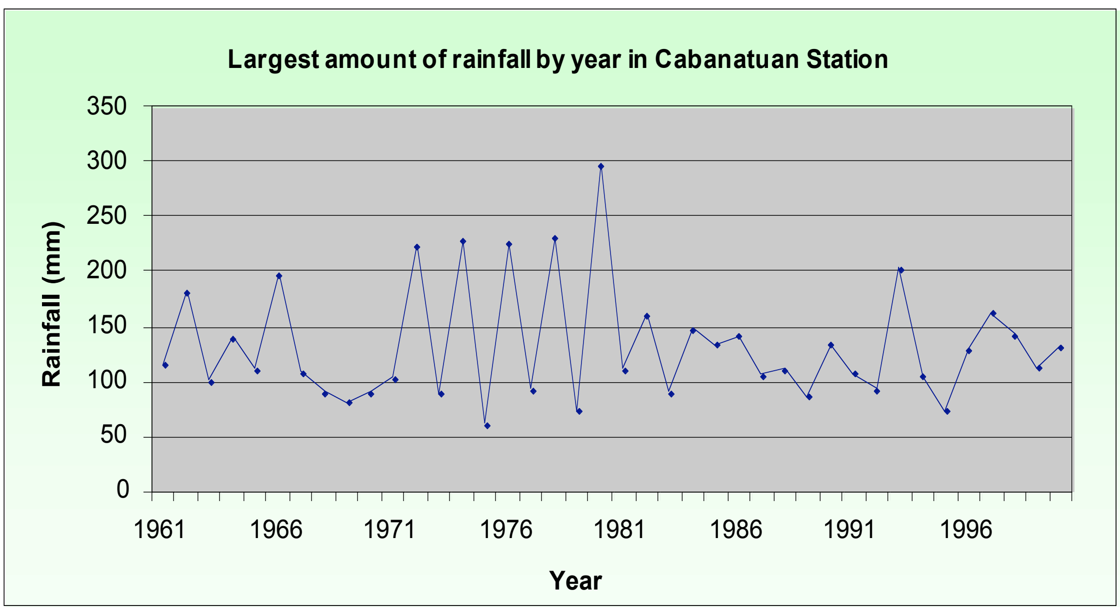


Fig. 2.4f: Largest amount of rainfall by year in Cabanatuan station.

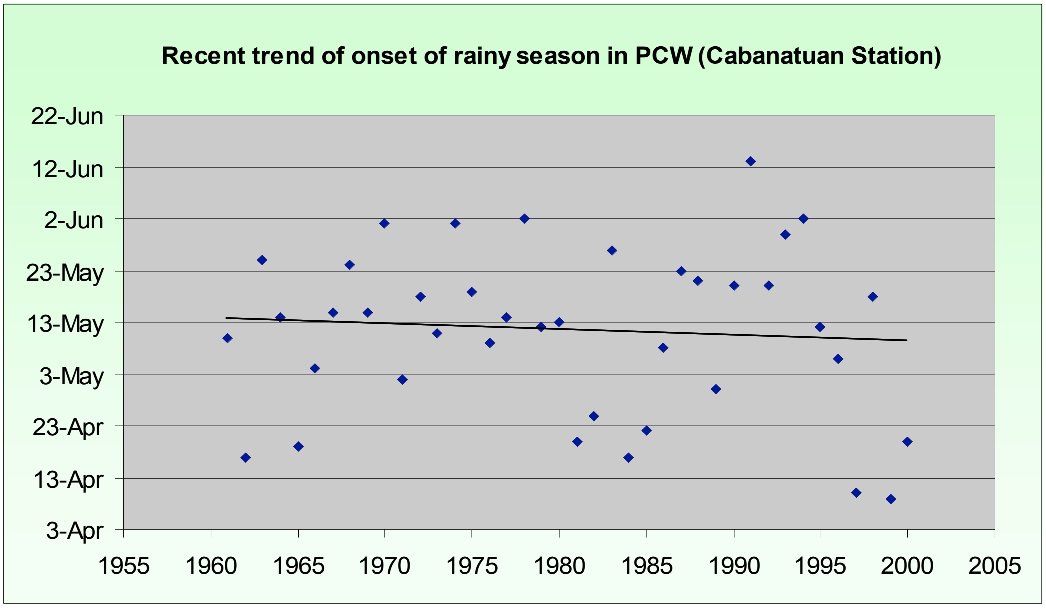


Fig. 2.4g: Recent trend of onset of rainy season in PCW (Cabanatuan station).

2.3.2 Trends in observed temperature

All parameters of temperature i.e., annual mean temperature, maximum and minimum temperature, and number of days temperature is above normal were observed to demonstrate a tendency to increase over time (Figures 2.5a to 2.5f). On the average the maximum temperature increased by 0.22 ^{0}C over the last 30 years. Increases in monthly maximum range between a low of 0.2 ^{0}C in January to as high as 2.4 in February for CLSU station. For Cabanatuan station the annual maximum temperature increase by about 0.24 ^{0}C for the last 40 years with monthly values increasing from as low as 0.27 ^{0}C in October to as high as 0.89 ^{0}C in January. For minimum temperature, a yearly average increase of 0.06 ^{0}C was noted with the monthly minimum temperature increasing between 0.12 ^{0}C in June and 0.77 ^{0}C in December.

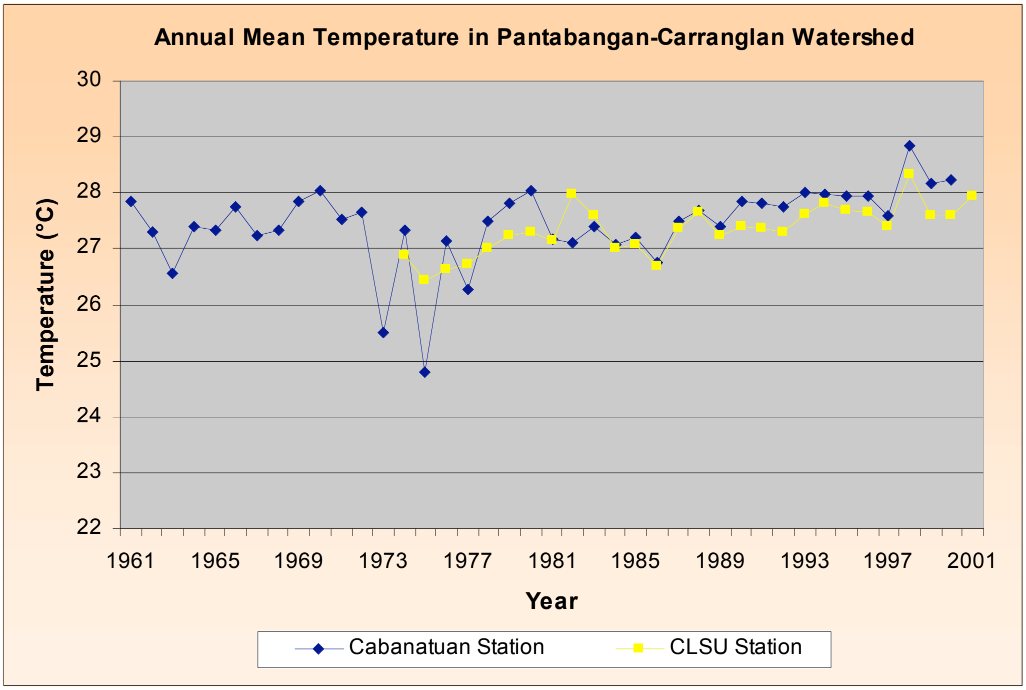


Fig. 2.5a: Annual mean temperature in Pantabangan-Carranglan watershed.

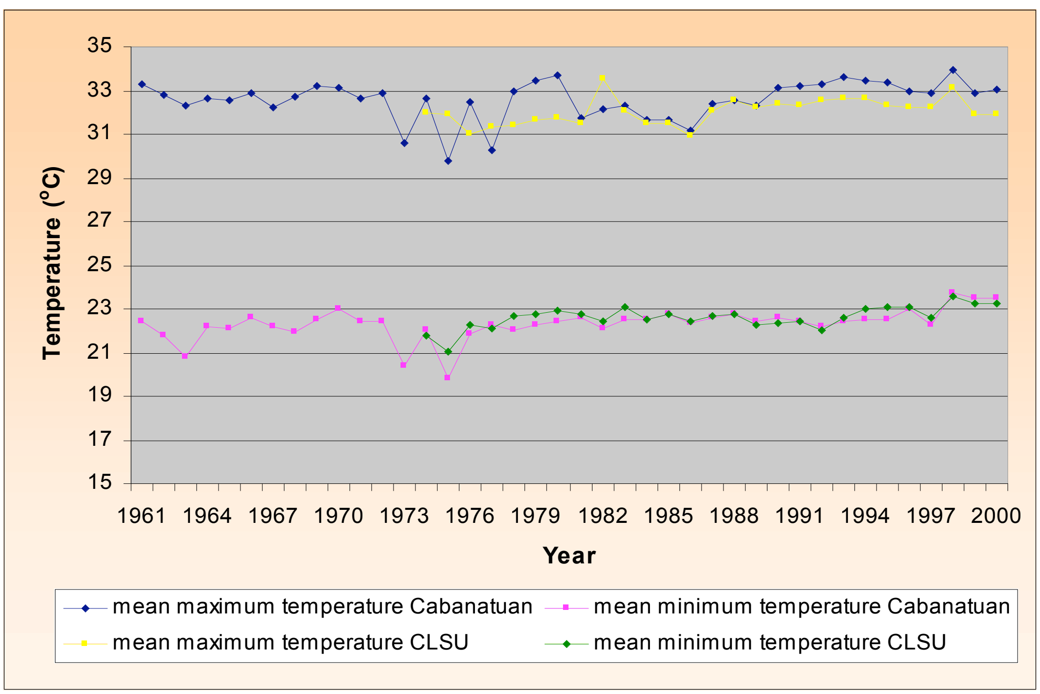


Fig. 2.5b: Annual mean minimum and mean maximum temperature in Pantabangan-Carranglan watershed.

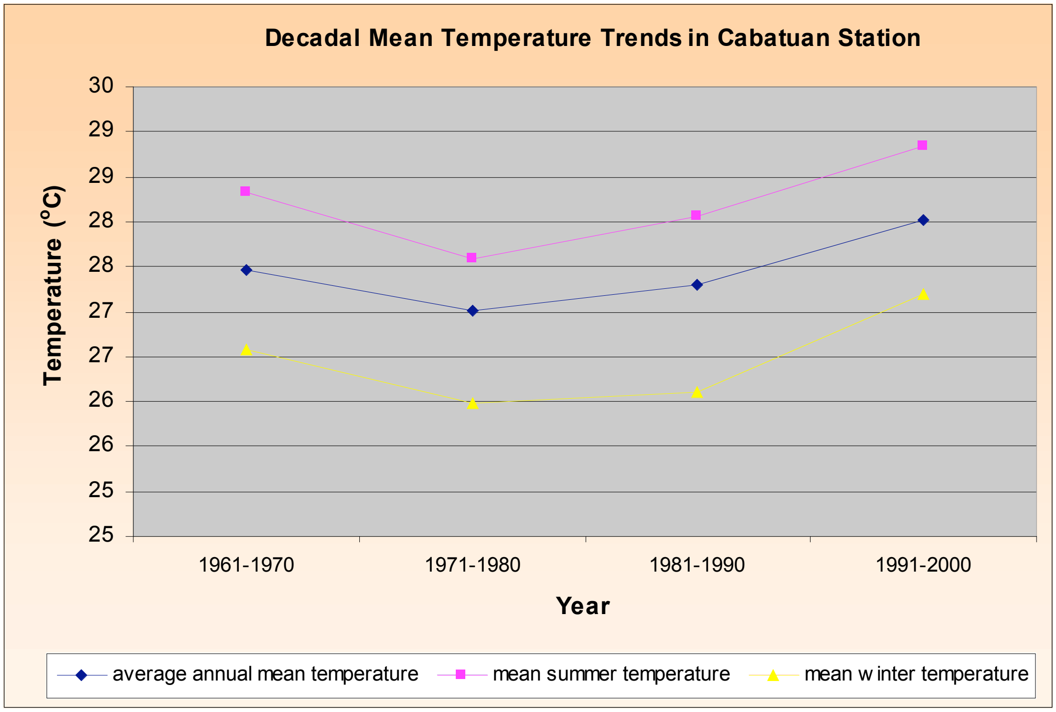


Fig. 2.5c: Decadal mean temperature trends in Cabanatuan station.

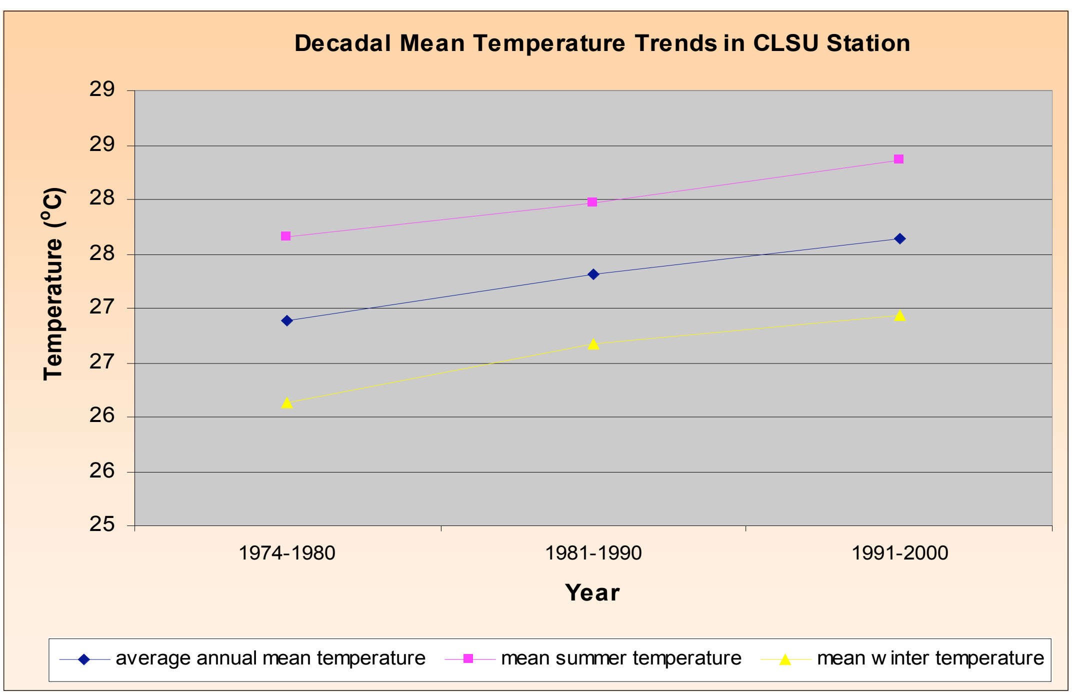


Fig. 2.5d: Decadal mean temperature trends in CLSU station.

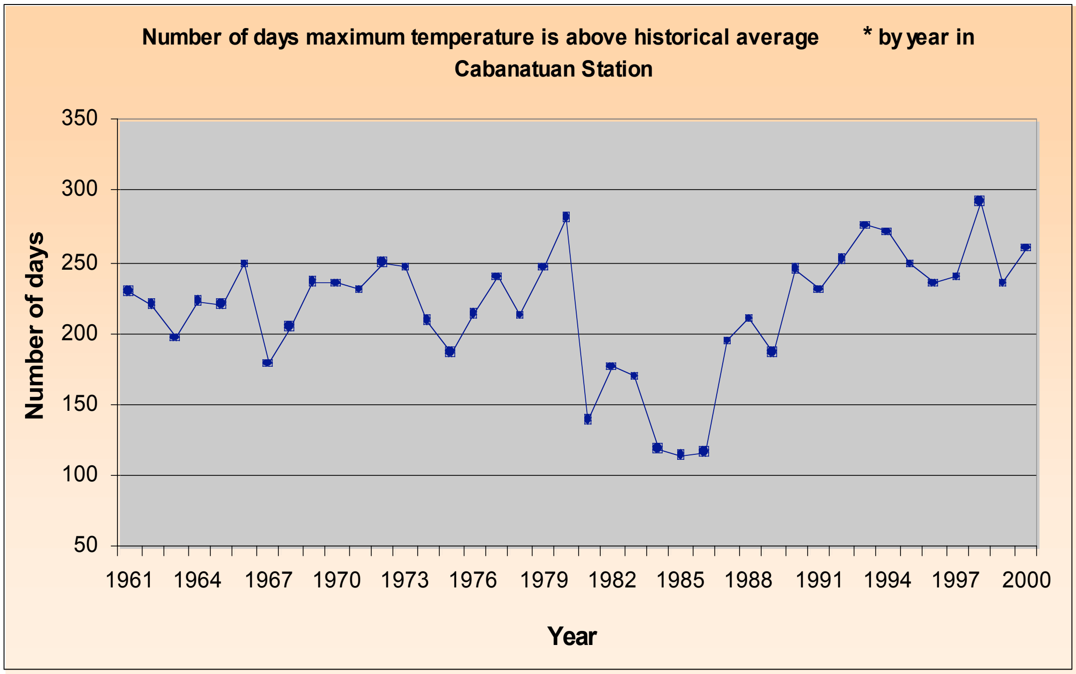


*Fig. 2.5e: Number of days maximum temperature is above historical average in Cabanatuan station. (*historical average is the average of annual rainfall from 1961-2000)*

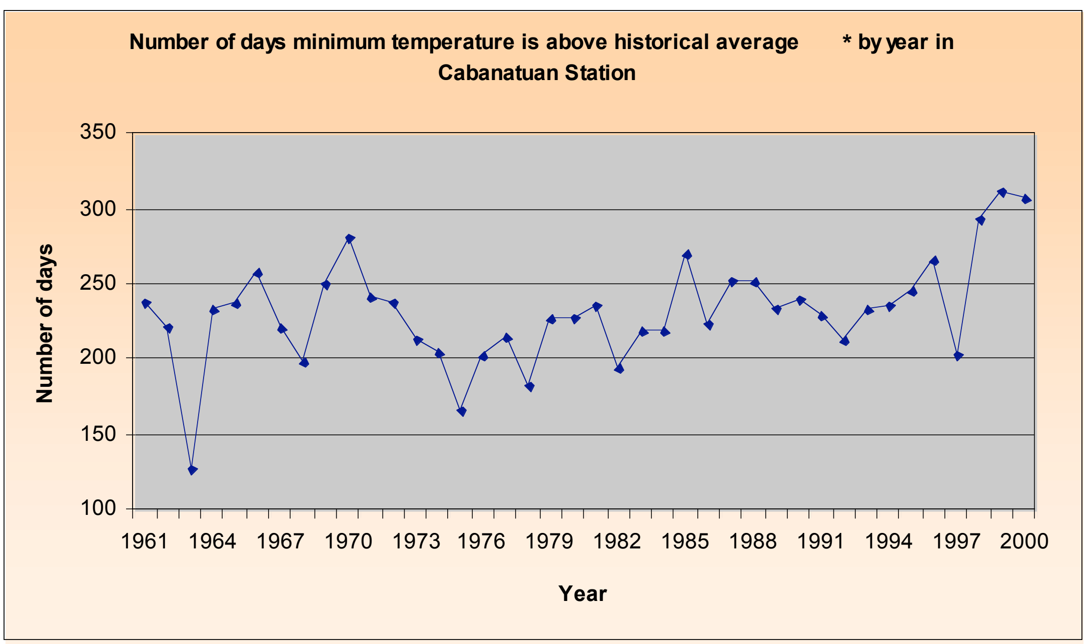


*Fig. 2.5f: Number of days minimum temperature is above historical average in Cabanatuan station. (*historical average is the average of annual rainfall from 1961-2000)*

2.3.3 Recent trends in ENSO events

Over the last 20 years (1980-2000) increasing frequency in the occurrence of ENSO events is noted (Table 2.3a). Two of the strongest ENSO events were recorded during the same period (1982-83 and 1997-98).

YEAR	1st Q	2nd Q	3rd Q	4th Q		YEAR	1st Q	2nd Q	3rd Q	4th Q
1950	C	C	C	C		1976	C			W-
1951	C			W-		1977				W-
1952						1978	W-			
1953		W-	W-			1979				
1954			C-	C		1980	W-			
1955	C	C-	C-	C+		1981				
1956	C	C	C	C-		1982		W-	C	W+
1957		W-	W-	W		1983	W+	W		C-
1958	W+	W	W-	W-		1984	C-	C-		C-
1959	W-					1985	C-	C-		
1960						1986			W-	W
1961						1987	W	W	W+	W
1962						1988	W-		C-	C+
1963			W-	W		1989	C+	C-		
1964			C-	C		1990			W-	W-
1965	C-		W	W+		1991	W-	W-	W	W
1966	W	W-	W-			1992	W+	W+	W-	W-
1967						1993	W-	W	W	W-
1968				W-		1994			W	W
1969	W	W-	W-	W-		1995	W			C-
1970	W-					1996	C-			
1971	C	C-	C-	C-		1997		W	W+	W+
1972		W-	W	W+		1998	W+	W	C-	C
1973	W		C-	C+		1999	C	C-	C-	C+
1974	C+	C	C-	C-		2000	C+			
1975	C-	C-	C	C+						

Legend: C - Weak La Niña C Moderate La Niña C+ Strong La Niña

W - Weak El Niño W moderate El Niño W+ Strong El Niño

Table 2.3a: Occurrence of El Niño and La Niña episodes through the years.

2.3.4 Trends in observed typhoons and other related calamities

Limited records of climate related calamities show that there is an apparent decline in the number of damaging typhoons defined in terms of the amount of damages caused (Table 2.3b). It also observed that number of damaging typhoons is lesser in times when there are strong ENSO events (i.e., 1982-83 and 1997-98) consistent with many observations in other regions. Drought records also bear the relation with

ENSO events except in 1997-98 events when no drought was recorded on or after the event. This is likely due to the mitigating effect of the transbasin transfer of water which started in 1998.

Year	Number of Damaging Typhoons	Number of Drought Episodes	Number of Earth-quakes	Year	Number of Damaging Typhoons	Number of Drought Episodes	Number of Earth-quakes
1970	2			1987	3	1	
1971	1			1988	3		
1972	1			1989	7		
1973	2			1990	6	1	1
1974	6			1991	1		
1975	0			1992	7		
1976	3			1993	6		
1977	4			1994	5		
1978	4			1995	7		
1979	4			1996	2		
1980	2			1997	3		
1981	2			1998	4	1	
1982	4			1999	6		
1983	1	1		2000	4		
1984	2			2001	2		
1985	3			2002	3		
1986	3			2003	3		

Source: Unpublished reports of the provincial and regional disaster coordinating councils of Pampanga and Region 3.

Table 2.3b: Natural calamities in PCW from 1980-2003.

2.3.5 Trends in observed streamflow

Information on streamflow characteristics is essential in understanding and coping with water related disasters like floods and droughts. The rise and fall of the streamflows have far ranging influences on the occurrence and magnitude of floods and droughts. Characterizing streamflow patterns is however a complicated process owing to the many interacting factors and processes that determine the rise and fall of the streamflow. Among others, rainfall, land use and land cover, soil and topography belong to the key set of factors that influence streamflow. In this part of the study focus will be on the influence of rainfall.

Between 1980 and 2000, observed streamflow data show that as the rainfall rise and fall so does the streamflow. Figure 2.6 shows that the pattern of rainfall from 1980 to 2000 is very similar to the pattern of monthly streamflow averages for both the wet and dry season. This rainfall streamflow relation has been documented in many studies such as those reported in IPCC Third Assessment Report (2001). It can also be seen that the monthly observed streamflow averages are following a perceptible upward path except for the dry season flow that seems to be more static. The ENSO events appear to also affect the pattern of streamflow as the significant rise and drop of the hydrograph are coincide with the strong ENSO events of 1982-83 and 1997-98.

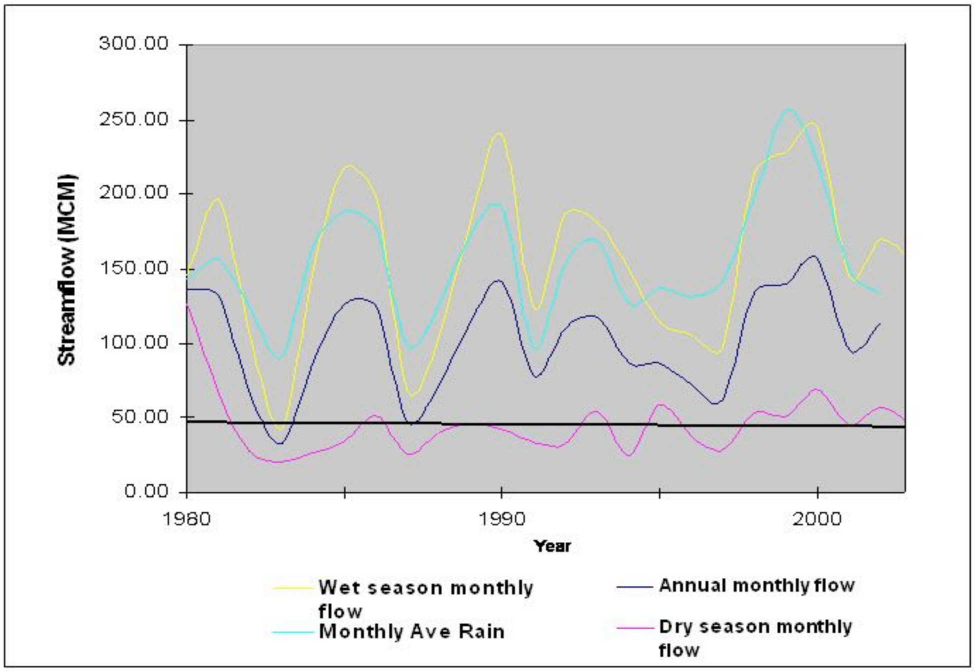


Fig. 2.6: Observed monthly average streamflow in PCW.

2.3.6 Future climate trends

Figure 2.7 illustrates the spatial distribution of a climate variable such as rainfall over the entire PCW using interpolation between the four grid point estimates of the regional climate generated through GCM experiments. The 3 points inside the PCW show the relative positions of the weather stations from where the observed climate data that was used for perturbing the GCM generated values came from. Color coded lines indicate areas with more or less the same downscaled rate of projected climate change at certain time period and emission scenario.

2.3.6.1 Future rainfall trends

In general, rainfall amount is expected to increase in 2020, 2050 and 2080 relative to the observed climatology from 1961-1990 (Table 2.4 and Figures 2.8a and 2.8b). For the 3 time slices, the increase will be less than the GCM results but greater than the projected estimates for Southeast Asia (IPCC, 2001). For 2020 the increase of 5.3 mm in the average daily rainfall is projected, 5.5 mm for 2050 and 5.6 mm for 2080. The increase is observed across the various climate scenarios (Figures 2.8c – 2.8e).

The maximum rainfall events per year is also detected to increase in the 3 future time periods compared to the long term average rainfall records in PCW with the exception of 3 projections, CCCma_A2a, CCCma_B2a 2050 and CCCma_A2a 2080, where the average maximum rainfall event was noted to decrease (**Figure 10a**). From the observed average maximum event of 20.6 mm, the increase over most of the projections range between 21.3 mm to 26.8 mm.

The average daily rainfall per month could generally decrease during the drier months (i.e., December to April) and increase during the wetter months (i.e., May to November) as shown in Figure 10c-10e. The dry months average daily rainfall will fall from the observed average of 0.67 mm to 0.58 mm average for all scenarios across all time slices with decrease rate increasing over time. In contrast, the wet months average daily rainfall will increase from the observed average of 8.3 mm to 9.01 mm average for all scenarios and future time slices.

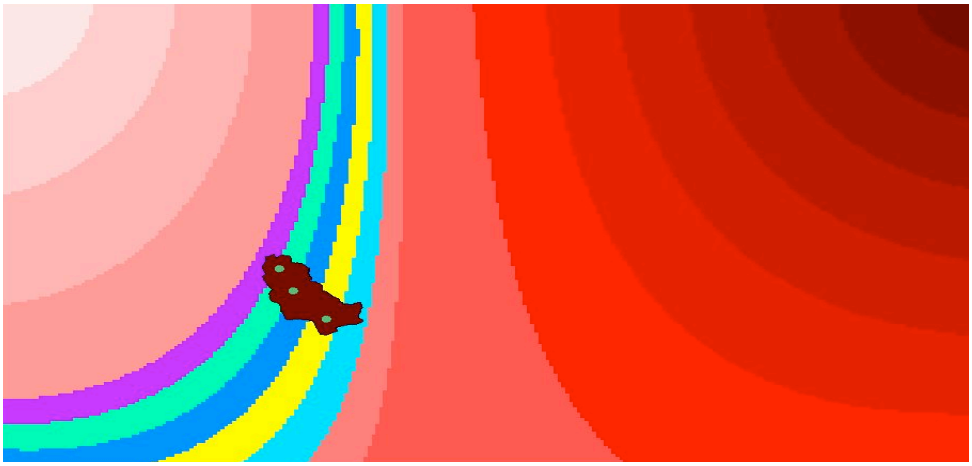


Fig. 2.7: Illustrative example of a downscaled climate scenario for PCW.

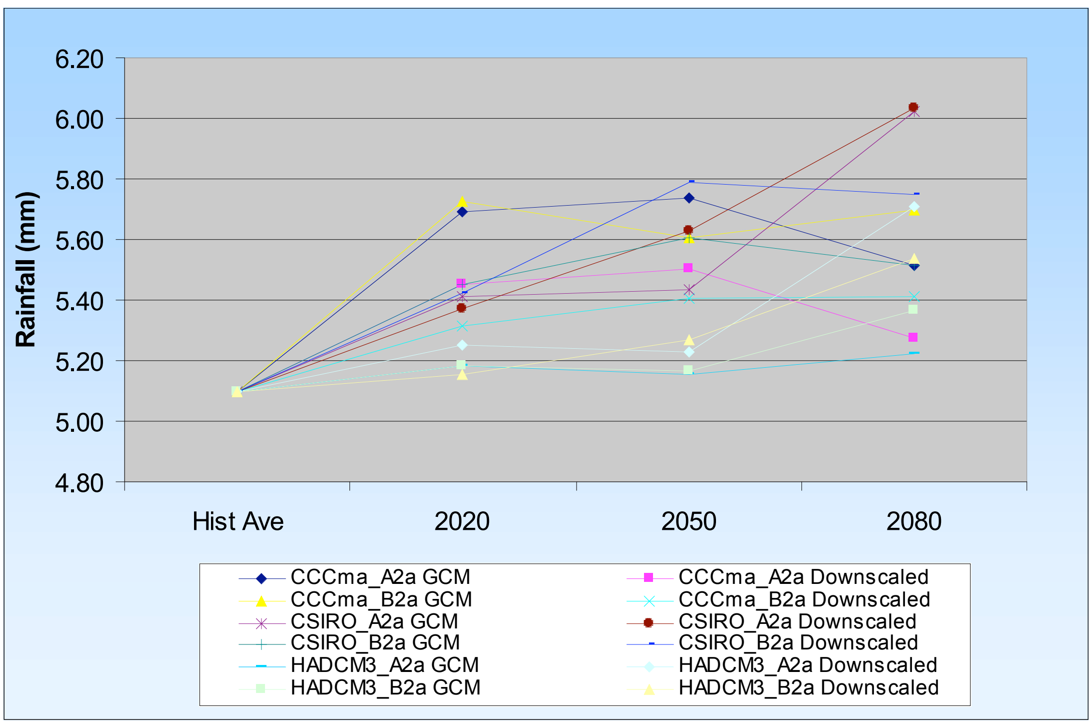


Fig. 2.8a: GCM Projected and Downscaled daily average rainfall for PCW.

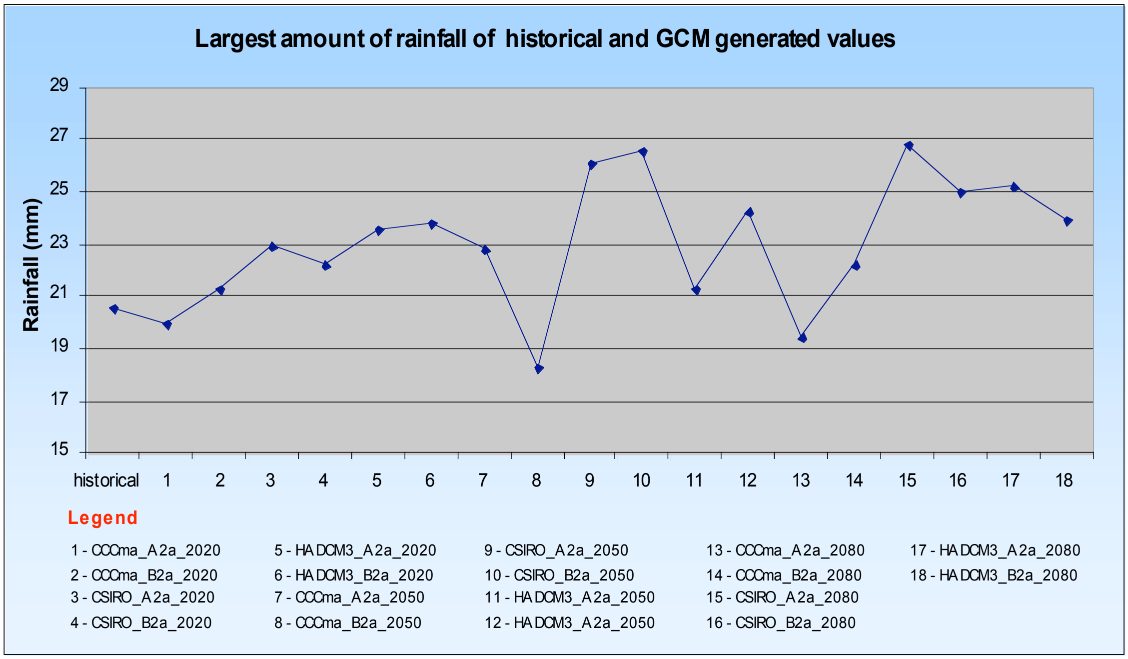


Fig. 2.8b: Largest amount of rainfall of historical and GCM generated values.

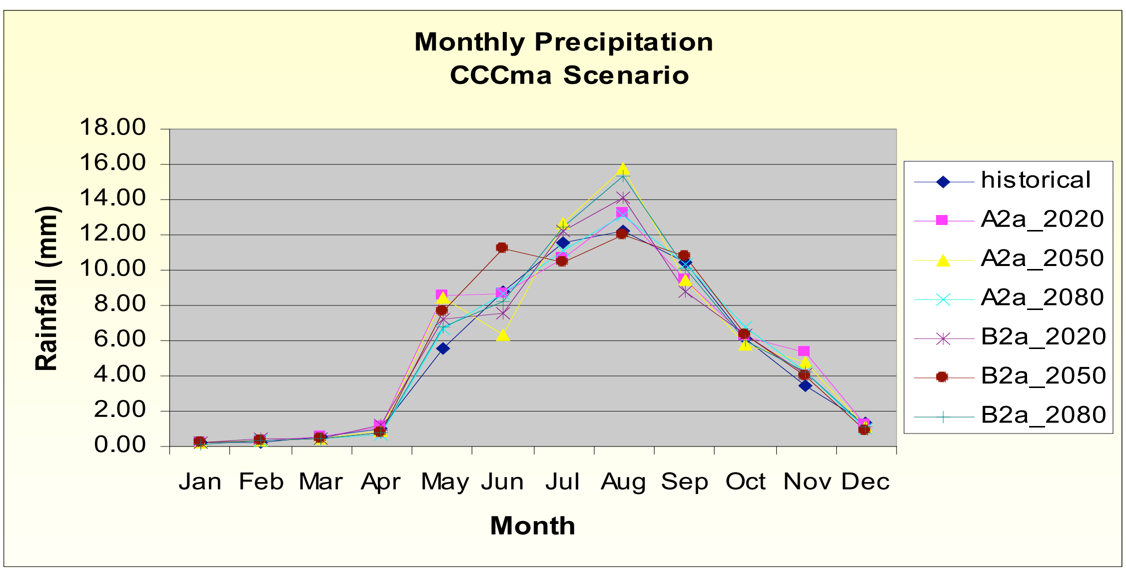


Fig. 2.8c: Monthly precipitation using CCCma.

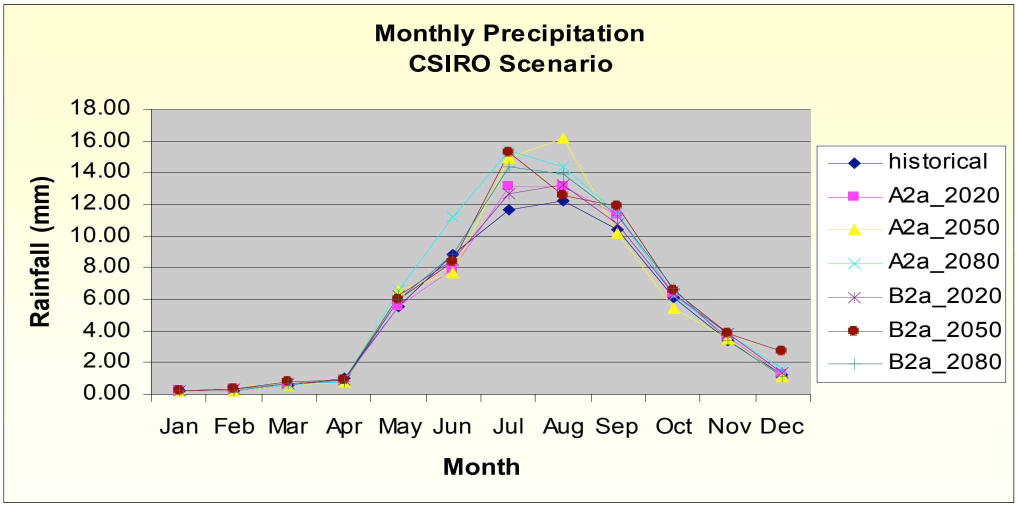


Fig. 2.8d: Monthly precipitation using CSIRO.

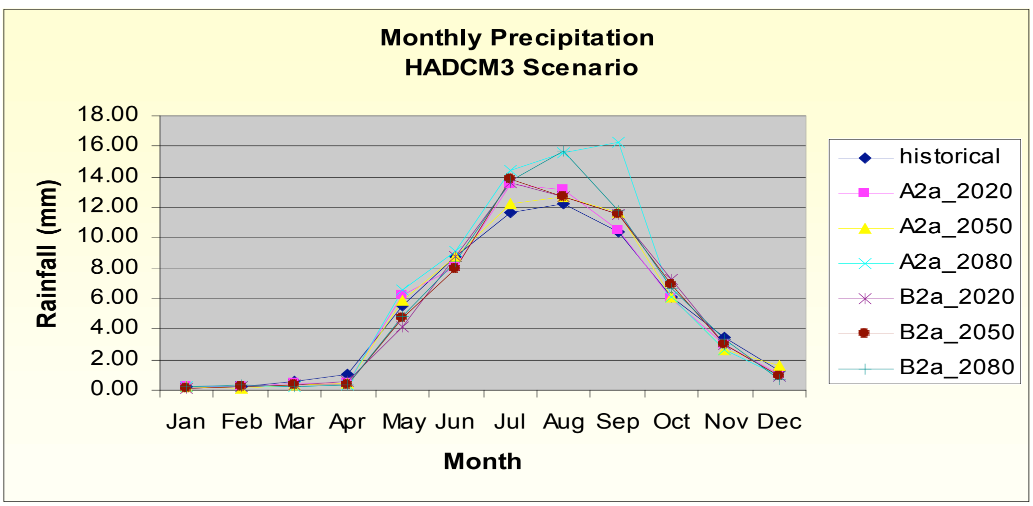


Fig. 2.8e: Monthly precipitation using HADCM3.

2.3.6.2 Future temperature trends

Generally (downscaled) temperature is projected to increase in 2020, 2050 and 2080 relative to the observed climatology from 1961-1990 (Tables 2.5a – 2.5b and Figures 2.10a – 2.10i). For the 3 time slices, temperature is projected to be less than the GCM results. Warming trend was also noted generally across all scenarios and future time periods relative to the observed temperature. These projections for the PCW are also higher than the projected estimates for Southeast Asia (IPCC, 2001). An exception to this is the tendency of almost half of the projections for minimum daily average temperature which was noted to cool down in 2020 based on the observed values and thereafter follow a warming path (Figure 2.9b).

The average daily maximum temperature is projected to increase over the observed values by 0.7 ^{0}C (2.1%) for 2020, 1.23 ^{0}C (3.8%) for 2050 and 2.05 ^{0}C (6.3%) for 2080 (Table 2.5a and Figure 2.9a). For average daily minimum temperature, warming over the observed average values is estimated to be 1.22 ^{0}C (3.0%) for 2020, 1.20 ^{0}C (5.4%) for 2050 and 2.0 ^{0}C (9.0%) for 2080 (Table 2.5b).

The warming trend is also seen in the increasing number of days the maximum and the minimum temperatures are above the daily normal values (Figures 2.10a and 2.10b). The number of days maximum temperature is above normal values decreased in almost all scenarios for 2020 but then is seen to increase over the normal values in 2050 and 2080. For the number of days the minimum temperature is above the long term average values, the trend is increasing in all the 3 future time slices. Likewise, the highest maximum and minimum temperature values per year is estimated to increase in all 3 future time periods and across all scenarios compared to the long term observed highest annual maximum and minimum temperatures (Figure 2.10c).

The average daily maximum and minimum temperatures per month are estimated to increase during the drier months (i.e., December to April) and during the wetter months (i.e., May to November) as shown in and Tables 2.5c and 2.5d, and Figures 2.10d – 2.10i. The dry months' average daily maximum temperature will increase from the observed average of 32.75 ^{0}C to 33.88 ^{0}C average for all scenarios across all time slices. In the wet months, the average daily maximum and minimum temperature will also increase from the observed average of 21.20 ^{0}C to 22.34^{0}C average for all scenarios and future time slices.

During the wet months, the average daily minimum and maximum temperatures are also seen to increase from the observed average values, from 23.11 ^{0}C to 24.35 ^{0}C for minimum temperature and from 32.42 ^{0}C to 33.65 ^{0}C for the maximum temperature. Furthermore ranges in projected change in rainfall and maximum and minimum temperature is shown in Table 2.5e.

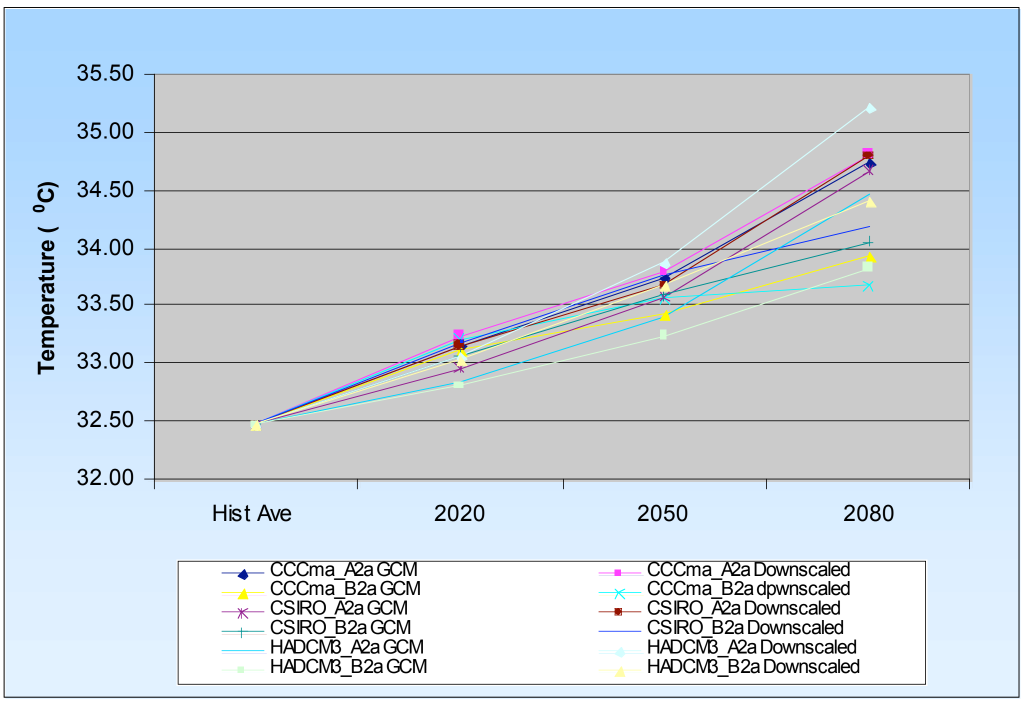


Fig. 2.9a: GCM and downscaled mean daily maximum temperature scenario for PCW.

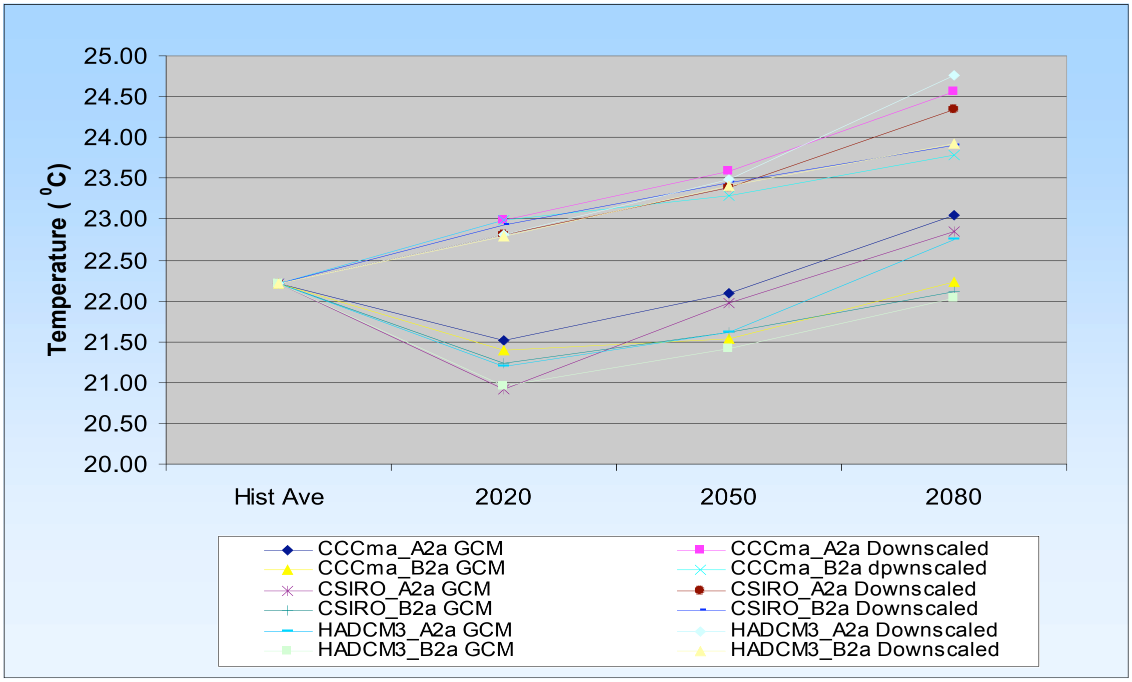


Fig. 2.9b: GCM and downscaled mean daily minimum temperature scenario for PCW.

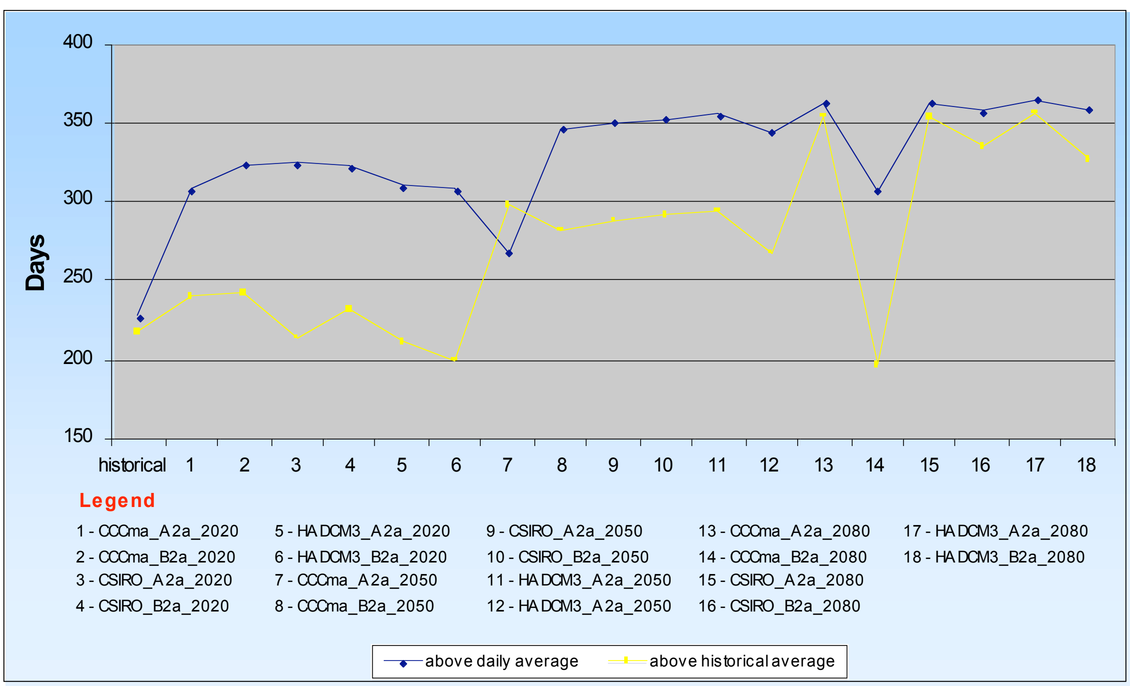


Fig. 2.10a: Number of days maximum temperature is above daily and historical average. (daily average is the average of daily values by month from 1961-2000)

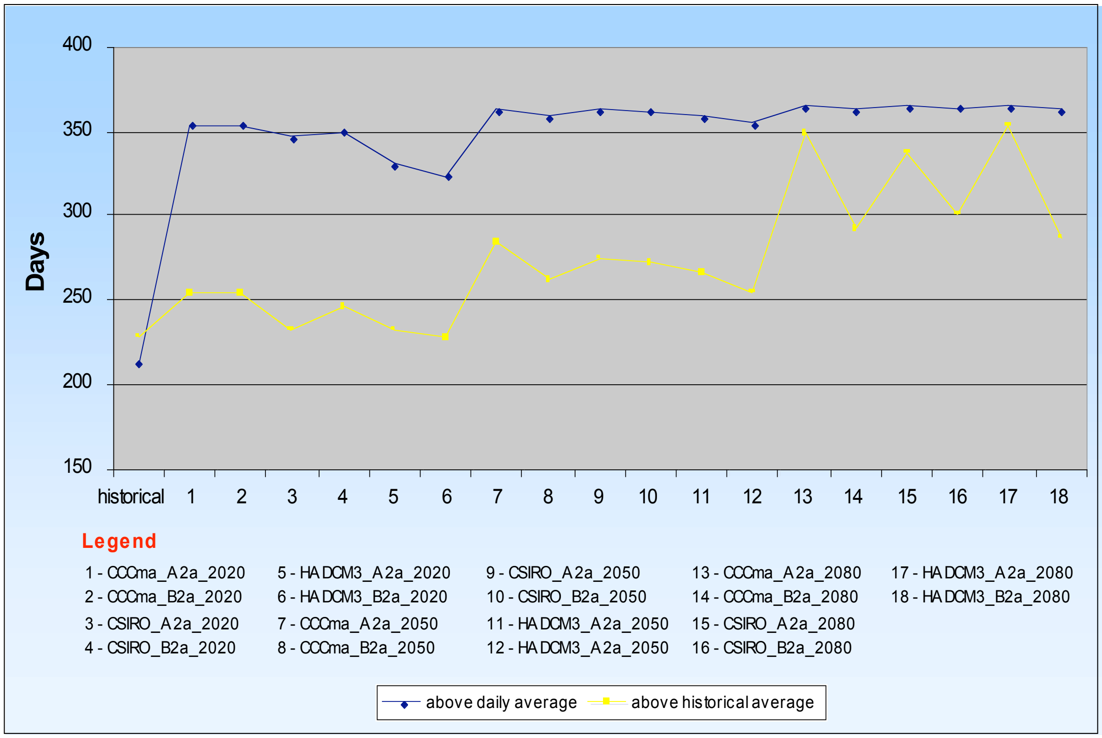


Fig. 2.10b: Number of days minimum temperature is above daily and historical average.

(daily average is the average of daily values by month from 1961-2000)

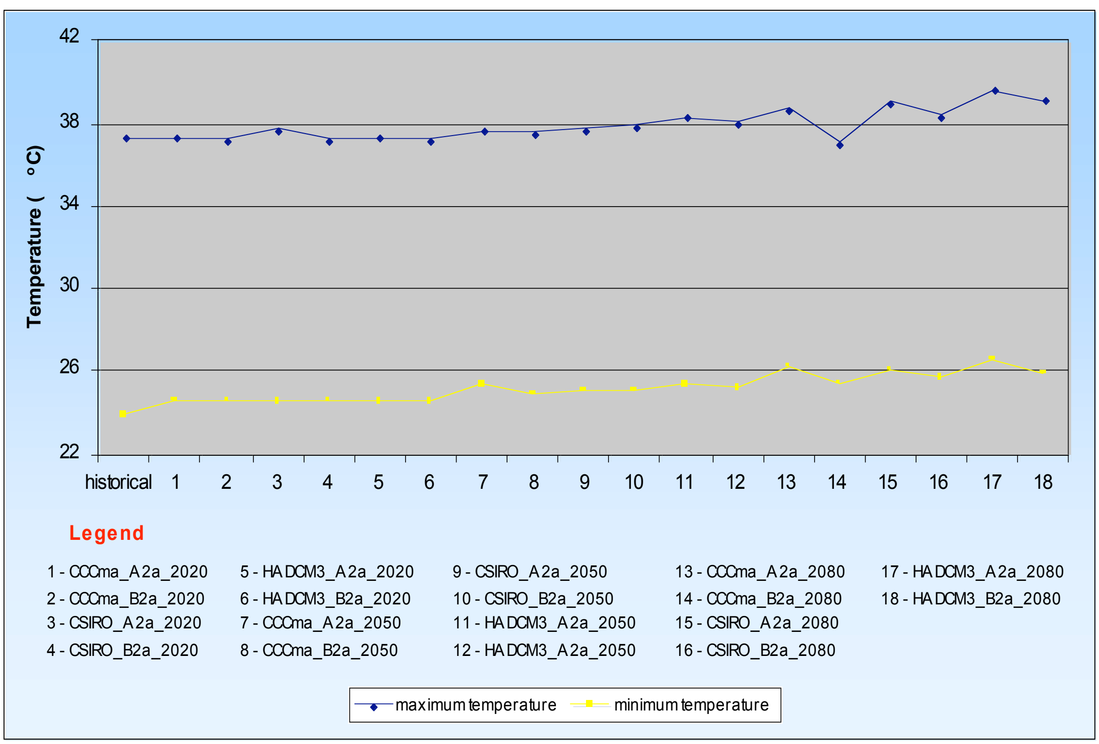


Fig. 2.10c: Highest maximum and minimum temperature of historical and GCM generated values.

Scenario	2020				2050				2080			
	GCM*		**Down-scaled GM***		**GCM***		**Down-scaled GCM***		**GCM***		**Down-scaled GCM***	
	mm	%	**mm**	%	**mm**	%	**mm**	%	**mm**	%	**mm**	%
CCCma_A2a	5.7	11.6	5.5	6.9	5.7	12.5	5.5	7.9	5.5	8.1	5.3	3.4
CCCma_B2a	5.7	12.3	5.3	4.2	5.6	9.9	5.4	5.9	5.7	11.7	5.4	6.1
CSIRO_A2a	5.4	6.1	5.4	5.3	5.4	6.5	5.6	10.3	6.0	18.1	6.0	18.4
CSIRO_B2a	5.5	6.9	5.4	6.4	5.6	9.9	5.8	13.5	5.5	8.2	5.7	12.7
HADCM3_A2a	5.2	1.6	5.3	2.9	5.2	1.1	5.2	2.5	5.2	2.4	5.7	12.0
HADCM3_B2a	5.2	1.6	5.2	1.0	5.2	1.3	5.3	3.3	5.4	5.2	5.5	8.6
Average	5.4	6.7	5.3	4.5	5.5	6.9	5.5	7.2	5.6	8.9	5.6	10.2
SE Asia IPCC (2001)		2.4		2.4		4.6		4.6		8.5		8.5
*Average Daily Value observed average daily value 5.10												

Table 2.4: GCM and downscaled mean daily rainfall for PCW.

Scenario	2020				2050				2080			
	GCM*		**Down-scaled GCM***		**GCM***		**Down-scaled GCM***		**GCM***		**Down-scaled GCM***	
	C	%	**C**	%	**C**	%	**C**	%	**C**	%	**C**	%
CCCma_A2a	33.2	2.1	33.2	2.3	33.7	3.9	33.8	4.1	34.7	6.9	34.8	7.1
CCCma_B2a	33.1	2.0	33.2	2.3	33.4	2.9	33.6	3.3	33.9	4.5	33.7	3.7
CSIRO_A2a	33.0	1.5	33.2	2.1	33.6	3.4	33.7	3.7	34.7	6.7	34.8	7.1
CSIRO_B2a	33.1	1.8	33.2	2.2	33.6	3.4	33.8	3.9	34.0	4.8	34.2	5.2
HADCM3_A2a	32.8	1.1	33.1	1.8	33.4	2.8	33.9	4.3	34.5	6.1	35.2	8.4
HADCM3_B2a	32.8	1.0	33.0	1.7	33.2	2.4	33.7	3.7	33.8	4.1	34.4	5.9
Average	33.0	1.6	33.2	2.1	33.5	3.1	33.7	3.8	34.3	5.5	34.5	6.3
SE Asia IPCC (2001)		1		1		2		2		2.8		2.8
*Average daily values observed average daily value 32.48												

Note: SE Asia values are summer average temperature

Table 2.5a: GCM and downscaled mean daily maximum temperature for PCW.

Scenario	2020				2050				2080			
	GCM*		Down-scaled GCM*		GCM*		Down-scaled GCM*		GCM*		Down-scaled GCM*	
	^{0}C	%	^{0}C	%	^{0}C	%	^{0}C	%	^{0}C	%	^{0}C	%
CCCma_A2a	21.5	-3.1	23.0	3.5	22.1	-0.6	23.6	6.1	23.1	3.7	24.6	10.5
CCCma_B2a	21.4	-3.7	23.0	3.5	21.5	-3.0	23.3	4.8	22.2	0.0	23.8	7.0
CSIRO_A2a	20.9	-5.9	22.8	2.7	22.0	-1.2	23.4	5.2	22.8	2.8	24.4	9.6
CSIRO_B2a	21.2	-4.4	22.9	3.2	21.6	-2.7	23.5	5.6	22.1	-0.5	23.9	7.6
HADCM3_A2a	21.2	-4.6	22.8	2.7	21.6	-2.7	23.5	5.7	22.8	2.4	24.8	11.4
HADCM3_B2a	21.0	-5.7	22.8	2.5	21.4	-3.6	23.4	5.3	22.0	-0.8	23.9	7.7
Average	21.2	-4.6	22.9	3.0	21.7	-2.3	23.4	5.4	22.5	1.3	24.2	9.0
SE Asia IPCC (2001)		1.1		1.1		2.3		2.3		3.2		3
*Average daily values observed value 22.22												

Note: SE Asia values are winter average temperature

Table 2.5b: GCM and downscaled mean daily minimum temperature for PCW.

Month	Observed	Average for all Scenarios	Average for all Scenarios 2020	Average for all Scenarios 2050	Average for all Scenarios 2080
January	31.37	32.21	31.69	32.06	32.90
February	32.24	33.45	32.80	33.38	34.17
March	33.49	34.74	34.18	34.74	35.31
April	35.11	36.75	36.06	36.68	37.50
May	35.24	36.61	36.00	36.53	37.31
June	32.71	34.14	33.55	34.13	34.76
July	32.36	33.57	32.93	33.59	34.20
August	30.85	32.24	31.70	32.25	32.77
September	32.05	33.31	32.75	33.27	33.92
October	31.56	33.14	32.54	33.17	33.72
November	32.18	32.54	31.93	32.51	33.19
December	31.57	32.26	31.70	32.17	32.91
Average	**32.56**	**33.75**	**33.15**	**33.71**	**34.39**
Dry Average	**32.75**	**33.88**	**33.28**	**33.81**	**34.56**
Wet Average	**32.42**	**33.65**	**33.05**	**33.64**	**34.27**

Table 2.5c: Averages of projected average daily maximum temperature for PCW.

Month	Observed	Average for all Scenarios	Average for all Scenarios 2020	Average for all Scenarios 2050	Average for all Scenarios 2080
January	20.13	21.33	20.68	21.30	22.00
February	20.41	21.48	20.93	21.34	22.18
March	21.45	22.65	22.09	22.52	23.33
April	22.97	24.35	23.74	24.25	25.07
May	23.83	24.74	24.06	24.65	25.52
June	23.12	24.63	23.97	24.57	25.34
July	23.61	24.91	24.27	24.79	25.66
August	23.48	24.89	24.24	24.85	25.59
September	23.40	24.75	24.10	24.67	25.49
October	22.27	23.84	23.16	23.82	24.56
November	22.08	22.70	22.05	22.60	23.46
December	21.04	21.91	21.31	21.78	22.62
Average	**22.31**	**23.52**	**22.88**	**23.43**	**24.23**
Dry Average	**21.20**	**22.34**	**21.75**	**22.24**	**23.04**
Wet Average	**23.11**	**24.35**	**23.69**	**24.28**	**25.09**

Table 2.5d: Averages of projected average daily maximum temperature for PCW.

Variable	Range	2020	2050	2080
Rainfall (mm)	Min	0.05 (0.9)	0.13 (2.5)	0.18 (3.5)
	Max	0.35 (6.9)	0.69 (13.5)	0.65 (12.7)
Minimum temperature (^{0}C)	Min	0.56 (2.5)	1.08 (4.9)	1.2 (5.4)
	Max	0.76 (3.4)	1.38 (6.2)	2.73 (12.3)
Maximum temperature (^{0}C)	Min	0.57 (1.8)	1.06 (3.3)	1.56 (4.8)
	Max	0.77 (2.4)	1.36 (4.2)	2.54 (7.8)
Note: Values in parenthesis are percent change				

Table 2.5e: Range of projected change in climate at PCW using various GCM results.

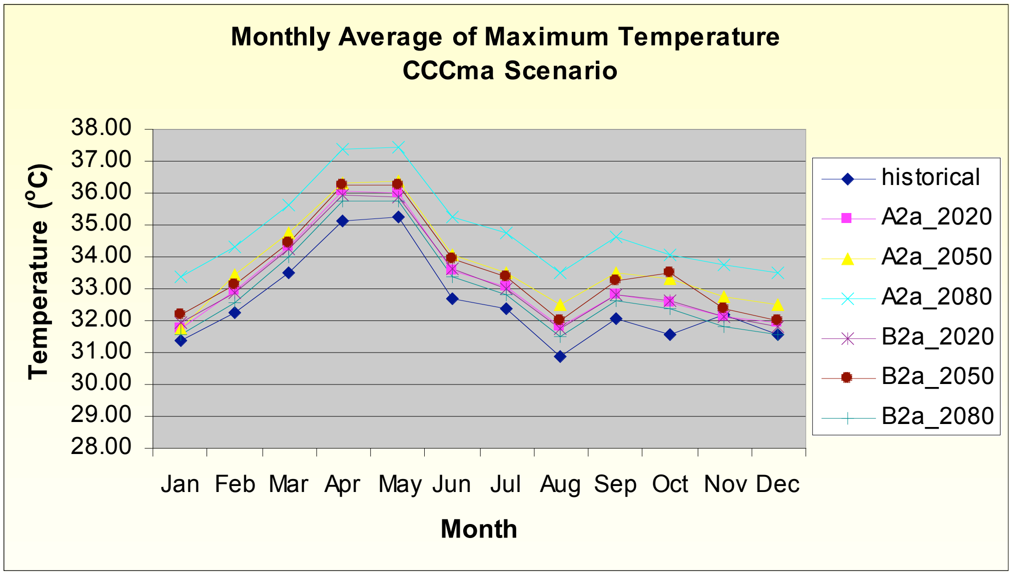


Fig. 2.10d: Monthly average of maximum temperature using CCCma.

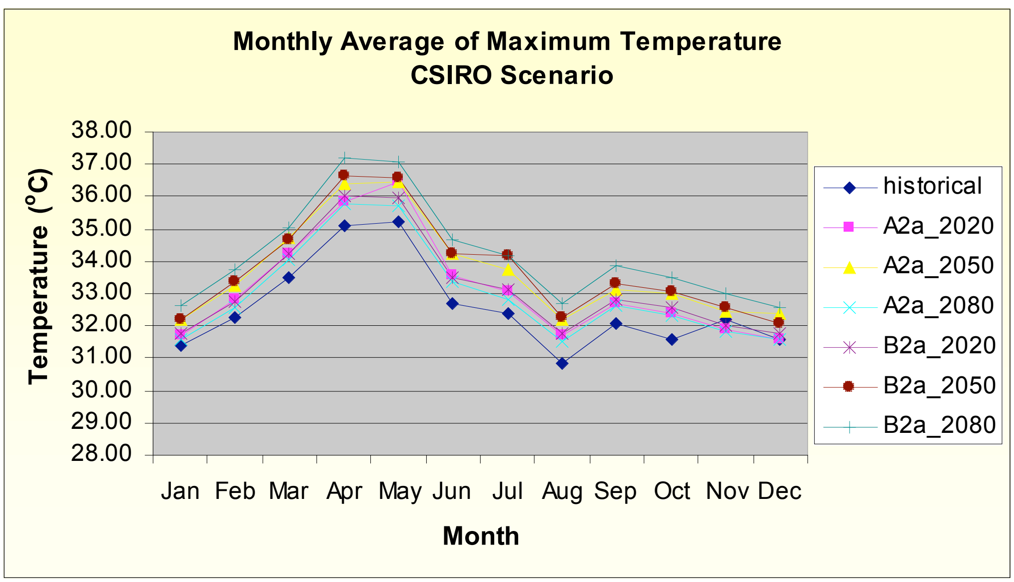


Fig. 2.10e: Monthly average maximum of temperature using CSIRO.

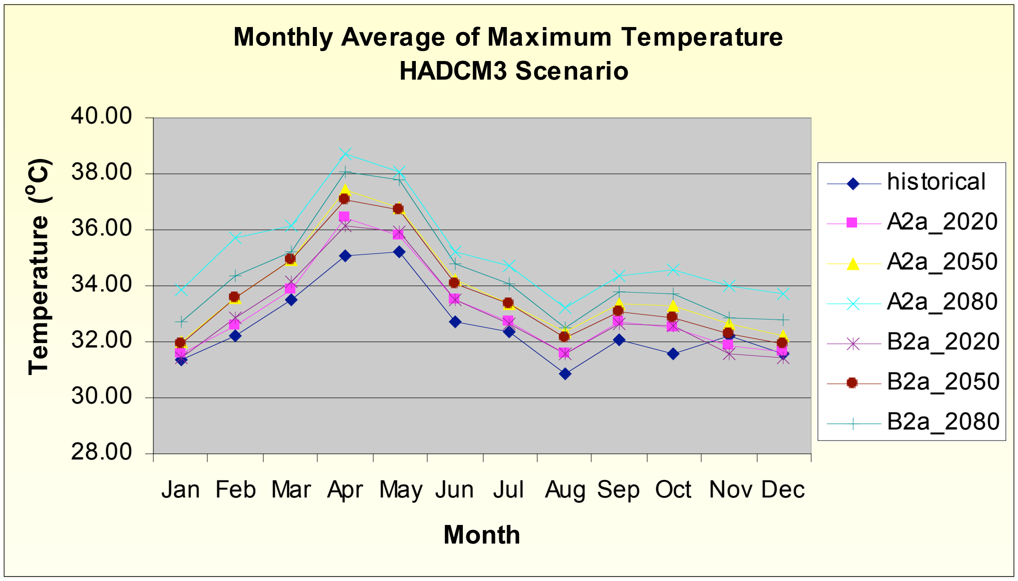


Fig. 2.10f: Monthly average of maximum temperature using HADCM3.

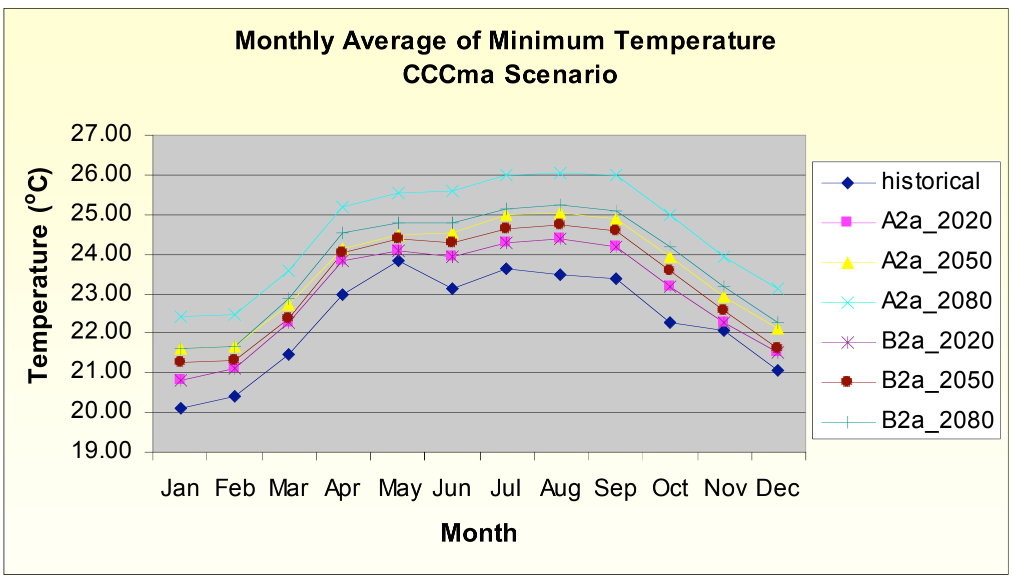


Fig. 2.10g: Monthly average minimum temperature using CCCma.

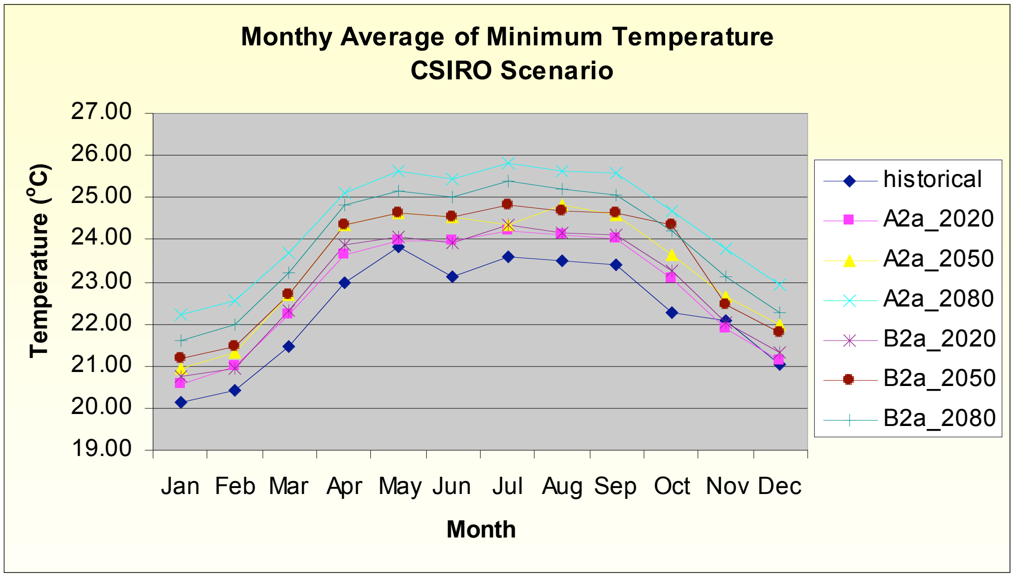


Fig. 2.10h: Monthly average of minimum temperature using CSIRO.

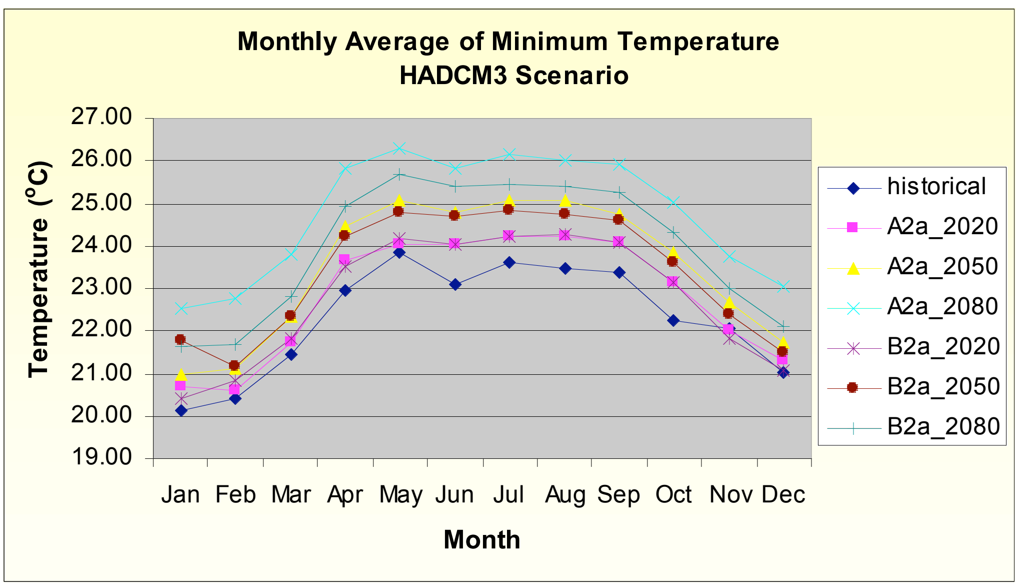


Fig. 2.10i: Monthly average minimum temperature using HADCM3.

2.3.6.3 Future Land Use and Land Cover

Land use and land cover affect to a considerable extent the streamflow behavior in a watershed. It affect the water balance in a watershed by influencing most hydrologic processes particularly infiltration, surface runoff and evapotranspiration. Hence, the assessment of potential impacts of climate change on streamflow needed information on the likely land use and land cover condition during the 3 time slices selected so that more accurate projection of streamflows in the future could be made considering the combined influences of future climate and land use and land cover conditions. In this regard several land use scenarios were formulated using CLUE-S model. A summary of the key results of the simulation of future land use and land cover conditions in PCW is shown in Table 2.6.

Generally an expanding trend is noted for forests cover and agroforestry in PCW. On the other end, brushland and grassland were noted from the results of simulation to decrease through time. Settlement areas are projected to increase in 2018 all the way to 2100 relative to 1999. Lastly, alienable and disposable lands including paddy fields are projected to decrease by more than 1,000 ha.

Land Use	**CLUE-S Result**					
	1999	**2018**	**2040**	**2050**	**2070**	**2100**
Brushland	375	305	112	75	38	22
Forest	30,376	46,146	52,490	53,632	54,569	54,643
Forest Plantation	12,231	11,851	11,411	11,211	10,811	10,211
Grassland	38,819	18,474	10,508	9,102	8,002	8,045
ISF / Agroforestry	664	5,689	7,942	8,444	9,043	9,543
Lake	4,023	4,023	4,023	4,023	4,023	4,023
A and D / Paddy	10,474	9,294	9,294	9,294	9,294	9,294
Settlement	359	1,538	1,538	1,538	1,538	1,538
TOTAL	**97,319**	**97,319**	**97,319**	**97,319**	**97,319**	**97,319**

Table 2.6: Projected land uses in Pantabangan-Carranglan watershed using CLUE-S.

2.4 Conclusion

The study characterized the recent and future trends in rainfall and temperature along with land use and land cover and the associated patterns of streamflow. Description of recent trends was made using primarily available records of observed climatology and hydrology. To characterize future trends in climate, downscaling of regional GCM results was undertaken. CLUE-S model was used to project the likely land use scenarios while SEA-BASIN model was used to predict the future changes in streamflow resulting from changes in climate and land use and land cover.

In 2080 rainfall is projected to increase by as much as 12.7 % and temperature to increase by more than 5% of the average observed values between 1960 and 1990. This change in climate could translate to about 17% increase in wet season streamflow and a decrease of around 35% in dry season streamflow of PCW.

3 Impacts and Vulnerability

3.1 Forest Ecosystems in the Pantabangan-Carranglan Watershed

3.1.1 Activities conducted

Climate change is expected to affect tropical forest ecosystems of the world. The impacts of climate change on forest ecosystems vulnerability are a major concern in developing countries like the Philippines. The Philippine watersheds are predicted to be adversely affected by climate change effects due to their present critical state and the varying stages of deterioration that they experience. Thus, the study assessed the impacts and vulnerability of forest ecosystems in Pantabangan-Carranglan Watershed to climate change. During the study series of workshops, consultation meetings, and focus group discussions were held with local communities, local government units and stakeholders.

3.1.2 Description of scientific methods and data

3.1.2.1 Data Collection

The study employed a combination of data collection methods: secondary data gathering, focus group discussions, workshops, consultation meetings, and direct field observation. The following sections briefly discussed these methods.

Secondary data gathering: Available secondary information on the biophysical aspect of the watershed was gathered from relevant agencies. These include data on land use, climate, soil, and topography.

Focus group discussion: Focus groups discussions (FGDs) were done to determine the impacts and vulnerability of forest ecosystems to climate change and at the same time validate present land use of the watershed. Participants of the FGDs include stakeholders, local government units, non-government organization, and the local communities. Qualitatively, the degree of present vulnerability of the forest ecosystems was assessed by aggregating and analyzing the results of FGDs.

3.1.3 Results and discussion

The following impacts of climate variability and extremes in the forest ecosystems in Pantabangan-Carranglan Watershed were identified by the local communities, stakeholders, LGUs, and people's organization during workshops, consultations, FGDs, and interviews.

3.1.3.1 Lowland farms

Early and late onset of the rainy season: Cropping pattern of lowland farms in Carranglan is being altered when rainy season begins earlier than the normal schedule. In Pantabangan, on the positive side, early onset of rainy season results to earlier planting of palay and other agricultural crops. Participants from Pantabangan also noted that during this season, there is an increase in the production of energy and irrigation. Thus, lowland farms in Carranglan are considered to be strongly vulnerable to impacts of early onset of rainy season while lowland farms in Pantabangan are moderately vulnerable.

Similarly, late onset of rainy season alters the cropping pattern of lowland farms in Carranglan. In Pantabangan, rainfed farms in lowland areas are the most affected by late onset of rainy season since they depend heavily on frequency of rain during the year. Moreover, decreases in the production of palay, other agricultural crops and irrigation water were observed. Thus, lowland farms in Pantabangan are strongly vulnerable to late onset of rainy season.

La Niña: La Niña causes flooding and excessive crop damages to lowland farms in Carranglan. Consequently, these result to occurrences of excessive soil erosion and revenue losses. On the other hand, in Pantabangan lowland farms, occurrences of flash flooding were usually observed. These result to less fertility of the soil, erosion, siltation, and low production of agricultural products. In terms of vulnerability to La Niña, lowland farms in Carranglan are more vulnerable than those farms in Pantabangan.

El Niño: In lowland farms of Carranglan, El Nino event results to stagnation of the growth of the crops and most often leads to death of crops. As a consequence, farmers have low production of their crops hence, low revenue. Likewise, during El Niño episode, occurrences of fire that can destroy lowland farms are likely to happen. This is due to the presence of highly combustible agricultural wastes that can ignite easily. Similarly, productions of agricultural products from lowland farms of Pantabangan are affected by El Niño event. Likewise, irrigation water is not much during El Niño event thus, only farms near the source are being serviced with irrigation water. Thus, lowland farms in both Pantabangan and Carranglan areas are very strongly vulnerable to El Niño.

High temperature/summer season: High temperature/summer season reduces the productivity of the lowland farms in Carranglan and Pantabangan resulting to decreased revenue. To increase income derived from farming, farmers put more inputs into their farms resulting to increased farm costs. In terms of degree of vulnerability, lowland farms in Pantabangan are more vulnerable than those farms in Carranglan.

Rainy season: Rainy season has favorable effect on the lowland farms of Pantabangan and Carranglan. During this climate event, farmers incur low cost in producing their agricultural products. As a consequence, more profit is gained by the farmers from their farm produce. Thus, lowland farms in Pantabangan are only moderately vulnerable to rainy season.

3.1.3.2 Upland farms

Early and late onset of rainy season: Early onset of rainy season results to early cultivation of upland farms and expansion of kaingin areas in Pantabangan, Nueva Ecija. According to the farmers in Pantabangan, there is relatively high agricultural production during such time resulting to higher income from farming.

Late onset of rainy season on the other hand results to further destruction of forest in Pantabangan area because the farmers have to resort to other sources of livelihood to feed their families. When rain comes late, farmers experience low production of their farms thus, farm produce are not at all sufficient to meet the needs of the family. Thus, in terms of vulnerability, upland farms in Pantabangan are moderately affected by early onset of rainy season. Pantabangan on the other hand is very vulnerable to late onset of the rainy season. For the farmers at Carranglan, early or late onset of rainy season has adverse impact on the cropping pattern. For the farmers from Ma. Aurora, this climate variability has not been observed because the climatic condition in the area is more or less the same all throughout the year. According to the participants, rain is evenly distributed all throughout the year.

La Niña: Too much rain resulting from occurrence of La Niña affects the crops. Based on experiences, farmers mentioned that flooding and excessive soil erosion occurs during this type of climate extreme. As a consequence, soils in the upland farms lose their fertility and crops were being damaged. This observation is true for upland farms of Carranglan and Ma. Aurora. In Pantabangan however, upland farms are not very much affected by La Niña. According to the participants, there is less erosion occurring in their upland farms despite the pouring of more rains. Among the three municipalities, Carranglan area is the most vulnerable to La Niña. Pantabangan on the other hand is moderately vulnerable while Ma. Aurora is slightly vulnerable.

El Niño: While characteristics of La Niña and El Niño episodes are very much different, both of them have similar effects on the crops. As what the participants from the Carranglan and Pantabangan areas mentioned, both La Niña and El Niño are damaging to crops. The unavailability of moisture during El Niño episodes causes the crops to experience water stress inhibiting the growth of the plants. For flowering crops, El Niño limits or at worst hinders the production of flowers of the plants. This obviously results to non-productivity of the crops and loss of income of the farmers. Moreover, for some farmers, El Niño episodes results to loss of opportunity for farmers to plant as rain is an essential element in the early stages of life of the plants/crops. Furthermore, the participants noted that extreme dryness in the area increases the possibility of the occurrence of fire in the area resulting to burning and/or damaging of the upland farms.

Aside from its effect on the growth of the plants/crops, the absence of rain results to extreme dryness of the soil causing the soil organisms to die. Soil microorganisms are important components of the soil. They mix the plant and animal residues into the soil creating humus, an essential component to attain good soil physical and chemical conditions (Brady, 1984).

Participants from Ma. Aurora noted that no serious impact of El Niño has occurred to them since they experience barely El Niño. In terms of the degree of vulnerability of the upland farms in the Pantabangan and Carranglan, the participants noted that the upland farms are very much vulnerable to El Niño

High temperature/summer season: Impacts of high temperature/summer season are quite similar to the observed impacts of El Nino. According to the participants of Carranglan and Pantabangan, this climate variability causes damage to crops. Likewise, during this season, upland farms are observed to be prone to fire. On the positive note however, high temperature/summer season prevents attacks of fungi because there is not much moisture present. Fungi thrive well in moist areas.

Upland farms in Ma. Aurora on the other hand, do not experience any impact caused by high temperature/summer season because they have rain all year round. The degree of vulnerability varies among areas. For instance in Carranglan, the participants reported that the upland farms are not very much vulnerable to high temperature/summer season while Pantabangan is very much vulnerable to the mentioned climate variability.

Rainy season: Characterized by an abundant supply of water, this climate variability is found to be favorable to the growth of crops in upland farms in Carranglan. However, with too much moisture available during this season, risk of attack of fungal infestation is very high. In Pantabangan, rainy season results to expansion of kaingin farms resulting to reduction of forest cover, occurrence of soil erosion and decrease in soil fertility. On the positive note, the participants mentioned that rainy season results to increase in agricultural production. The degree of vulnerability of upland farms in Carranglan and Pantabangan to the rainy season is not very profound. According to the participants, upland farms in the mentioned areas are only moderately vulnerable to the rainy season.

3.1.3.3 Tree plantation

Early or late onset of rainy season: Early onset of the rainy season has positive effect on the trees in the plantation areas of Pantabangan and Carranglan, Nueva Ecija and Ma. Aurora, Aurora. Early onset of rain in the area results to fast growth rate of the trees. As a consequence, the areas covered by the Pantabangan-Carranglan watershed are moderately affected by early onset of the rainy season. Late onset of rainy season on the other hand, results to the death of seedlings in the Carranglan area thus decreasing survival rate of seedlings planted. In Pantabangan, grown trees in the plantation areas dry-up whenever rain comes in late. During this time, the participants mentioned that planting of trees is not at all possible. In Ma. Aurora, late onset of rainy season results to moderate growth of the trees or decreased productivity of the tree plantation areas.

Degree of vunerability in the plantation areas of the Pantabangan, Carranglan and Ma. Aurora varies with the type of climate variability. For instance, tree plantations are moderately or slightly vulnerable to early onset of the rainy season while these same areas are strongly vulnerable to late onset of the rainy season.

La Niña: La Niña has no pronounced impact on the tree plantations in Ma. Aurora. Tree plantation areas in Carranglan and Pantabangan on the other hand, are affected by the occurrence of La Niña. Because of too much rain, tree plantations are more prone to pests and diseases resulting to decay of the trees. In some instances, growth of trees is hampered during La Niña events. Likewise, this climate variability enhances occurrence of soil erosion in the area because the soil particles become loose due to excessive rainfall. In terms of degree of vulnerability of the plantation areas, it was noted by the participants from Carranglan that tree plantation areas in their municipality are strongly vulnerable to La Niña events.

El Niño: Impacts of El Niño episodes to tree plantation areas in Carranglan include: (1) increased vulnerability to fire; (2) increased mortality due to drought; (3) increased cost of maintenance; (4) decreased activity of the soil organisms; and (5) stunted/slow growth of trees. In Pantabangan however, participants mentioned that the growth of trees are observed to be slow. In Ma. Aurora, El Niño has no pronounced impact because as mentioned earlier, rain is evenly distributed all throughout the year. Among the municipalities covered by the Pantabangan-Carranglan watershed, tree plantation areas in Carranglan were observed to be very strongly vulnerable to El Niño events.

High temperature/summer season: The degree of impacts of high temperature/summer season was lesser compare to that of El Niño in the Pantabangan and Carranglan areas. Since tree plantation areas get enough rain in Ma. Aurora, no impact of El Niño has been recorded. Thus, in terms of degree of vulnerability of the tree plantations to El Niño event, participants mentioned that the ecosystem is moderately vulnerable to the mentioned climate variability.

Rainy season: The rainy season is found to be favorable to the tree plantation areas in the Pantabangan-Carranglan watershed. As mentioned by the participants, such season is the best time to plant trees because there is sufficient supply of water. Likewise, it promotes good growth to already established tree plantations. Furthermore, a participant mentioned that rainy season is found to promote lesser maintenance cost in the tree plantation areas. Degree of vulnerability of the plantation areas is mild only thus, no adaptation measure is undertaken in the area.

3.1.3.4 Grassland

Early onset of the rainy season: Experiences showed that early onset of rainy season protect the grassland areas from fire. This observation is also true in grassland areas in Pantabangan and Carranglan. The participants also mentioned that grassland areas are less prone to be burned during this season because grasses cannot be easily ignited since they are not too dry. In addition, grassland areas in Pantabangan were observed to have early regeneration during this season. However, early onset of rainy season promotes occurrence of soil erosion. Thus, grassland areas in Pantabangan and Carranglan are moderately vulnerable to early onset of rainy season while grasslands in Ma. Aurora are not vulnerable to the mentioned climate variability.

Late onset of rainy season: Late onset of rainy season results to drying up of grasses and accumulation of fuel in the grassland areas. As a consequence, grassland areas in Pantabangan and Carranglan become more prone to fire during this season. Moreover, in Pantabangan, soil becomes too dry resulting to cracking of the soil.

La Niña: Characterized by too much rainfall, La Nina episodes caused the occurrence of soil erosion in the grassland areas of Pantabangan and Carranglan. Moreover, in Carranglan, La Niña causes flooding and death of soil organisms resulting to the decrease in soil fertility. Aside from soil organisms, the mortality of birds, rats and other predator species were observed during La Niña event. Hence, grassland areas in Pantabangan and Carranglan are moderately vulnerable to La Niña.

El Niño: Extreme dryness caused by El Niño results to occurrence of grass fires in Pantabangan and Carranglan. El Niño episodes also reduce the amount of forage resulting to a low production of cattle. In Carranglan, there was also decreased in soil fertility as a consequence of the decreased in soil organisms population. As mentioned before, soil organisms are important components of soil to maintain its fertility. Unwanted microorganisms were eradicated during El Niño, thus it favorable in some ways. Therefore, grassland areas in Pantabangan and Carranglan areas are strongly vulnerable to El Niño.

High temperature/summer season: The effects of high temperature/summer season in grassland areas of Carranglan are similar to the effects of El Niño to the mentioned ecosystem. However, observed impacts were in lesser degree during summer season/high temperature compared to the impacts of El Niño. In Pantabangan, grasses were observed to die and soils become more compacted during the summer season or when temperature is extremely high. In terms of degree of vulnerability, grassland areas in Pantabangan and Carranglan areas are strongly vulnerable to high temperature/summer season.

Rainy season: Rainy season is found to be favorable to grassland areas in Carranglan. However, in Pantabangan, rainy season has both positive and negative effects. According to the participants, negative effects of rainy season are erosion, siltation and flash floods while positive effects include increased production in livestock. Generally, grasslands in Pantabangan and Carranglan are mildly vulnerable to rainy season.

3.1.3.5 Natural forests

Early onset of the rainy season: Early onset of the rainy season affects the flowering of the trees inside the natural forests of Carranglan. While no concrete effect was mentioned, it is assumed that early onset of rainy season caused early flowering of the trees. In Pantabangan however, presence of water in the springs is observed during this climate variability. Likewise, the participants mentioned that early onset of rain promotes early composting of the soil resulting to higher soil nutrition.

Natural forests in Carranglan are moderately vulnerable to the early onset of rainy season while natural forests in Pantabangan are strongly vulnerable.

Late onset of the rainy season: When there is late onset of rainy season, it was observed that trees in the natural forests of Pantabangan dried up. As a consequence, wildlife present in the area migrates to other thickly forested areas. In terms of vulnerability, natural forests of Pantabangan are moderately vulnerable to impacts of late onset of rainy season.

La Niña: Impacts of La Niña vary on the location of the natural forests. For instance, in the natural forests of Carranglan, La Niña affects cross pollination of trees while in Pantabangan, forests are destroyed and soil erosion occurs during La Niña event. In the natural forests of Ma. Aurora, occurrence of soil erosion is the common impact of La Niña. In terms of degree of vulnerability, participants from Pantabangan noted that natural forests in their area are moderately affected by La Niña while participants from Ma. Aurora mentioned that natural forests in their place are very much vulnerable to La Niña.

El Niño: Compared with La Niña, impacts of El Niño are more severe. For instance in Carranglan, natural forests are in greater risk of forest fire during El Nino event. Moreover, extraction of forest products in the natural forests is more prevalent during El Niño because climate is very dry. Access roads to the natural forests are passable and safe hence very conducive to transporting harvested forest products. As a consequence, reduction of forest resources is observed during El Niño. Another impact of El Niño to natural forests is the reduction of available water needed for the growth of the trees. As a result, there is less productivity of the forests observed during El Niño event. In Pantabangan however, El Niño has no significant impact in most parts of the natural forests although there are portions of the mentioned ecosystem that are affected. Hence, natural forests of Carranglan and Pantabangan are moderately vulnerable to El Niño event.

High temperature/summer season: High temperature/summer season affects only portions of the natural forests in Pantabangan while it has no significant effect on the natural forests of Carranglan and Ma. Aurora. In terms of degree of vulnerability, natural forests of Pantabangan are moderately prone to high temperature/summer season.

Rainy season: Similar to the noted effects on natural forests whenever there is high temperature/summer season, rainy season brings very small impact on the natural forests because there are only small portion of natural forests that are affected. Moreover, the mentioned ecosystem is only moderately vulnerable to rainy season.

3.1.3.6 Soil and water

Early onset of the rainy season: Early onset of the rainy season results to abundant supply of water in all the three areas. In the soil, there is increased decomposition rate resulting to increased fertility of the soil. Soil and water in the three areas are moderately vulnerable to early onset of the rainy season.

Late onset of rainy season: Late onset of rainy season results to hardening of soil in Carranglan while in Pantabangan, the consequences include: decrease in elevation of water level in dam, decrease in potable water supply and agriculture and livestock, and increase in water demand. In Ma. Aurora, late onset of the rainy season results to decreased stream/spring flow. Degree of vulnerability of the three areas to late onset of rainy season varies. For instance, Carranglan and Ma. Aurora are moderately vulnerable to late onset of rainy season while Pantabangan is strongly vuilnerable to the mentioned season

La Niña: The impacts of La Niña in soil and water resources of Pantabangan, Carranglan and Ma. Aurora are the same. These include: (1) replenishment of water in the reservoir, (2) occurrence of excessive soil erosion resulting to siltation in the water resources; (3) flooding; and (4) loss of soil fertility. In terms of degree of vulnerability however, it was noted by the participants that among the three areas, soil and water resources of Ma. Aurora was less likely to be vulnerable compared with those in Carranglan and Pantabangan.

El Niño: The absence of enough water results to the lowering of ground water level in all three areas covered by the Pantabangan-Carranglan watershed. Moreover, according to the participants from Carrangalan, the soil in their area cracks during El Niño event. In Pantabangan, observations noted other than lowering of ground water level include: (1) acidity of the soil decreases; (2) soil nutrients are reduced; (3) areas that are usually underwater appear during drought days resulting to availability of additional areas for crop production. Among the three areas, participants noted that soil and water resources of Ma. Aurora are moderately vulnerable while soil and water resources of Carranglan and Pantabangan are very strongly vulnerable to El Niño.

High temperature/summer season: According to the participants, impacts of high temperature/summer season to soil and water resources of Pantabangan are the milder versions of the effects of El Niño in the same resources. In Carranglan area, participants noted that there is rapid evaporation and disturbance of the activities of soil microorganisms. Soil and water resources of Pantabangan are strongly vulnerable to high temperature/summer season while the same resources of Carranglan are very strongly vulnerable to the mentioned season.

Rainy season: In general, rainy season is favorable to soil and water resources of the Pantabangan-Carranglan watershed. Specifically, it results to abundance of water supply both for domestic and irrigation purposes. Likewise, it is favorable for land preparation needed for crop production. Thus, rainy season only moderately affects the soil and water resources of Pantabangan.

3.1.4 Conclusions

Climate change may have positive or negative impacts to different forest ecosystems in Pantabangan-Carranglan Watershed. The degree of impacts of climate change varies depending on the type and location of forest ecosystems being affected. La Niña and El Niño have the most negative impacts to forest ecosystems. The lowland farms, grasslands and natural forests are the most vulnerable among the forest ecosystems.

3.2 Social Systems: Vulnerability of Watershed Communities and Different User-Institutions to Climate Variability and Extremes in the Philippines

3.2.1 Activities conducted

- Determined the major natural occurrences experienced by the local communities in PCW that reflect climate variability and extremes over the last few decades;
- Identified the vulnerable socio-economic groups in the communities and their location in the watershed;
- Identified the different user-institutions in the watershed;
- Categorized the extent and nature of their vulnerability in relation to climate variability and extremes;
- Identified the socioeconomic factors influencing the vulnerability of local communities; and

- Identified the conclusions that could be 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.

3.2.2 Description of scientific methods and data

3.2.2.1 Analytical framework

"Vulnerability" is one of the key terms in the climate change literature that has many different definitions and subject to various interpretations and usage. A number of authors have recently reviewed the various definitions and approaches to vulnerability in relation to climate change (see for instance Cutter 1996, Adger 1999, UNEP 2001, Brooks 2003). Despite this, confusion appears to continue and the term seems to defy consensus usage (Few 2003).

This study views vulnerability along the lines of the IPCC Fourth Assessment Report which defines vulnerability to climate change as "the propensity of human and ecological systems to suffer harm and ability to respond to stresses imposed as a result of climate change impacts" (Chapter 17, Zero Order Draft). Specifically, vulnerability refers to the propensity of households and communities in the Pantabangan-Carranglan Watershed to suffer harm and their ability to respond to stresses resulting from the impacts of climate variability and extremes. This conceptualization is consistent with Moss et al. (1999) who view vulnerability to be a function of at least two major variables: sensitivity of the system to climate-related events and its coping capacity.

On the other hand, climate variability refers to the variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events (IPCC 2001). It may be due to natural internal processes within the climate system (internal variability) or to variation in natural or anthropogenic external forcing (external variability).

Meanwhile, climate extreme is an event that is rare within its statistical reference distribution at a particular place (Gray 2000). By definition, its characteristics vary from place to place. Gray (2000) further refers to it as an event that is average of a number of weather events over a certain period of time (e.g., rainfall over a season).

For the purpose of this study and in consideration of the climatic type in PCW, the occurrence of the following climate variability and extremes were assessed: such as El Nino, La Nina, early onset or delay of rainy season, prolonged rains, and occurrence of typhoons.

At the operational level, the nature and degree of people's vulnerability to the mentioned climate-related events were examined at two levels: community and household levels. At the community level, the degree of vulnerability of various socioeconomic groups was assessed by looking at the extent of impacts (positive or negative) of climate variability and extremes to four major areas of concern of local communities, namely, food availability, water supply, livelihood, and health condition. In addition, the communities' adaptation strategies are also identified and their effectiveness determined, as a measure of their degree of vulnerability.

To better understand the nature of the household's vulnerability to climate variability and extremes, vulnerability indicators were identified and an index developed, based on abovementioned four major areas of concerns of PCW communities. This approach was patterned after the framework of Moss et al. (1999) on "multi-level indicator of vulnerability to climate variability and climate change" where vulnerability index was developed from several indicators based on the system's sensitivity and coping capacity. Such an index was also necessary to determine the factors influencing the households' vulnerability to climate variability and extremes. In the present study, a number of factors were hypothesized to influence their vulnerability. These are demographic (age, gender, ethnic affiliation, educational attainment, household size, migration), socioeconomic (income, household assets, expenditures, land ownership, farm size, farm practices, no. of organizations, access to transportation, credit, and information), geographic (distance to market), and number of coping mechanisms).

Figure 3.1 presents the analytical framework used in the present study. Community level analysis is represented by the arrow from the climate variability and extremes box at the upper left hand side, to the impacts and adaptations boxes on the middle portion, and finally to the degree of present vulnerability box. As illustrated, the degree of present vulnerability of the different socioeconomic groups at the community level is influenced by the combined impacts of climate variability and extremes and the effectiveness of the groups' adaptation strategies. On the other hand, the household level analysis is represented by the box on the hypothesized factors at the lower left hand corner, and the vulnerability index/indicators box at the extreme right corner. The direction of arrow from the hypothesized factors to the vulnerability index represents a causal relationship, that is, the socioeconomic factors as determinants of the household's vulnerability.

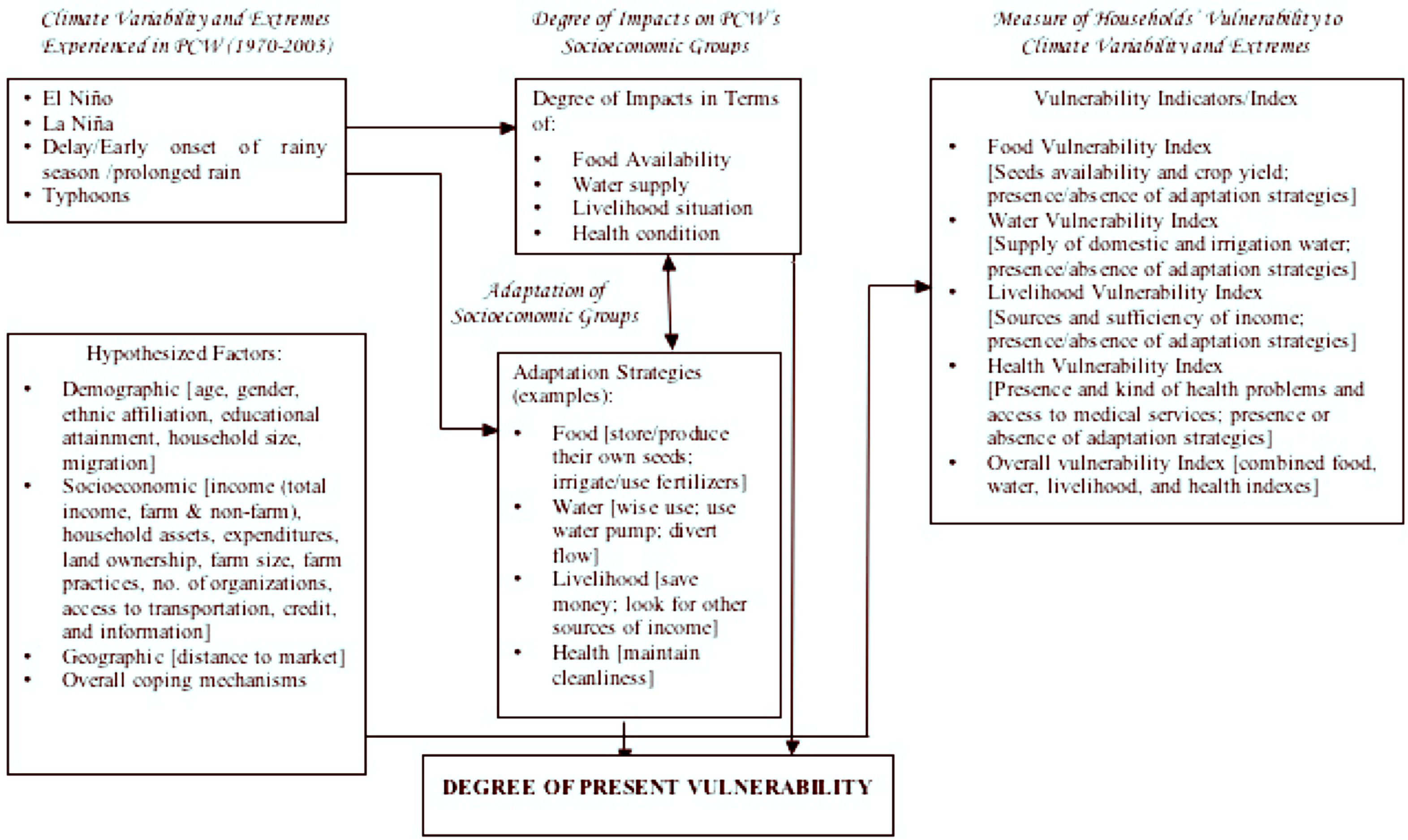


Fig. 3.1: Conceptual framework showing the determinants of vulnerability of households and communities in the Pantabangan-Carranglan watershed (PCW) to climate variability and extremes.

3.2.2.2 Data collection

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

Secondary data gathering: Available secondary information on the biophysical and socioeconomic aspects of the watershed was gathered from relevant agencies to understand the local and regional context of the watershed communities. Sources of information include municipal and provincial development plans, socio-demographic 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 as briefly discussed below.

Meanwhile, climatic data like rainfall, temperature, El Niño and La Niña episodes, and other natural calamities that occurred in the PCW were obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and the weather station near the watershed. These data were gathered on a historical basis.

Household survey: Household survey was conducted to determine the vulnerability of households to climate variability and extremes and the socioeconomic factors influencing their vulnerability. It made used of a pre-tested interview schedule that contained 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 heath; and 5) adaptation strategies.

The survey covered the four municipalities of the three different provinces encompassing the watershed. These are Pantabangan and Carrangalan in Nueva Ecija, Alfonso-Castañeda in Nueva Vizcaya, and Ma. Aurora in Aurora. Twenty-six (26) of the 36 barangays within the watershed area were covered. Ten (10) of 36 barangays were excluded since a very small portion of their respective areas is within the watershed boundary and hence very few people live in these areas. A total of 375 respondents were randomly selected using the barangay records. This sampling technique employed was adopted from Chua (1999) which allows a 0.05 permissible error and 95% confidence interval level.

Use of PRA techniques: Focus groups discussions (FGDs) were 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 was 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 were also conducted for purposes of mapping these areas.

3.2.2.3 Data analysis

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

Qualitative analysis: Results from FGDs conducted in 21 barangays were combined and synthesized to identify the climate variability and extremes experienced by the local communities in the last few decades, determine the more vulnerable groups and their location in the watershed, and assess the nature and extent and of their vulnerability. This qualitative analysis centered 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 the community vulnerability and complements the more micro and quantitative analysis done at the household level.

Development of vulnerability index: Results from the household survey were used to develop a vulnerability index. The index consisted of four major component indicators: food, water, livelihood, and health. The indicators were further divided into subcategories each of which were given corresponding weights. Drawing from the framework of Moss et al. (1999), the subcategories comprised relevant variables that involved 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 were considered in the development of the index, that of the researchers' representing the experts' view and that of the watershed communities' representing the local stakeholders' view. The first iteration for the vulnerability index computation was based on the researchers' judgment that made use of composite weighing where all the four major components (food, water, livelihood, and health) were given equal weights (25 points each) with a grand total of 100 points. The subcategories under each major component were also given corresponding weights with each level of the subcategories given equal points.

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

Table 3.1 presents the vulnerability index developed using the researchers' judgment and that of the local communities'. Discussion on the index is reserved under the section on results and discussions.

Correlation and regression analysis: The computed final vulnerability index, food index, water index, livelihood index and health index were correlated with the factors hypothesized to influence vulnerability using Spearman Correlation. As indicated in Figure 3.1, these included 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 was done using SPSS for Windows, version 10. 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 was assessed using an arbitrary set of rules (Table 3.2) related to five key parameters, namely: slope, elevation, distance form 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 was determined for the entire watershed using the category of low, medium and high vulnerability. A single vulnerability map was developed by overlaying all the individual maps produced for each of the five parameters.

On the other hand, GPS readings were 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 were plotted in the vulnerable map of the watershed developed through GIS. The idea was to determine whether there will be congruence between vulnerable areas identified using biophysical parameters though GIS with what the stakeholders see as vulnerable places.

Vulnerability Index	Weights Provided by Researchers	Weights Provided by Local Communities		
		Pantabangan	Carranglan	P & C Combined
A. Food	25	25	40	32.5
a.1 Seeds availability	12.5	20	15	17.5
a.1.1 Availability of planting materials	4.17	8	7	7.5
i. Available anytime of the years	0	3	2	2.5
ii. Seasonal or hard to find	4.17	5	5	5
a.1.2 Is it affecter 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
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
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
iii. Others: hepatitis, bronchitis, sore eyes, etc.	2.09	2	1	1.5
d.3 Access to medical services	6.25	3	2	2.5
i. Sufficient	0	1	0.5	0.75
ii. Not sufficient	6.25	2	1.5	1.75
d.4 Adaptation strategies	6.25	4	2	3
i. With adaptation	0	1.8	0.5	1.15
ii. Without adaptation	6.25	2.2	1.5	1.85

Table 3.1: Multi-level indicator of vulnerability of PCW households to climate variability and extremes using varying weights.

LAND-USE	SLOPE			ELEVATION (M)			DIST FROM ROAD (M)			DIST FROM RIVER (M)			DIST 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 3.2: Criteria used for the assessment of vulnerability of PCW to climate change.

3.2.2.4 Description of the different user-institutions of the Pantabangan-Carranglan watershed

Department of Environment and Natural Resources (DENR): The DENR as provided for under Section 4 of Executive Order 192 is mandated to be 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. The department 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 there from for the welfare of the present and future generations of Filipinos.

The watershed is covered by the DENR Region 3 (Central Luzon) Office. There are two Provincial Environment and Natural Resources Office and Community Environment and Natural Resources Officers that manage the watershed. These are from Aurora and Nueva Ecija. (DENR, 2004)

National Irrigation Administration (NIA): The National Irrigation Administration of the Republic of the Philippines is a government-owned and controlled corporation (GOCC) tasked with the development and operation of irrigation systems all over the country.

On March 20, 1980, Letter of Instructions No. 1002 granted the NIA the authority to manage, protect, develop and rehabilitate certain portions of the Pantabangan-Carranglan Watershed Reservation. Republic Act No. 3601, as amended by Presidential Decrees No. 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. The areas under the jurisdiction of NIA are Ma. Aurora, Aurora, Alfonso-Castañeda, Nueva Vizcaya, Carranglan and Pantabangan, Nueva Ecija (NIACOMBISCON, 2003).

The Pantabangan dam irrigates some 100,000 hectares of farmland during wet and dry season for the whole Upper Pampanga River Integrated Irrigation System (UPRIIS) service area. (NIA, n.d).

National Power Corporation (NPC): The Corporation was created in 1936, and has since engaged in power generation and transmission all over the country. In more than 60 years of existence, NPC dominated the local power sector, having enjoyed a virtual monopoly of the generation f power and transmission facilities in the country. At present, their services were close to 300 billion power users, consisting primarily of utilities and electric cooperatives as well as industries (NPC, n. d.)

A memorandum of agreement signed on April 1, 1997 turned over to NPC total of 14,166 hectares of Pantabangan-Carranglan Watershed. The areas under the jurisdiction of NPC are Daldalayap, Bunga, Carranglan, of Sector I, Burgos, Carranglan of Sector II and Conversion, Pantabangan of Sector III.

Local Government Unit (LGU):

A. ***Province:*** Chapter 1 section 45 of the Local Government Code of the Philippines stated that a province is composed of a cluster of municipalities, or municipalities and component cities, and as a political and corporate unit of government serves as a dynamic mechanism for developmental processes and effective governance of local government units within its territorial jurisdiction.

B. ***Municipality:*** Chapter 1 section 440 of the Local Government Code of the Philippines, define a municipality as consisting of a group of barangays, which serves primarily as a general-purpose government for the coordination and delivery of basic, regular and direct services and effective governance of the inhabitants within its territorial jurisdiction.

C. ***Barangay Development Council:*** The barangay is the basic political unit of the Philippines (title one chapter I section 384of Local Government Code) it serves as the primary planning and implementing unit of government policies, plans, programs, projects, and activities in the community, and as a forum wherein the collective views of the people may be expressed, crystallized and considered, and where disputes may be amicably settled. The sanggunian, its legislative body, is primarily responsible for the enactment of ordinances to promote the general welfare of its inhabitants. It is composed of the punong barangay, the presiding officer, and the seven (7) regular sangguniang barangay members elected at large, and Sangguniang Kabataan chairman, as members (Chanrobles, 2003).

The different provinces and municipalities that cover the watershed are:

1. Pantabangan and Carranglan, Nueva Ecija;
2. Alfonso Castañeda and Dupax del Sur, Nueva Vizcaya and;
3. Ma. Aurora, Aurora.

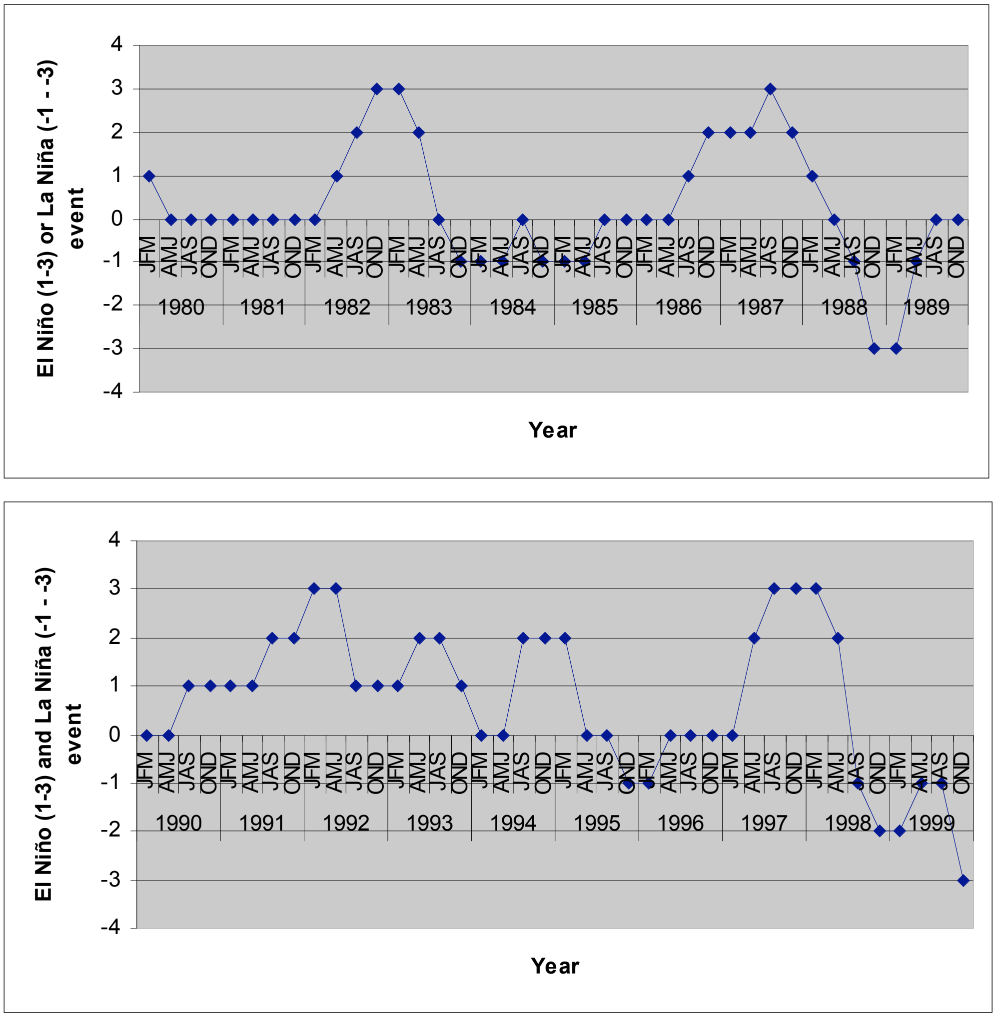
3.2.3 Results and discussion

3.2.3.1 Major climate variability and extremes in PCW

The major climate variability and extremes experienced in the area as identified by the respondents are listed in Table 3.3. The respondents also noted several El Niño episodes, particularly its occurrences in 1979-1980, 1982-1983, and 1997-1999. These observations agreed with El Niño events recorded by PAGASA, as shown in Figure 3.2. Prolonged rains were also observed by the respondents in the 1984 which also marked the occurrence of a weak La Niña event (Figure 14).

Year	Climate Variability and Extremes
1974	Typhoon Didang
1978	Destructive typhoon Kading
1979-1980	Drought / El Niño
1982-1983	El Niño
1984	Prolonged rains
1989	Delay on the onset of rainy season
1997-1999	El Niño
2000	Delay on the onset of rainy season
2001	Early onset of rainy season
2002	Delay on the onset of rainy season
2003	Early onset of rainy season

Table 3.3: Major climate variability and extremes identified by respondents from key informant interviews and FGDs.



Legend: 3 = strong El Niño event; 2 = moderate El Niño event; 1 = weak El Niño event
-3 = strong La Niña event; -2 = moderate La Niña event; -1 = weak El Niña event
0 = no El Niño or La Niña event

Fig. 3.2: El Niño and La Niña events recorded by PAGASA from 1980-1999.

Variability in the onset of rainy season has become a "common" event since the year 2000. This indicates the unpredictability in the arrival of rains which may be early or delayed. On the other hand, forest fires are frequent in the area and occur yearly since 1980s. Between the years 1980-1988 alone, DENR has recorded an average of 43 forest fires occurred in the PCW yearly, damaging an average of 600 ha of forests a year or a total of 25,783 ha for nine years. Though the high frequency of forest fire incidences coincided with the almost cyclic occurrences of climate variability and extremes such as El Niño and delays in the onset of rainy season, its prevalence cannot be highly attributed to the latter. According to the respondents, most forest fires were intentional since people are practicing kaingin (slash and burn) and charcoal making. These practices have become a source of livelihood for them after the termination of the RP-Japan Reforestation Project which provided jobs to the residents.

3.2.3.2 Impacts of climate variability and extremes: local communities and institutions

Local communities:

Considering PCW's geographic location, it can be said that all the communities living in PCW are generally vulnerable to climate variability and extremes including the other natural calamities like earthquake. Data available from PAGASA indicates that from 1980 to 1995, a total of 58 strong typhoons ─ an average of 3.62 typhoons per year ─ inflicted major damages in the area (Table 3.4). In addition, three major drought episodes occurred during the same period with an average interval of only about years per episode. These drought episodes occurred in 1983, 1987 and 1991 during which the lowest total annual rainfall and water inflow were registered in the period 1980-2001 (Figure 15). This is not to mention the major 1990 earthquake that claimed thousands of lives in Northern Luzon and almost ravaged Baguio into a ghost City, which also wreaked havoc on the watershed.

Year	**Number of Damaging Typhoons**	**Number of Drought Episodes**	**Number of Earthquake Occurrences**
1980	2		
1981	3		
1982	4		
1983	3	1	
1984	2		
1985	3		
1986	3		
1987	3	1	
1988	3		
1989	7		
1990	6		1
1991	1	1	
1992	7		
1993	1		
1994	4		
1995	6		

Source: Data from PAGASA

Table 3.4: Natural calamities in PCW from 1980-1995

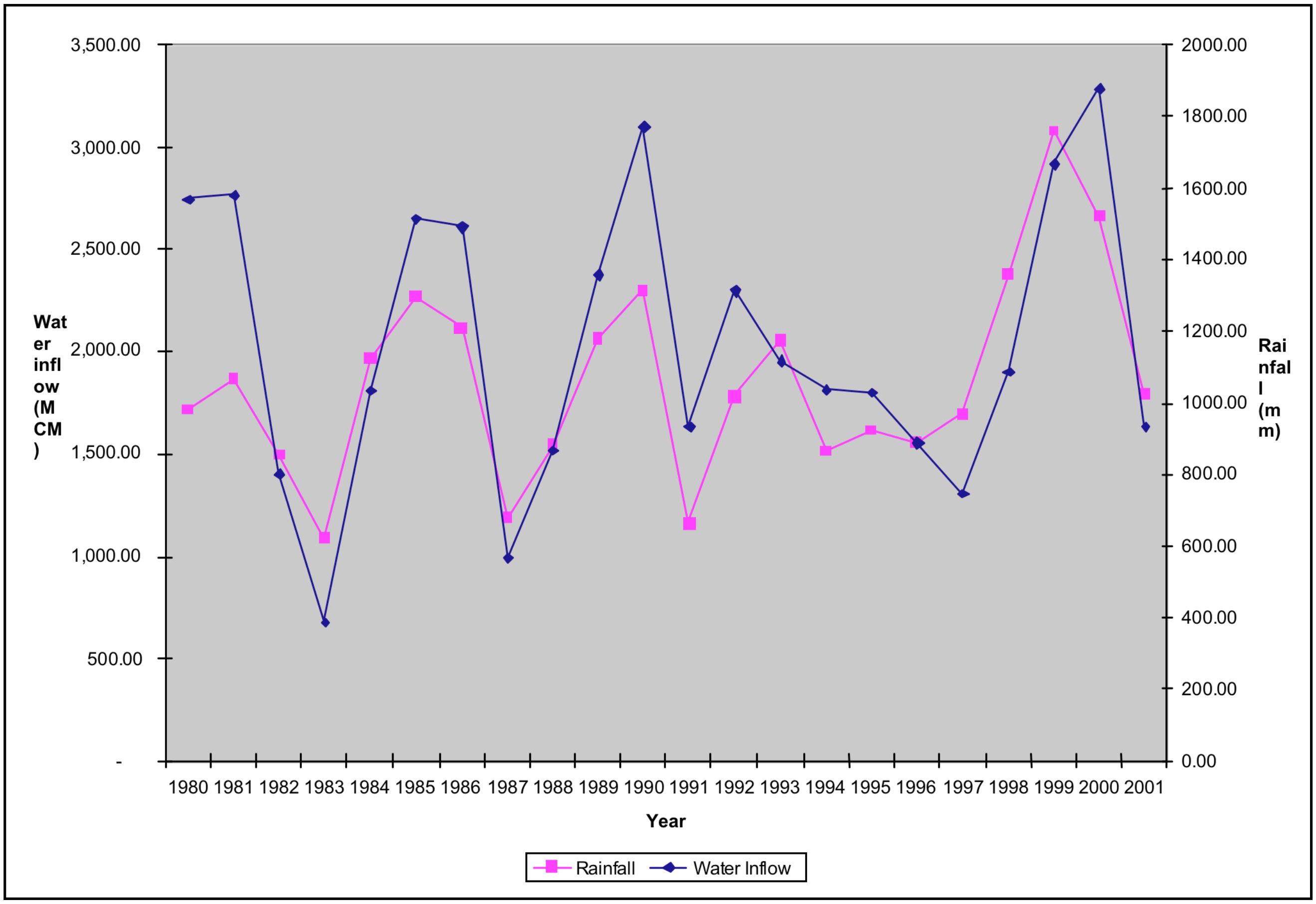


Fig. 3.3: Total annual water inflow and total annual rainfall in the Pantabangan-Carrangalan watershed (1980-2001).

While the exact value of damages inflicted by the past climate-related events in PCW is not available, anecdotal evidences gathered during the survey and FGDs affirmed that significant losses were incurred. These were in the form of claimed human lives, destroyed properties and infrastructures, and damaged sources of livelihood especially farmlands and fishing areas. Decrease in crop yield was also pronounced in specific years. For instance, record from NIA indicates that in 1990, rice yield fell below average by more than two cavans per hectare in both wet and dry season cropping as a result of drought and typhoons during this year. Local people however claimed during the interviews and FGDs that crop lost could be as much as 100% as a result of droughts and floods (Table 3.5). Indeed, some community members are so vulnerable that even before they could fully recover from adverse impacts of previous events, another calamity will strike again that bring them back to the original desperate condition.

% Losses	Pantabangan	Carranglan	Ma. Aurora	Alfonso-Castañeda	Total
< 20	6.4	11.5		12.5	10.1
21 – 40	27.7	28.2	50.0	25.0	28.6
41 – 60	36.2	39.7	33.3	37.5	38.7
61 – 80	17.0	14.1			13.8
81 - 100	12.8	6.4	16.7	25.0	8.7
Total	100	100	100	100	100

Table 3.5: Percent (%) losses in rice production during CV&E.

Climate-related events were observed to have triggered several health problems such as diarrhea, amoebiasis, dehydration, dysentery, dengue, malaria, and typhoid. In the meantime, among the leading causes of morbidity in the PCW were respiratory ailments like pneumonia, bronchitis, acute respiratory infection and tuberculosis. Although not yet proven, these diseases may have also been caused by severe climate conditions. Skin disorders are also prevalent in the area which can be attributed to non-potability of water, poor health and unsanitary practices.

Assessment of vulnerability of the watershed by land use types using the five parameters discussed earlier (slope, elevation, distance from the road, distance from the river, and distance from the community center) with the aid of GIS revealed that more than 65% of the entire PCW is moderately vulnerable to climate extremes and change while more than 25% is highly vulnerable (Figure 3.4). Most of the areas that are highly vulnerable are forests, grasslands and brushlands by virtue mainly of their location in steep and highly elevated areas and proximity to roads. Areas that are moderately vulnerable are largely grasslands, brushlands and forests.

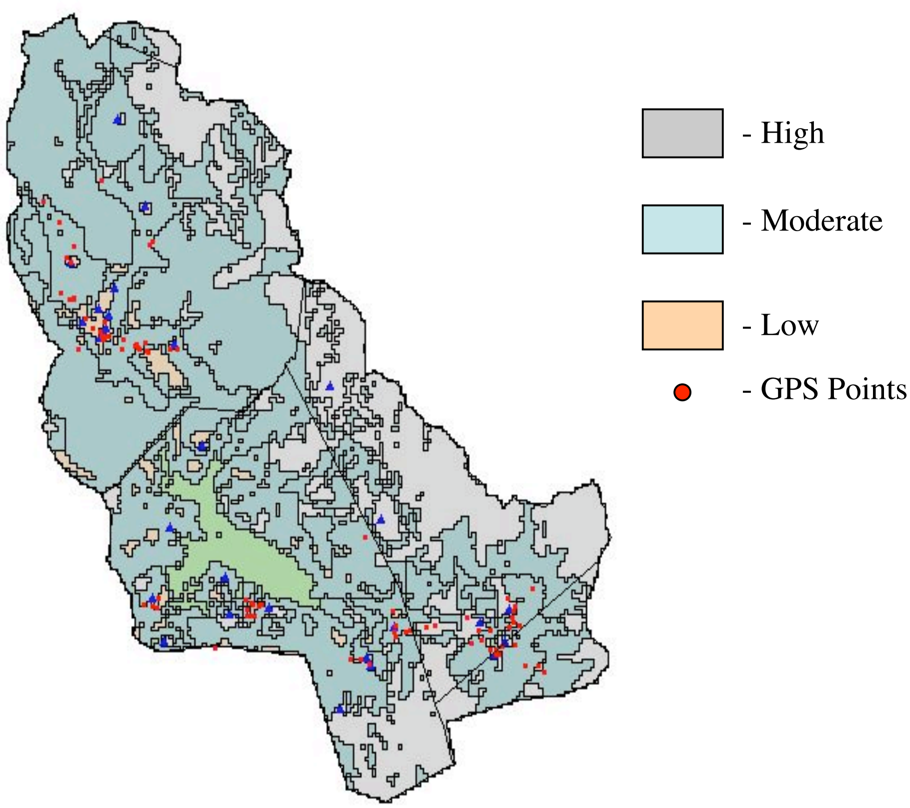


Fig. 3.4: Level of vulnerability by land use types and location of vulnerable places as identified by local communities (GPS points)

On the other hand, among the vulnerable places identified by the local communities themselves during FGDs include low-lying flood-prone settlement areas, agricultural areas prone to floods and droughts, dying streams/rivers, farmlands at the tail-end of irrigation canal, highly erodible areas (in steep slopes) along riverbanks, unstable areas with steep slope that support infrastructure, and grasslands and forested areas/plantations near roads and settlements susceptible to fire.

Plotting the GPS readings of vulnerable places identified by the local communities during FGDs in the vulnerability map generated through GIS, provides an interesting result. As shown in Table 3.6, there is high congruence between the GIS-generated levels of vulnerability with the vulnerable places identified by the local communities. Sixty-four (64) of the 86 of the GPS readings or about 74% fell within the moderate vulnerable areas while 15% and 11% fell in the high and low level categories, respectively. This implies that the approach of combining the two methods of identifying vulnerable areas could be a useful tool to provide a more comprehensive assessment of vulnerable areas/places.

Province/Municipality (No. of GPS Readings)	**Vulnerability Level**			**Total GPS Readings**
	Low	**Moderate**	**High**	
Nueva Ecija				
Carranglan	6	29	0	**35**
Pantabangan	2	21	2	**25**
Nueva Vizcaya				
Alfonso Castañeda	0	8	9	**17**
Aurora				
Maria Aurora	1	6	2	**9**
Total GPS Readings	**9**	**64**	**13**	**86**

Table 3.6: Number of GPS readings of vulnerable places identified by the local communities per municipality in PCW that fell within the different vulnerability levels generated through GIS.

Extent and nature of people's vulnerability: Based on the vulnerability index developed from the results of the household survey, farmers in general are more vulnerable to climate variability and extremes compared to non-farmers (Table 3.7). This is regardless of the source of weights used in the index, i.e., whether determined by the researchers or the local communities themselves. However, the index developed using the researchers' weights produced both the highest (66.53) and lowest value (4.37) compared to the weights provided by the local communities (59.12 for maximum and 11.8 for minimum value). Indeed, the values of the index are relative since they are sensitive to the perceptions of whoever is giving the weights. There is therefore the need to involve the different stakeholders in coming up with vulnerability index particularly those directly affected by climate variability and extremes like the local communities to ensure the appropriateness of the index.

On the other hand, local communities are themselves very heterogeneous. During the FGDs, the local community members identified at least three categories of farmers as well as other socio-economic groupings in PCW that have varying degrees of vulnerability to climate variability and extremes. These are "small", "average", and "rich" farmers, fishermen, employees, and small business entrepreneurs. The group showing evidences of being the most vulnerable based from the FGDs and households surveys are the small farmers. Most of them have very low educational attainment, do not own a parcel of land, have very meager income, without capital, and do not have access to other productive resources. Some may even live in vulnerable places and have ineffective adaptation strategies to variable and extreme climate conditions. This group is considered the most vulnerable because even if the overall climate-related losses may not be that devastating at the community level, the damage it creates to the household could have lasting impacts and could lead to a chain-reaction of negative effects.

Source of Index's Weights	No. of Respondents	Vulnerability Index (Possible Value from 0-100)		
		Mean	**Minimum**	**Maximum**
Researchers				
Farmers	70	38.14	6.87	66.53
Non-Farmers	38	24.56	4.37	43.00
Combined	108	33.37	4.37	66.53
Local Communities				
Farmers	70	42.87	18.95	59.12
Non-Farmers	38	26.30	11.80	55.12
Combined	108	37.04	11.80	59.12

Table 3.7: Values of vulnerability index for farmers and non-farmers based on the weights provided by researchers and local communities.

The group considered to have moderate vulnerability is composed of fishermen, farmers with small land and little capital, owners of small enterprises, sawali makers, and employees of various agencies. They are better educated compared to the small farmers and may have access to productive resources such as land, capital, and technology although they don't have control over them. Despite this, however, few of them may have income below the annual per capita poverty threshold recorded at 13,843 pesos for the Central Luzon Region (PSY, 2000). Some of them may also live in vulnerable areas such as in low-lying flood-prone places and those where sources of water are limited in case of drought. Compared to the most vulnerable group, they are relatively less sensitive to climate-related losses due to their access to limited resources, and have relatively better adaptation strategies.

The last group considered to be the least vulnerable constitutes the rich farmers and the overseas workers. Affluent farmers in general are the most educated among the three groups. They usually own large tract of land/farm, possess investment capital, own farming machineries and tools, and have control over other factors of production including technology. They also live in favorable areas which are less susceptible to flooding and have effective adaptation strategies. On the other hand, overseas workers are also better educated like the more affluent farmers. They have some access to financial resources and have linkages with other institutions outside the community. Their families are considered among the least vulnerable group because the financial support they provide is fix and stable and not affected at all by variable and extreme climate events in the local area. Similar to the well-off farmers, their families also live in safer places and have better adaptation strategies.

DESCRIPTION	**SOCIOECONOMIC GROUPS**			
	Small farmers	**Average farmers & fishermen**	**Employees/ Small entrepreneurs**	**Rich farmers**
General socioeconomic characteristics	Mostly with low educational attainment, no farm land and capital, very low income, almost no access to other productive resources.	Finished elementary education or reached high school, some access to productive resources such as land, capital, and technology	College or high-school graduates, some access to productive resources such as land, capital, and technology	College or high-school graduates; more access and control over productive resources including appropriate linkages
Nature of impacts of climate variability and extremes	Decline in crop production, food, livelihood, health condition; more debt incurred	Decline in crop/fish harvest and income, food availability, livelihood sources; health condition may or may not be affected	Increase in prices of commodities; limited sales	Decline in production and income; no change in food availability, livelihood and health
Degree of negative impacts	High	Moderate	Moderate	Low
Examples of adaptation strategies	Avail of high interest loan or borrow from relatives; plant vegetables along rivers/plant other crops; work in nearby towns; engage in other jobs	Plant vegetables along rivers/plant other crops; engage in other sources of livelihood	Avail of government loans; engage in backyard project; store food supply and other farm inputs for sale	Store food and farm inputs
Effectiveness of adaptation strategies	Some effective, others not	Effective	Effective	Effective
Location of settlement/properties relevant to vulnerable areas	Some are located in vulnerable areas	Some are located in vulnerable areas	Some are located in vulnerable areas	Generally located in secured areas
Degree of vulnerability	High	Moderate	Moderate	Low

Table 3.8: Vulnerability of various socioeconomic groups to CV & E based on certain characteristics.

Table 3.8 presents a detailed description of the different socioeconomic groups in PCW relevant to their degree of vulnerability to climate variability and extremes. It should be highlighted that among the three groups, the small farmers in general may in fact have the most number of adaptation strategies. Some of these strategies however, like availing high-interest loan, are ineffective thereby increasing their degree of vulnerability.

Vulnerability of People to Future Climate Variability and Extreme: Various climate change scenario models have predicted decrease in precipitation and increase temperature in the Pantabangan-Carrangalan Watershed in the next 20, 50, and 80 years (Chapter 2). This is expected to further cause negative effects in the food availability, crop production, livelihood, health and water supply of the residents in the watershed.

Further increase in temperature and decrease in precipitation presents a gloomy scenario to the small farmers in PCW (Table 3.9). Not only will their crop production decline, but starvation is likely to be experienced which would result to malnutrition and other kinds of diseases. Many of them will be engaging in other jobs since the farms that they used to tend will be confiscated because of unpaid debts. Availing of high interest loans may no longer be an available adaptation option since they do not have collateral to guarantee their loan. Moreover, lenders will also be selective of their clients and provide loans only to individuals who have capacity to pay. The poor farmers also have no choice but to stay in their area because they do not have money to transfer to other locations. Hence, in times of extreme weather conditions like typhoons, they need to evacuate to safer places like schools.

Meanwhile, average farmers and fishermen and employees or small entrepreneur will still have moderate vulnerability to probable increased temperature and decreased precipitation in the future. Though their food, livelihood, health, and water supply may be affected by future climate variability and extreme, a few adjustments on their expenditures and other activities will enable them to cope to the negative impacts. Should the need arises, they also have the capacity to transfer to less vulnerable places in times of extreme weather conditions.

Finally, the rich farmers, although slightly affected by the probable changes in climate, appear to benefit more from the situation. This will be in terms of increased farmlands and other possessions from the collateral of the poor farmers who will not be able to repay their debts.

DESCRIPTION	**SOCIO-ECONOMIC GROUPS**			
	Small Farmers	**Average Farmers & Fishermen**	**Employees/Small Entrepreneurs**	**Rich Farmers**
Impacts:				
Food availability and crop production	Decline in crop production; starvation	Decline in crop production and other livelihood resources	Increase in prices of commodities, hence increase in expenditures	Supply of food is not affected because they have money to buy
Livelihood	Worsening poverty condition; more debts incurred and longer time to repay	The livelihood sources of some will decline, while others will improve, especially those who loan money to the poor farmers with collateral.	Decline in business activities of small entrepreneurs, and limited money to spend due to increase in prices of commodities. However, they are not much affected because some have alternative sources of livelihood, like livestock raising.	They become richer because they obtain the farms and other possessions (collateral) of the poor who loaned money and was not able to repay. The poor farmers also approached them for farm inputs which

				they return with interest. The rich farmers are also the buyers of "palay" hence they have control over the prices of crops.
Health	Their health will be affected by intense climate condition and malnutrition. Since they don't have money to consult a doctor or buy medicine, they will just resort to medicinal herbs or consult an "albularyo".	Their health will not be much affected.	Their health will not be much affected.	Their health will not be much affected.
Water supply	Shortage in water supply for farm and domestic uses. The assistance given by government in terms of water pump usually does not reach them.	Some will experience water shortage, while others will not be much affected because they have money to buy water for domestic and drinking purposes, as well as water storage facilities.	Their expenditures for water will increase, but their water supply will not be much affected because they have money to buy water for domestic and drinking purposes, as well as water storage facilities.	Their water supply will not be much affected because aside from the capacity to make/find alternative sources of water, they also have money to buy water for domestic and drinking purposes, as well as water storage facilities.
Degree of negative impacts	High	Moderate	Moderate	Low
Examples of adaptation strategies	They work in other farms, engage in other jobs, work in nearby towns, or even apply for jobs abroad. They also plant crops that can adapt to the dry season, like onions and	They plant fast growing crops and store food supplies. They also invest in other businesses or find other sources of income. They look for job in	They decrease budget in some expenditures and store food supplies.	They will be selective of whom to lend money to. They plant crops in other areas where there is water. They store food supplies.

	tomatoes. Others make "sawali" from cogon grasses that can be harvested in the mountain.	other places.		
Effectiveness of adaptation strategies	Some effective, others not	Some effective, others not	Some effective, others not	Some effective, others not
Location of settlement/ properties relevant to vulnerable areas	They have no choice but to stay in their area because they don't have the capacity to transfer to safer locations. In times of extreme weather events like typhoons, they need to evacuate to safer areas like schools.	They have the capacity to select or transfer to safer locations. Also, most of them live in high and safe places and their homes are made of sturdy materials like concrete.	They have the capacity to select or transfer to safer locations. Also, many of them live in safer places and their houses are made of sturdy materials like concrete.	They have the capacity to select or transfer to safer locations. Their houses are located in safer places and are made of concrete. There are some who have houses in other places.
Degree of vulnerability	High	Moderate	Moderate	Low
Present distribution of farmers	75-85%	5-15%	5-10%	2-5%
Probable distribution of farmers in the future	85-90%	5%	5-8%	2-5%

Table 3.9: Vulnerability of various socioeconomic groups to future CV & E based on certain characteristics.

Factors influencing vulnerability: As implied in the previous sections, while the PCW communities are generally vulnerable to climate variability and extremes by virtue of their geographic location, their degree of vulnerability varies based on a combination of other factors. These factors include the farmer's or household's socioeconomic circumstances as well as the broader sociopolitical and institutional contexts.

<u>Socioeconomic factors:</u> Table 3.10 presents the significant factors associated with vulnerability based on Spearman correlation analysis considering the weights provided by the researchers and the local communities. Using the researchers' weights, three factors have significant correlation with vulnerability: farm income, monthly food expenditures, and farm distance to market. In the case of the first factor, people with high farm income have the tendency to be more vulnerable compared to those with low farm income. This implies that the more dependent people are in their income from the farm, the more they become vulnerable to climate-related disorders. On the other hand, the variable on monthly food expenditures is negatively correlated with vulnerability. This means that people who spend less on food – presumably because they have limited financial resources – are likely to be more vulnerable to adverse climate conditions. Finally, farm distance to market is also positively correlated with vulnerability although the degree of associated is quite weak (at 0.05 confidence interval). As learned during the field work, households from far flung areas are cut off from market during rainy season and flooding that make them more vulnerable.

Similarly, three factors were also found to have significant relationship with compliance using the weights provided by the local communities themselves: number of organizations joined, farm size, and monthly food expenditures. A positive relationship existed between the number organizations joined by the farmers and their vulnerability. This implies that what really matters in terms of reducing vulnerability is not the quantity of organizations joined by the farmers but the quality of services provided by these organizations. Similarly, farm size was positively correlated with vulnerability, meaning the larger the farm size owned by the household the more they are likely to be more vulnerable. This can be explained by the fact that most farmers in PCW usually devote their farms into single commodity, rice – making them more vulnerable to variable and extreme climate conditions.

Postulated factors	**Weights by Researchers**		**Weights by PCW Communities**	
	Vulnerability coefficients	**Level of significance**	**Vulnerability coefficients**	**Level of significance**
1. Demographic				
age	-0.07935		-0.1208	
gender				
ethnic affiliation				
educational attainment	-0.06391		-0.0398	
household size	0.01438		0.0015	
2. Socio-economic				
total income	0.03483		0.0266	
household asset	-0.1782		-0.0845	
number of organizations joined	0.18399		0.2205	0.05
farm size	-0.1199		0.3241	0.01
farm income	0.26165	0.01	0.4393	
number of transportation system	-0.07328		-0.0168	
monthly food expenditures	-0.29576	0.01	-0.295	0.01
no. of loan applied	0.06742		0.12755	
no. of information sources	0.01012		0.1116	
3. Geographic				
farm distance to market	0.24182	0.05	0.212	
4. Overall coping mechanisms				
number of coping mechanisms	-0.08644		0.0282	

Table 3.10: Correlation coefficients between the postulated factors and vulnerability.

To identify and evaluate the combination of factors that significantly affect the households' vulnerability, vulnerability index was regressed with the different predictor variables. Out of the 17 postulated predictor variables, five variables were found to be significantly related with housholds' vulnerability using the weights provided by the researchers (Table 3.11). These were: sex and ethnic affiliation for demographic factors, number of organizations joined and land ownership for socioeconomic factors, and farm distance to market for geographic factor.

In terms of demographic factors, women were found to be more vulnerable compared to men while migrants were more vulnerable than native inhabitants. The vulnerability of women may be attributed not only to their limited physical capacity but also since they have to bear most of the family burdens associated with climate variability and extremes like borrowing money and/or making both ends meet in case of crop failure and caring for the sick children. These, they have to do, on top of the already burdensome household chores that they have to religiously perform. On the other hand, the migrants' vulnerability may be related to their unfamiliarity to the area hence they are unable to better prepare or develop appropriate adaptation strategies to cushion the adverse impacts of variable and extreme climate conditions.

Postulated Predictors	**Code**	**Weights by Researchers**		**Weights by PCW Communities**	
		Regression Coefficient	**Level of Significance**	**Regression Coefficient**	**Level of significance**
1. Demographic					
age	AGE				
gender	SEX	-9.66	0.01		
ethnic affiliation	NATIVE	-10.11	0.01	-0.2907	0.01
educational attainment	EDUC				
household size	HHMMDEPD			0.2781	0.05
2. Socio-economic					
total income	TOTNCOM				
household asset	HHASSET				
number of organizations joined	NORGJ	9.74	0.01		
farm size	FARMSIZE				
farm income	FARMNCOM				
number of transportation system	NTRANSP				
monthly food consumption	FUDMON			-0.3929	0.01
no. of loan applied	NLOAN				
no. of information sources	NFOSURZ				
land ownership	LANDOWN	-8.3	0.05		
3. Geographic					
farm distance to market	FRMDSTMK	0.0006	0.01	0.4010	0.01
4. Overall coping mechanisms					
number of coping mechanisms	NOCOPING				
Intercept		46.25		43.73	
Coefficient of determination		0.46		0.43	

Note: Variables without corresponding coefficient values does not meet the 0.05 level of significance for entry into the model.

Table 3.11: Coefficients of the postulated predictors of household's vulnerability by step - wise regression analysis.

For the predicted socioeconomic variables, the increase in the number of organizations joined by the farmers does not necessarily redound to the reduction of their vulnerability but may in fact exacerbate it. More organizational involvement has the potential to use up the farmers' time which they could otherwise devote to other productive purposes. Meanwhile, households who don't own land are likely to be more vulnerable since land is a very important asset in the area since farming is the major source of occupation of the majority of the households.

In terms of geographic consideration, farm distance to market was positively and significantly related to vulnerability. This affirms the significant relationship between these two variables using the correlation analysis.

Using the weights provided by the communities, four variables were found to be significantly related with households' vulnerability: ethnic affiliation, household size, monthly food consumption, and farm distance to market. Two of these variables, namely, ethnic affiliation and farm distance to market, were also found to be significantly related with the household's vulnerability using the weights provided by the researchers. On the other hand, bigger-size households are likely to be more vulnerable compared to smaller size probably because the former have more mouths to feed compared to the latter. Moreover, monthly food consumption was found to be negatively and significantly related with vulnerability. This affirms the output of the correlation analysis that households who are unable to spend much for food potentially because they have limited financial resources are inclined to be more vulnerable than those who can spend more.

Based on the computed coefficient of determination, about 46.25% and 43.73% of the total variation in vulnerability rating using the weights provided by the researchers and the local communities, respectively, are explained by the above mentioned significant variables (Table 3.11). This means that an average of around 55% of the vulnerability variance based on the weights provided by the two groups are still unaccounted for on an aggregate level. There is thus the need to look for other factors that may help explain the households' vulnerability aside from those identified in the regression model.

Contextual factors: In addition to the above mentioned significant factors, the broader sociopolitical context by which the communities participate influence their level of vulnerability. As mentioned earlier, the chain of development projects implemented in the area from 1971 to the present have in some ways created a sense of dependency in the part of the local communities for external assistance. This is because these projects, especially the resettlement one, were more of a "dole-out" in their orientation with very little attempt towards building local capacities. Consequently, the culture of self-reliance was not fully developed contributing to the vulnerability of some members of the local community especially with the termination of these projects.

Similarly, there is lack of enabling national policies and institutional support that could help reduce the local communities' vulnerability and enhance their adaptive capacity to minimize the adverse impacts of climate variability and extremes. For instance the government forest policy does not allow timber harvesting in all watershed areas that support big infrastructure project such as the PCW even if the communities themselves are involved in plantation establishment. This has discouraged their active participation in reforestation and forest protection activities and has led in many cases to deliberate burning of established plantations. In the absence of direct benefits from established plantations and due to limited sources of livelihood opportunities in the area, community members are compelled to engage in illegal cutting and charcoal-making to augment their meager income that has led to the degradation of some parts of the watershed contributing to its biophysical vulnerability. Similarly, despite the presence of the different institutions in the area such as NIA, NPC, and DENR their main focus is to protect their investments. The interest of the local communities while these are seen as important is only of secondary priority. Through time, there has been declining support towards community development and the provision of more sustainable sources of livelihood. Moreover, institutional support to anticipate and adequately plan for the occurrence of variable and extreme climate conditions is yet to be developed. Similarly there are yet not initiatives directed towards enhance current adaptation strategies and build capacity at the local level.

Finally, the prevailing inequity that characterizes the Philippine social structure is very much evident in PCW that further contributes to the vulnerability of the poor community members. The community's own typology of small, average and rich farmers is a concrete reflection of the inequitable social structure that prevails in the area. As already mentioned the well-off sector of the community has better access and control over productive resources and has the option to live in safer places putting them at a less vulnerable situation. The same sector are also more inclined to capture most of the benefits from the different development projects due to their better association and linkage with the institutions that implement these projects.

Institutions: Table 3.12 presents the different impacts both positive and negative that the climate variability and extremes brings. Some of the positive impacts that were mentioned especially during the occurrence of rains are increase in the level of water in the reservoir, which is good in power generation, and in irrigation. And after the rains, the condition of the soil and other elements become conducive to planting. The Local Government Unit also mentioned that in times of typhoon, they are given a share of 5% from the Internal Revenue Allocation, which they use to minimize the negative impacts of the events. Meanwhile, the negative impacts of climate variability are discussed below:

Operation: Most respondents indicated that the presence of climate variability and extreme hampers their operation. This is due to the lack of sufficient water in the reservoir (especially in times of El Niño), which is the necessary resource for their operation (NIA and NPC). Meanwhile, DENR mentioned that the presence of El Niño leads in the decline of their tree planting activities and it increases the occurrence of forest fires. LGUs on the other hand are concerned with finding solutions to help the communities have sufficient supply of water for their daily activities. Most of the interviewees from the BDC responded that El Niño have no significant effect on them because the people are already adjusted to many climate variability and extremes that they have been experiencing. Only 3 out of 20 (15 %) respondents from BDC said that the presence of climate variability and extremes affected them (Gen Luna, Lublub, and East Poblacion.). The presence of typhoons also brought also negative effects to the institutions. Some of the effects are the destruction of irrigation canals that lead to the problems in water delivery (NIA), destruction of forest plantation roads resulting delays and difficulties in the reforestation activities of DENR, and falling down transmissions lines of NPC due to strong winds and rains that affect supply of power to the communities. LGU also said that typhoons increases the cost of their operation, due to additional manpower/workforce, equipment and instruments needed to help the communities.

On the other hand, to forest fires result to a decrease in the accomplishment of many institutions in terms of the number of trees planted (DENR, NPC, LGU, and BDC). Respondents from NIA also mentioned that this event increases their area of their responsibility because the fire affects not only the area where the fire occurs but also the whole watershed. Delay on the onset of rainy season also affects the institutions negatively. In the case of DENR it, disrupts the planned schedules of tree planting. Many do the planting before the rainy season because newly planted trees need a lot of water for their growth. However, when the rainy season starts early this results to a decrease in the survival rate for the established plantations.

Budget: Many respondents emphasized that the presence of climate variability and extremes resulted to an increase in their expenses; hence, they need additional budget. The additional amount will be used to repair properties destroyed, procure new equipments, and continue their operation.

Manpower/Workforce:Almost all the institutional respondents mentioned that the occurrence of climate variability and extremes such as typhoons and El Niño resulted to decreased manpower/workforce and triggers the needs fro additional hiring. Insufficient manpower/workforce affects the institutions in carrying out efficiently and effectively their activities, especially in solving the problems they encounter. They need additional labor to continue their operations and execute and implement planned programs and schedules. However, some institutions like DENR experienced difficulty in the hiring casual laborers if rainy season starts early. This is because most of the people in the area are farmers, and they have to attend to their farms to ensure that it will have enough water.

Programs: The different programs, both planned and implemented, of the institutions are also affected by the presence of climate variability and extremes. These events cause some delays and changes in the programs. Sometimes, they have to terminate or totally cease the operation of a program to give way to the most urgent problems that need urgent solutions. Such problems include reforestation, tree planting, and Small Water Impounding Program (SWIP) during the times of El Niño, and forest fires, and rehabilitation activities (infrastructures, etc.) for typhoons.

Others: Many of the respondents shared that the delivery of the services coming from them was also affected by climate extreme and variability. It leads to difficulty in delivering water for irrigation (NIA) and decrease in power generation (NPC), which leads to blackouts occurrences in the communities. It also causes difficulty in transporting seedlings from the nursery to the reforestation sites, lower of survival rates of the established nurseries (DENR), and reduction of IRA (Internal Revenue Allocation) collections from the communities because of the burden experienced by the communities.

It can be noticed that the different impacts of climate variability and extremes to the institutions exhibited a ripple effect. When the operation of institutions is affected negatively, in budget allocation, manpower/workforce, program implementation among others, are also negatively affected.

It is also noteworthy that either the delay or onset of rainy season is not given much attention by the institutions. Instead, than the presence of El Niño or prolonged rains, concerns them a lot because these cause more damage or problems in their operation, manpower, budget, and programs.

Nature of CV&E / Stakeholders	**Operations**	**Budget**	**Manpower**	**Programs**	**Others**
Typhoons					
NIA Positive effects :full resource reservoir reached the maximum level	cannot deliver water due to the destruction of canals	decrease in tax collection due to non-payment of fees for irrigation water	none	delayed implementation of programs for rehabilitation	cannot deliver irrigation services to other areas destroyed infrastructure
DENR Positive Effects : after the typhoon, the condition is conducive for planting and it lessened the occurrence of forest fire	destruction of forest plantation roads difficulty in field work and supervision	needs additional budget for forest rehabilitation	addition of casual employee	intensive rehabilitation programs were formulated and implemented sometimes leads to terminating jobs/ programs	difficulty in transporting seedlings from the top (mountains)
LGU	increased in operation cost	lack of budget	needs additional manpower	intensive rehabilitation, socio-economic and infrastructure programs	additional services and cost
NPC Positive effects:Increase water in the reservoir	transmission lines were destroyed w/c hamper power generation	higher restoration cost of emergency lines	additional hiring	give way to most urgent programs and needs	decrease in power generation
Barangay Development Council (BDC)	cannot travel to the municipal hall to ask help due to floods (Gen. Luna)	insufficient budget (Lublub)	none	none	none

Drought/ El Niño					
NIA	decline in level of water in the reservation	shortage of budget due to non-payment of fees for irrigation water	delay in salary/wages of casual employee)	decrease in program target production in water supplied to service area decreased area covered by the regular operation	None
DENR	increase in the occurrences of forest fires delayed planting of trees	additional budget requirements to minimize slash and fire	additional manpower	focus on forest protection	Low survival rate of established nursery/plantation
LGU	additional projects/activities, e.g., establishment of water impounding projects (irrigation) searching for potential spring development (SPSP)	additional budget/funds needed for the spring development	none	some programs activities either delayed or set aside to give way to additional water related projects	some farmers are not able to pay (tax) resulting to a reduction in water supplied to the service area
NPC	decline in available water in the reservoir resulting to decline in power generation	special addition of budget to offset financial request	none	delayed activities (e.g., reforestation) adjustment of program schedules	shortage in electricity delivered
BDC	none	increased expenses (Lublub & Cadaclan) Insufficient funds (East Pob.)	none	destroyed water pump (Fatima) Delayed project implementation (East Pob.)	none
NIA	increase area of responsibility in the forest/ plantation	additional budget required	additional manpower	change in priorities additional areas to be replanted supply gaps	diversion of focus of normal/ irregular activities to control forest fires
Forest Fires					

DENR/NPC and LGU-BDC	reduction in the refo project accomplishment	additional budget Increased in labor cost	addtl manpower Mobilization of forest guards & fire brigades Training of people	none	none
Delay onset of rains					
DENR	disrupt planned schedules				
NPC	shortage of available power			delayed training activities	
LGU-BDC		decreased in tax collection (Conversion) additional funds (Galintuja, Ma. Aurora)			
Early onset of rains					
DENR NPC BDC/ LGU NIA	decreased survival rate in plantation none none	none (+) effects triggers more power generation none none	deplete manpower none	none delayed const. of structures none	none

Table 3.12: Institutional impacts of climate variability and extremes.

3.2.4 Conclusion

- The small or poor farmers are the most vulnerable group in the PCW. These are farmers who do not own a land, have no capital, without farming machineries, live in vulnerable areas, and whose adaptation strategies are ineffective.
- In indexing, assigning weights affects outcomes.
- Looking on the multiple stressors both at the micro and macro levels (scale issue) that contribute to people's vulnerability is a useful way of understanding this complex concept.
- Need for bottom-up assessment and planning to address vulnerability and enhance adaptive livelihood at the local level. Participatory action research engaging the different stakeholders

should be pursued to minimize vulnerability of the poor and enhance adaptive capacity at the local level.

- To reduce vulnerability, policies and development programs should aim at empowering the local communities to broaden their range of choices of appropriate strategies rather than making them dependent on external support. Should not preclude questioning the large scale structural causes of vulnerability such as poverty, inequity, institutional and economic barriers to development. Should not neglect the issue of power and conflict (Brooks, 2003).

3.3 Water Resources

3.3.1 Activities conducted

The activities conducted under this study were the following:

1. Assessed the impacts of climate change and variability on water resources and water use in Pantabangan Watershed;
2. Assessed the impacts of changes in water resources and water use on water resources management and water supply;
3. Assessed the vulnerability of the water resource sector to climate change; and

3.3.2 Description of scientific methods and data

The Pantabangan-Carranglan Watershed supplies the irrigation requirements of 24 municipalities in the provinces of Nueva Ecija, Bulacan, and Pampanga (Figure 3.5) through the Upper Pampanga River Integrated Irrigation System (UPRIIS) which is operated by the National Irrigation Administration (NIA). As shown in Table 3.13 it has a total service area of 102,532.21 ha which is divided into four districts. A total of 369 irrigators' associations consisting of 62,039 farmers depend on the PCW for their farm irrigation needs (NIA-UPRIIS 2004).

Province/Municipalities	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		
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. Zaragosa			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

Table 3.13: Pantabangan-Carranglan watershed service area.

Rice, vegetables, corn, onion and other agricultural crops are grown on cultivated lands. Rice, onions and vegetables are the primary crops raised in the service areas of the watershed. Water pumped from well and run-of-the-river irrigates some areas for rice production. With this existing cultivation practice, rice growing cannot maximize the best use of the land. Hence, other crops are also planted which include vegetables, like eggplant, tomatoes, bitter gourd, and squash. Aside from rice, the most popular crop during dry season is onion. In irrigated rice lands, second cropping is practiced by farmers while rain-fed areas depend on the frequency of rain during the year.

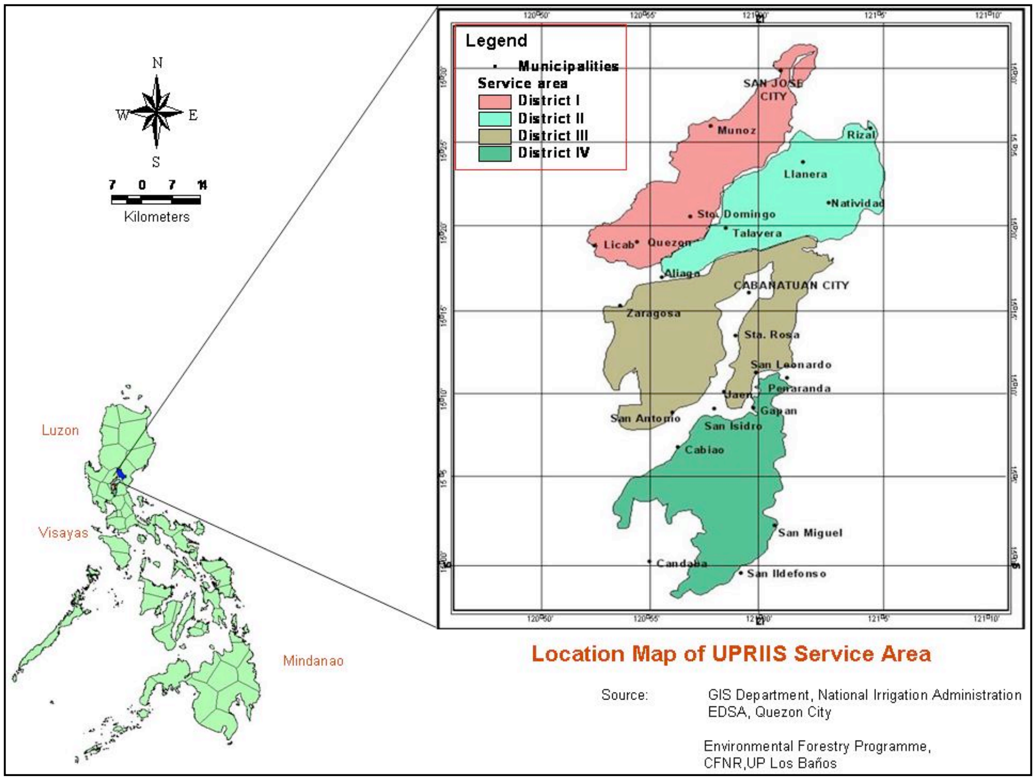


Fig. 3.5: Location Map of UPRIIS-NIA service area.

3.3.2.1 Data Collection

Various research techniques such as focus group discussions (FGDs), secondary data gathering, key informant interview, and direct field observations were used to acquire the data needed for the assessment of impacts and adaptation strategies of the communities in the Pantabangan-Carranglan Watershed/UPRIIS service area to water shortage and drought.

Focus group discussions: Focus group discussions (FGDs) were also done in Irrigator's Association in four districts of UPRIIS-NIA to solicit information from the participants about the occurrences of water shortage and floods in the service area in the past 25 years and establish its impacts as well as adaptation strategies developed by the communities in the service area, and their recommendations to the institutions that manage the service area.

Secondary data gathering: Information on the PCW/UPRIIS service area was collected from the NIA-UPRIIS district offices. Sources of information include Service Area Development Plan and list of Irrigator's Association (IA) in the service area.

Key informant interview: An interview instrument was developed to obtain the necessary and relevant information from the informants. The respondents were composed of Irrigator's Association members from different municipalities in the service area, government officials from different barangays, Municipal Agriculture Officer (MAO), and NIA-UPRIIS district officers. Key informant interviews were employed to establish the services provided by the Pantabangan-Carranglan watershed to its service area and the impacts as well as adaptation strategies in the area to water shortage and flood.

3.3.3 Results

3.3.3.1 Current impacts and vulnerabilities

Floods and droughts: There are two major concerns related to water resources in the watershed as influenced by climate change and variability and extreme events, floods and droughts. These concerns become more vital in the light of the downstream communities depending on the PCW for their irrigation needs and protection against floods. As defined by the National Irrigation Administration (NIA), the number of months when floods and droughts were of particular concern was determined based on the level of water in the reservoir shown below (Table 3.14).

For Flood

Low – water level <190m

Mod – water level 191-215m

High – water level >215m

For Water Shortage

Low – water level >190m

Mod – water level 176-189m

High – water level <176m

Table 3.14 shows that most of the time there seems to be abundant water in the reservoir as indicated by the large number of months when flood is a moderate concern and by the small number of months when water shortage is of low concern. However, it is worth noting that there is a tendency for the number of months when water shortage is of high concern to increase indicating the imminent risk of water shortage to the lowland farmers. This is illustrated by the sudden drop of rice harvest by about 0.3 tons/ha based on average production during the dry season (Table 3.15).

Hydroelectric power generation though not the primary use of the multipurpose reservoir supported by PCW plays a critical role in the overall power supply mix of the country. It is shown in Figure 3.6 that from a maximum of more than 300,000 Mwh in the early 80's the gross power generated in the reservoir dropped to almost zero in the late 90's mainly attributed to the decreased capacity of the reservoir to store enough water as a result of excessive siltation (Table 3.16).

The siltation problem in the reservoir could be related to the increasing incidence of monsoonal rains. It is however common knowledge that the watershed has been suffering from severe degradation of the forests, chronic grass fires and extensive cultivation of the upland areas. For so many years, reforestation efforts involving the people in various modes together with physical protection measures constitute the core of strategies to reduce the magnitude of siltation problems in the reservoir. Unfortunately, efforts to sustain the early gains from reforestation initiatives failed as funds from donor agencies ran out. In the late 90's water transfer from an adjoining basin was initiated to augment the receding water storage in the reservoir while minimal efforts to protect the watershed from further degradation and restore denuded areas continue.

Year	Flood Concern			Water Shortage Concern		
	Low	**Mod**	**High**	**Low**	**Mod**	**High**
1977		9		9		
1978		8	4	12		
1979		12		12		
1980	5	6		6	6	
1981	3	9		9	3	
1982	4	8		8	4	
1983	7	5			7	5
1984	8	4		4	5	3
1985	5	7		7	5	
1986	4	8		8	4	
1987	9	3		3	9	
1988	10	2		2	8	2
1989	8	4		4	6	2
1990	5	7		7	5	
1991		12		12		
1992	5	7		7	5	
1993	7	5		5	4	3
1994	4	8		8	4	
1995	8	4		4	4	4
1996	9	3		3	8	1
1997	11	1		1	9	2
1998	9	3		3	3	6
Total	**121**	**135**	**4**	**134**	**99**	**28**

Table 3.14: Number of months when water level in Pantabangan Dam was critical.

Year	Service Area (ha)	Irrigated/Planted Area (ha)				Yield (Cavans/ha)	
		Wet Season		Dry Season		Wet Season	Dry Season
		Program	Actual	Program	Actual		
1990	103,285	91,045	84,813	78,285	77,402	77.00	78.25
1991	103,285	87,700	83,701	83,603	77,568	78.00	79.25
1992	103,285	88,843	86,058	80,676	78,441	79.25	81.00
1993	103,285	90,145	83,252	75,549	75,655	79.75	82.00
1994	103,285	92,447	85,674	75,792	77,800	80.00	81.75
1995	103,285	89,233	84,566	71,265	69,975	80.50	81.75
1996	103,285	89,008	81,850	48,694	56,501	81.00	82.50
1997	103,285	89,001	83,805	54,259	55,501	81.75	83.50
1998	103,285	87,144	74,693	50,575	48,484	81.25	74.25
1999	103,285	87,446	82,857	70,461	74,689	82.50	85.25
2000	103,285	90,293	81,392	79,680	78,380	76.00	80.25
2001	103,285	89,464	85,188	80,292	75,075	-	-
Average	103,285	89,314	83,154	70,761	70,456	79.73	80.89

Note: 1 cavan of unmilled rice is approximately 50kg

Table 3.15: Irrigation performance of UPRIIS, PCW from 1990-2001.

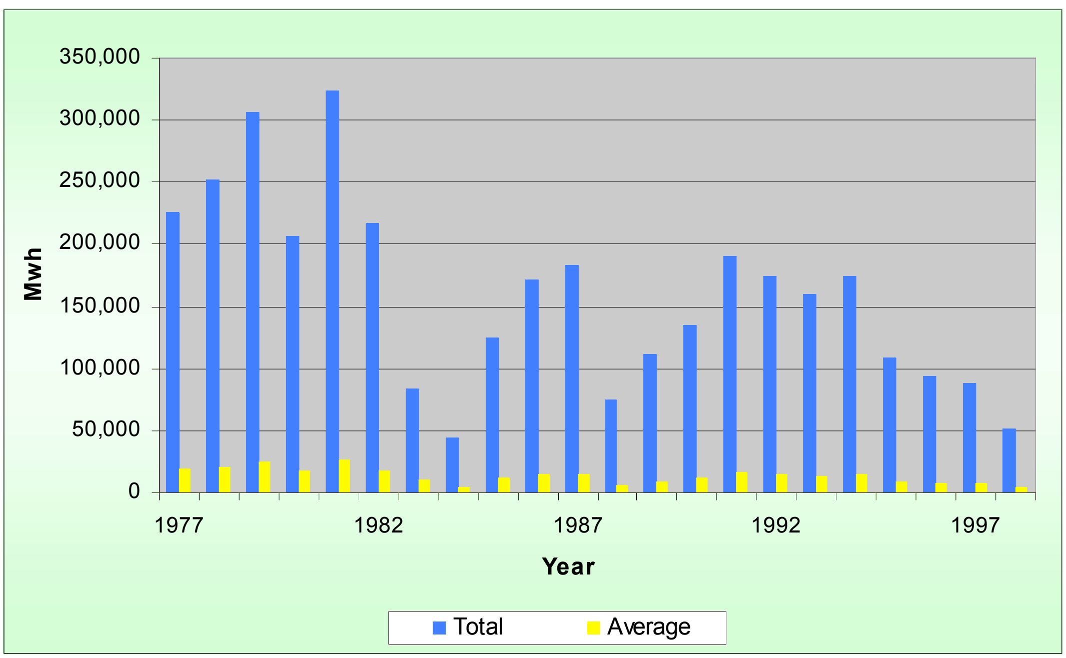


Fig. 3.6: Gross power generation (Mwh) at UPRIIS, PCW.

Year of Survey	No. of Monsoon After Impoundment	Volume of Sediment (MCM)	Sedimentation/Year (MCM/Year)	Total Capacity Lost (%)	Estimated Sediment Yield (t/ha)
1985	12	84.74	7.06	5.5	114.70
1989	15	105.25	6.84	6.6	107.20
1995	21	147.42	7.02	7.6	110.26
2000	26	197.60	7.60	10.2	123.50
Designed for : CY 1989 Survey					
Sedimentation Rate = 1.3 MCM/YEAR[3]			Sedimentation Rate = 6.84 MCM/YEAR		
Reservoir Life = 100 years			Projected Reservoir Life[2] = over 100 years		
Note: Estimated catchments sediment yield is based on the following: a. Sediment Density = 1320kg/m^3 b. Sediment Trapping Efficiency is 98% c. Drainage/Catchments Areas is 82,900 ha The Projected Reservoir Life is calculated using the Empirical-Area-Reduction Method Estimated Sedimentation Rate obtained during the Feasibility of the Dam. Based on the actual sediment pool/storage of the dam, designed rate is about 7.50mcm/yr					

Table 3.16: Sedimentation rates in Pantabangan reservoir, PCW.

Lowland rice production: The sensitivity of the service area to changes in water resources coming from PCW reservoir was evaluated in terms of drought and flood susceptibility. The proneness of the various districts of the irrigation service area zones was determined through focus group discussions (FGD) and interviews of key informants from the farmers groups, local government officials and the NIA.

Occurrences of water shortage and drought in the service area in the past 25 years identified by the respondents are listed in Table 3.17. The respondents were able to recall water shortages and floods that occurred in 1980s and 1990s and noted specifically the El Niño episode in 1998 that brought extreme water shortage in the service area. Respondents attributed the incidence of water shortage and flood to various reasons as listed in Table 3.18.

Year	District 1	District 2	District 3	District 4
1980s	Extreme water shortage	Extreme water shortage	Extreme water shortage	Extreme water shortage
1980s-present	Flood during rainy season	Flood during rainy season	Flood during rainy season	Flood during rainy season
1997	Extreme flood			
1998	El Niño	El Niño	El Niño	El Niño
2000-present	Water shortage and floods	Water shortage and floods	Water shortage and floods	Water shortage and floods

Table 3.17: Water shortage and flood occurrences identified by respondents from key informant interviews and FGDs.

Description	District 1	District 2	District 3	District 4
Water Shortage	Occurrences of El Niño	Occurrences of El Niño	Occurrences of El Niño	Occurrences of El Niño
	Poor irrigation infrastructures	Poorly maintained irrigation canals	Poor irrigation infrastructures	Poor irrigation infrastructures
	Distance from the dam and low water level in the reservoir	Improper use of irrigation water	Distance from the PCW	Distance from the PCW
	Greediness of other farmers and irrigators			
Flood	Natural calamities (heavy rainfall) and deforestation	Natural calamities (heavy rainfall) and deforestation	Natural calamities (heavy rainfall) and deforestation	Natural calamities (heavy rainfall) and deforestation
	If the farmers in the upper service area are not using the water, they let the water flow down to the low-lying service areas	Poor irrigation canals and drainages, and poor construction of water controls	Poor irrigation canals and drainages, and poor construction of water controls	Poor irrigation canals and drainages, and poor construction of water controls
	Location (located in low-lying area)	Location (located in low-lying area)	Location (located in low-lying area)	Location (located in low-lying area)

Table 3.18: List of reasons of floods commonly cited by the respondents.

The respondents also noted that the location of rice lands in the service area is one of the major reasons why the farmers experience water shortage. Those municipalities that lie at the tail of the service area are the most affected especially during dry season. Similarly, the respondents attributed occurrences floods to location and natural calamities such as typhoon and heavy rainfall. Figure 3.7a and Figure 3.7b show that the areas that suffer the most from droughts and floods are those located along the fringes of the service areas mainly owing to the topographical and topological limitations. These areas invariably experience decline in rice production levels from 20% to 100% (of 90-100 cavans/ha) and escalation in production cost by at least 25% during periods of drought (Table 3.19).

It is interesting to note that based on the accounts of many farmers during the FGD and interview, water shortage and floods occur yearly in the most vulnerable areas. This highlights a common discrepancy between the appreciation by the farmers and by government agencies of what constitute a problem or risk to the farmers which could be attributed to the inability of the methods used in the formal or official assessment of risks and hazards to natural events.

During floods most of the vulnerable areas suffer between 40-100% (of 60-90 cavans/ha) loss in production. Incidence of water borne diseases, damages to irrigation structures, properties and livestock were also identified by the farmers and other key informants as common problems associated with floods.

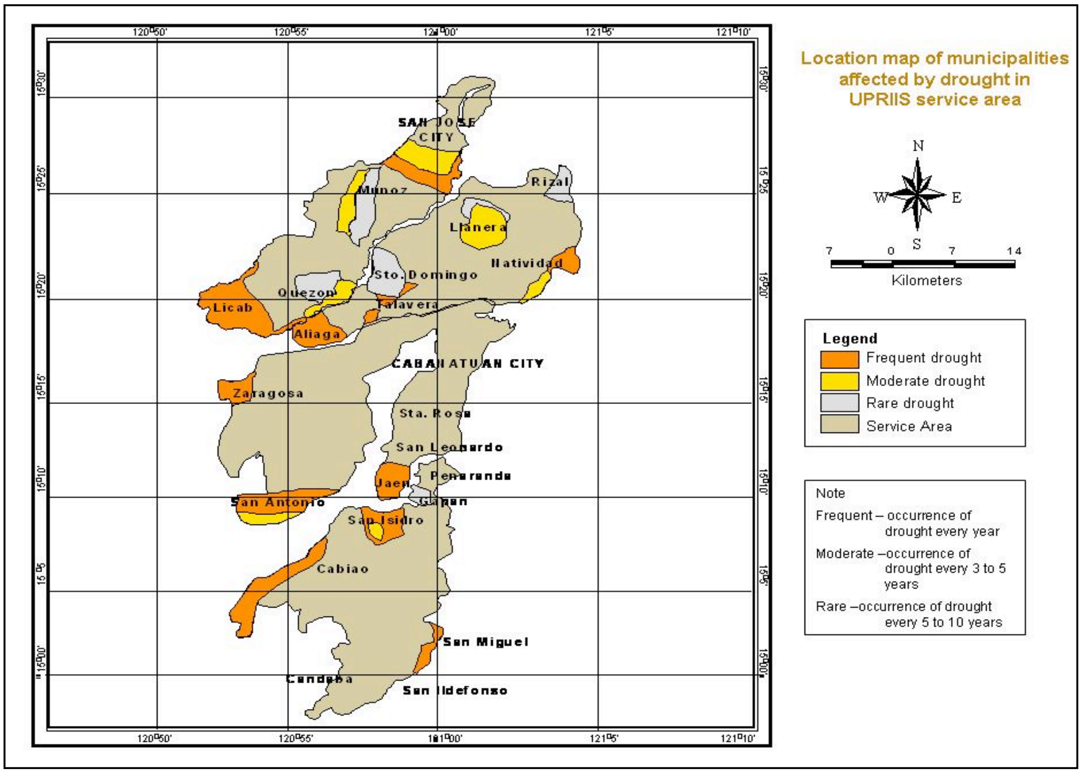


Fig. 3.7a: Current vulnerability to droughts of the various service area districts of UPRIIS, PCW.

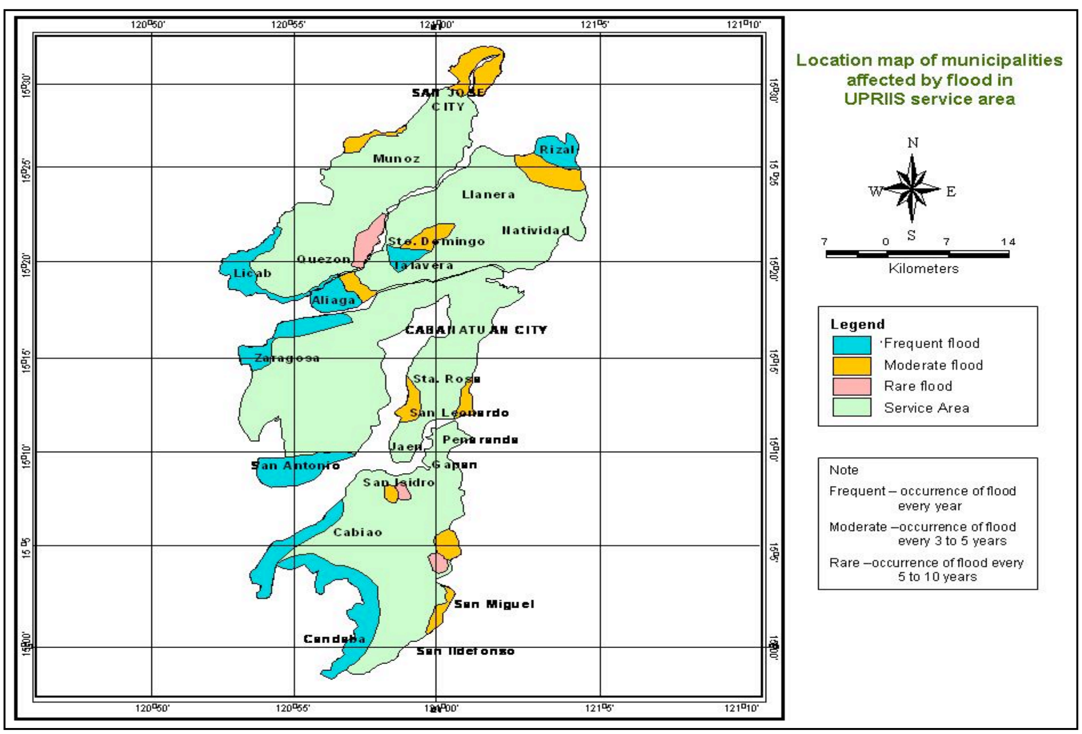


Fig. 3.7b: Current vulnerability to floods of the various service area districts of UPRIIS, PCW.

Description	District 1 Licab and Quezon	District 2 Talavera and Aliaga	District 3 Jaen	District 4 San Miguel, Bulacan Candaba, Pampanga
Water Shortage				
Impacts	decreased productivity by at least 20% high production cost for agricultural products	decreased productivity by at least 70% (from 100 cavans per hectare to 15-30 cavans per hectare) high production cost for agricultural products	decreased productivity by at least 70% (from 100 cavans per hectare to 15-30 cavans per hectare) high production cost for agricultural products	decreased productivity by at least 90% (from 100 cavans per hectare to 0-10 cavans per hectare) high production cost for agricultural products
Floods				
Impacts	Low agricultural production (decreased by at least 40%) and low soil fertility Occurrences of water borne diseases, damages to irrigation infrastructure and siltation	decreased productivity by at least 40% to 100% Occurrences of water borne diseases, damages to livestock, crops, and properties	decreased productivity by at least 40% (from 60-90 cavans per hectare to 0-30 cavans per hectare) Occurrences of water borne diseases, damages to livestock, crops, and properties	decreased productivity by at least 50% (from 60-90 cavans per hectare to 0-40 cavans per hectare) Occurrences of water borne diseases, damages to livestock, crops, and properties

Table 3.19: Current vulnerability to floods and droughts of the different service area districts of UPRIIS, PCW.

3.3.3.2 Future impacts and vulnerability

Streamflow: Relative to the observed data of 1990, the streamflow in PCW is projected to increase all the way through 2080 (Figures 3.8a – 3.8d) under all future climate and land use scenarios. The increase from 1990 ranges from as low as 41.19 mcm to as high as 42.96 mcm per day.

For the dry season flow, a declining trend can be noted from 1990 values for all future land use and climate scenarios (Table 3.20, Figures 3.9a – 3.9d). The decreasing streamflow projected for dry season could be attributed to the decreasing dry season rainfall and the increasing temperature. In effect there will be less water coming into the watersheds from rain but the evaporative demand will increase due to increase in temperature. Dry season flow ranges between 8.84 mcm to 11.2 mcm.

As far as the wet season flow is concerned, there is however a noticeable increase in the daily average streamflow from 1990 to 2080 (Table 3.21, Figure 3.10a – 3.10d). This could be largely related to the projected increase in rainfall during the wet season. The highest flow is noted 66.45 mcm in 2080 and the lowest projected flow is 63.21 mcm.

Land Use 1990							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	11.61	11.61	11.61	11.61	11.61	11.61	11.61
2020	11.12	11.25	10.94	11.28	11.00	10.96	11.09
2050	10.86	10.92	10.37	11.19	10.91	10.89	10.86
2080	10.44	10.87	10.31	11.05	10.15	10.58	10.57
Land Use 2018							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	11.36	11.36	11.36	11.36	11.36	11.36	11.36
2020	11.16	11.17	11.05	11.19	11.10	11.08	11.12
2050	10.84	10.73	10.36	10.68	10.75	10.79	10.69
2080	10.53	10.30	10.23	10.21	10.46	10.76	10.41
Land Use 2040							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	11.62	11.62	11.62	11.62	11.62	11.62	11.62
2020	11.41	11.34	11.42	11.49	11.35	10.16	11.19
2050	9.98	11.05	10.00	10.19	10.73	9.63	10.26
2080	9.47	10.76	9.53	9.92	9.86	8.92	9.74
Land Use 2070							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	11.40	11.40	11.40	11.40	11.40	11.40	11.40
2020	11.27	10.36	9.24	9.12	10.23	9.68	9.98
2050	10.31	9.63	9.03	7.41	9.99	9.04	9.23
2080	9.60	9.06	8.75	7.29	9.40	8.96	8.84

Table 3.20: Projected dry season daily average streamflow (mcm) under future climate and land use scenarios.

L1990							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	57.24	57.24	57.24	57.24	57.24	57.24	57.24
2020	63.32	63.75	62.60	63.93	63.03	63.46	63.35
2050	64.00	64.13	63.25	64.07	63.79	63.77	63.84
2080	66.12	65.31	63.82	64.81	64.87	64.60	64.92
L2018							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	57.45	57.45	57.45	57.45	57.45	57.45	57.45
2020	63.60	63.79	63.85	63.50	63.94	63.88	63.76
2050	64.12	64.78	64.99	64.52	64.92	64.33	64.61
2080	66.02	65.83	66.21	65.96	66.20	65.31	65.92
L2040							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	57.71	57.71	57.71	57.71	57.71	57.71	57.71
2020	63.48	63.78	63.63	63.78	63.96	63.75	63.73
2050	64.99	64.24	64.90	64.84	64.83	65.26	64.84
2080	66.02	65.33	66.52	66.50	66.64	66.05	66.18
L2070							
Year	**CCCma A2a**	**CCCma B2a**	**CSIRO A2a**	**CSIRO B2a**	**HADCM3 A2A**	**HADCM3 B2a**	**Average**
1990	57.49	57.49	57.49	57.49	57.49	57.49	57.49
2020	63.96	64.07	63.65	63.48	62.63	61.45	63.21
2050	64.88	65.80	65.24	65.39	63.81	62.99	64.69
2080	66.05	66.91	66.36	66.19	66.44	66.78	66.45

Table 3.21: Projected wet season daily average streamflow (mcm) under future climate and land use scenarios.

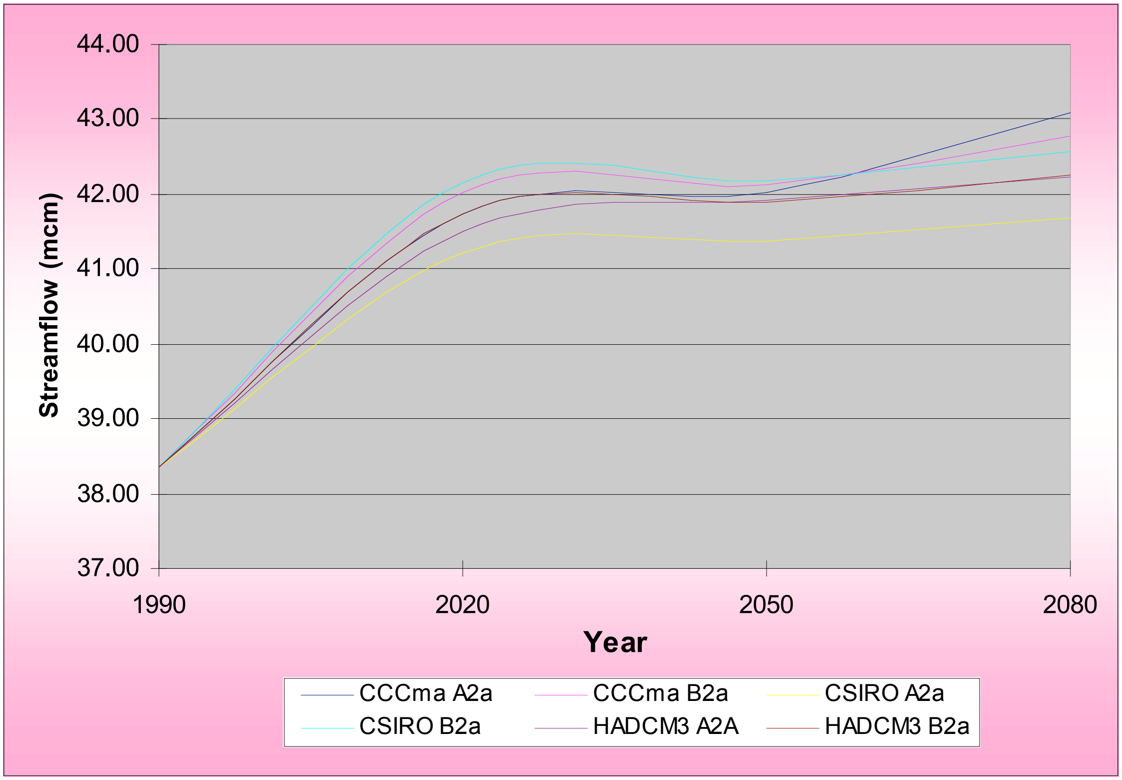


Fig. 3.8a: Projected average daily streamflow for PCW using 1990 landcover.

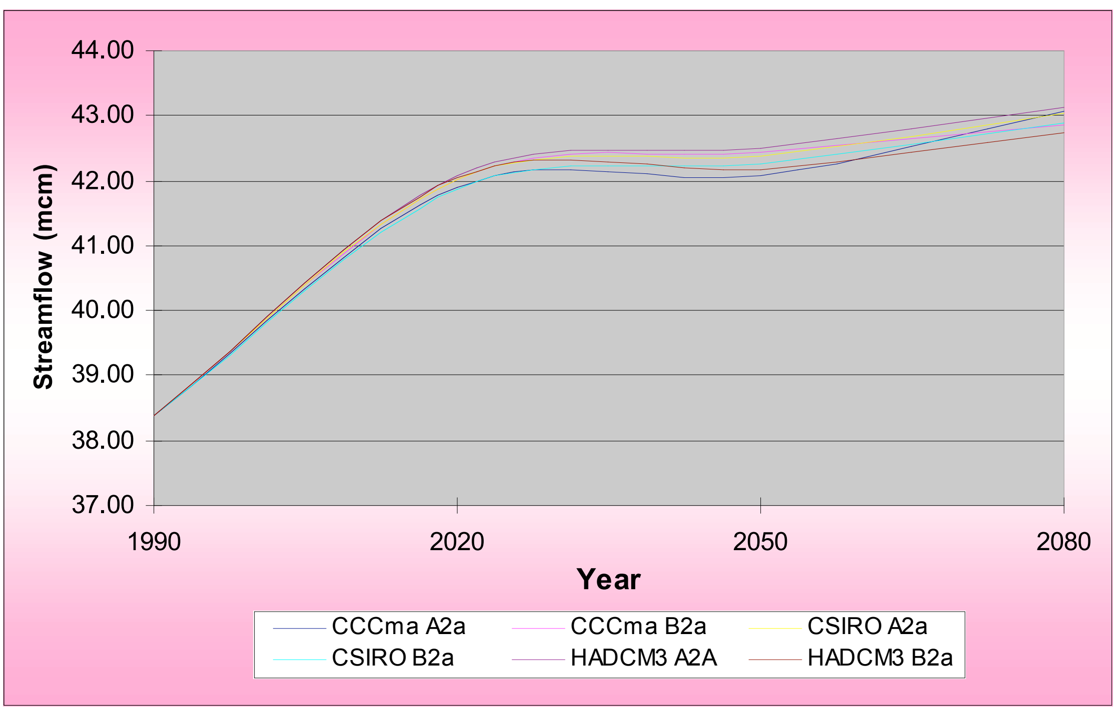


Fig. 3.8b: Projected average daily streamflow in PCW using 2018 land cover.

Fig. 3.8c: Projected average daily streamflow in PCW using 2040 land cover.

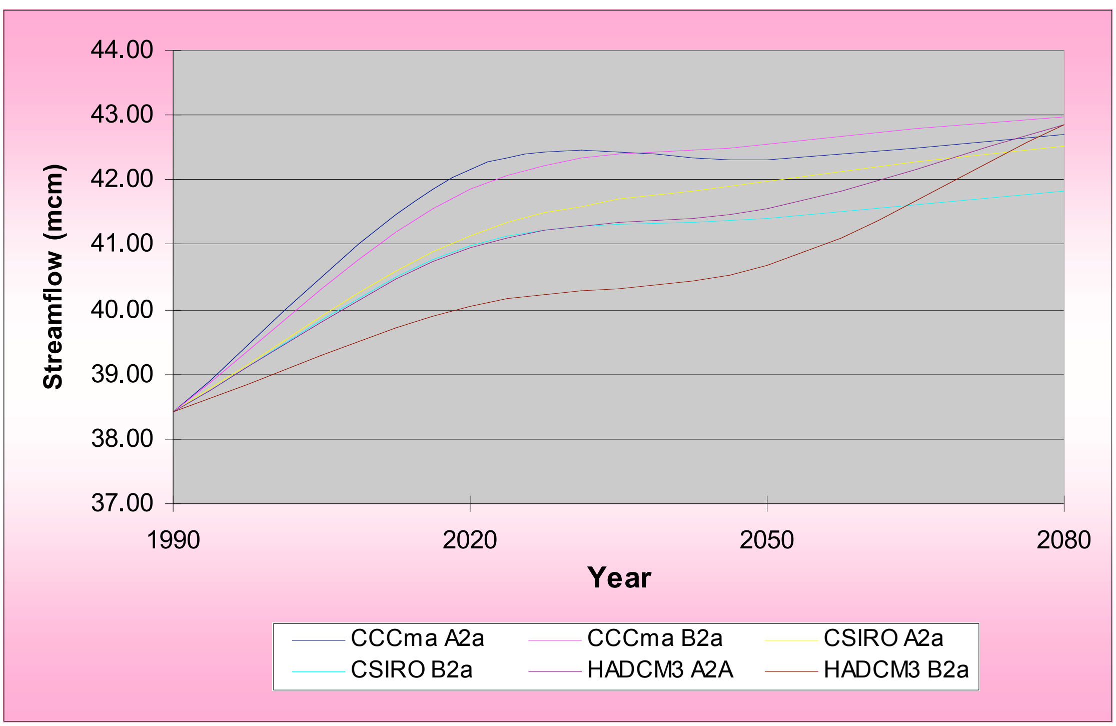


Fig. 3.8d: Projected average daily streamflow in PCW using 2070 land cover.

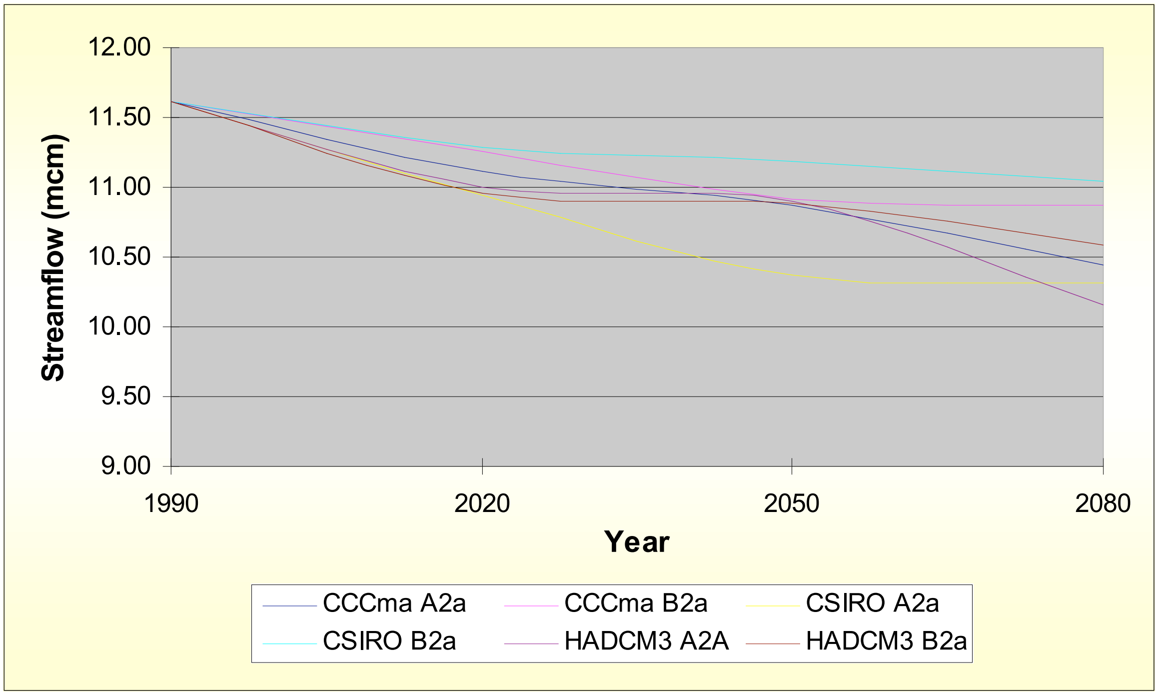


Fig. 3.9a: Projected daily average dry season flow in PCW using 1990 landcover.

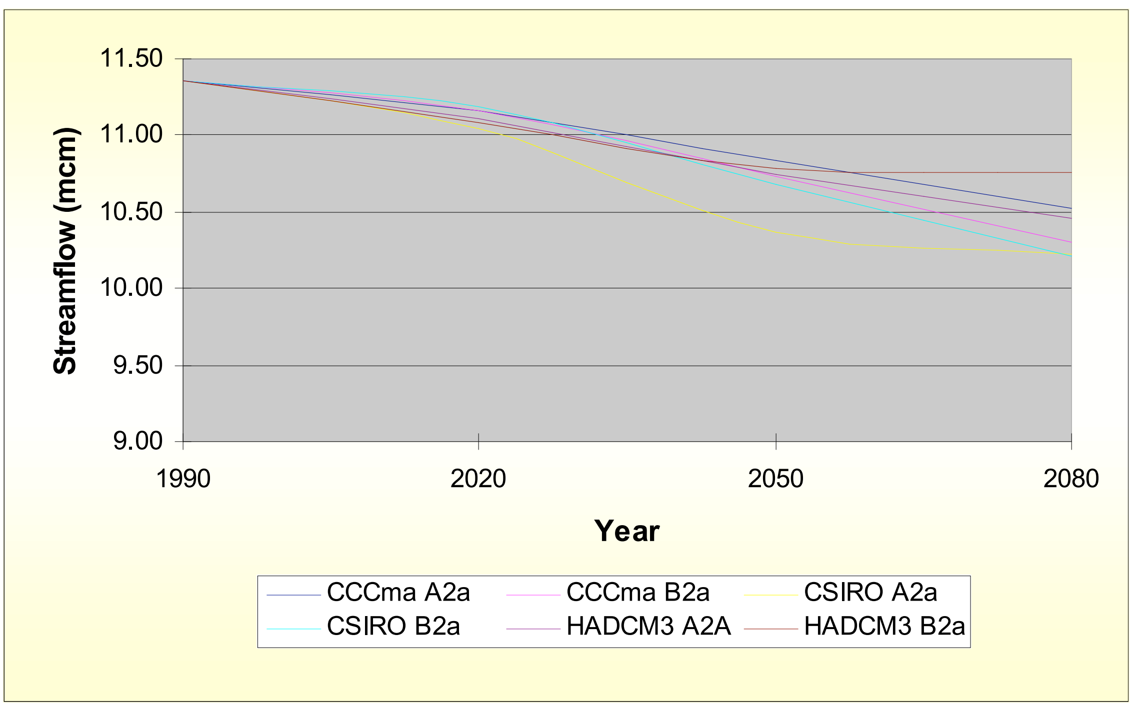


Fig. 3.9b: Projected daily average dry season flow in PCW using 2018 land cover.

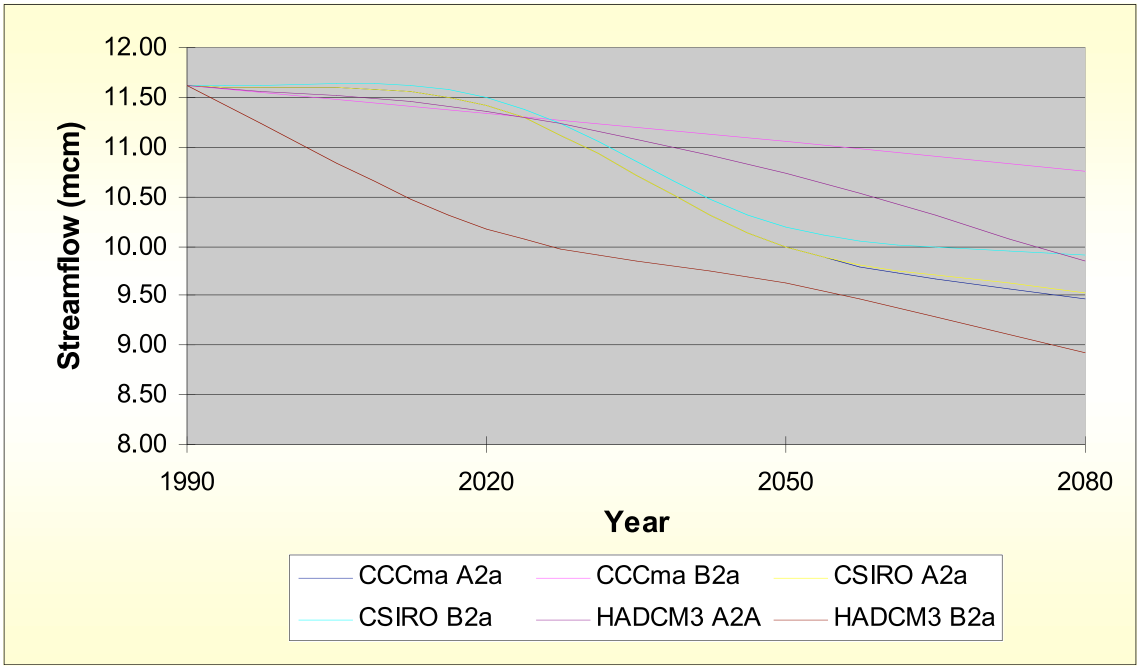


Fig. 3.9c: Projected daily average dry season flow in PCW using 2040 land cover.

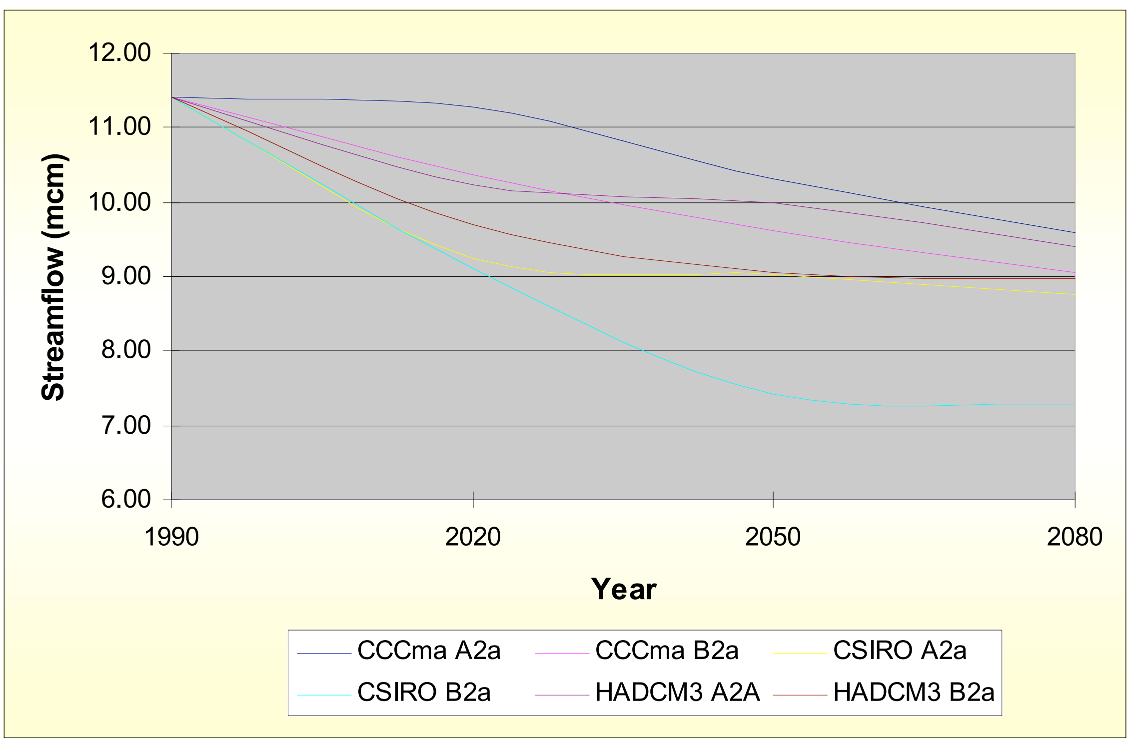


Fig. 3.9d: Projected daily average dry season flow in PCW using 2070 landcover.

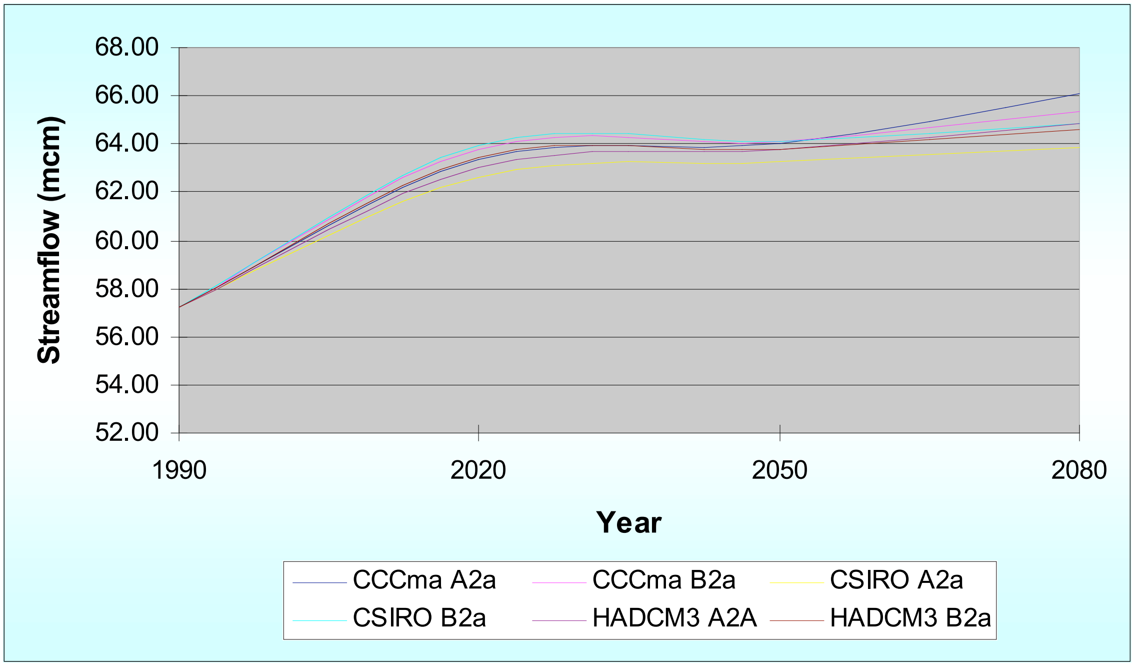


Fig. 3.10a: Projected daily average wet season flow in PCW using 1990 land cover.

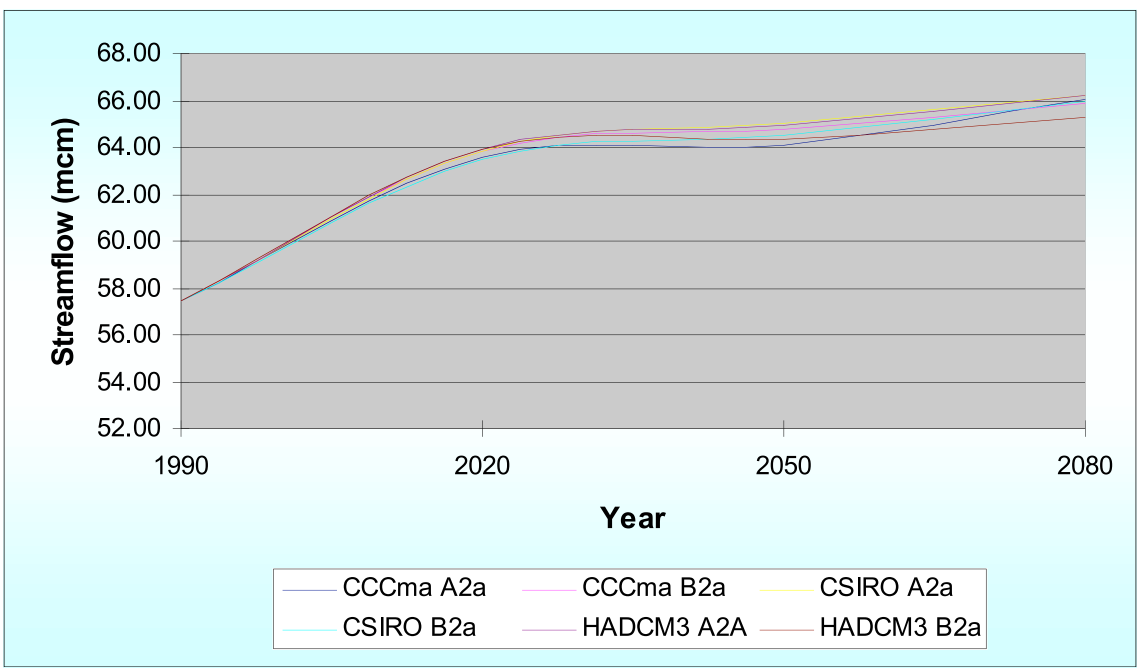


Fig. 3.10b: Projected daily average wet season flow in PCW using 2018 land cover

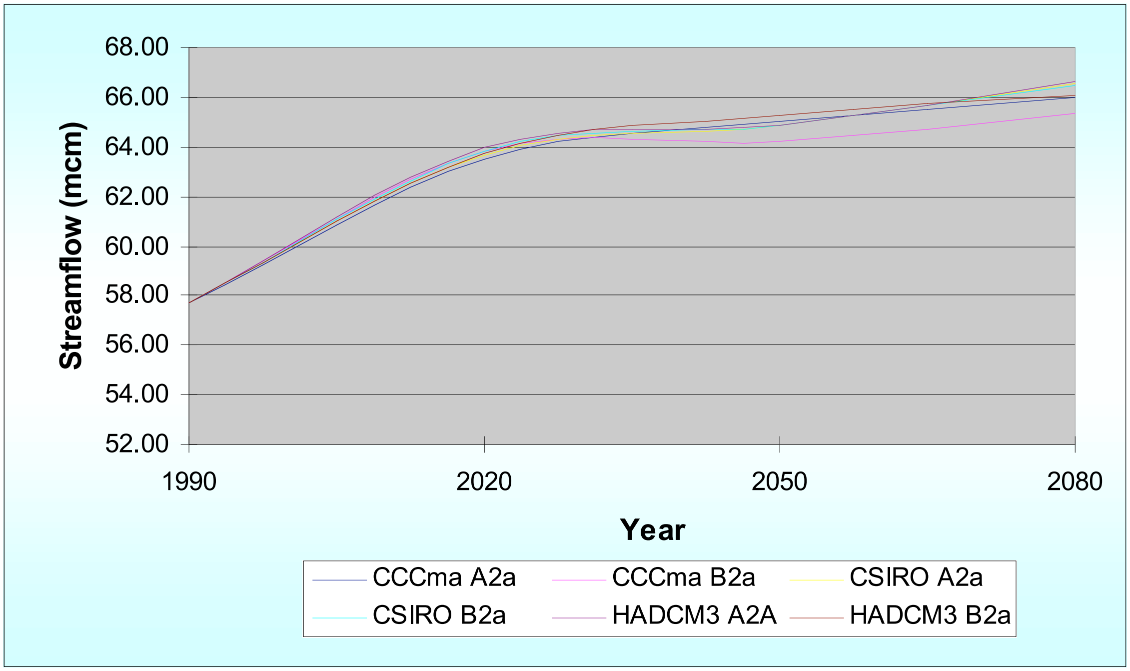


Fig. 3.10c: Projected daily average wet season flow in PCW using 2040 land cover.

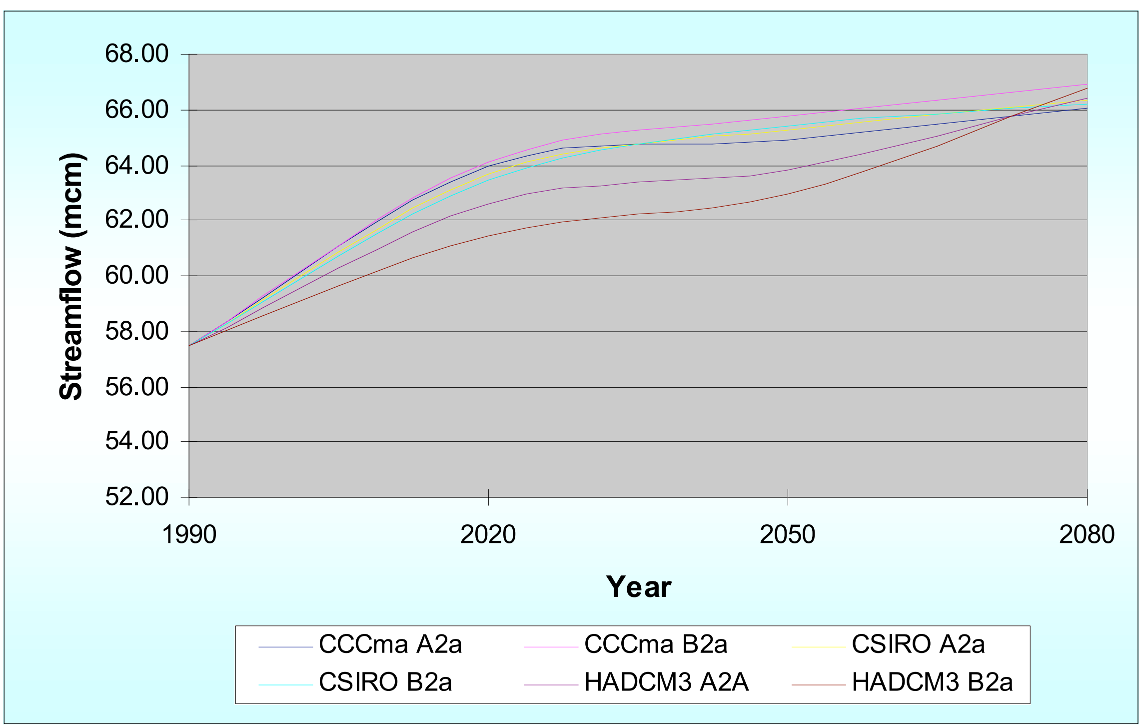


Fig. 3.10d: Projected daily average wet season flow in PCW using 2070 land cover.

The projected alteration in the current streamflow pattern in PCW in 2020, 2050 and 2080 due primarily to projected change in climate and land use and land cover will likely have equally serious if not graver effects on the lowland farmers in the service area of UPRIIS than the current impacts described above. The projected reduction in the streamflow of PCW during the dry season will tend to heighten the difficulties that farmers are now experiencing. Mainly this is not because of the less water flowing into the reservoir during dry season but more because of the greater need for water and the likely reduction in the water available from the traditional alternative sources such as adjoining rivers and shallow wells.

On the other hand, the increasing trend of the wet season flow could likely increase the chances and magnitude of floods in the service area of PCW. Being in the flood plains and inherently vulnerable to floods, most of the service area would be placed at greater risks of being affected by floods that could be magnified by the projected increase in streamflow from PCW. The currently vulnerable sites in each of the service area districts will likely remain to be vulnerable if not more vulnerable to floods and water shortages than these areas are already. Most vulnerable will be the more than 53,000 ha of the service area that are susceptible to both floods and water shortages (Table 3.22). Based on the responses of the farmers interviewed during the FGDs and workshops, the basket of options available to farmers who are in areas vulnerable to floods and water shortage is limited to at most 3 or 4 options depending on the location. Given these limited traditional responses to floods and water shortages and the apparent inadequacy of capacity to fully adopt such measures as indicated by the number of farmers who resort to doing nothing and relying on others to meet their needs, and by the absence of financial and other support services from the national and local government agencies, many of the farmers will remain as vulnerable if not more vulnerable in the future than they are now.

District	**Service area (ha)**	**Prone to Flood**		**Prone to Water Shortage**		**Prone to Flood and Water Shortage**	
		ha	%	**ha**	%	**ha**	%
I	24,962.0	7,190.8	28.81	14,580.5	58.41	18,103.3	72.52
II	23,912.9	8,265.3	34.56	8,312.3	34.76	11,325.2	47.36
III	29,846.3	8,489.8	28.45	5,464.9	18.31	11,643.4	39.01
IV	23,811.0	10,223.8	42.94	5,803.0	24.37	12,365.6	51.93
TOTAL	**102,532.2**	**34,169.8**	**33.33**	**34,160.7**	**33.32**	**53,437.5**	**52.12**

Table 3.22: Vulnerable areas in the different UPRIIS service area districts.

3.3.4 Conclusions

The impacts of the changing streamflow patterns in PCW on the lowland rice farmers served by the UPRIIS were characterized largely through FGDs, key informant interviews and workshops that heavily involved farmers, key personnel from the National Irrigation Administration, National Power Corporation, local government units and local community leaders among many stakeholder groups in PCW. Review of relevant documentations was also useful in this part of the study.

The increase in streamflow could lead to higher likelihood of floods in the service areas of UPRIIS than it is at the present. Likewise, the projected decrease in streamflow of PCW during the dry season will likely increase the incidence of water shortage which could be aggravated by the increasing water demand due to increasing temperature. The projected changes in climate and the associated changes in streamflow patterns of PCW will likely have more serious impacts on the lowland farmers in view of the absence of deliberate program to reduce the vulnerability of the lowland farmers to floods and water shortages.

4 Adaptation

4.1 Forest Ecosystems

4.1.1 Activities conducted

Watershed forest ecosystem in the Philippines is one of the systems predicted to be adversely affected by climate change (Jose et al. 1992). The occurrence of climate variability and extremes threatens the state of this vulnerable ecosystem as well as the services that it provides to the communities. This calls the attention of concerned watershed actors/players to develop adaptation strategies needed for the abatement of the adverse effects. These include changes in practices or technology to take advantage of the opportunities the climate presents and limit the harms suffered from its variations (IPCC 1996). Aside from scientists, key institutions play a critical role in this important task.

Thus, the study identified and assessed current and potential adaptation measures to mitigate the impacts of climate change to watershed forest ecosystems in Pantabangan-Carranglan watershed.

4.1.2 Description of Scientific Methods and Data

The study employed various research methods to obtain the information needed for the assessment of current and future adaptation measures to mitigate the impacts of climate change to forests and watershed ecosystem of the Philippines, specifically in Pantabangan-Carranglan Watershed. These include surveys, focus group discussions, workshops, secondary data gatherings, and key informant interview. These methods were discussed in Chapter 3: Impacts and Vulnerability.

4.1.3 Results

The following adaptation strategies to mitigate impacts of climate change to Pantabangan-Carranglan watershed forest ecosystems were identified by the local communities, stakeholders, LGUs, and People's Organization during workshops, FGDs, and interviews. Adaptation strategies identified were based on what kind of ecosystem is being affected by climate change.

4.1.3.1 Lowland farms

- Early onset of the rainy season: Adaptation measure used by farmers in Carranglan is the utilization of short term varieties while those from Pantabangan install small water impounding (SWIP).
- Late Onset of Rainy Season: As lowland farms in Pantabangan are strongly vulnerable to late onset of the rainy season, adaptation measure done to cope with its impacts is the choice of adaptable species for climate change.
- La Niña: Adaptation measure undertaken in Pantabangan includes increase consultation with the different agencies concerned and the involvement/participation of the different stakeholders.
- El Niño: Farmers in Pantabangan and Carranglan shift to drought resistant crops and apply supplemental watering to adapt to El Niño.
- Rainy Season: Lowland farms in Pantabangan are only moderately vulnerable to rainy season thus, no adaptation measures is being undertaken by the farmers.

4.1.3.2 Upland farms

- Early or Late Onset of Rainy Season: Some of the adaptation measures mentioned by the participants from Pantabangan and Carranglan areas during early or late onset of rainy season are the use of appropriate variety of planting materials, installation of firelines, strict implementation of forest laws, adoption of modern method of farming suited for upland and visibility of enforcement agencies to the area.

- La Niña: Adaptation measure undertaken by farmers when La Nina comes is the delay of their planting activity.

- El Niño: As an adaptation measure, the participants mentioned that farmers shift to more tolerant crops. For instance, farmers plant crops whose growths are not inhibited by limited supply of water. Thus, traditional crops such as rice are not produced during occurrence of El Nino episode.

- High Temperature/Summer Season: Measures undertaken by the farmers to adapt to high temperature/summer season, the participants mentioned that use of drought resistant crops is commonly practiced.

- Rainy Season: As an adaptation strategy, the farmers use fungicides/pesticides in their upland farms to control the attacks of the fungi.

4.1.3.3 Tree plantation

- Early or Late Onset of Rainy Season: Adaptation measures being undertaken by the communities whenever there is an early or late onset of rainy season are: (1) adjust silvicultural treatment schedules; (2) plant species that can adjust to variable climate situations; and (3) plant trees at the proper time.

- La Niña: Adaptation measure being undertaken to overcome effects of La Nina is the implementation of proper silvicultural practices.

- El Niño: Measures being undertaken by the concerned sectors to adapt to the effects of El Nino include construction of fire lines to avoid widespread of forest fires in case such event occur, practice of control burning and supplemental weeding.

4.1.3.4 Grassland

- Early Onset of the Rainy Season: Adaptation measures undertaken in Pantabangan include: (1) dependence on forest resources as source of livelihood; (2) increase fund for forest protection, regeneration from national government; and (3) increase linkage among local government units (LGUs), government organizations (GOs) and Non-government organizations (NGOs).

- La Niña: Adaptation measure undertaken to minimize impacts of La Nina in Carranglan is the introduction of immediate drainage.

- El Niño: Grassland areas in Pantabangan and Carranglan areas are strongly vulnerable to El Nino. To cope with the impacts of El Nino, adaptation measures undertaken were application of controlled burning and introduction of drought resistant species.

- High Temperature/Summer Season: To decrease the degree of impacts of high temperature in the grassland areas of Pantabangan and Carranglan areas, intensive information dissemination campaign among the stakeholders were undertaken.

4.1.3.5 Natural forests

- Early Onset of the Rainy Season: Adaptation measures that are being undertaken to reduce the impacts of early onset of rainy season on the natural forests are: placing safety measures for kaingineros by the local and national government, develop strong linkage between the LGU and the government agency to protect the forests, and empowerment of the local communities.

- Late onset of the rainy season: Adaptation measures being implemented to abate the impacts of late onset of rainy season include: (1) urging the kaingineros to apply safety measures, (2) developing strong linkage between the LGU and the government agency to protect the forests; and (3) empowering the local communities.

- La Niña: No adaptation measure was mentioned in Pantabangan and Carranglan, however in Ma. Aurora, drastic move such as cancellation of the timber license agreement (TLA) or implementation of total logging ban is being implemented.

- El Niño: Among the municipalities of Pantabangan, Carranglan, and Ma. Aurora, only Pantabangan noted the adaptation measures that are undertaken. These are: (1) safety measures being undertaken by kaingineros; (2) strong linkage between the LGUs and the different government organizations; and (3) empowerment of the local communities.

4.1.3.6 Soil and water

- Early Onset of the Rainy Season: Adaptation measures mentioned include: (1) adaptation of the SALT method in upland farms; (2) implementation of the reforestation program; (3) strict implementation of forest laws; (4) consultations among constituents; (4) implementation of programs; and (5) conduct of research on ground water for the household.

- Late Onset of the Rainy Season: Adaptation measures being undertaken in Pantabangan are the same when there is early onset of the rainy season while no adaptation measures were noted by the participants from Carranglan and Ma. Aurora.

- La Nina: Adaptation measures being undertaken in Carranglan is the adoption of SALT as a farm technology while in Pantabangan, construction of deep well is being done. In Ma. Aurora, adaptation measure being undertaken is the construction of small water impounding program.

- El Nino: Adaptation measures undertaken in Carranglan to cope with El Nino event include cloud seeding and introduction of water conservation measures (SWIP, SWIS, STW). In Ma. Aurora on the other hand, stabilization of the watershed is being done.

- High Temperature/Summer Season: Despite the degree of vulnerability mentioned by the participants from Pantabangan and Carranglan (please refer to Chapter 3: Impacts and Vulnerabiluty), no adaptation measure was mentioned to cope with the impacts of high temperature/summer season. In Ma. Aurora, on the other hand, adaptation measure mentioned is the seeding of clouds to induce rainfall.

- In general, there had been little consideration of an overall climate change adaptation strategy and its various options for Philippine forest ecosystems. The 1999 Philippines Initial National Communication contains adaptation options for watershed management that partly apply to forest ecosystems.

- There are many laws and polices governing the use and conservation of forest resources in the Philippines. The more pertinent of these include the following:

- Presidential Decree 705 of 1975 (Revised Forestry Code of the Philippines)- PD 705 embodies the general mandate of the Constitution in managing and conserving forest resources.

- DENR Administrative Order No. 24 Series of 1991- This order promulgated the shift of logging from old-growth forests to secondary (residual) forests effective 1992. Prior to this, logging is confined to old-growth forests.

- R.A. No. 7586 "National Integrated Protected Areas Systems Act of 1992"- The law stipulates that the management, protection, sustainable development and rehabilitation of protected areas shall be undertaken primarily to ensure the conservation of biological diversity. However not all of the remaining natural forests are covered by NIPAS. All remaining old-growth forests are protected but logging are still allowed in secondary forests.

- Republic Act (R.A.) No. 8371 "Indigenous People's Rights Act of 1997"- This law recognizes the vested rights of indigenous peoples over their ancestral lands within forestlands including secondary forest. The implementing guidelines of this law are still being finalized.
- Executive Order 363 of 1995- This presidential order adopted Community-Based Forest Management (CBFM) as the national strategy to ensure the sustainable development of the country's forests and promote social justice.
- Executive Order 318 of 2004 "Promoting sustainable forest management in the Philippines"- This order is an attempt to revise PD 705 and aims to attain sustainable forest management in the country's production forests.

In terms of actual ground activities, the government has been actively pursuing several initiatives in spite of its limited resources. These include the following:

- Conservation of remaining forests in NIPAS sites and watershed areas.
- Reforestation and rehabilitation of barren upland areas through tree planting and agroforestry.
- Community-based forestry activities such as community organizing and development.

The private sector is less involved today compared to the height of logging activities in the 1950s and 1960s. However, civil society is more involved as community-based programs increase.

Climate change is hardly being considered at all in the planning process of the government for forest resources. Its more urgent concern is to save the remaining forests from human exploitation which is the more imminent threat.

4.1.4 Conclusions

As we have shown earlier in Chapter 3, climate change may have positive or negative impacts to different forest ecosystems in Pantabangan-Carranglan Watershed. The degree of impacts of climate change varies depending on the type and location of forest ecosystems being affected. La Niña and El Niño have the most negative impacts to forest ecosystems

In the light of this, an overall adaptation strategy should probably focus on identifying which forest ecosystem in the watershed is more at risk. Specific adaptation options could include assisting local communities shift from forest products from forests at risk, etc.

4.2 Social Systems

4.2.1 Activities conducted

The watershed ecosystem in the Philippines is predicted to be adversely affected by the occurrences of climate variability and extremes. This study explored the adaptation strategies developed by various institutions and local communities in the Pantabangan-Carrangalan Watershed (PCW) to abate the impacts of climate variability and extremes. The activities conducted under this study were:

1. Analyzed the different strategies developed and implemented by the different institutions and local communities to cope with and adapt to climate variability and extremes; and
2. Recommended institutional strategies to the key watershed institutions to better adapt to the impacts of climate variability and extremes.

4.2.2 Description of scientific methods and data

4.2.2.1 Data collection

The study employed various research methods to obtain the information needed to identify and analyze the adaptation strategies of PCW institutions and local communities to climate variability and extremes. For the purpose of this study and in consideration of the climatic type in PCW, the occurrence of the following climate variability and extremes were assessed: delay on the onset of rainy season, early onset of rainy season, prolonged rains, El Niño or drought, La Niña or flooding, typhoons, forest fires, and other events that may be specified by the respondents.

Key informant interview: Key informant interviews were conducted to determine the services provided by PCW to its different stakeholders, the different climate variability and extremes experienced in the area, its impacts, as well as the adaptation strategies developed to cope with the adverse effects. A structured interview schedule was developed to obtain the necessary information from the respondents. The informants were composed of government officials from different barangays or communities within the watershed, such as barangay captains, councilors, and secretaries, representatives from different institutions in PCW.

Focus group discussions: Focus group discussion (FGD) was also done to seek from the participants the natural occurrences of climate variability and extremes that occurred in the PCW in the past 50 years, and to determine what are the adaptation strategies developed by the communities, and their recommendations to the different institutions that manage the watershed. The respondents were composed of representatives from various institutions concerned with PCW. The FGD was conducted through the use of various participatory rural appraisal techniques like historical and cognitive mapping.

Survey: The survey aimed to determine the different strategies developed by the communities to cope with the impacts of climate variability and extremes, to assess the assistance provided by the different institutions present in the area as well as the satisfaction of the communities, and solicit recommendations from the community people on how to improve the services given by the institutions.

The survey covered the four municipalities of the three different provinces encompassing the watershed. These are Pantabangan and Carrangalan in Nueva Ecija, Alfonso-Castañeda in Nueva Vizcaya, and Ma. Aurora in Aurora. From a complete list of 36 barangays located in the watershed, 25 barangays were selected to constitute the sampling areas. A total of 375 respondents were randomly selected using the barangay records. This sampling technique employed was adopted from Chua (1999) which allows a 0.05 permissible error and 95% confidence interval level.

4.2.3 Results

4.2.3.1 Local communities

Local communities are employing different adaptation strategies for food, water, livelihood and health.

Food: Availability of planting materials

From the 156 (64.20%) respondents who mentioned that climate events have an effect on availability of planting materials, 96 were employing adaptation strategies during variable and extreme climates (Table 4.1). The most common strategies were improving water system (25%), using fertilizers and pest control (18.75%), waiting for the perfect planting time (13.54%), changing crops (12.50%), buying seeds from the Department of Agriculture/Philippine Rice Research Institute (10.42%), producing their own seeds (10.4%), storing seeds (5.21%), exchanging seeds (3.13%), and planting early (1.04%).

Response	Pantabangan	Carranglan	Ma. Aurora	Alfonso-Castañeda	Total
Improve water system	21.88	21.57	42.86	50.00	25.00
Use pest control /fertilizer	28.13	11.76	28.57	16.67	18.75
Wait for the right time of planting	9.38	17.65		16.67	13.54
Change crops	12.50	9.80	28.57	16.67	12.50
Buy seeds from DA/ Phil Rice	9.38	13.73			10.42
Raise/ produce own seeds	12.50	11.76			10.42
Store seeds	6.25	5.88			5.21
Exchange seeds		5.88			3.13
Early planting		1.96			1.04
Total	100.00	100.00	100.00	100.00	100.00

Table 4.1: Adaptation strategies employed in the absence or lack of planting materials as affected by variable and extreme climates.

Food: Crop production

Table 4.1 also shows that adaptation strategies also differ among the different municipalities under study. In Pantabangan, the most common adaptation strategy is the use of fertilizer (28.13%), which is followed closely by improving the water system (21.88%). Meanwhile, in Carranglan (21.57%), Ma. Aurora (42.86%) and Alfonso-Castañeda (50.00%) improving water system is the most adopted strategy to make planting materials available especially during variable and extreme climates.

Of the 251 respondents who believed that crop production is affected by variable and extreme climate events, only 129 respondents are actually employing strategies to reduce the impact of climate-related events as shown in Table 4.2. Among the strategies adopted by the 129 respondents are: using of more fertilizers (37.21%), using and/or devising water pump (19.38), planting other crops that do not require much water (12.40%), planting early (7.75%), using good quality seeds (11.63%), storing palay seedlings (also known as "binhi") (4.65%), and closing other water tributaries to centralize flow of water as well as maximize the volume of water that irrigates the farms (6.98%).

The last strategy mentioned above is practiced by some residents of Carranglan. Meanwhile, the most common strategy of respondents in Pantabangan (42.86%), Carranglan (35.80%) and Ma. Aurora (50.00%) was the use of fertilizers, while respondents in Alfonso-Castañeda (60%) used water pumps.

Strategy	Pantabangan	Carranglan	Ma. Aurora	Alfonso-Castañeda	Total
Use fertilizers	42.86	35.80	50.00	20.00	37.21
Use water pump	14.29	19.75	16.67	60.00	19.38
Plant other crops	14.29	12.35	16.67		12.40
Early planting	8.57	7.41		20.00	7.75
Use good quality seeds	14.29	11.11	16.67		11.63
Store palay	2.86	6.17			4.65
Close the other tributary of water	2.86	7.41			6.98
TOTAL	100.00	100.00	100.00	100.00	100.00

Table 4.2: Adaptation strategies employed to improve crop production during variable and extreme climates.

Domestic water

The majority of the respondents (210) also employ several adaptation strategies whenever water supply for domestic uses becomes limited (Table 4.3). The most common strategy was using water wisely or conserving water (56.67%). This pertains to recycling used water for other purposes. For instance, laundry water can be used to clean house or water plants. The rest of the respondents employed strategies such as fetching water from neighbor's wells when their own dries up (13.81%), installing more water pumps (9.52%), improving water system through repair or change of damaged hose (5.24%), digging another well (5.24%), storing water (4.29%), buying water (3.81%), planting instead of cutting trees (0.95%), and scheduling of usage (0.48%).

Strategy	Pantabangan	Carranglan	Ma. Aurora	Alfonso-Castañeda	Total
Wise Use	60.49	57.28	63.64	26.67	56.67
Fetch water from neighbors' wells	11.11	14.56	18.18	20.00	13.81
Install more water pumps from rivers/streams	9.88	9.71	9.09	6.67	9.52
Improve water system mechanism	2.47	5.83		20.00	5.24
Dug another deep well	3.70	5.83		13.33	5.24
Store water	3.70	3.88		13.33	4.29
Buy bottled water	8.64	0.97			3.81
Plant trees		0.97	9.09		0.95
Scheduling		0.97			0.48
Total	100.00	100.00	100.00	100.00	100.00

Table 4.3: Adaptation strategies employed for domestic water supply.

Irrigation water

The most common adaptation strategies practiced in the watershed are using water pumps and generator (46.15%), cessation of planting or waiting for the rain to come (19.66%), scheduling water distribution (8.55%), digging wells (5.98%), sourcing water directly from the rivers (4.27%), reducing production (2.56%), early planting (2.56%), diverting the flow of water (0.85%) and choosing drought-resistant crops (0.85%) (Table 4.4). To cope with the impacts of El Niño, Pantabangan (37.93%) and Carranglan (64.94%) respondents resorted to using more water pumps and generator to produce water needed for crop production. On the other hand, 40% of the respondents from Ma. Aurora used water pumps and generator while the same percentage did not plant at all. In Alfonso-Castañeda, half of the respondents did not plant at all to avoid the risk of losing.

Strategy	**Pantabangan**	**Carranglan**	**Ma. Aurora**	**Alfonso-Castañeda**	**Total**
Use water pump and generator	37.93	64.94	40.00	16.67	46.15
No planting/ wait for the rainy season	27.59	15.58		50.00	19.66
Scheduling of water distribution	13.79	3.90	40.00	16.67	8.55
Dig wells	3.45	7.79			5.98
Directly gets water from the nearby body of water	13.79		20.00		4.27
Reduce the production or planting	3.45	2.60			2.56
Early planting		2.60		16.67	2.56
Divert the flow of the water		1.30			0.85
Change crops		1.30			0.85
Total	100.00	100.00	100.00	100.00	100.00

Table 4.4: Adaptation strategies employed by the respondents to cope with impacts of variable and extreme climates on water requirements for irrigation.

Livelihood

Various adaptation strategies (Table 4.5) were also employed by 104 respondents to decrease the negative impacts of variable and extreme climate on their livelihood. More than half of the respondents saved their income (65.38%), while 27.88% of them borrowed money from relatives and others and 6.73% asked for support from affluent relatives. Although not a major strategy to reduce livelihood vulnerability, PCW residents had a tendency to seek the assistance of relatives to reduce the impacts of variable and extreme climate events.

Strategy	Pantabangan	Carranglan	Ma. Aurora	Alfonso-Castañeda	Total
Save	61.54	77.36	14.29	40.00	65.38
Loans to relatives	28.21	18.87	85.71	40.00	27.88
Support of relatives	10.26	3.77		20.00	6.73
Total	100.00	100.00	100.00	100.00	100.00

Table 4.5: Adaptation strategies employed for livelihood during variable and extreme climates in the watershed.

Health

Among the adaptation strategies being practiced by watershed communities when they experienced health problems were eating healthy foods (55.19%), cleanliness of the surroundings (24.07%), taking herbal medicines or consulting with faith healers / "albularyo" (12.59%), and going to the hospital for check–up and medicines (8.15%) (Table 4.6).

Strategy	Pantabangan	Carranglan	Ma. Aurora	Alfonso-Castañeda	Total
Eat healthy foods	51.96	55.07	50.00	81.25	55.19
Cleanliness	24.51	26.09	21.43	6.25	24.07
Herbal Medicines / Faith healer	10.78	13.77	21.43	6.25	12.59
Go to hospitals for medicines	12.75	5.07	7.14	6.25	8.15
Total	100.00	100.00	100.00	100.00	100.00

Table 4.6: Adaptation strategies used for health problems during variable and extreme climates.

General adaptation strategies employed by communities

An examination of the adaptation strategies practiced by the households is important in assessing their vulnerability to climate variability and extremes. Adaptation strategies pertain to strategies/mechanisms that communities employ to minimize or reduce the impacts of climate variability and extremes. Households tend to be more vulnerable when the adaptation strategy being employed is not effective. Also, since time, money and effort are also needed in many adaptation strategies, households adversely affected by climate variability and extremes become three times more vulnerable if such coping mechanisms proved to be ineffective.

For each of the component index, i.e. food, water, livelihood and health, each household employs different adaptation strategies. Results of the survey revealed that the respondents employed a maximum of eight (8) adaptation strategies whenever households' food, water, livelihood and health are at risk. Table 4.7 shows the coping mechanisms employed by the communities totaling 1,581 (multiple responses). Almost 18% of the respondents practiced reduction in terms of consumption, i.e., food and water. About 14% availed of loans/credit to increase farm inputs, particularly fertilizer and water generation, which is an added cost for the farmers. Although, it is hard to prove that praying reduces vulnerability, still 13% of the respondents believed that divine guidance had helped them cope with all kinds of problems, may it be climate-related or not. Other strategies employed are: storing food, firewood, medicine, and water; community and kinship ties; off-farm work; government/NGO assistance; crop diversification; asset disposal; treebelts/wind breaks/hedgerows; resettlement/ rehabilitation; and the ability to forecast natural hazards/disasters based on community's/ indigenous traditional knowledge.

A closer look at the municipalities revealed that the respondents in Pantabangan (75.91%), Carranglan (72.22%) and Ma. Aurora (94.12%) reduced their consumption, except in Alfonso-Castañeda where treebelts/ windbreaks/hedgerows (86.36%) and storing food, firewood, medicine and water (86.36%) are the most commonly practiced strategies. The town of Alfonso-Castañeda faces the sea; hence, windbreaks and treebelts were established to break the intensity of wind. In the three towns, this is not a problem since they are surrounded by mountains and forests. In the towns of Pantabangan and Carranglan, only a small number of respondents were employing the strategy on treebelts/windbreaks/hedgerows, with only 26.28% and 18.18%, respectively (Table 4.7). This is because the residents in these towns were cutting trees for fuelwood, which is also the reason why there are only few trees in these towns.

Availing of loans, as a strategy, was also popular for the respondents (Table 4.7). At least more than half of the respondents in the four towns were availing of loans/credit. It is also important to note that this strategy, as seen by the participants of the FGD, is not effective, especially among small farmers. According to them, this practice even made them more vulnerable.

At least half of the respondents in the four towns were seeking help from their community and kin. Relatives, friends and neighbors serve as the support group, from which the respondents can turn into during times of climate variability and extremes.

Table 4.7 shows that involvement in off-farm work is also a common strategy, which is practiced by 30% of the respondents. Most of the respondents look for work outside their town as factory worker, saleslady, housemaid, construction worker, among others.

STRATEGIES	PANTABANGAN (N=137)		CARRANGLAN (N=198)		MA. AURORA (N=17)		ALFONSO-CASTAÑEDA (N=22)		TOTAL (N=374)	
	Freq*	%	**Freq***	%	**Freq***	%	**Freq***	%	**Freq***	%
Reduced consumption	104	75.91	143	72.22	16	94.12	15	68.18	278	74.33
Loans/credit availability	79	57.66	119	60.1	10	58.82	13	59.09	219	58.56
Pray or make offerings to Anito	88	64.23	126	63.64	10	58.82	16	72.73	204	54.55
Store food, firewood, medicine and water	70	51.09	120	60.61	7	41.18	19	86.36	198	52.94
Community and kinship ties	72	52.55	86	43.43	7	41.18	11	50	176	47.06
Off-farm work	49	35.77	60	30.3	5	29.41	8	36.36	122	32.62
Government/ NGO assistance	33	24.09	71	35.86	7	41.18	6	27.27	113	30.21
Crop diversification	39	28.47	42	21.21	6	35.29	4	18.18	91	24.33
Asset disposal	33	24.09	44	22.22	2	11.76	5	22.73	84	22.46
Treebelts/ wind breaks/hedgerows	36	26.28	36	18.18	2	11.76	19	86.36	59	15.78
Resettlement/ rehabilitation	7	5.11	14	7.07			7	31.82	18	4.81
Ability to forecast natural hazards/disasters based from community's/indigenous traditional knowledge	16	11.68	9	4.55			8	36.36	19	5.08

* multiple responses

Table 4.7: General adaptation strategies employed by PCW communities during variable and extreme climates.

4.2.3.2 Institutions

Table 4.8 summarizes the various adaptation strategies employed by the different institutions in order to adapt to the impacts of climate variability and extremes. Among the institutions studied, LGU has the most number of adaptation strategies with 23, which can be attributed to their accountability as the one responsible for the whole community and they are the one who really associates personally with the people. This is followed by the DENR with 11, then by NIA and NPC both with 4. It can be noticed that reforestation/tree planting is very common adaptation strategy among all institutions. They all recognized the importance of trees in water generation and in averting global warming because of their capacity to be a carbon sink. Furthermore, they also recognized the role of trees in controlling floods whenever typhoon comes. In some cases, however, reforestation is not included in with the cultural practices of the people, like the Igorots who prefer to plant vegetables rather than trees.

Forest protection activities such as the formation of fire brigade and hiring of forest guards were also practiced as forms of adaptation strategies. These help in controlling and preventing any forest fires due to kaingin and charcoal making, and in the denudation of forest due to illegal logging. These are also connected to the monitoring activities conducting. However, most of the time the number of forest guards in the area is insufficient, hence, they are in guarding the forest.

Institutions	Adaptation Strategies
NIA	Reforestation Forest protection (campaign) Physical rehabilitation Letting go freely of excess water from the reservoir/dam especially in rainy season when the dam is overflowing to avoid flooding
DENR	Reforestation Forest protection (fire brigade) Adjustment in schedule of program implementation/prioritization Monitoring Shading of seedling in reforestation sites Deploying of forest guards to patrol the forest Planting of fire breaks Information, education and communication (IEC) Hiring of additional manpower especially of casual laborers Adjustment in program prioritization Integrated Social Forestry Program (Gen. Luna)
NPC	Reforestation Information, education and communication (IEC) Proper choice of species Adjustment in schedule and implementation
LGU	Tree planting and reforestation (Conversion) Provision of relief goods (Bunga and FC Otic)) Information, education and communication (EIC), information dissemination and conduct of seminar on proper farming, and house visits especially during typhoon season (Villarica, East Poblacion, and Bantug) Creation of task force El Niño/La Niña, formation of disaster brigade (Fatima) Planned action to be taken to avert current and destructive effects of El Niño and La Niña Diversion of program to other urgent problems (Pantabangan), and adjustment in program schedules

	Bridge development (Abuyo), hanging bridge construction (San Agustin) Repair, development, construction and maintenance of roads (including DPWH) Development and road construction (San Agustin) Provision of solar dryer, multi-purpose pavement for drying palay, (Bunga, Galintuja, Ma. Aurora,) Free medicines (G.S. Rosario) Hiring of extension worker especially BHW (Fatima and Galintuja, Ma. Aurora)) Request for free seedlings from DA Helping people in evacuation centers Lending of seedlings (Marikit Repairs of deep well and canals Rehabilitation of destroyed infrastructure and reporting it to the Department of Public Works and Highways (DPWH) (San Juan) Relay information about the status of the barangay after a calamity to the municipal government (Bunga) Barangay. Tanods are visiting the community to help with their problems (Bantug) Small organization that buy palay in higher prices and sell rice in lower prices (Salazar), training of Peoples organization (PO) (Lublub) Digging possible water sources for irrigation, , spring or deep diverting the flow of water from the river into the direction of the people farm fields (Bantug) Diverting the flow of water from the river into the direction of the people farm fields through the help of Barangay Tanod (Bantug) Spring Development, formulation and Implementation of Small Water Impounding Project (SWIP), provision of additional water tank, pump and hose, finding other sources water sources, deep well construction and dissemination of water distribution schedules.

Table 4.8: Adaptation strategies of different user-institutions to minimize the negative impacts of climate variability and extremes.

Another adaptation strategy mentioned was the adjustment in program implementation and prioritization. This involves, for instance, the implementation of programs planned and scheduled to be operated and executed for the 2nd quarter but was immediately implemented in the 1st quarter in hope that it would minimize or solve the pressing problems experienced in the area. It also includes formulation of new programs of action to minimize the negative impacts of climate variability and extreme. Among the programs that they are implement are planting of fire breaks for forest fires, livelihood opportunities for the jobless people, and the Small Impounding Water Program and spring development to help the communities to have a continuous supply of water even if there is El Niño. In time of El Niño/La Niña, a task force is also created to help and coordinate with the people.

Additional manpower/workforce is also needed for the proposed program to be implemented. In connection with this, additional money/budget is also needed. For institutions like NIA, DENR, and NPC, the budget is already fixed for a certain year and comes from the central office. Hence, it is very difficult for them to have extra budget for the wages of their employees and in acquiring instruments and materials for the implementation of the programs.

Physical rehabilitation and repairs were also mentioned. These involve the repairs of properties and in infrastructures destroyed by typhoons, such as bridges and roads used by the community to travel and transport their products to the market, transmissions lines of NPC and construction and improvement of deep wells, and water pump and canals (NIA and LGU).

The distribution of relief goods is also a common practice in the area. Among the goods given include rice and medicines. However, this may result to, dependency especially if the distribution is in a dole out manner. Others are asking the Department of Social Welfare and Development to help in sourcing and gathering of relief goods.

The construction of multi-purpose pavement for drying palay was a strategy to help the farmers dry the palay even in rainy seasons. Region III wherein the Pantabangan-Carranglan Watershed is located is the rice granary of the country. Most of the residents in the region are farmers. Likewise, the acquisition of a solar dryer will also greatly help the farmers especially during the rainy season.

Another adaptation strategy mentioned were asking assistance from different institutions of the government, such as the Department of Agriculture (DA) for free seedlings of palay, which lessens the expenses of the farmers in farm terms of farm inputs. They also request water pumps from the same department.

Meanwhile, some barangays are encouraged and initiate the formation of small organization that buy palay in higher prices and sell rice in lower prices (Salazar). Information dissemination was also an adaptation strategy practice by the institutions. Many barangays councils disseminate information about the coming climate variability and extremes. These make the communities prepare themselves by obtaining the necessary food and clothing to help them survive the upcoming catastrophic event. BDCs are also concern about the farming technologies and practices of the residents; hence they also conduct seminars on these matters. Also do house-to-house visits whenever such events happened to see the conditions of the residents.

From these examples, it can be observed that the function of BDCs is in general on communicating messages of the relaying of messages of the communities to their respective LGUs. Then the LGU either makes an action or provide solution to the problem reported or pass it to concerned government agencies such as DA, DENR and DOH.

Information, education and communication were also identified as adaptation strategies. The Institutions give advance information about the coming climate events (effects), educate and train the people on proper farming that will give them high profit, ask for the feedbacks on certain projects implemented from the community and identify the needs of the community.

It also important to note that two respondents (Maglanoc and R.A. Padilla) from the BDCs said that they do not employ any strategy to help the communities in adapt to climate variability and extremes because the communities themselves have already adapted to and survived these events.

4.2.4 Conclusions and recommendations

The institutions in the PCW are faced with varying impacts from the occurrences of climate variability and extremes. Though these climate events both presented positive and negative effects, the adverse impacts outweighed the beneficial ones. These affect the operation, budget requirement, workforce, program implementation, and the delivery of services of these institutions. Particularly, these events affect the major services provided by the watershed, i.e., irrigation and power generation.

Among the major strategies developed by the institutions to cope with the negative impacts of climate change are reforestation, forest protection, IEC, and adjustments in the implementation of programs. At the community level, several technological adaptations were also performed such as construction of multi-purpose pavement for drying palay, acquisition of a solar dryer, SWIP, and spring development. The LGUs also have the most number of adaptation strategies developed.

Advance information on the occurrence of severe climate events is the support mostly received by the communities from the institutions. However, a great portion of this comes from NGOs. Nevertheless, the communities are highly satisfied (80%) by the support that they received.

While most negative impacts of climate variability and extremes affect the various aspects of operation of institutions in the PCW, its adaptation strategies focused more on reforestation and forest protection. Although these play an integral and critical part in their operation, particularly in improving the condition of the watershed, adaptation measures that will address the needs of the institutions themselves in order to provide efficient service to its clients should also be developed. This could include procurement of new equipment, construction of facilities, and adoption of relevant technologies that could enhance their mechanism to cope with the adverse impacts of severe climate events. Obviously, availability of funds is a major hindrance in the implementation of these strategies. Alternative financial sources should be explored to support the other activities of the institutions in order to successfully adapt to the impacts of climate variability and extremes.

4.3 Water Resources

4.3.1 Activities conducted

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 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. Thus, the study identified and assessed alternative management strategies to cope with the impacts of climate change on water and its uses and on water resources management.

4.3.2 Description of scientific methods and data

4.3.2.1 Data collection

Various research techniques such as focus group discussions (FGDs), secondary data gathering, key informant interview, and direct field observations were used to acquire the data needed for the assessment of impacts and adaptation strategies of the communities in the Pantabangan-Carranglan Watershed/UPRIIS service area to water shortage and drought.

Focus group discussions: Focus group discussions (FGDs) were also done in Irrigator's Association in four districts of UPRIIS-NIA to solicit information from the participants about the occurrences of water shortage and floods in the service area in the past 25 years and establish its impacts as well as adaptation strategies developed by the communities in the service area, and their recommendations to the institutions that manage the service area

Secondary data gathering: Information on the PCW/UPRIIS service area was collected from the NIA-UPRIIS district offices. Sources of information include Service Area Development Plan and list of Irrigator's Association (IA) in the service area.

Key informant interview: An interview instrument was developed to obtain the necessary and relevant information from the informants. The respondents were composed of Irrigator's Association members from different municipalities in the service area, government officials from different barangays, Municipal Agriculture Officer (MAO), and NIA-UPRIIS district officers. Key informant interviews were employed to establish the services provided by the Pantabangan-Carranglan watershed to its service area and the impacts as well as adaptation strategies in the area to water shortage and flood.

4.3.3 Results

4.3.3.1 Common adaptation measures

During workshops and focus group discussions there were various adaptation strategies identified to mitigate climate change impacts and vulnerability of water resources in Pantabangan-Carranglan Watershed.

On the other hand, whenever there is water shortage, farmers commonly resort to shallow tube wells to irrigate their farms (Table 4.9). Others source their water from nearby streams using pumps to bring water to their cultivated fields.

From the list of adaptation measures, switching to alterative crops is a common practice. However, this is done only in selected areas because the soil type is not suitable for other crops aside from rice. Although the production cost in planting alternative crops like vegetables is more expensive than the production cost of rice, some farmers take the risk rather than wait for the next cropping season. Production cost for rice averaged at about P25, 000 per hectare while average production cost for vegetable is between P38, 000 to P 40,000 per hectare depending on the source of irrigation. It is cheaper when irrigation is provided through the UPRIIS than getting water from shallow tube wells or other alternative sources. Nevertheless, this adaptation strategy is very effective since the net income the farmer gets is higher than from the net income from rice production. The yearly net income of the farmers in vegetable production is about P 110, 000 per hectare since they can harvest at most 12 times in a cropping season while the annual net income in rice production is only P 25, 000 per hectare on the average.

Furthermore, the respondents also acknowledge the role of UPRIIS-NIA in program implementation and physical rehabilitation and repairs of the infrastructures like irrigation canals and water pumps although there are limited funds and resources to cover the expenses. The NIA also offers loans to qualified farmers and use it as incentives to Irrigator's Association (IAs) that are able to pay at least 80% of the Irrigation Service Fee (ISF). During dry season the farmers pay 3.5 cavans per hectare which is approximately P 1, 750, while during wet season they pay 2.5 cavans per hectare which is approximately P 1, 125.

The IAs seek assistance from the local government units to provide them a multi-purpose pavement for drying *palay* to help farmers dry *palay* even during rainy seasons. Since most of the residents in the service area are farmers, a facility like this is a must for them. Likewise, the acquisition of a solar dryer is another technological adaptation that could help them cope with the threats of floods or extended rainy days to adversely affect their livelihood.

Agencies like Department of Agriculture (DA) and LGUs from time to time provide free rice seedlings and water pumps to reduce the expenses of the farmers in terms for farm inputs. In addition, the Municipal Agricultural Officer (MAO) provides trainings to inform the farmers about the latest techniques in farming and provides them with hybrid rice seeds that yield more than the ordinary rice varieties. A well-informed community is most of the time the best weapon to cope with the impacts of water shortage and floods.

Among the various facilitators and promoters of adaptation measures, the MAOs have either developed or administered the most number of coping mechanisms. This can be credited to their mandated responsibility to the community, as well as to the strong personal relation they have established with the people in the course of time. Meanwhile, the UPRIIS-NIA is responsible for the maintenance of the irrigation infrastructures. However, NIA is often limited by inadequate funds and resources that reduce their effectiveness in helping reduce the vulnerability of the farmers to water shortage and floods.

	DISTRICT 1	DISTRICT 2	DISTRICT 3	DISTRICT 4
Adaptation Strategies for Drought	Use of shallow tube wells Planting of new varieties of rice (i.e. Gloria rice) and other crops that have less water requirements Rotation method of irrigation is being implemented. Others are hanging around and relying on the crops of their neighbors.	Use of shallow tube wells Planting early maturing varieties of crop and vegetables Scheduling (rotation method) of irrigation is being implemented Use the direct seeding method which requires less water	Use of shallow tube wells Use of other water sources (i.e. from the Atate river that is connected directly to the irrigation main canal) Others are hanging around and relying on the crops of their neighbors	Use shallow tube wells Use of other water sources (i.e. from the Peñaranda river that is connected directly to the irrigation main canal) Others are hanging around and relying on the crops of their neighbors
	District 1	**District 2**	**District 3**	**District 4**
Adaptation Strategies for flood	None. Wait for the next cropping season	Repair the damages Switch to other crops that can sustain floods and heavy rainfall Livelihood diversification (swine production, vegetable farming, canton making and fruit juice making) through Farmers' Business Resource Cooperative Construct fish ponds in the flooded area	Switching to early maturing varieties of crops (i.e. from palay to corn) Attend seminars and trainings conducted by stakeholders about crop production Use of solar dryers	Use of solar dryers

Table 4.9: Current adaptation to floods and droughts at the UPRIIS, PCW.

4.3.3.2 Potential adaptation strategies

The identification of the adaptation strategies was done through review of relevant documents such as the National Action Plan/National Communication of the Philippines, solicitation of experts' judgment through interviews, participatory workshops involving the farmers, local government officials, officials and personnel of the National Irrigation Administration among other key stakeholders in the watershed. The results of these various activities were analyzed and synthesized and submitted to the stakeholders for validation and approval.

Engagement of the various stakeholders in the development of adaptation strategy is critical not only because much of the strategy will be directly implemented by stakeholders but also because most of the strategies has wide ranging implications on the general public as well as on many institutions and agencies of the government. The decision to implement particular set of adaptation measures normally entails significant changes or adjustments in the way people think and do things relative to its natural environment individually and in relation to one another. The challenging part is how to bring all the stakeholders together to agree on what the real risks are related to climate change and then agreeing further on what steps to take so as to cope with these risks in the most effective and efficient way. Arrival at an agreement on what strategy to implement rests on the facilitation of negotiation between and among the stakeholders on whose interests come first and how much cost if at all will any stakeholder have to bear once the strategy is implemented.

In the PCW, the development and implementation of the adaptation strategy was envisioned to be carried out using a three-level mode where the selection, approval and commitment to support the implementation of a strategy heavily involved the local communities, the LGUs and the DENR along with other stakeholders. However due to lack of material time and resources, the project never got to the approval and commitment seeking phase.

Based on the outcomes of the FGDs, key informant interviews, workshops and review of relevant documents, a list of the potentially suitable adaptation measures was made and shown in Table 4.10. Most of the measures listed are commonly practiced by the farmers while others were identified as essential measures that must be implemented to cope with the changing climate and at the same time promote sustainability of the watershed resources and the services they provide. Of these measures the most common recourse for farmers is to resort to alternative sources of water i.e., shallow tube wells and tapping into nearby rivers. The attractiveness of this strategy lies in the opportunity they provide to do farming even with the shortage of water from their irrigation system. The downside to this strategy is the cost involved that cuts significantly into the net revenue of the farmers from its produce. It is also worth noting that many of these adaptation measures are applied autonomously by farmers with almost no support or intervention from the government. This could explain why for most of the measures listed, the absence of adequate support services is identified as a common limitation to the adoption of these measures.

Many of the farmers who are currently constrained by the cost of adaptation measures and the limited funds they have are crying out for government intervention to help them carry the extra financial burden of adaptation mainly by helping them raise the highly regulated price of rice in the market. Under the current pricing scheme for rice, there seems to be little incentive for the farmers to undertake measures that will entail additional production cost to alleviate losses from floods or droughts or simple water shortage when in the final analysis they will still end up losers. Another constraining factor identified is the absence of skills for adaptation. The success of others in adapting to extreme climate related events can provide motivation for others to do the same. However, the lack of proficiency for adaptation usually hampers farmers from even trying and if ever they do they are often discourage by the poor initial results they get. This is where training and skills development program become useful. But like other adaptation measures training and skills development measures are also constrained by limited funds. The farmers alone will not have the capacity to carry out this measure though in extremely extraordinary case some farmers may be able to do it. Obviously such adaptation measure will have to be facilitated by technically and financially able government and private agencies.

Improved watershed management, reforestation and soil erosion control were also identified by the farmers and other lowland stakeholders as potential adaptation measures. In relation to the lowland farmers these measures will not really improve their ability to adapt to floods and water shortage but its successful implementation could minimize the occurrence of floods and water shortage that will reduce vulnerability of the farmers.

Adaptation	Common Features					
	Costs	**Benefits**	**Technical Viability**	**Acceptability to Farmers**	**Support Services**	**Key Limitations**
Drought/Water Shortage						
Shallow tube wells	Medium to high	High	High	High	Inadequate	Lack of capital
Nearby rivers	Medium	High	High	High	Inadequate	Lack of capital
Switching to vegetable farming	High	High	Low to medium	High	Inadequate	Initial skills and capital, site suitability
Switching to early maturing crops	High	High	Low to medium	High	Inadequate	Initial skills and capital
Rotation in receiving water	High	High	Low to medium	High		Lost opportunity
No planting	High	High	Low to medium	Low	Inadequate	Lost opportunity
Reliance on neighbors and friends	High	Low	Low to medium	Medium		Lost opportunity
Floods						
Use of solar dyers	Medium to high	Medium	High	Medium	Inadequate	Capital
Switching to early maturing crops	High	High	Low to medium	High	Inadequate	Initial skills and capital
Livelihood diversification	Variable	High	Low to medium	Variable	Inadequate	Initial skills and capital
Wait for next cropping season	High	Low	Low to medium	High	None	Lost opportunity
Construction of fishponds in flooded area	High	High	High	High	Inadequate	Capital
Training and seminars on crop production	Low	High	High	Medium	Inadequate	Time and interest
Others						
Improved watershed management	High	High	High	Low to medium	Low to medium	Funds
Reforestation	High	Medium	High	Low to medium	Low to medium	Funds
Soil erosion control	High	High	High	Low to medium	Low to medium	Skill and funds

Source: Based on the results of FGDs, workshops, interviews and review of relevant documents.

Table 4.10: Potential adaptation measures for the lowland farmers of UPRIIS, PCW.

4.3.4 Conclusions

An ideal program for reducing the vulnerability of farmers should combine improvement of the conditions of the denuded watersheds of PCW, improvement of the physical and administrative infrastructure of UPRIIS, and enhancement of the ability of the farmers to cope with floods and water shortages. To enhance the coping capacity of the farmers in the service areas of UPRIIS, there is a need to increase the ability of the farmers: to gain access to cheaper alternative water sources, to engage in alternative cropping systems and viable alternative livelihoods, and to set in place systematic and deliberate mechanisms for providing technical and other logistical assistance to the farmers particularly designed to increase and sustain adoption of appropriate adaptation strategies.

5 National Forestry

5.1 Activities Conducted

Climate change is expected to affect tropical forest ecosystems of the world. Thus, the study quantitatively assessed the impacts and vulnerability of forest and biodiversity resources in the Philippines to climate change. Furthermore, the study also

- determined the potential vegetative cover of the Philippines without human intervention using the Holdridge Life Zones; and
- simulated changes in present vegetative cover as a result of climate change using GIS and the Holdridge Life Zones.
- The study also assessed the impacts and vulnerability to climate change of different ecosystems in the Pantabangan-Carranglan Watershed through household survey, use of participatory rural appraisal techniques, direct field observations, interviews, and workshops.

5.2 Description of Scientific Methods and Data

The study made use of GIS and the Holdridge Life Zones to quantitatively assess climate change impacts and vulnerability of Philippine forests ecosystems. Three synthetic scenarios each of precipitation (increase of 50%, 100% and 200%) and air temperature (increase of 1ºC, 1.5ºC and 2ºC) were used in the study. These scenarios are within the limits of GCM projections for the country.

5.2.1 Simulating potential vegetation using the Holdridge Life Zones

In general, the study followed the approach adopted used by Somaratne and Dhanapala (1996) in Sri Lanka and which was given as an example in the Adaptation Policy Framework (APF) of the UNDP (Jones and Boer, 2003).

The Holdridge Life Zone is an ecological classification system based on the three climatic factors, ie. precipitation, heat (biotemperature) and moisture (potential evapotranspiration ratio). These can be defined as follows (Holdridge, 1967):

- Precipitation= annual rainfall (mm)
- Biotemperature:

  Mean annual biotemperature (MAB)= Σ $(0 < T < 30)$/ 12 months or

  Mean annual biotemperature= Σ $(0 < T < 30)/365$ days

- Moisture:

  Mean Annual PET= (MAB) (58.93)

  PET Ratio= Mean Annual PET/Mean Annual P

Based on the above, Philippine life zones were characterized using the Holdridge system as shown on Figure 5.1. Through GIS, the potential vegetation of the entire Philippines using the Holdridge system was determined. This was compared to the existing vegetation cover.

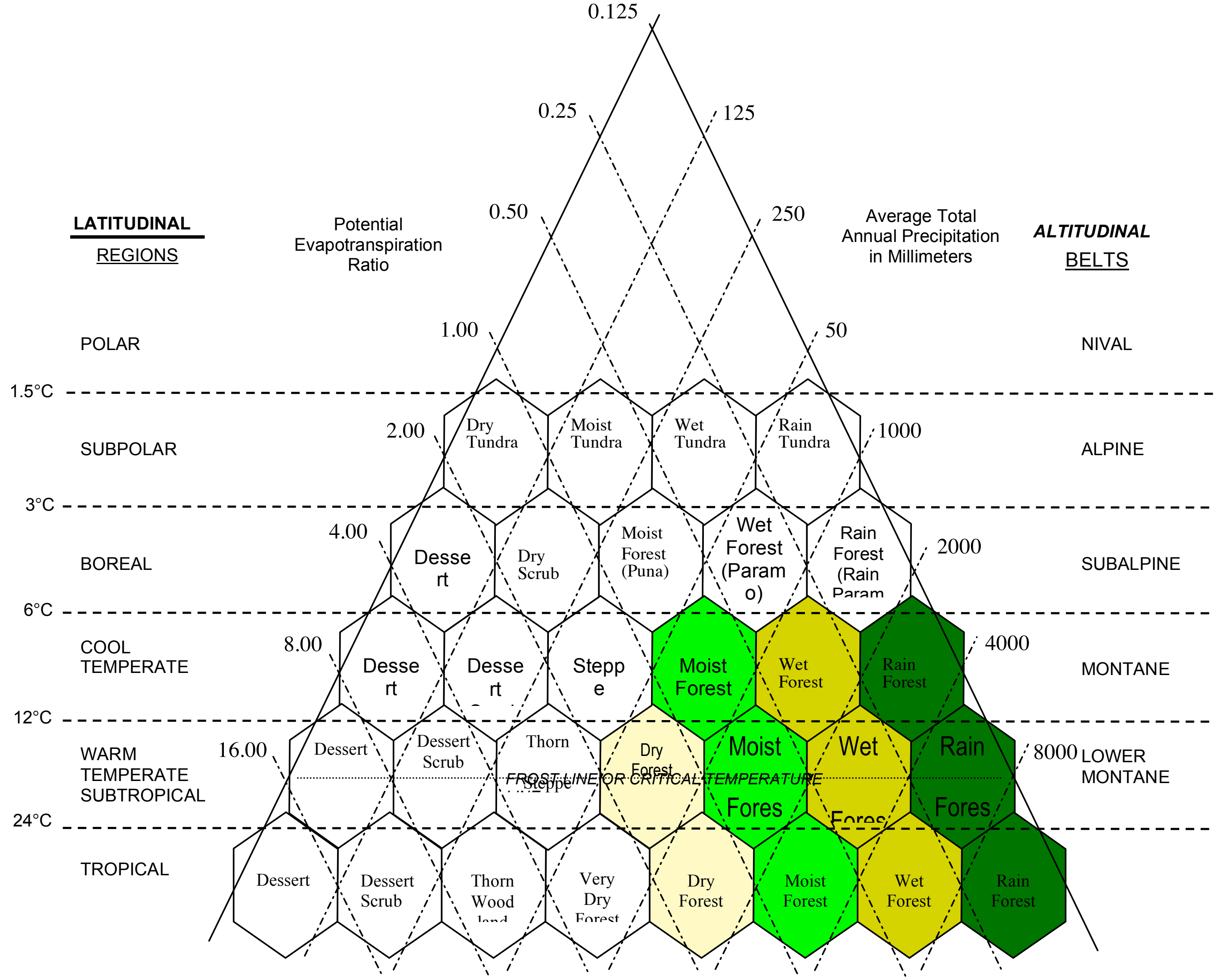


Fig. 5.1: The Holdridge System of vegetative cover classification (Holdridge, 1967).

5.2.2 Climate change impacts of vegetative cover and biodiversity resources

The Holdridge life zones were used to determine the change of natural forests cover under a climate change scenario. A set of synthetic climate scenarios was used (Table 5.1). These precipitation and temperature scenarios are within the limits of GCM projections in the country (The Philippines Initial National Communication, 1999).

Increase in Rainfall (% relative to present)	Increase in Temperature (ºC)		
	1	1.5	2.0
50	Scenario 1a	Scenario 1b	Scenario 1c
100	Scenario 2a	Scenario 2b	Scenario 2c
150	Scenario 3a	Scenario 3b	Scenario 3c

Table 5.1: Synthetic climate change scenarios used in the study.

5.2.3 GIS

ArcGIS 8.1 was used to process the maps needed for the Holdridge Life Zone. Rainfall map was based on the data collected by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). Average rainfall (1961-1990) in the Philippines ranges from 1000mm – 4000mm. Temperature data was gathered from the PAGASA. A Thiessen map was created from the 55 stations all over the Philippines. Average temperature (1949-2002) in the Philippines ranges from 19.3°C – 28.2°C.The land use map is based on 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 and less than 1 million hectares are old growth forest (Environment and Natural Resources Atlas of the Philippines). The following are the identified vegetation types in the Philippines:

1. closed canopy, mature trees covering > 50%
2. open canopy, mature trees covering < 50%
3. mossy forest
4. pine forest

This land use map was used compare with the calculated Holdridge Life Zone.

In addition, the study employed a combination of data collection methods: secondary data gathering, use of participatory rural appraisal techniques, interviews and workshops to assess climate change impacts and vulnerability of different ecosystems in the Pantabangan-Carranglan Watershed.

5.3 Results and Discussion

5.3.1 Forest and biodiversity resources in the Philippines

5.3.1.1 Potential vs actual life zones

All Philippine forests can be classified under the tropical belt because biotemperature is always greater than 24ºC. Thus, the main determinant of life zone classification is precipitation.

Without any humans present, simulation of potential vegetation at current temperature and precipitation showed that the Philippines would be dominated by the dry tropical, moist tropical and wet tropical forest life zones (Figure 5.2). Such a condition must have existed when the Spanish colonizers first set foot in the Philippines in 1521. At that time it was estimated that 90 % of the country was covered with lush tropical rainforest. By the year 1900, there were still 70% or 21M ha of forest cover (Garrity et al. 1993; Liu et al. 1993). However, by 1996 there were only 6.1 M ha (20%) of forest remaining (FMB 1997). The average deforestation rate from 1969 to 1973 was 170,000 hectares per year (Forest Development Center 1987). For the past 20 years, it was about 190,000 to 200,000 hectares per year (Revilla 1997). However, in the last few years it was estimated to be in the vicinity of 100,000 ha (Lasco and Pulhin 1998). In the Philippines, the direct and indirect causes of deforestation include shifting cultivation, permanent agriculture, ranching, logging, fuel wood gathering and charcoal making (Kummer 1990).

We overlaid through GIS, the actual forest cover of the Philippines in 1993 over the potential life zones predicted by the Holdridge system. As might be expected, all the forest types declined with the highest decline in dry forests and the least decline in wet forests (Table 5.2).

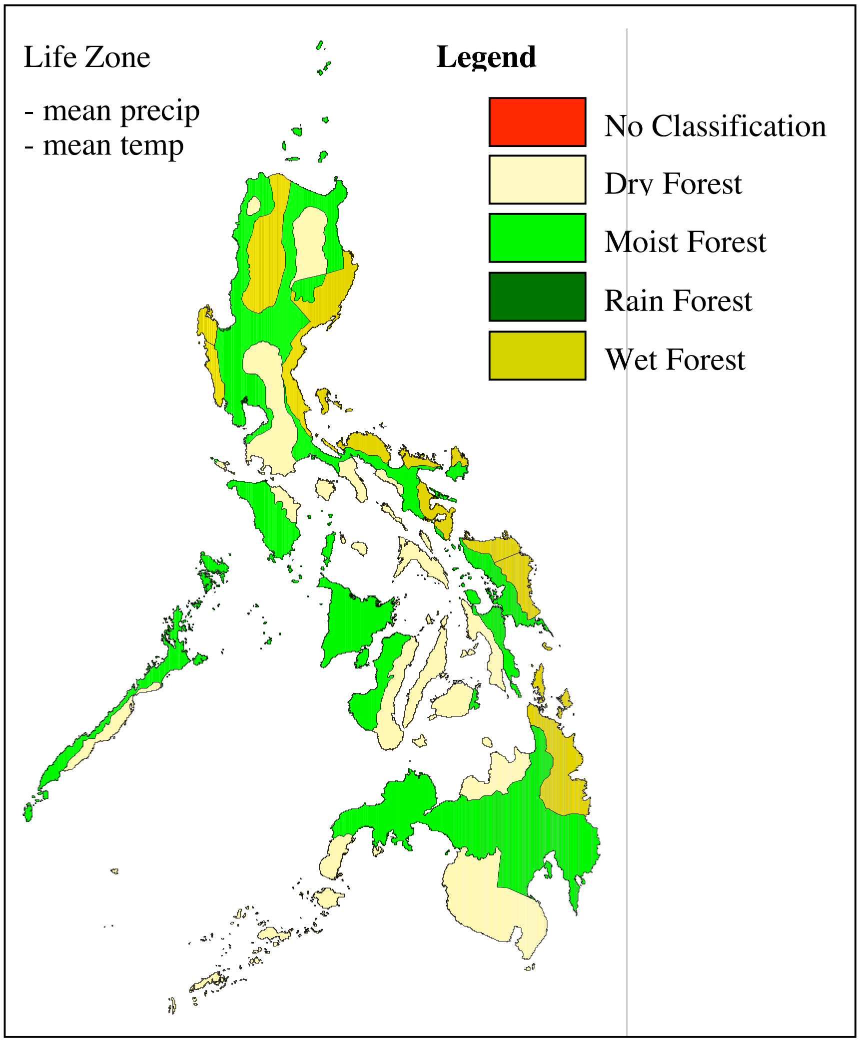


Fig. 5.2: Potential Holdridge life zones in the Philippines without human influence.

Life Zone Type	Area Distribution (Ha)		Percent Distribution	
	Potential	**1993 Life Zone**	**Potential**	**1993 Life Zone**
Dry Forest	8,763,696.10	1,082,197.20	29.65%	3.66%
Moist Forest	15,149,315.26	3,534,636.30	51.25%	11.96%
Rain Forest	0	0	0	0
Wet Forest	5,646,414.43	2,266,455.20	19.10%	7.67%
TOTAL	**29,559,425.79**	**6,883,288.71**	**100.00%**	**23.29%**

Table 5.2: Comparison of potential and actual (based on 1993 data) life zones in the Philippines.

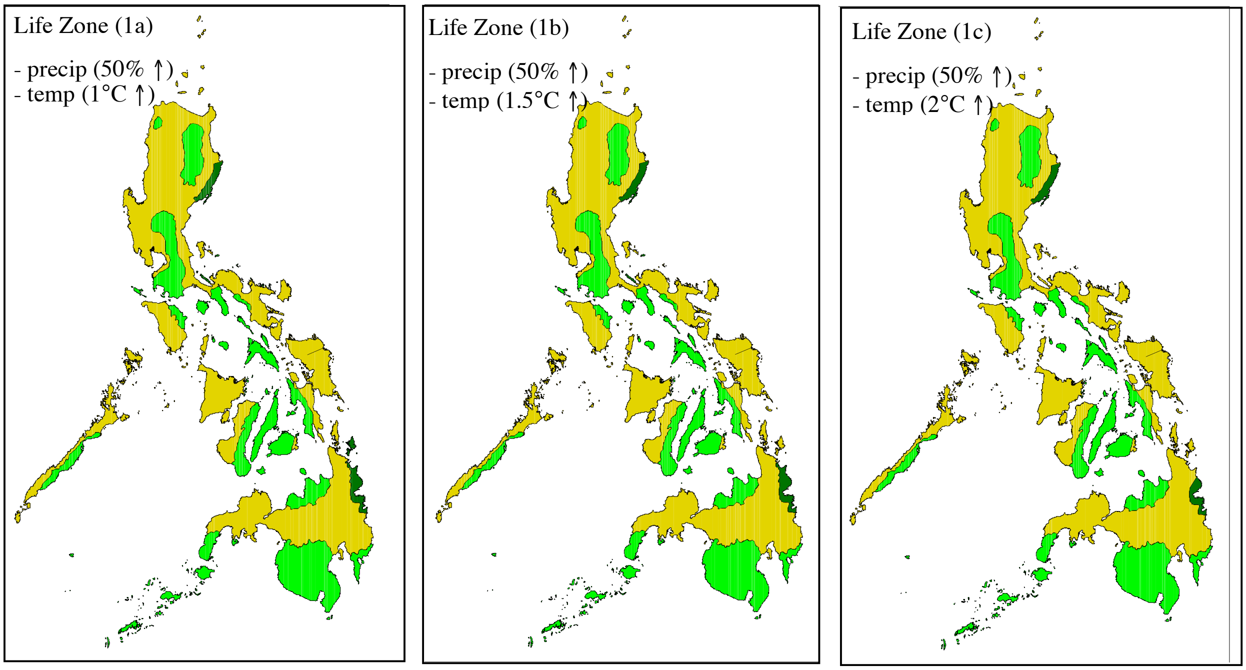
5.3.1.2 Effects of climate change scenarios to vegetative cover

Scenario 1 (Increase in precipitation by 50%):

A 50% increase in precipitation will lead to the following changes (Figures 5.3a – 5.3c):

- Total loss of all dry forests even at the lowest temperature change. This is expected considering the increase in available water.
- A 66% decline in moist forests across all temperatures.
- An increase in rainforests from nothing under current conditions to 365,000 ha under a 1ºC increase in temperature. As temperature increases, there is a slight decline in rainforest area.
- A 135% increase in wet forest cover as a result of greater precipitation

It is noteworthy that temperature increase had minimal effect on life zones in the Philippines (see also Tables 5.3a – 5.3b). This is because all parts of the country already fall within the tropical belt under the Holdridge system (> 24ºC). It is assumed in this study that the total forested area remains fixed in the analysis.



Figs. 5.3a – c: Holdridge life zones in the Philippines under scenario 1 (50% increase in rainfall) and at three levels of temperature increase.

Life Zone Type	**Area Distribution (Ha)**			
	Actual	**1a**	**1b**	**1c**
Dry Forest	1,082,197.20			
Moist Forest	3,534,636.30	1,201,671.10	1,201,671.097	1,201,671.097
Rain Forest		365,181.26	361,099.218	321,736.614
Wet Forest	2,266,455.20	5,316,436.35	5,320,518.395	5,359,880.999
No Classification				
TOTAL	**6,883,288.705**	**6,883,288.710**	**6,883,288.710**	**6,883,288.710**

Table 5.3a: Projected change in area of existing life zones in the Philippines under scenario 1 (50% increase in precipitation).

Life Zone Type	Percent Distribution			
	Actual	**1a**	**1b**	**1c**
Dry Forest	3.66%			
Moist Forest	11.96%	4.07%	4.07%	4.07%
Rain Forest		1.24%	1.22%	1.09%
Wet Forest	7.67%	17.99%	18.00%	18.13%
No Classification				
TOTAL	**23.29%**	**23.29%**	**23.29%**	**23.29%**

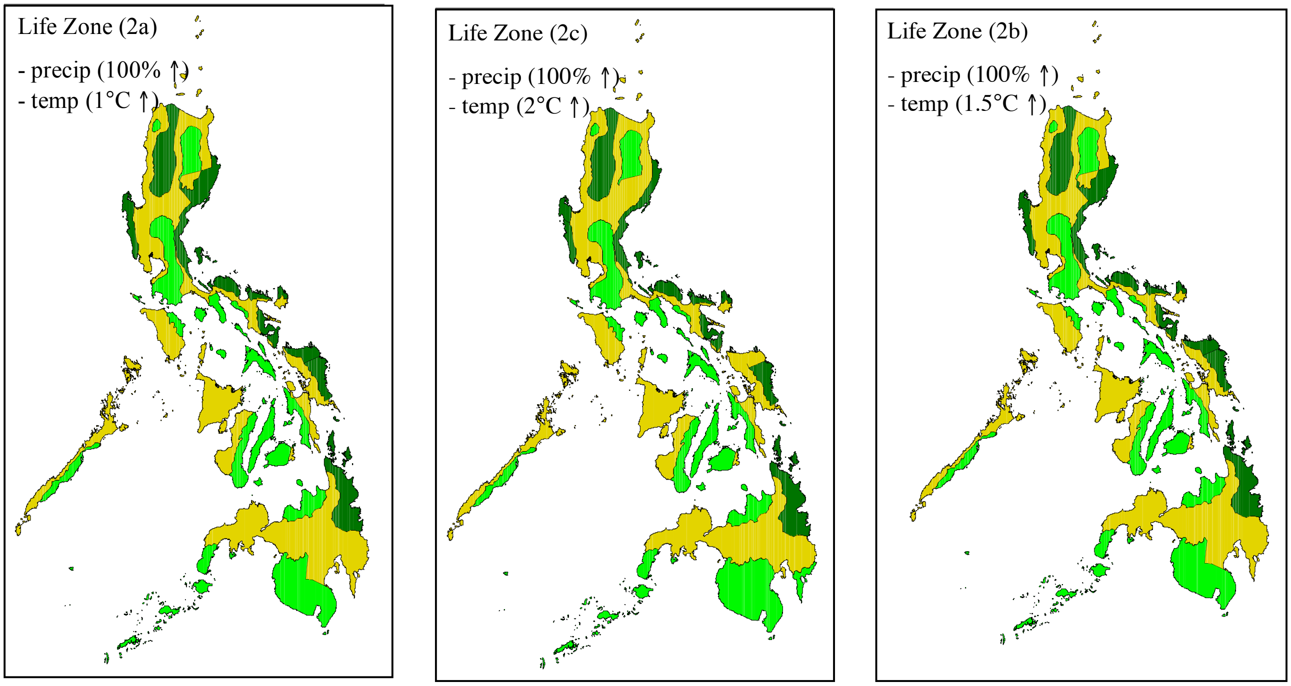
Table 5.3b: Projected change in percent distribution of existing life zones in the Philippines under scenario 1 (50% increase in precipitation).

Scenario 2 (Increase in precipitation by 100%)

A 100% increase in precipitation will lead to the following changes in the life zone pattern in the Philippines (Figure 5.4a – 5.4c; Table 5.4):

- Total loss of all dry forests (> 1M ha).
- A 69% decline in moist forests area.
- A significant rise in area of rain forests from zero under current conditions to more than 2M ha.
- A 56% increase in wet forests, about half of the increase under Scenario 1.

Just like Scenario 1, the increase in temperature has minimal effect on life zone changes.



Figs. 5.4a – c: Holdridge life zones in the Philippines under scenario 2 (100% increase in rainfall) and at three levels of temperature increase.

Life Zone Type	**Area Distribution (Ha)**			
	Actual	**2a**	**2b**	**2c**
Dry Forest	1,082,197.20			
Moist Forest	3,534,636.30	1,082,197.203	1,082,197.203	1,201,671.097
Rain Forest		2,266,455.202	2,266,455.202	2,007,262.944
Wet Forest	2,266,455.20	3,534,636.300	3,534,636.300	3,674,354.666
No Classification				
TOTAL	**6,883,288.705**	**6,883,288.705**	**6,883,288.705**	**6,883,288.707**

Table 5.4a: Projected change in area of existing life zones in the Philippines under scenario 2 (100% increase in precipitation).

	Percent Distribution			
Life Zone Type	**Actual**	**2a**	**2b**	**2c**
Dry Forest	3.66%			
Moist Forest	11.96%	3.66%	3.66%	4.07%
Rain Forest		7.67%	7.67%	6.79%
Wet Forest	7.67%	11.96%	11.96%	12.43%
No Classification				
TOTAL	**23.29%**	**23.29%**	**23.29%**	**23.29%**

Table 5.4b: Projected change in percent distribution of existing life zones in the Philippines under scenario 2 (100% increase in precipitation).

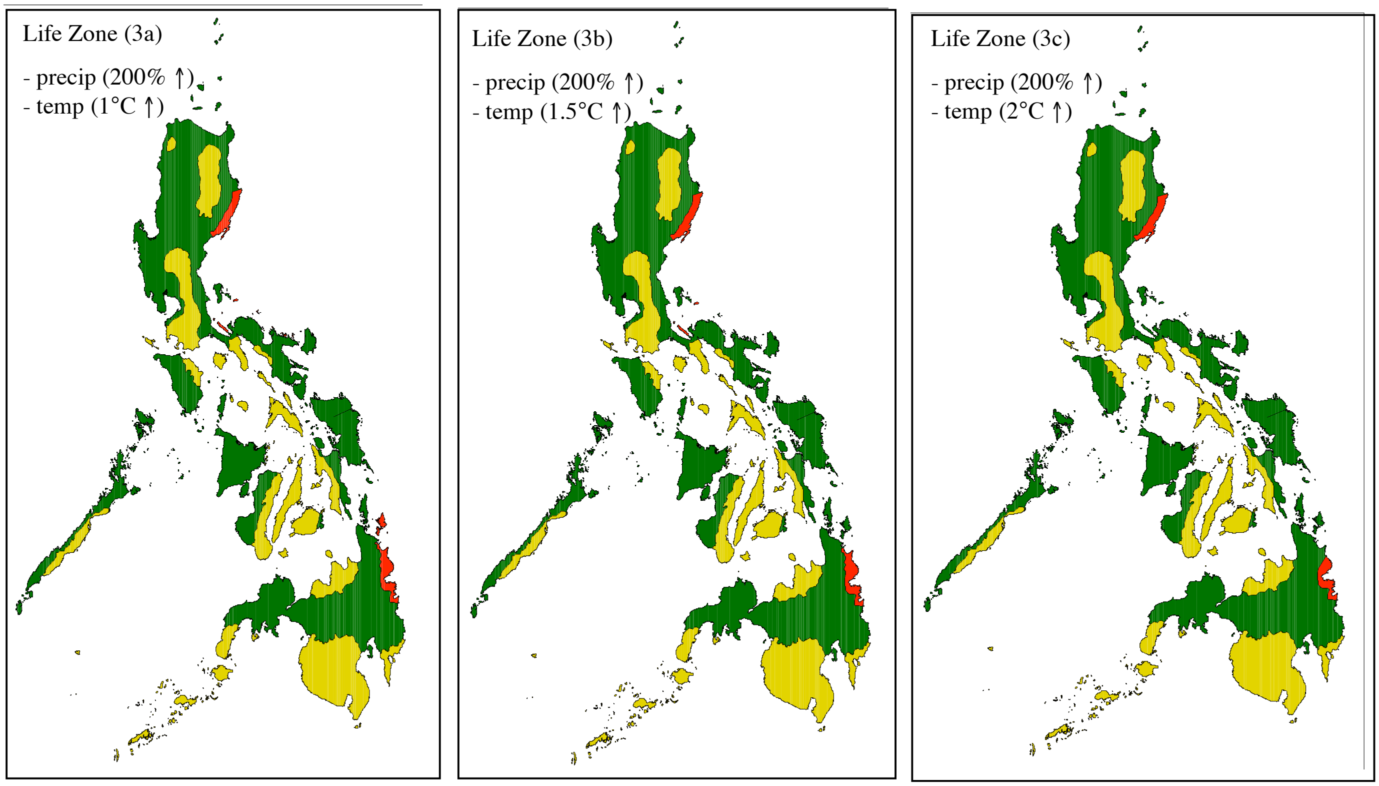
Scenario 3 (Increase in precipitation by 200%)

A 200% increase in precipitation will lead to the following changes in Philippine life zones (Figure 5.5a – 5.5c; Table 5.5):

- Total loss of all dry forests (> 1 M ha) and all moist forests (3.5 M ha).
- Increase of area of rainforest from zero under current conditions to more than 5M ha under a doubling of precipitation.
- Decline by 47% in the area of wet forests.

Just like the two previous scenarios, the effect of temperature change is minimal.

Thus, overall, the simulation study showed that the total area of Philippine forests will not change. However, there will be re-distribution of forest types. The dry forests are the most vulnerable. They could be totally wiped out even under a 50% increase in precipitation. Moist forests are also vulnerable especially under higher precipitation increase. On the positive side, there will be a significant increase in rain forest types as precipitation level increases.



Figs. 5.5a – c: Holdridge life zones in the Philippines under scenario 3 (200% increase in rainfall) and at three levels of temperature increase.

Life Zone Type	**Area Distribution (Ha)**			
	Actual	**3a**	**3b**	**3c**
Dry Forest	1,082,197.20			
Moist Forest	3,534,636.30			
Rain Forest		5,316,436.354	5,320,518.395	5,359,880.999
Wet Forest	2,266,455.20	1,201,671.097	1,201,671.097	1,201,671.097
No Classification		365,181.259	361,099.218	321,736.614
TOTAL	**6,883,288.705**	**6,883,288.710**	**6,883,288.710**	**6,883,288.710**

Table 5.5a: Projected change in area of existing life zones in the Philippines under scenario 3 (200% increase in precipitation).

	Percent Distribution			
Life Zone Type	**Actual**	**3a**	**3b**	**3c**
Dry Forest	3.66%			
Moist Forest	11.96%			
Rain Forest		17.99%	18.00%	18.13%
Wet Forest	7.67%	4.07%	4.07%	4.07%
No Classification		1.24%	1.22%	1.09%
TOTAL	**23.29%**	**23.29%**	**23.29%**	**23.29%**

Table 5.5b: Projected change in percent distribution of existing life zones in the Philippines under scenario 3 (200% increase in precipitation).

PART II: INDONESIA

6 Introduction

Citarum River is one of the most potential rivers for water supply in West Java, Indonesia. Alongside the river, there are three reservoirs which were constructed in series namely Saguling, Cirata and Juanda. The first and second reservoirs are particularly operated for hydro electrics power, while the third is multipurpose reservoir which is operated for irrigating 225,000 ha of paddy field, and for supplying drinking water and other uses (industries, flushing canals, etc) for downstream districts and capital of Indonesia, Jakarta. The first two reservoirs are managed by PT. Perusahaan Listrik Negara (PT. PLN), while Juanda Reservoir is managed by PT. Jasa Tirta II (Perum Jasa Tirta II 2003). In dry seasons, water inflow to these dams decrease quite often to a level that affects normal operation of power plants in the three dams and normal supply of irrigation water to the downstream agriculture areas. Therefore, reports on drought and flood occurrences in districts within and surrounding the watershed are quite often. During extreme years such as El-Nino years, total area of drought in rice growing area receiving irrigation water from the Juanda reservoir increased significantly compared to normal years (Alimoeso et al. 2004).

Role of forest in the upper catchments area of a watershed is very important in maintaining hydrology function of the watershed. Therefore, managing upper catchments area of a watershed in sustainable way is very important to support living of many ecosystems in the watershed. In the context of water management, converting forest to other uses in the upper catchments area without careful supervision will result in increasing run off to an alarming level. This will increase the flood risk during rainy season and drought risk during dry season. These risks may increase under changing climate. From dialog between stakeholders and scientist at Bandung, it was suggested that at least 40% of watershed area should be maintained as conservation zone (forest cover). Under this condition, it is expected that impact of climate extreme events and possible climate change can be minimized. Ecological function of the watershed can also be revitalized and in turn it will improve quality of life of the people (Bapeda Jawa Barat, 2001).

Protecting watershed without good participation of local community and other related stakeholder might not be successful. Therefore, the policy of local government for managing the watershed will focus on how to involve stakeholders in the process of setting up land use planning (participatory planning). This approach could accommodate various interests, minimize conflict between sectors and districts, importantly it will create social control to any effort for using the land (Bapeda Jawa Barat, 2001). On the other hand, creating system that can encourage communities living in the upper watershed to maintain and increase forest cover at upper watershed is also very crucial. In this case, a study to assess willingness to pay of downstream communities or other stakeholders (such as hydropower and drinking companies) to upper stream communities who actively participate in protecting watershed function through reforestation and forest protection activities, is also very important.

Considering above, this study was aimed to study past, present and future climate characteristics and to assess the impact of present and future climate variability on stream flow and hydrology function of the watershed. In addition, this study was also aimed to understand community perception on climate change and their willingness to participate in mitigating impact of climate change as basis in developing action plan for adaptations.

To achieve these objectives, this study consists of three main components. First component is assessing the past, current and future climate condition which consist of two research activities namely:

1. Evaluating current and future rainfall variability in Indonesia. This study was aimed to overview rainfall variability in the past based on historical data and to assess the strength of global climate forcing factors such as ENSO in affecting rainfall variability in Indonesia. In addition the study also assess future rainfall variability in the future under a number of GHG emission scenarios based on a number of general circulation models

2. Developing statistical downscaling model. This study was aimed to develop simple statistical model for downscaling global rainfall data from GCM into the study region (Citarum Watershed). This analysis is required as GCM outputs may not be able to provide detail information about climate variability at local level.

Second component is evaluating the impact of current and future climate change on hydrology system of the watershed. This component consists of three research activities namely:

1. Assessing hydrology balance of Citarum Watersheds under current and future climate. This study was aimed to quantify balance between water supply and water demand in districts within the watershed under present and future climate assuming the change in land used pattern in the future.

2. Developing land use change prediction model. This study was aimed to develop simple model for predicting likely land use change in the future based on changes in a number of physical and socio-economic predictors. This model was required to predict the likely land use change in the future under a number of different physical and socio-economic scenarios. The socio-economic scenarios should be consistent with global scenarios used by the GCM.

3. Assessing the impact of land use and climate changes on stream flow in upper Citarum River. This study was aimed to evaluate the likely impact of changing land use policy in the upper watershed under different climate change scenarios on stream flow. This study is important to evaluate whether there is an increasing risk of drought and flood in the future when a certain policy on land use was imposed.

Third component is assessing community perception and participation in mitigating impact of climate change. This component consists of only one research activity. The study was aimed to assess perception of communities to climate change and to evaluate the impact of climate hazards on upstream and downstream communities, to evaluate driving factors for deforestation at the upper Citarum wahtershed, to assess perception of downstream communities to the need of increasing forest cover of the upper Citarum watershed as effort to mitigate impact of climate hazards and to assess willingness of downstream community of Citarum watershed to pay for protecting and improving forest cover at upper Citarum Watershed. This result of this study will be required for developing action plan for adaptation. The relation between the components of the research activities is illustrated in Figure 6.1.

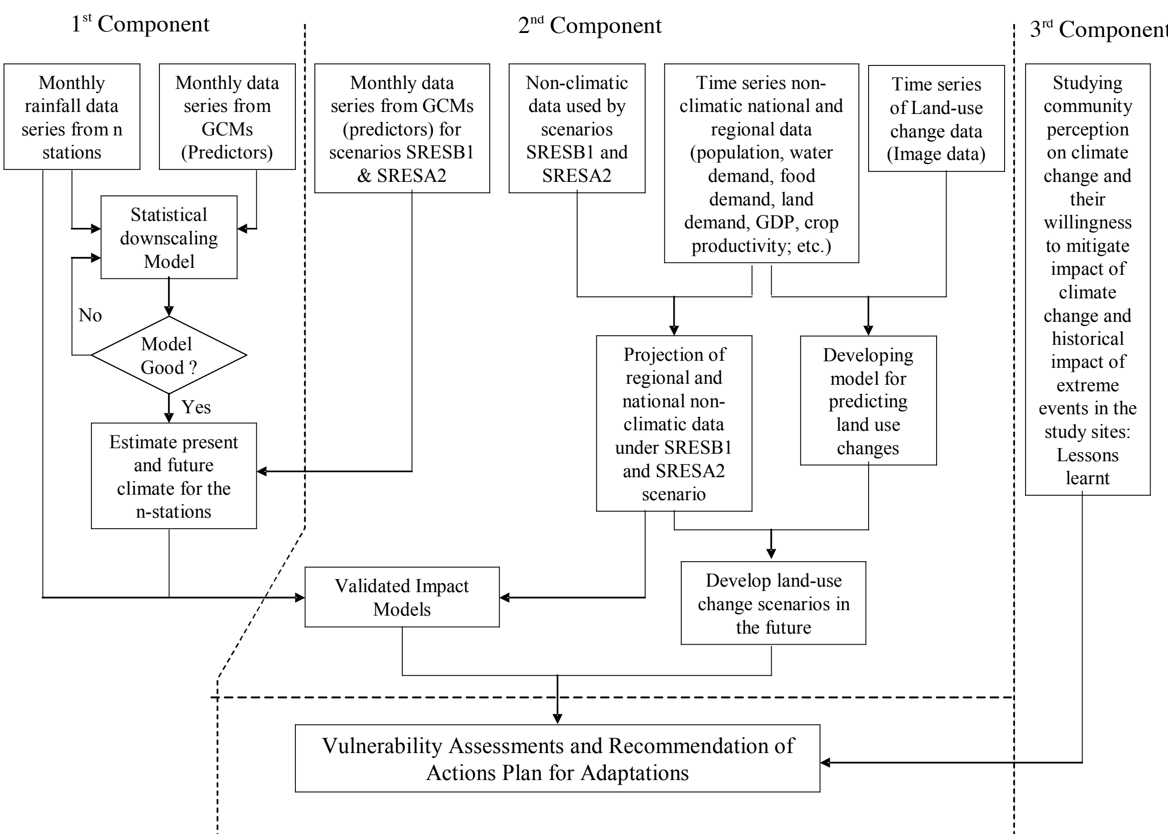


Fig. 6.1: Relationship between main components of the research activities.

7 Characterization of Current and Future Rainfall Variability in Indonesia

7.1 Activities Conducted

Activities conducted under this study were (i) to assess rainfall changes since early 1990s to present, (ii) to evaluate relationship between global climate forcing factors and rainfall variability, and (iii) to assess future rainfall changes based on outputs from a number of general circulation models (GCMs) run under two different emission scenarios.

7.2 Description of Scientific Methods and Data

Rainfall patterns in Indonesia can be broadly divided into three namely monsoonal type, equatorial type and local type. Monsoon type has uni-modal rainfall pattern (one peak of rainy season), six months receive high rainfall (called as rainy season, in general from October to March; some regions have longer dry season in particular eastern part of Indonesia such as Kupang), and other six months receive less rainfall (called dry season, in general from April to September). Rainfall in Indonesia regions is dominated by this monsoon system. Equatorial type is characterized by bi-modal rainfall pattern (two peaks of rainy season, normally occurs in March and in October). Local type has uni-modal rainfall but the pattern is the opposite of the monsoonal type. This study selected four rainfall stations to represent the three rainfall types which have rainfall record of more than 50 years and started in late 1870s (Table 7.1). About five additional stations which have rainfall record of less than 30 (1970-1997) years were also included in the analysis, i.e. one for equatorial type (Bukittinggi) and four for monsoonal types (Kendari, Jogyakarta, Semarang, and Bandung).

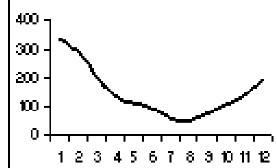
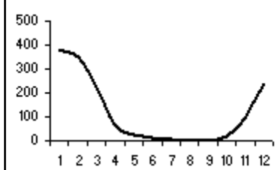
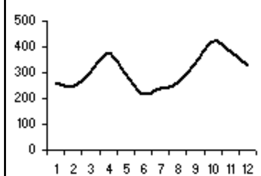
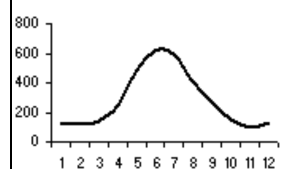
Station Name	Position			Period of record	Rainfall pattern
	Position	Dry Season	Rainy Season		
Jakarta	Lat. 6°10'S Long. 106°49'E Alt. 7 m a.s.l.	May to Oct.	Nov. to April	1876-1997 (data in 1877 missing	
Kupang	Lat. 10°07'S Long. 123°20'E Alt. 2 m a.s.l.	April-Nov.	Dec. to March	1879-1996 (some years have incomplete data, i.e 1879, 1965-1974, 1978-1996; some years have no data record, i.e. 1942-1946)	
Maulaboh	Lat. 4°12'N Long. 96°09'E Alt. 1 m a.s.l.	Mar-May and Sep-Nov.	Jun-Aug and Dec-Feb	1895-1975 (some years have no data record, i.e. 1942-1952). Note: No distict different between rainy and dry season	
Ambon	Lat. 3°25'S Long. 28°03'E Alt. 10 m a.s.l.	Oct to March	Apr. to Sep.	1879-1996 (some years have incomplete data, i.e 1879, 1950, 1957/58, 1960, 1970-1996; some years have no data record, i.e. 1941-1947	

Table 7.1: Geographical position, length of record and, rainfall pattern of the four rainfall stations.

Changes in rainfall means since early 1870s was evaluated using trend analysis and moving average. Relationship between global climate forcing factors and rainfall variability in the four stations (Table 7.1) was assessed using regression analysis. The global climate forcing factors being used were Indian Dipole Mode and El-Nino Southern Oscillation (ENSO) phenomena. Indian Dipole Mode is similar to El-Nino where a warm pool in the Indian Ocean moves eastward in a cycle of 3 to 7 years (Saji *et al*. 1999). Index for Indian Dipole Mode is called as Dipole Mode Index (DMI) which is defined as the difference in SST anomaly between the tropical western Indian Ocean (50E - 70E, 10S - 10N) and the tropical south-eastern Indian Ocean (90E - 110E, 10S - equator). Index for ENSO is Southern Oscillation Index which is defined as $SOI = (P_{Tahiti}-P_{Darwin})/S_{d(Ptahiti-Pdarwin)} \times 10$. P is air pressure and S_d standard deviation.

Relationship between rainfall means and standard deviation was also developed using regression analysis. It is expected that the variability of rainfall can be explained from its long-term means. A study in Cambodia showed that rainfall means was significantly correlated with their variances (MOE, 2002). If we assumed that this empirical relationship remains valid in the future, then the change of rainfall variability in the future can be estimated from change of rainfall means. For this analysis, rainfall data from 62 stations in West Java (all are monsoon type) with length of record between 10-25 years were used.

The change in rainfall and temperature means all over Indonesia in the future was assessed based on outputs from 5 general circulation models (GCMs) run under two different emission scenarios SRESA2 and SRESB2. SRESA2 describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slow. SRESB2 gives emphasize on local based-solution. The economic, social, and environmental problems are solved locally. The population growth rate was slower than that of SRESA2 and there will be a medium change in economic structures toward a service and information economy. These two different assumptions will lead to two different GHG emission rates. Rate of GHG emissions under SRESA2 will be higher than those under SRESB2. Therefore concentration of GHG in the future under SRESA2 will be higher than that of SRESB2. The GCMs will assess how the different level of GHG concentration in the atmosphere will affect rainfall pattern in the future. In this study five GCM models were used namely: CCSR, CGCM1, CSIRO, ECHAM4 and HadCM1. The monthly rainfall and temperature data of the five GCMs from the two scenarios were taken from Data Distribution Center. Mean temperature and rainfall changes over Indonesian region in 2020, 2050 and 2080 were calculated based on grids data in the areas of between 17 N-17 S and 90 E-147 E (Table 7.2).

	Latitude (°)		**Longitude (°)**		**Resolution**
CCSR-NIESS	13,8445 N	13,8445 S	90 °E	146,25 °E	5,625 Long. x 5,625 Lat.
CGCM1	16,7001 N	16,7001 S	90 °E	142,5 °E	3,75 Long. x 3,75 Lat.
CSIRO	14,3357 N	14,3357 S	90 °E	146,25 °E	5,625 Long. x 3,214 Lat
ECHAM4	15,3484 N	15,3484 S	90° E	143,4375 °E	2,8125 Long. x 2,8125 Lat.
HadCM3	15 N	15 S	90 °E	142,5 °E	3,75 Long. x 2,5 Lat

Table 7.2: Resolution of the five GCMs and the coverage area for the analysis.

7.3 Results

The analysis suggested that there were significant trends in rainfall in some station. For example, annual rainfall in Jakarta showed no significant trend, while in Kupang the rainy season rainfall tended to decrease and the dry season rainfall tended to increase (Figures 7.1a – 7.1b). In Ambon, dry season rainfall tended to decrease while wet season rainfall relatively constant over the 100 years period (Figure 7.1c). In Maulaboh, either wet or dry season rainfall both tended to decrease, in particular wet season rainfall (Figure 7.1d). A study conducted by Pawitan (2002) focused on annual rainfall at Citarum watershed (West Java), found that the annual rainfall in upper Citarum stations decreased at a rate of about 10 mm per year (1896-1994). He also found similar findings in other two stations, i.e. in Palumbon station (1922-1980) decreased at a rate of 28 mm per year, and in Nanjung station (1918-1991) at a rate of 46 mm per year.

Further analysis in the four stations showed that there were three interesting features on the change in pattern of 30 years moving average data. Firstly, in stations that have moonson types (Jakarta and Kupang), the mean of 30 years rainfall data gradually decreased from early 1900s to 1920s (before pre-industrial era) and from 1920s to 1940s it was relatively stable and then increased (Figure 7.1a and 7.1b). Secondly, in Ambon (local type) the pattern of change was in the opposite direction of the moonsonal types, in particular for dry season rainfall (Figure 7.1c). The mean of 30 years rainfall data from 1890s to early 1920s decreased quickly and then increased again slowly up to early 1950s before it dropped. For wet season rainfall, the mean of 30 years rainfall data from 1890s to early 1920s was relatively stable and then it increased quickly and stable again after 1930s. Thirdly, in Maulaboh (equatorial type) the mean of 30 years rainfall data decreased from early 1990s up to early 1940s and increased sharply, in particular for wet season rainfall before it decreased again in early 1950s (Figure 7.1d).

Analysis of spatial change of rainfall all over Indonesia was conducted by Kaimuddin (2002). The analysis was based on means rainfall data of two periods, i.e. 1931-1960 and 1961-1990 over 210 stations across Indonesia. It was indicated that between the period 1931-1960 and 1961-1990, annual rainfall in most of area in the southern regions (e.g. Java, Lampung, South Sumatra, South Sulawesi, and Nusa

Tenggara) has decreased, while in the northern part (e.g. most of Kalimantan, North Sulawesi) it increased (Figure 7.2). Further analysis showed that the difference between wet season (representing by seasonal rainfall September to November and December to February) and dry season (representing by seasonal rainfall March to May and June to August) increased. This means that for the southern region, the wet season rainfall tended to increase whereas the dry season rainfall tended to decrease. The opposite pattern was observed in the northern region (Figures 7.3 and 7.4).

El-Nino Southern Oscillation (ENSO) phenomenon has been found to be one of important factors that affect rainfall variability in Indonesia. Recent studies indicated that Indian Dipole Mode also has significant influence on rainfall variability in Indonesia. Yamagata *et al.* (2001) and Kumar *et al.* (1999) stated that if Indian Dipole Mode occurred at the same time with El-Nino (indicated by the increase in temperature in the tropical south-eastern Indian Ocean above normal or DMI is strongly negative), it would counteract the reducing effect of El-Nino on rainfall. Analysis in the four stations suggested that this type of relationship were true only for dry season rainfall in monsoonal type region (Figures 7.5 and 7.6). Previous study in nine stations located at Bandung District also gave similar result. However, the correlations between DMI and dry season were not as strong as those between SOI and the dry season rainfall and in a few stations the correlations were not significant (Boer and Faqih, 2005). In equatorial type (Maulaboh), these two global climate forcing factors showed no significant correlation with the rainfall variability of all seasons, while in Ambon (local type) only SOI showed significant correlation with April-September rainfall.

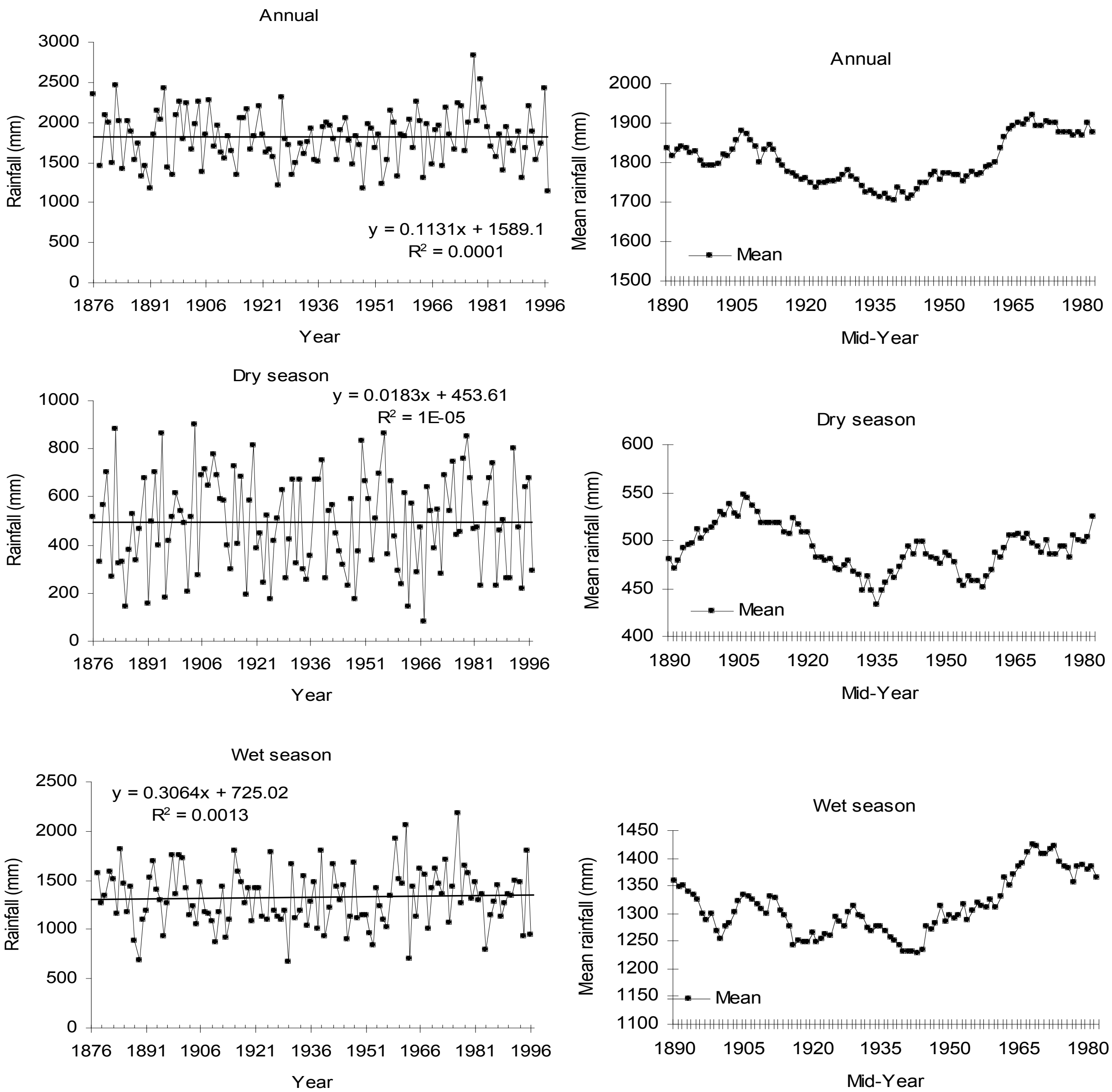


Fig. 7.1a: Annual and seasonal trend (right) and 30 years moving average (left) of rainfall at Jakarta (Monsoonal Type).

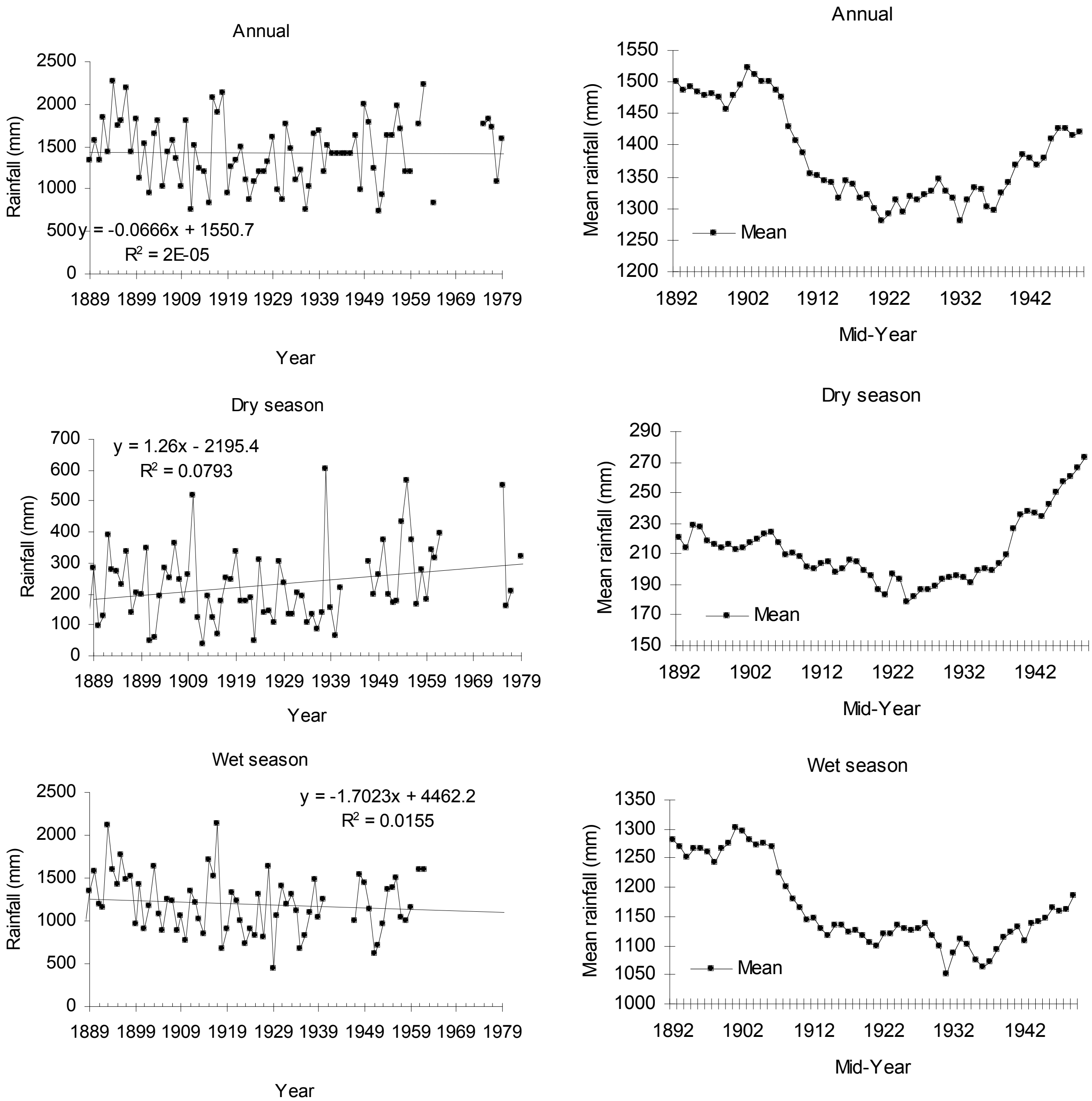


Fig. 7.1b: Annual and seasonal trend (right) and 30 years moving average (left) of rainfall at Kupang (Monsoonal Type).

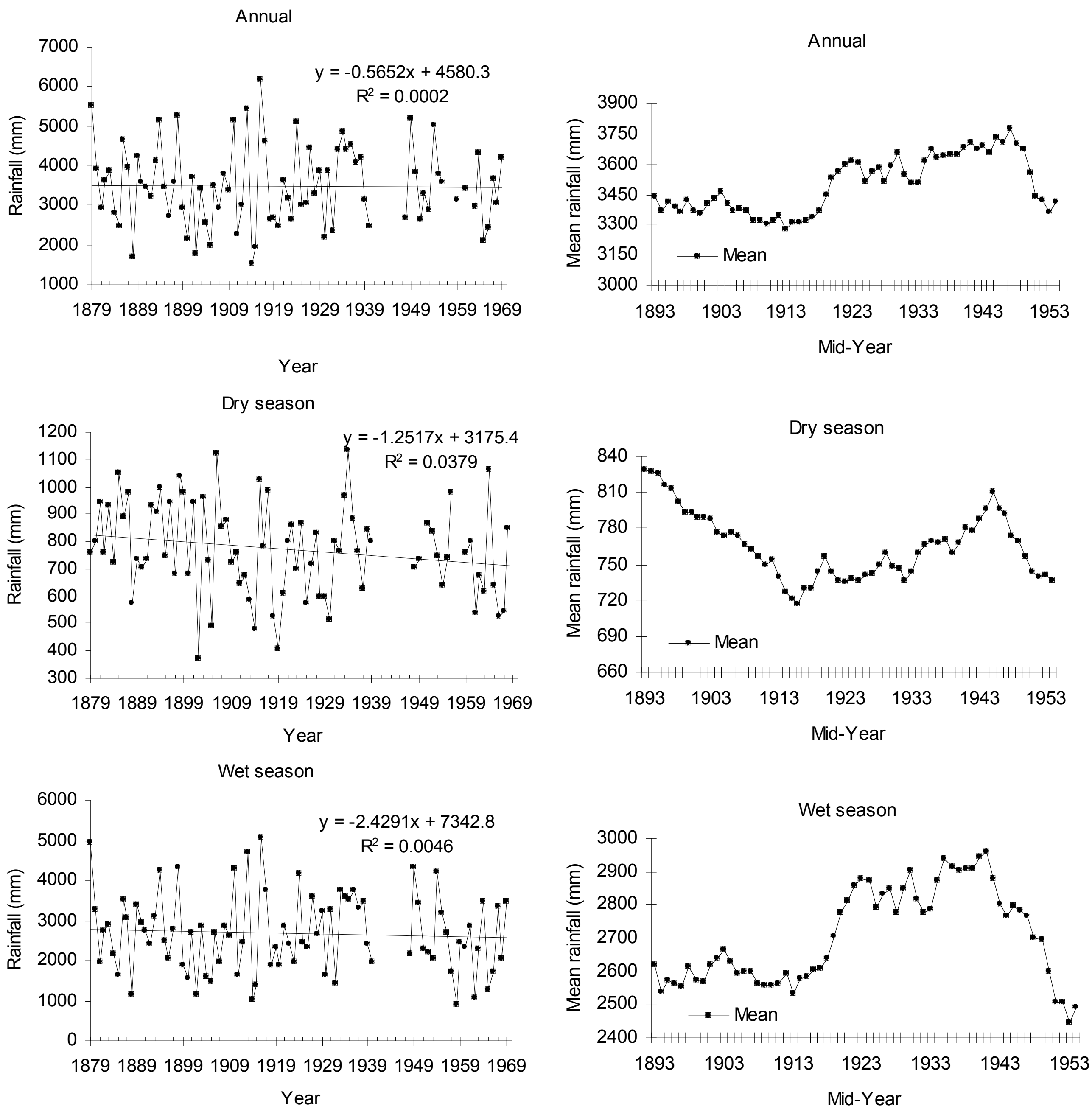


Fig. 7.1c: Annual and seasonal trend (right) and 30 years moving average (left) of rainfall at Ambon (Local Type).

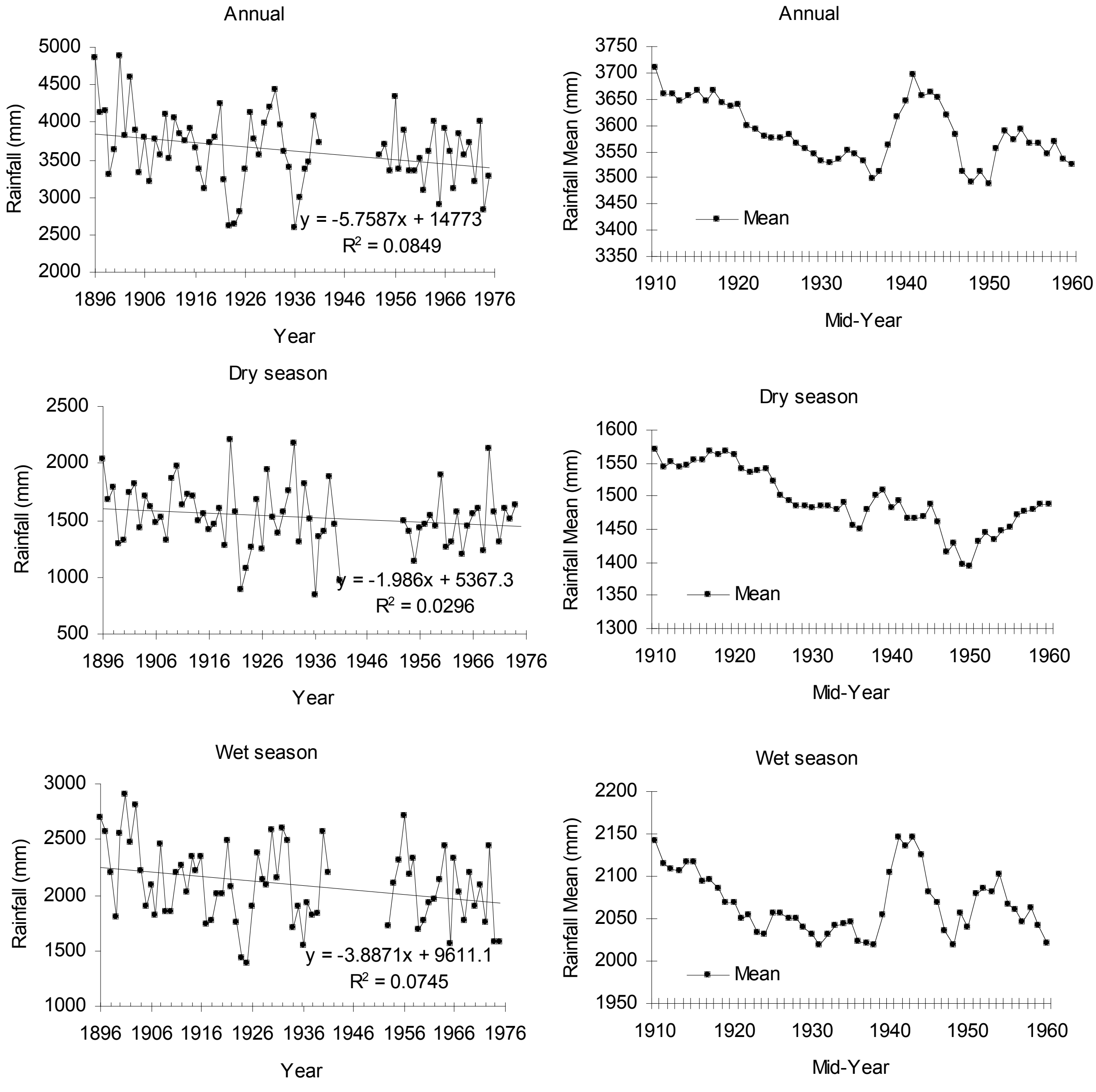


Fig. 7.1d: Annual and seasonal trend (right) and 30 years moving average (left) of rainfall at Maulaboh (Equatorial).

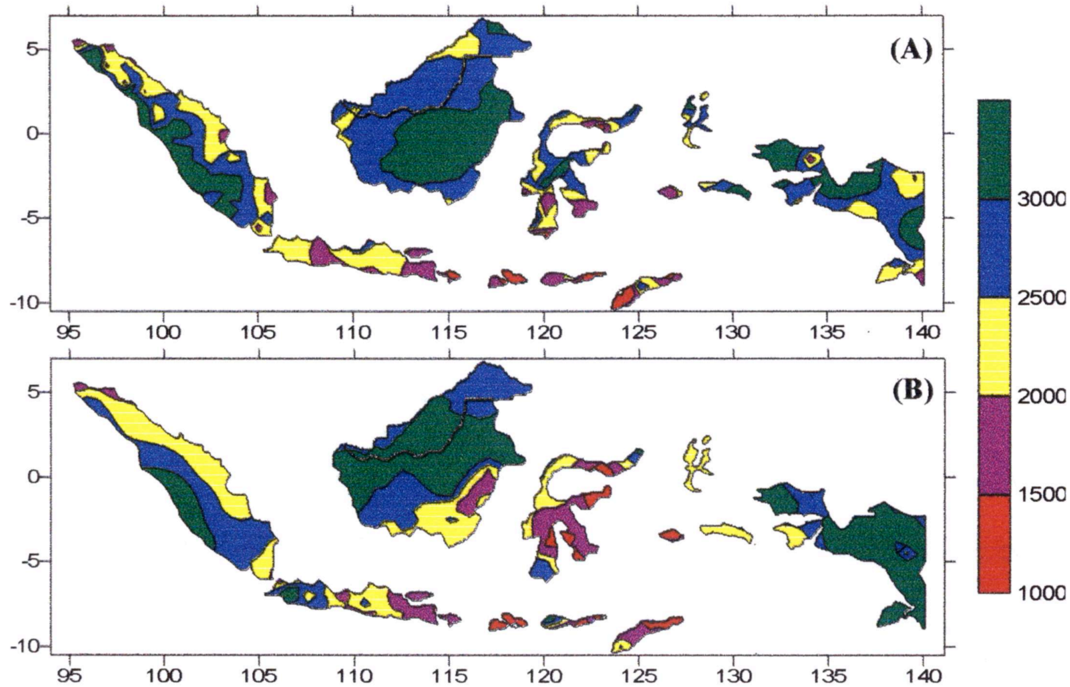


Fig. 7.2: Mean annual rainfall in the periods of (A) 1931-1960 and (B) 1961-1900 (Kaimudin, 2002).

Figure 7.5 and Figure 7.6 show that the correlations are very significant but not very high. However, this suggests that when SOI is strongly negative the probability of having lower rainfall than normal (anomaly rainfall negative) will increase, whereas when SOI is strongly positive the probability will decrease. Analysis in 7 rainfall stations indicated that probability of having negative rainfall anomaly when SOI is strongly negative (less than -5) will be more than 60% particularly in regions that have monsoonal type (Table 7.3).

Assessment of El-Nino impact on regional rainfall has been done by Irawan (2002). He evaluated impact of 1982 and 1997 El-Nino events on rainfall over Indonesia, two strongest El-Nino years in the last 25 years. The analysis was based on monthly rainfall data in 1970-1997 by province. The impact of El-Nino was measured based on percent change of seasonal rainfall relative to the rainfall means during the period. He found that all provinces had lower seasonal rainfall in these years (Table 7.4), in particular dry season rainfall (Apr-Sep or May-Oct depending upon the pattern of monthly rainfall of each province). While, the impact of 1997's El-Nino was stronger than that of 1982's El-Nino. The average decrease in dry season (Apr-Sep or May-Oct) and wet season (Oct-Mar or Nov-Apr) Indonesian rainfall in 1997's El-Nino was about 62% and 32% respectively while those in 1982's El-Nino was only 47% and 19% respectively (Table 7.4).

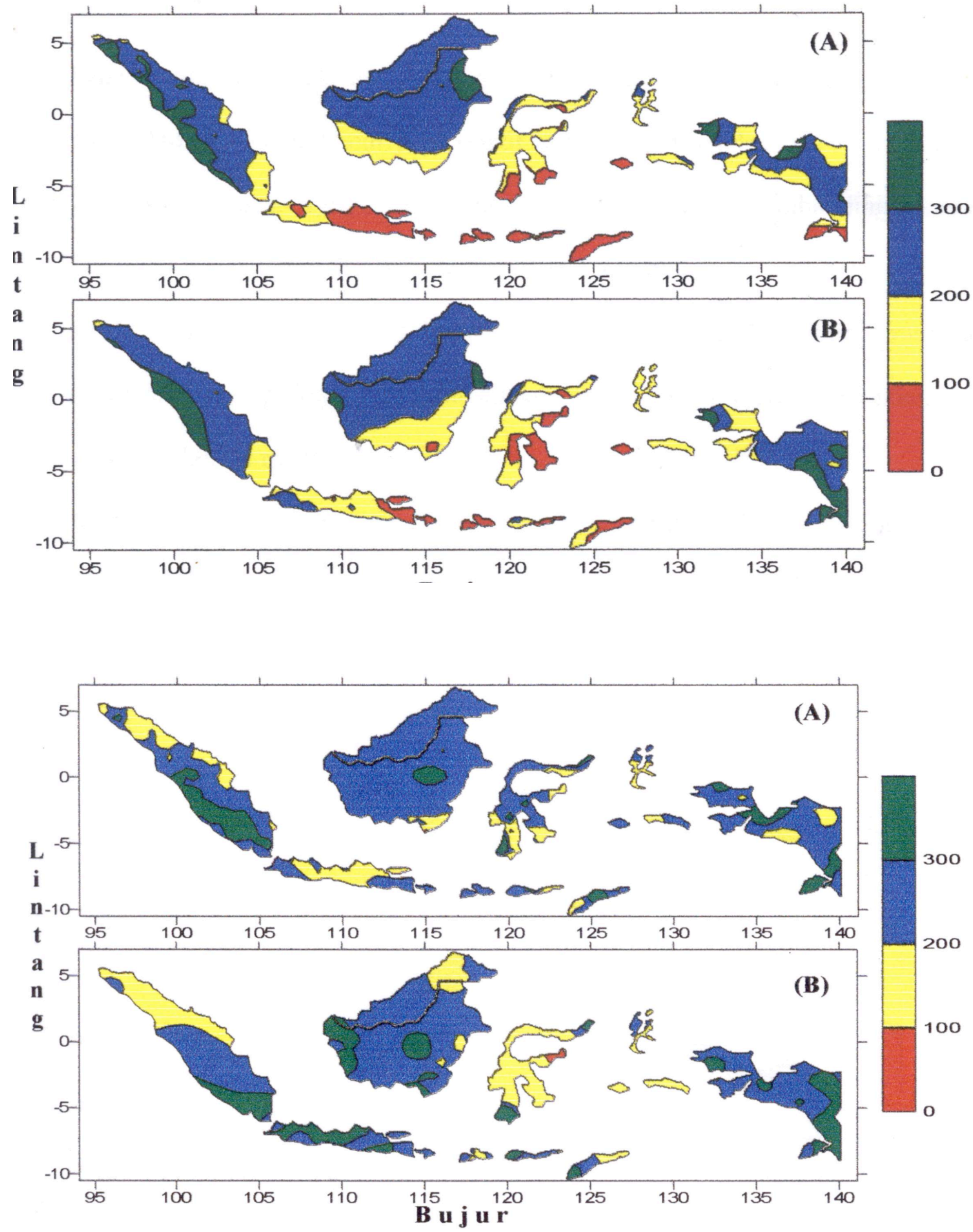


Fig. 7.3: September-November (top) and December-February rainfalls (bottom) in the periods of (A) 1931-1960 and (B) 1961-1990 (Kaimuddin, 2002).

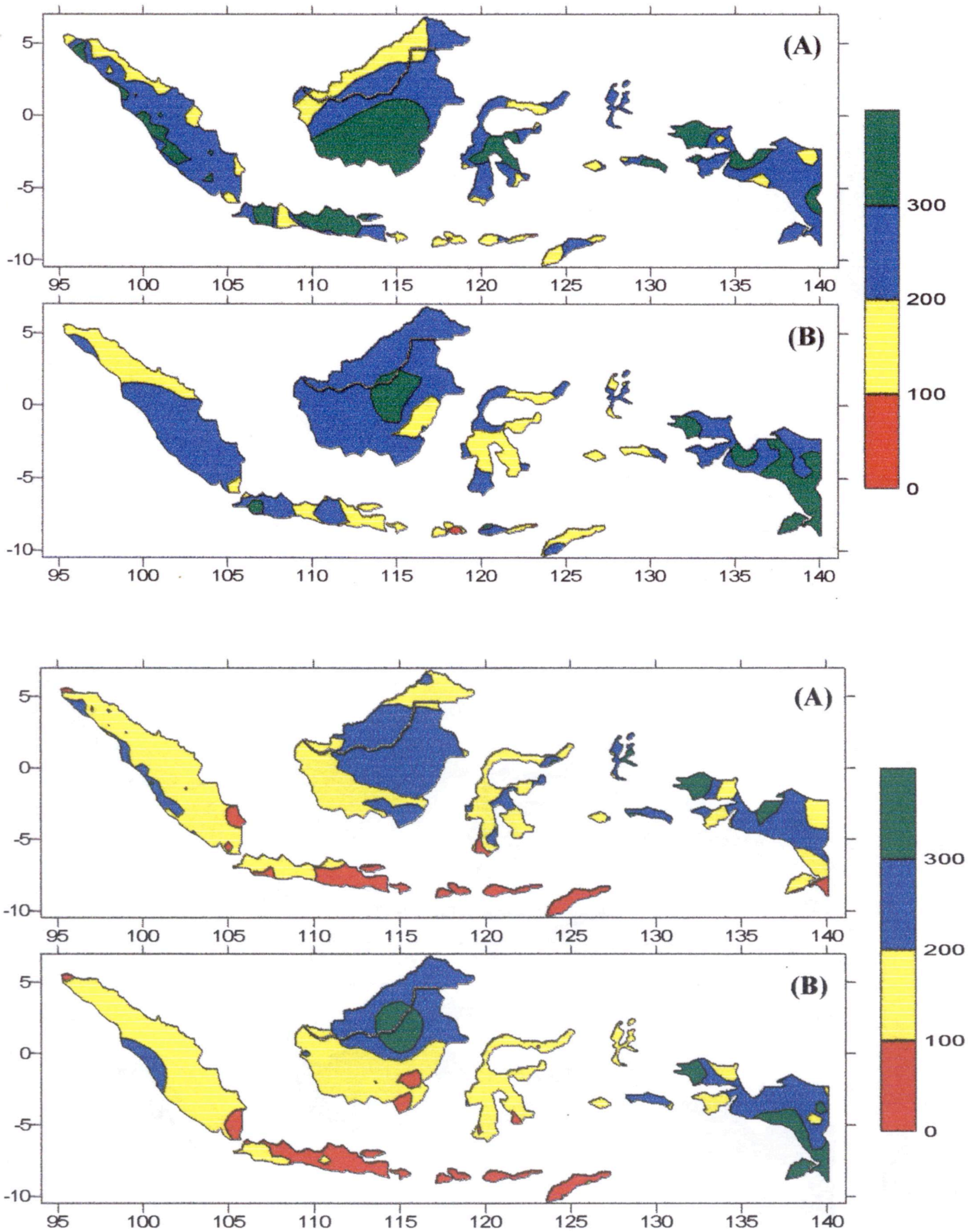


Fig. 7.4: March-May (top) and June-August rainfalls (bottom) in the periods of (A) 931-1960 and (B) 1961-1990 (Kaimuddin, 2002).

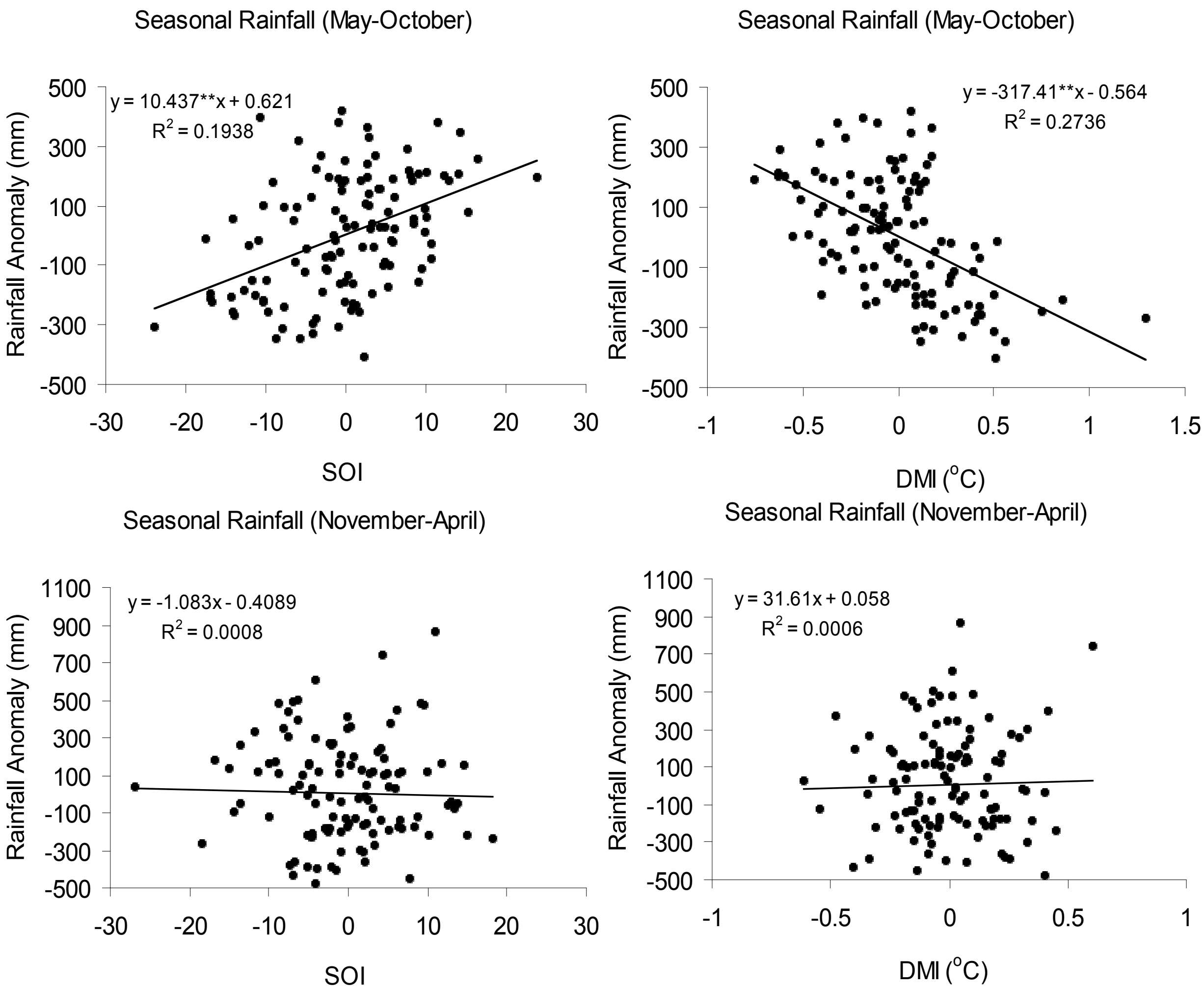


Fig. 7.5: Relationship between seasonal rainfalls and SOI/DMI at Jakarta.

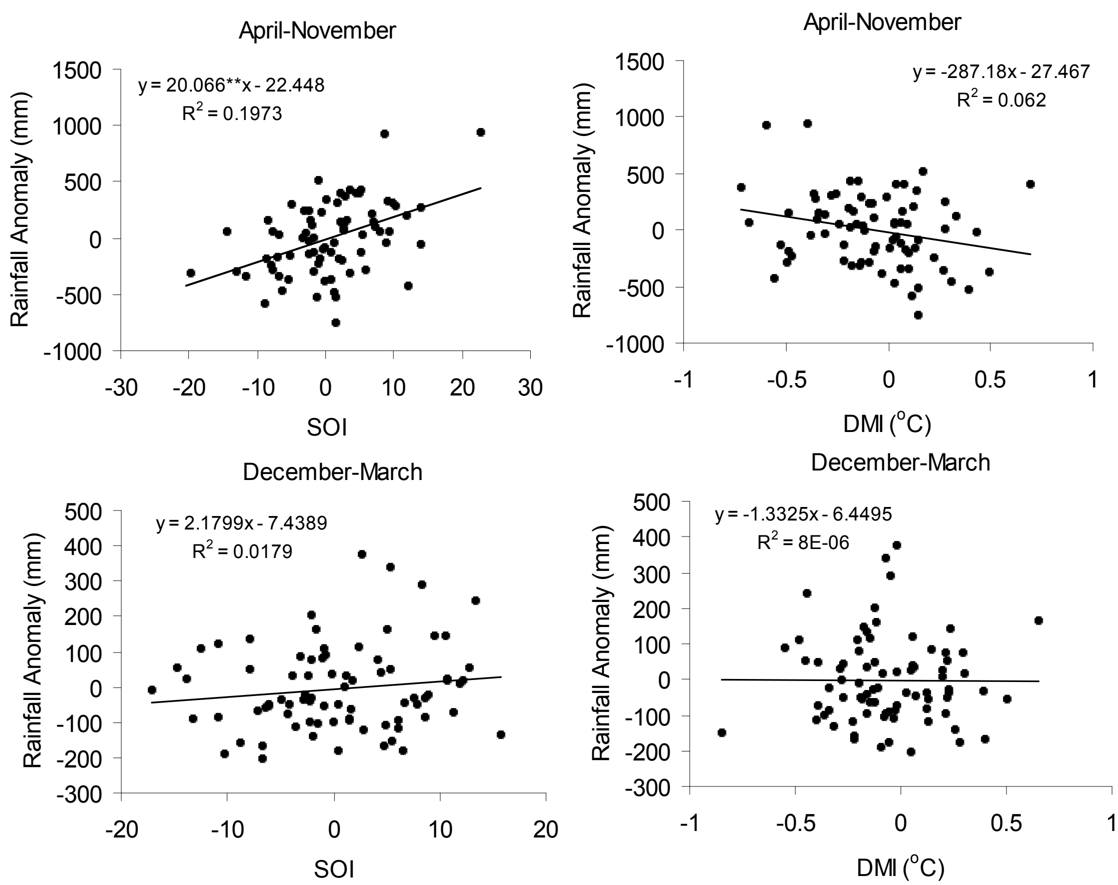


Fig. 7.6: Relationship between seasonal rainfalls and SOI/DMI at Kupang.

Location	SOI greater than (Indicating La-Nina)			SOI less than (Indicating El-Nino)			Rainfall type
	+5	+10	+15	-5	-10	-15	
Bukittingi	0.37	0.34	0.39	0.48	0.54	0.50	Equatorial
Ambon	0.45	0.49	0.43	0.52	0.59	0.55	Local
Kendari	0.44	0.45	0.39	0.61	0.64	0.71	Monsoon
Jakarta	0.48	0.53	0.65	0.69	0.72	0.76	Monsoon
Jogya	0.44	0.47	0.57	0.76	0.79	0.78	Monsoon
Semarang	0.49	0.45	0.52	0.73	0.90	0.86	Monsoon
Bandung	0.47	0.43	0.39	0.57	0.67	0.69	Monsoon

Note: Bandung station locates in a valley so that the local effect might reduce the ENSO influence. Length of rainfall record used for the analysis was 29 years (1970-1997).

Table 7.3: Chance of having positive rainfall anomaly during strong positive SOI, and negative anomaly rainfall during strong negative SOI.

	1997			1982		
Island	**Oct-Mar or Nov-Apr**	**Apr-Sep or May-Oct**	**Annual**	**Oct-Mar or Nov-Apr**	**Apr-Sep or May-Oct**	**Annual**
Sumatra	-35	-47	-38	-21	-32	-24
Java	-34	-80	-41	-11	-85	-23
Bali/Nusa Tenggara	-26	-82	-31	-26	-75	-32
Kalimantan	-33	-57	-40	-5	-36	-16
Sulawesi	-28	-67	-39	-35	-33	-30
Maluku/Ambon	-13	-53	-40	-5	-27	-20
Indonesia	-32	-62	-38	-19	-47	-24

Source: Irawan (2002)

Table 7.4: Percent change of rainfall relative to normal rainfall by provinces.

Other studies also indicated that the effect of El-Nino is not only reduced the amount of rainfall, but it also extends the length of dry season (Soerjadi, 1984; Kirono, 1998). Based on 1951-1998 rainfall data of West Java (Moonson type), it was found that in El-Nino years the onset of dry season could occur as early as decadal 15 (end of May; see Table 7.5), two decadal ahead of normal. In La-Nina years it delayed as far as four decadal (end of July). Whereas, in La-Nina years the onset of wet season occurred earlier, five decadal ahead of normal years (about 50 days), while in El-Nino years it delayed as far as four decadal (40 days).

	Onset of Dry Season		Onset of Wet Season	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
La-Nina	21	2	22	1
Normal	17	1	27	2
El-Nino	15	1	31	2

Source: Bureau of Meteorology and Geophysics (BMG). Note: Decadal 1: January 1-10, Decadal 2: Jan. 11-Jan. 20, Decadal 3: Jan21-end of the month, Decadal 4: Feb.1-10, …, Decadal 36: Dec. 21-end of the month.

Table 7.5: Onset of dry season and wet season in West Java based on decadal data (1951- 1998).

Relationship between rainfall means and their standard deviation of 62 stations in West Java is very significant. The relationship could be presented in the form of power function, i.e. $Y=aX^b$ (Figure 7.7). This suggests that by knowing the change in rainfall means, the likely change in rainfall variability can be roughly estimated using this equation. If the changes in monthly rainfall means under elevated CO_2 concentration are not more than 500 mm, this equation may remain valid to be used for estimating the rainfall variability under global warming.

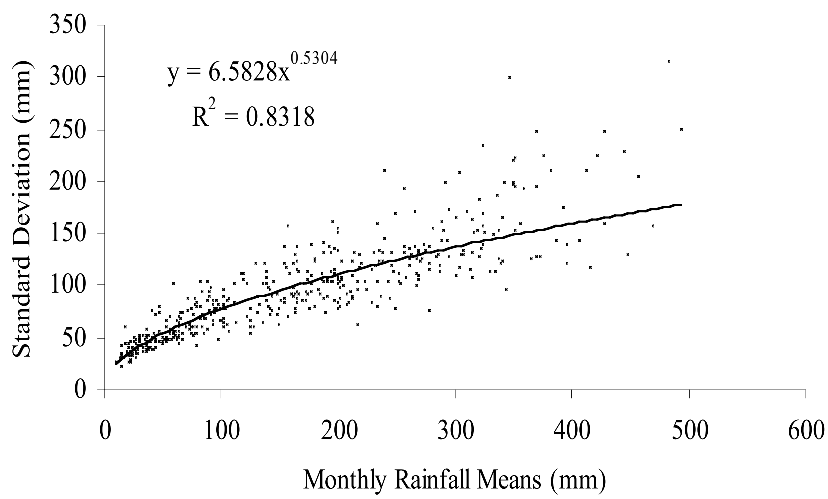


Fig. 7.7: Relationship between rainfall means with their standard deviation.

Other study showed that the mean in monthly rainfall can also be used to assess daily rainfall characteristics. Boer and Las (1998) found that the probability of having dry-spell of equal or more than 10 days ($p(x \geq 10)$) and equal or more than 15 days in a given month can be estimated from the monthly rainfall means (Figure 7.8). The forms of the equation are the following:

$$p(x\geq 10) = 1/[1+\exp(-0.2688+ 0.00745\, X)]$$

and

$$p(x\geq 15) = 1/[1+\exp(0.22913+ 0.00831\, X)]$$

These equations have been tested by Hasan (1997) using rainfall data from a number of stations in Central Java. He found that the equations performed well. Correlation between observed and estimated was more than 0.9 indicating the equation is widely applicable. Again this findings suggests that change in daily rainfall characteristics under global warming can also be estimated from the changes in monthly rainfall means.

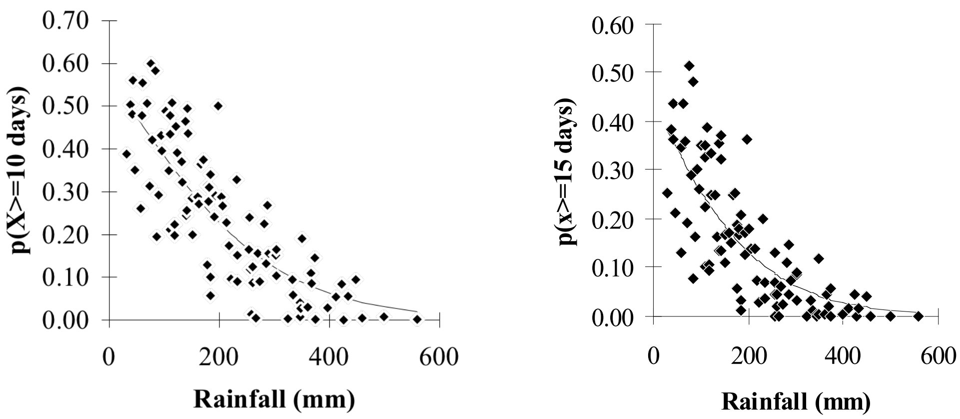


Fig. 7.8: Relationship between probability of having dry-spell and monthly rainfall means.

The assessment of temperatures and rainfalls changes under elevated CO_2 (from the two emission scenarios, SRESA2 and SRESB1) was done by averaging temperature and rainfall data from grids of the GCMs within Indonesian region (see Table 7.2). It was found that means of Indonesian temperature will increase at a rate of about 0.0344 ºC per year under SRESA2 scenario and about 0.0211ºC per year under SRESB2 scenario. On the other hand, the changes in rainfall varied between GCMs and between the scenarios. The CCSR and CSIRO suggested that the seasonal rainfall would increase consistently in the period between 2020 and 2080 under both scenarios, except for SON rainfall (Figure 7.9). Whereas, for ECHAM4 and CGCM1, the rainfall would decrease consistently while for HadCM3, the impact was not consistent. For example the DJF rainfall, it might not change up to 2020, but it would increase up to 2.5% from the baseline in 2050 and then it decreased up to 2% from the baseline in 2080 (Figure 7.9). The interesting findings were that (i) the SON rainfall might not change more than 5% from the baseline under the two emission scenarios, and (ii) the other seasonal rainfalls would increase or decrease up to 15% from the baseline in 2080. These findings imply that no generalization could be made on the impact of global warming on rainfall. However, decrease or increase in rainfall may lead to the increase of probability of having more intense and frequent extreme climate in the future.

7.4 Conclusions

From historical data, it is quite distinct that climate has changed. This evident confirms that adaptation plan of action to climate change should be developed now. The delay in taking actions to adapt to current climate risks, could increase vulnerability, or lead to increased costs at a later stage, and finally it will lead to unsustainable development. Whatever the direction of change in rainfall, it is very likely that under global warming the climate risk may increase. Thus increasing adaptation to current climate variability will be a good basis to develop strategy for adaptations to future climate risks.

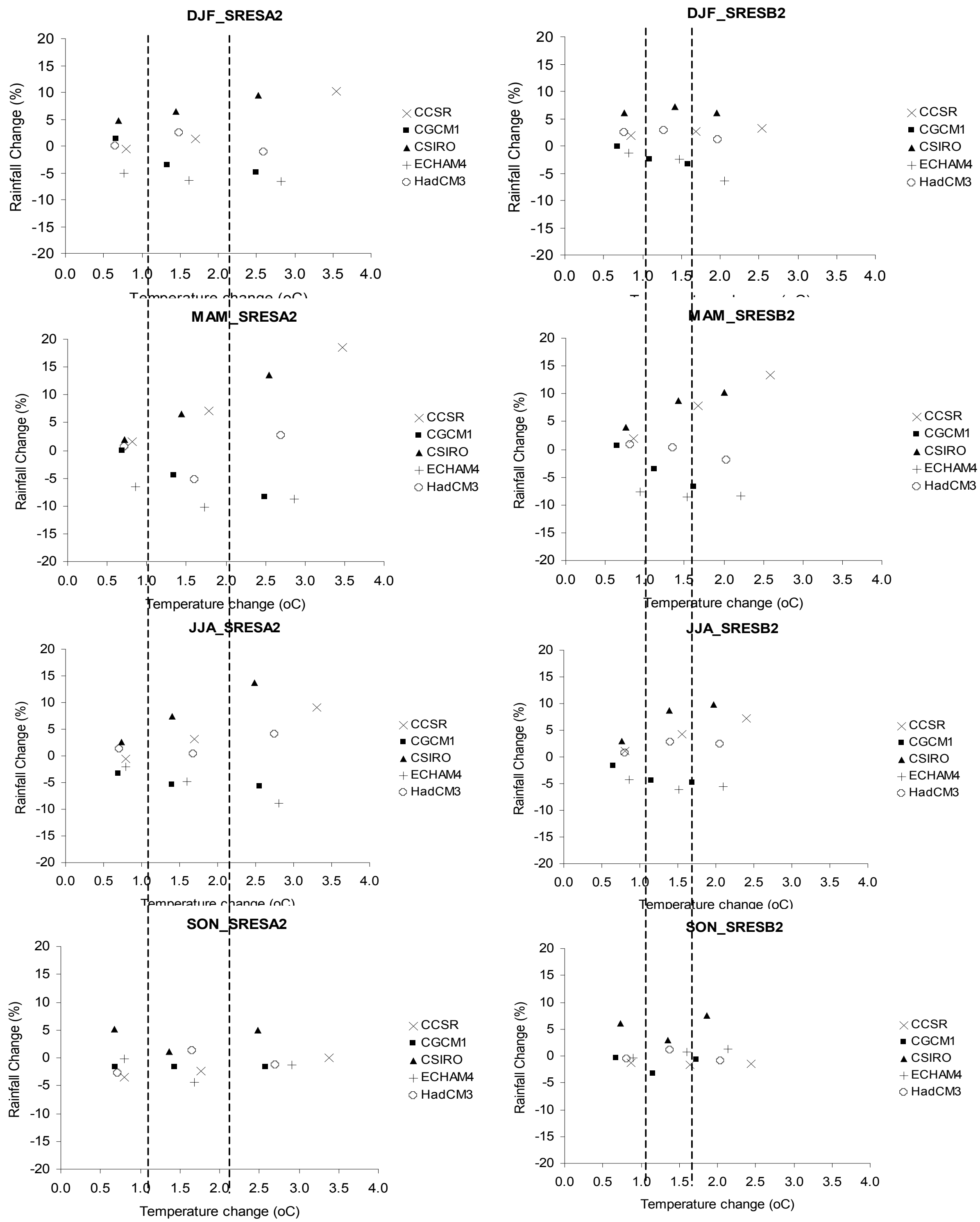


Fig. 7.9: The change in mean temperature and seasonal rainfall in Indonesia under the two emission scenarios for the five GCM models.

(The data points in the left represent data for 2020, the middle for 2050 and the right for 2080). Note: Exception for DJF and MAM (under SRES B2), the temperatures increase from baseline in 2050 for CCSR are higher than those in 2080 for CGCM1.

8 Developing Statistical Downscaling Model

8.1 Activities Conducted

The use of GCM outputs directly for impact assessment in small regions, e.g. watershed, may not be appropriate as the GCM has very coarse resolution. They can not capture the detail variation of climate condition of the small region. Therefore, a technique to downscale the GCM outputs into small region is required. This study was done to develop statistical downscaling model for GCM.

8.2 Description of Scientific Methods and Data

The downscaling process followed a number of steps. First is determining a climatic variable at local scale as predictant. Second is defining domain of GCM. Third is selecting GCM variables as predictors. Fourth is reducing number of predictors. Fifth is developing the downscaling model. This study used rainfall variable as predictant. Rainfall data were taken from 16 stations within the Citarum Watershed (Table 8.1). The GCM used in the analysis was ECHAM which has resolution of of 2,8125 °Lon. x 2,8125 °Lat (Roeckner, et al., 1992). The domain covers a region of 90,000°-149,063° E and 9,767°N-15,348°S. Thus total number of GCM grids within the domain was 220 grids.

No	Station	Lat	Long	Alt	Length of Record	Period
1	Bandung	-6.9	107.60	730	33	1962-1997
2	Malabar	-7.18	107.60	1550	24	1962, 1964, 1967, 1969-1972, 1978-1979, 1984-1986, 1989-2000, 2002
3	Margahayu	-6.80	107.65	1250	26	1961-1964, 1967-1975, 1980-1983, 1985-1989, 1993, 1997-2000
4	PasehCipaku	-7.05	107.78	910	27	1967-1989, 1991-1995, 1997-2000
5	Pasirmalang	-7.22	107.54	252	21	1971-1974, 1978-1981, 1983-1984, 1990-2000
6	Patuahwattee	-7.21	107.40	1772	27	1975-2002
7	Rajamandala	-6.84	107.35	330	10	1983, 1989-1998
8	Sukawana	-6.78	107.59	1543	24	1971-1981, 1988-2001
9	Sindangkerta	-6.99	107.4	730	13	1990-2002
10	Cikaobandung	-6.52	107.24	27	34	1961-1968, 1970-1983, 1985-1987, 1991-2000
11	Darangdan	-6.68	107.42	515	33	1961-1975, 1977-1982, 1984-1986, 1991-2000
12	Krawang	-6.30	107.30	14	36	1961-1966, 1968-1983, 1985-1987, 1991-2000
13	Purwakarta	-6.55	107.43	82	34	1961-1966, 1968-1982, 1985-1987, 1991-2000
14	Rengasdengklok	-6.15	107.30	7	25	1961-1983, 1985-1987, 1991-2000
15	Telukbango	-6.15	107.22	5	26	1961-1983, 1985-1987, 1991-2000
16	Walahar	-6.38	107.37	25	35	1961-1970, 1972-1983, 1985-1987, 1991-1999

Source: Bureau of Meteorology and Geophysics

Table 8.1: Rainfall stations at Bandung District used in the Analysis.

The PCA (Principal Component Analysis) was applied to 220 grids monthly rainfall data series of the GCM (Table 8.2). The Principal Components (Z_i) are a linear combination of variables X_1, X_2, …, X_p. In this case, p is number of grids. Thus grids are treated as variables. The principal components are defined as $Z_i = a_{i1}X_1 + a_{i2}X_2 + \ldots\ldots\ldots + a_{ip}X_p$. As the number of variables is equal to p, there would be p principal components. The Z_i will be used as predictors. Number of principal components used as predictors are the first few components that account for more than 80% of total variance of the original data. Thus the form of downscaling model would be a multiple linear regression (e.g. Huth and Kysely, 2000; Mpelaska et al., 2001; Uvo et al., 2001; Lanza et al., 2001):

$$R_k = a_0 + b_1Z_1 + b_2Z_2 + \ldots b_nZ_n$$

where R_k are the monthly rainfall of the k-station. In this case k=1, 2, …. 16 (see Table 5).

Before the downscaling model was used to estimate local rainfall in the future from the GCM rainfall, the validity of the downscaling model was evaluated by comparing the spatial pattern of the seasonal rainfall estimated from the downscaled model with the one developed from the observed rainfall data (using means of 1961-1990). The spatial pattern of seasonal rainfall over the study region was developed using Kriging technique. In this analysis, we assumed that the above empirical equations remain valid into the future. Thus the components Z_i in 2020, 2050 and 2080 will be estimated from the 2020, 2050 and 2080 rainfall data of the GCM (X_1, X_2, …, X_p).

MONTH/YEAR	GRID$_1$	GRID$_2$	GRID$_3$	GRID$_4$	…..	GRID$_P$
Jan-1961	X_{11}	X_{12}	X_{13}	X_{14}		X_{1p}
…	X_{21}	X_{22}	X_{23}	X_{24}		X_{2p}
…	X_{31}	X_{32}	X_{33}	X_{34}		X_{3p}
Dec-1961	…	…	…	…		…
Jan-1962	…	…	…	…		…
…						
…						
Dec-1962						
Jan-1963						
….						
….						
….						
Dec-2000	X_{n1}	X_{n2}	X_{n3}	X_{n4}		X_{np}

Table 8.2: The form of rainfall data for a principal component analysis.

8.3 Results

The result of analysis showed that simple linear regression could downscaled GCM rainfall data into local rainfall quite well (Figure 8.1). The models are also able to follow the spatial pattern of monthly rainfall data (Figure 8.2), however, they could not produce good downscaled data for months with very high rainfall, which commonly occur in wet season. Therefore, for DJF, monthly rainfall data from the downscaled models were slightly lower than those of observed ones as shown in Figure 8.2 (left hand side). For better analysis, the refinement of the downscaling model may be required.

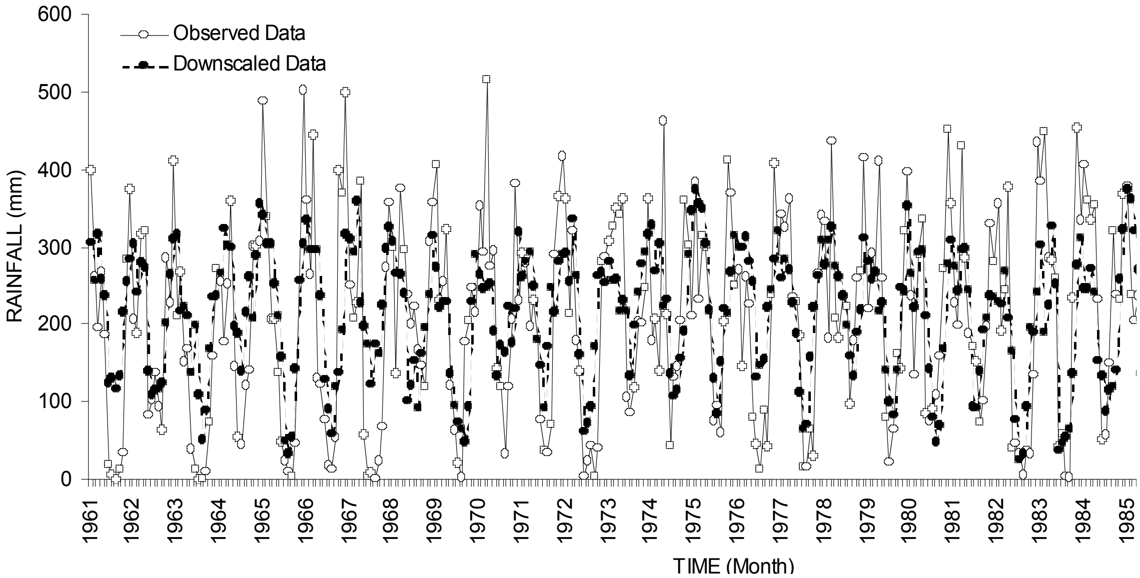


Fig. 8.1: Comparison of regional rainfall of Citarum watershed between observed and downscaled data.

The refinement of the model can be done by using more sophisticated statistical techniques in downscaling such as canonical correlation analysis(e.g. Landman and Tennant, 2000; Busuioc, 2001, Chen and Chen, 2001), tree-structure regression (e.g. Li and Sailor, 2000), Multiple Adaptive Regression Spline, and Artificial Neural Network (e.g. Sailor et al., 2000; Dawson and Wilby, 2001), analog method (e.g. Zorita and von Storch, 1999), and markov chain (e.g. Charles and bates, 1999). At present, application of these techniques in Indonesia is very limited. Other predictors from GCM, such as mean sea level pressure, 500 hPa and 850 hPa geopotential height, near surface relative humidity and specific humidity, geostrophic airflow velocity, Vorticity, zonal and meridional velocity components, wind direction and divergence may also be used for the refinement (Wilby and Dawson, 2001). However, we do not attempt to do the refinement under this study as the result of validation is good enough (Figure 8.2).

The result of projected annual rainfall for 2020, 2050 and 2080 under the two emission scenarios, SRESA2 and SRESB2 using the downscaled equations was presented in Figure 13. It was shown that rainfall for 2020 under SRESA2 would be a bit lower than that of the baseline, while the others would be higher. For impact analysis (see Figure 6.1 and Chapter 6), we selected only three climate scenarios, namely baseline, low scenario and high scenarios. Low scenario refers to projected output of 2020-SRESA2 and the high scenario refers to the projected output of 2080-SRESA2 (Figure 8.3).

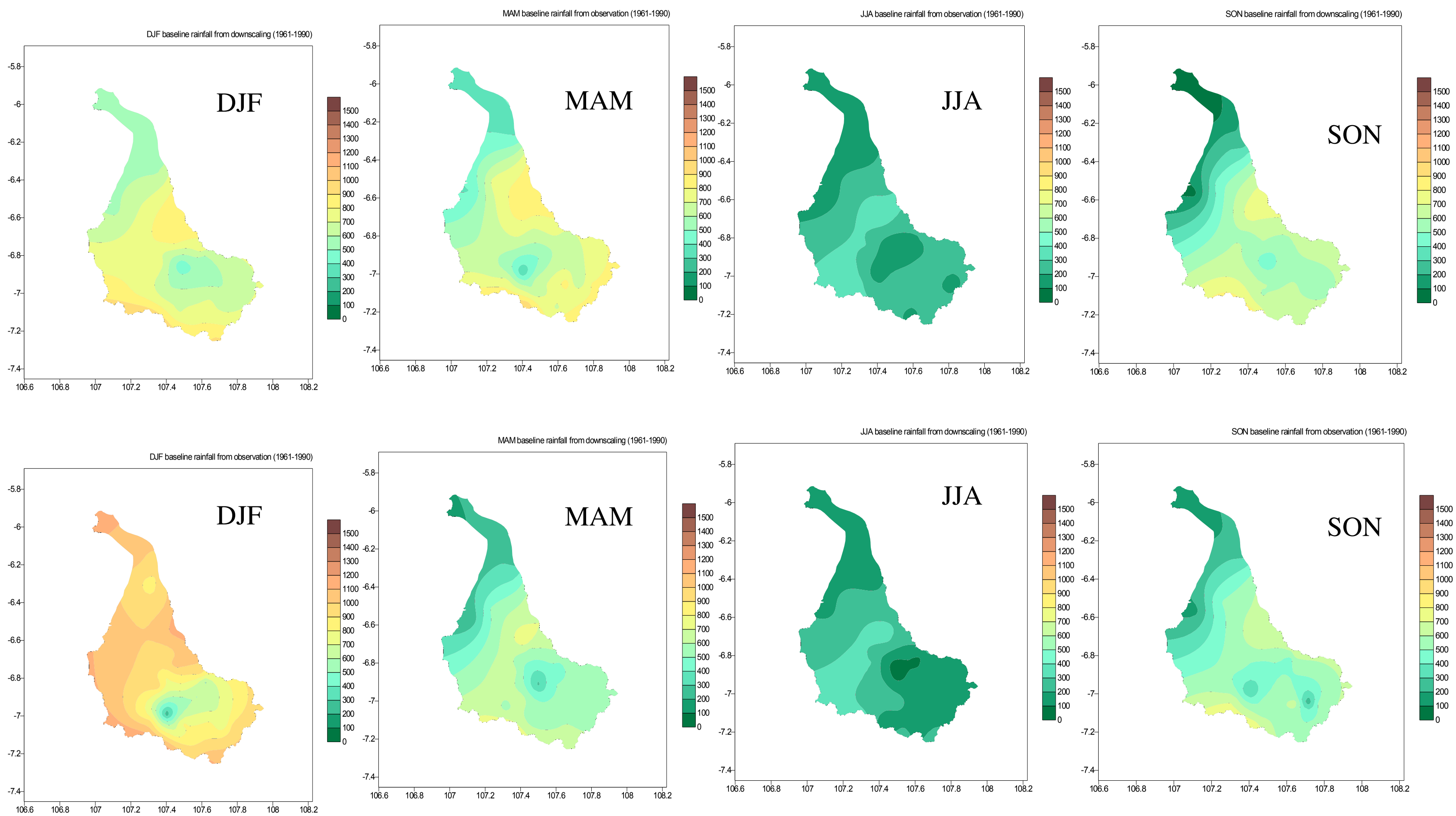


Fig. 8.2: Spatial patterns of observed (Above) and downscaled seasonal rainfall (Below) at Citarum Upper catchments.

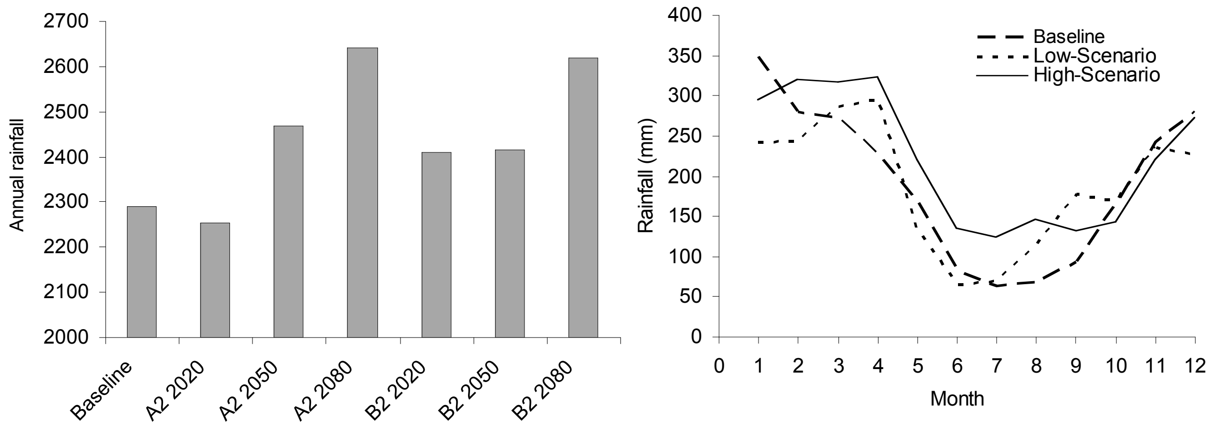


Fig. 8.3: Projected of mean annual and monthly rainfall at Citarum watershed for 2020, 2050 and 2080 using the downscaling equations.

8.4 Conclusions

Simple multiple linear regression model can be used for downscaled GCM outputs into local data. This technique produced quite good result. However, further refinement is suggested to get better result either through the use of more sophisticated statistical technique or adding a number of predictors into the equations.

9 Hydrology Balance of Citarum Watersheds under Current and Future Climate

9.1 Activities Conducted

This study is aimed to assess the vulnerability of the watershed to current climate variability and to evaluate status of water balance at the watershed under current and future climate using a number of climate change scenarios. During the study, the project team has discussed the issue with related stakeholders (electricity companies and drinking water companies) and presented the result in a seminar organized by local government.

9.2 Description of Scientific Methods and Data

The analysis consists of two steps. First step is to evaluate the impact of ENSO on stream flow. This analysis was to assess the level of vulnerability of the watershed to current extreme climate events. The second was to evaluate the hydrology water balance at Citarum watershed under current and future climate.

The behavior of streamflow during ENSO events was assessed using simple correlation analysis between SOI (Southern Oscillation Index) and streamflow data from one hydrology station with a long historical record. The five SOI phases of Stone et al. (1996) were used in the analysis. These phases are consistently negative (Phase 1), consistently positive (Phase 2), rapidly falling (Phase 3), rapidly rising (Phase 4), and neutral (Phase 5). The value of SOI phase can be downloaded from http://www.dpi.qld.gov.au. When SOI falls rapidly and then remains negative, it indicates that an El Niño occurrence is likely, which normally reduces rainfall in Indonesia, particularly in parts of South Sumatra, Java, and the eastern part of Indonesia. Conversely, when SOI increase rapidly and then remains positive, it indicates that La Niña is likely, which normally increases rainfall. The analysis uses streamflow data from Cigulung-Maribaya station (1953-2002).

A graphical analysis showing the change in mean streamflow between normal, El Niño, and La Niña years was also carried out. Total inflows from local rivers to each dam obtained from Perum Jasa Tirta II were used in the analysis. The period of record is from 1986 to 2002. This record covered five El Niño years (1987, 1991, 1994, 1997 and 2002), two La Niña years (1989 and 1998) and ten normal years.

The hydrology balance analysis was done up to sub-district level. The hydrology balance is expressed as the following:

Supply = Demand + Surplus

If the demand is higher than supply, the surplus becomes negative and vice versa.

9.2.1 Water Supply

In this analysis the annual water supply (surface flow or discharge) of the watersheds is expressed as a function of annual rainfall (Singh 1992 in Pawitan, 1996):

$$V_Q = aP - b$$

where V_Q annual surface flow or streamflow (mm), P annual precipitation (mm), *a* and *b* are constants. In this analysis, the Citarum watershed is divided into three regions, i.e., upper, middle and lower regions with area of about 1,874, 2,477, and 2,517 km^2, respectively. The relationship between annual streamflow of local rivers and annual rainfall for each region was developed using the above regression equation. As Cirata receives water outflow from Saguling and Jatiluhur receives water outflow from Cirata (see Figure 9.1), the equation of water supply for these two Dams became

$$V_Q = aP - b + I$$

where I is water outflow from the respective dams. As the streamflow data is in units of $m^3\ s^{-1}$, this was converted into annual streamflow measured as mm depth over the catchment. The calculation was done as follow:

$$V_Q = [I*(365*24*60*60)/A]*1000$$

where I is the average of annual inflow or outflow ($m^3\ s^{-1}$) and A area of the corresponding sub-watersheds (m^2). The rainfall data used in the analysis are taken from 26 stations (8 stations in the upper region, 7 stations in the middle region, and 11 stations in the lower region).

For safety reasons, the maximum annual streamflow (VQ) that can be used as water supply, should not be more than the minimum flow. Based on 15-year data, it was found that the minimum inflows to Saguling, Cirata, and Jatiluhur were about 21%, 23% and 22%, respectively. Therefore, this study used two water supply scenarios, i.e., 10% and 20% of the annual stream flow (discharge).

9.2.2 Water Demand

Demand for water comes from three sectors, namely domestic use (urban and rural), industry, and agriculture. Water demand for domestic use was estimated from the multiplication of population with water consumption per capita. Bina Program Cipta Karya (1991) stated that the level of water consumption could be categorized based on population size of city. The higher the population is, the higher the demand per capita (Table 9.1). Thus water demand projection will follow population projection assuming no changes in the patterns or management of demand.

Population size according to city category	**Water demand (l/cap/day)**			**Loss**	**Total**
	Household Use	**Drinking water**	**Non-household**		
>1.000.000	190	30	60	75	280
500.000- 1.000.000	170	30	40	55	230
100.000 - 500.000	150	30	30	50	200
20.000 - 100.000	130	30	20	40	165
< 20.000	100	30	10	30	125

Source: Bina Program Cipta Karya (1991).

Table 9.1: Consumption of fresh water per capita in Indonesia.

For industrial sectors, water demand is estimated based on the size of each industrial area. Two water demand categories were used by Bapenas (1991), namely 0.55 $l\ s^{-1}\ ha^{-1}$ (minimum) and 0.75 $l\ s^{-1}\ ha^{-1}$ (maximum). This analysis used a value of 0.65 $l\ s^{-1}\ ha^{-1}$. Data on industrial areas were not available. In this analysis, it was assumed that the industrial area of each sub-district follows the areal proportion of the sub-district relative the total area of the watershed. The industrial area of the watershed was estimated to be about 49,615 ha (0.3% of the total watershed).

For the agriculture sector, the dominant water use is for irrigation (rice cultivation). The length of irrigation season for rice in the two watersheds is between 90 to 150 days. The amount of water required is between 140 mm and 150 mm per month or equivalent to about 4,500 and 7,000 $m^3\ ha^{-1}\ season^{-1}$. Thus the total annual water demand for the irrigation was estimated by multiplying the annual planting area with the demand. The annual planting data of irrigated rice was obtained from Dinas Pertanian Propinsi Jawa Barat Website http://www.diperta-jabar.go.id.

9.2.3 Water supply scenarios

As the annual water supply is predicted using annual rainfall data, the scenario for water supply will follow rainfall scenarios. The rainfall scenarios were developed based on GCM outputs under two emission scenarios, SRESA2 and SRESB2. Changes in rainfall under global warming varied considerably between GCMs. Two GCMs models, CCSR and CSIRO suggested that the seasonal rainfall would increase consistently in the period between 2020 and 2080 under both scenarios, except for SON rainfall. Whereas, for ECHAM4 and CGCM1, the rainfall would decrease consistently while for HadCM3, the impact was not consistent. HadCM3 suggested that DJF rainfall might not change up to 2020, but it would increase up to 2.5% from the baseline in 2050 and then decreased up to 2% from the baseline in 2080. The interesting findings were that (i) the SON rainfall might not change more than 5% from the baseline under the two emission scenarios, and (ii) the other seasonal rainfalls would increase or decrease up to 15% from the baseline in 2080. Analysis prepared by XianFu (2002) also found similar features (Table 9.2).

Scenario	**Months**	**CGCM2**	**CSIRO-mk2**	**CSM-1.3**	**ECHam4**	**GFDL-R15b**	**MRI2**	**CCSR/NIES2**	**DOE-PCM**	**HadCM3**
A2	DJF	-9.16	5.09	-0.23	-7.3	52.21	10.69	10.62	2.18	3.65
A2	JJA	-8.28	12.54	-12.63	-44.92	-23.83	5.61	-5.08	10.04	-27.38
B2	DJF	-6.52	-2.82	-7.56	4.02	-2.05	7.44	-0.25	-2.8	10.72
B2	JJA	-15.72	12.68	-10.01	-13.82	-41.68	7.85	-15.74	19.05	-14.51

Source: Unpublished data (Xianfu, 2002)

Table 9.2: Precipitation anomalies of DJF and JJA in 2080 using SRESA2 and SRESB2.

Considering the impact of global warming on Indonesian rainfall is not consistent among GCMs, synthetic climate scenarios were therefore used. The rainfall changes scenarios adopted by this study are that rainfall assumed to change from the mean value in the magnitude of –20, -10, 0, +10 and +20%.

9.2.4 Water demand scenarios

For water demand, three scenarios were used. The first scenario is called baseline scenario, i.e., a scenario developed based on data of historical trend and long-term government plan (2025), and the other two scenarios were developed based on assumptions used in SRESA2 and SRESB2. Thus, the rate of population growth at each sub-district for the other two scenarios followed those of the SRESA2 and SRESB2. Hereafter, these other two scenarios used are named as SRESA2 and SRESB2. Similarly, the development of industry areas of the other two scenarios was assumed to follow the pattern of GDP growth rate of the SRESA2 and SRESB2. Meanwhile, the development of agriculture area was assumed to be the same as that of baseline. This assumption was used as the land available for the development of agriculture area is limited. The historical data suggested that the irrigated paddy area decreased at a rate of about 0.5% per year. The result of projection for population growth rate, rice planting area and industry area are presented in Tables 9.3, 9.4, and 9.5.

Scenario	Population growth rate (% per year)				
	2000-2005	**2006-2010**	**2011-2020**	**2021-2050**	**2051-2080**
Baseline[1/]	1.67	1.52	1.40	1.21	0.88
SRESA2[2/]	1.40	1.48	0.82	0.52	0.45
SRESB2[2/]	1.30	1.38	0.76	0.45	0.34

Note: [1/]Average values over a number of districts in Citarum watershed. [2/]Growth rate under these scenarios were developed based on growth rate of IPCC scenarios (IPCC, 2000). It was assumed that the maximum population density for city is 20000 people per km, while rural areas only 5000 people per km^2.

Table 9.3: Population growth rate at Citarum watershed under baseline, SRESA2, and SRESB2 scenarios from 2005-2080.

District Name	Rice planting area (ha/year)					
	2000	**2005**	**2010**	**2020**	**2050**	**2080**
Bandung City	4465	3422	1992	500	500	500
Bandung	105524	108243	109348	112000	120000	120000
Bogor	88185	92010	95280	102000	120000	120000
Cianjur	114415	99687	88707	80000	60000	60000
Sukabumi	124545	107111	101171	90000	70000	70000
Subang	167059	159166	147241	125000	125000	125000
Sumedang	69168	72625	73114	75000	77000	77000
Garut	110746	119941	128066	150000	190000	190000
Purwakarta	28886	33565	36820	45000	63000	63000
Karawang	185147	199085	208730	228000	228000	228000
Bekasi	101964	115243	124023	125000	125000	125000

Source: Dinas Pertanian Propinsi Jawa Barat (2002)

Table 9.4: Projection of rice planting area for 2000-2080.

Scenario	Industrial area (ha)					
	2000	**2005**	**2010**	**2020**	**2050**	**2080**
Baseline[1/]	19440	23000	27000	35000	50000	60000
SRESA2[2/]	19440	23000	28000	38000	52000	65000
SRESB2[2/]	19440	23000	30000	40000	55000	70000

Note: 1/ Perum Jasa Tirta II (2002), 2/Growth rate under these scenarios were developed based on growth rate of IPCC scenarios (IPCC 2000).

Table 9.5: Projection of Industrial area for 2000-2080.

9.3 Results

Impact of ENSO on inflows to the three dams was found to be significant in particular season. The impact in February-April stream flow was statistically insignificant and the impacts of El Niño and La Niña inconsistent. The impact of El Niño was clear for May-July, August-October, and November-January stream flows, while that of La Niña was clear only for May-July inflow. The reduction of inflow to the three dams during El Niño years could be as much as 60% of the normal (Figure 9.1).

Further analysis of the long-term historical stream flow data of Citarum-Nanjung also showed similar results. The impact of El Niño was significant only on May-July and August-September stream flows. From regression analysis between the seasonal rainfall and SOI, May-July stream flow increased by 0.37 $m^3 s^{-1}$ for every 10 unit increase in SOI, while August-October stream flow increased by 0.24 $m^3 s^{-1}$ for every 10 unit increase in SOI (Figure 9.2). The November-January and February-April stream flows were not significantly correlated with the SOI.

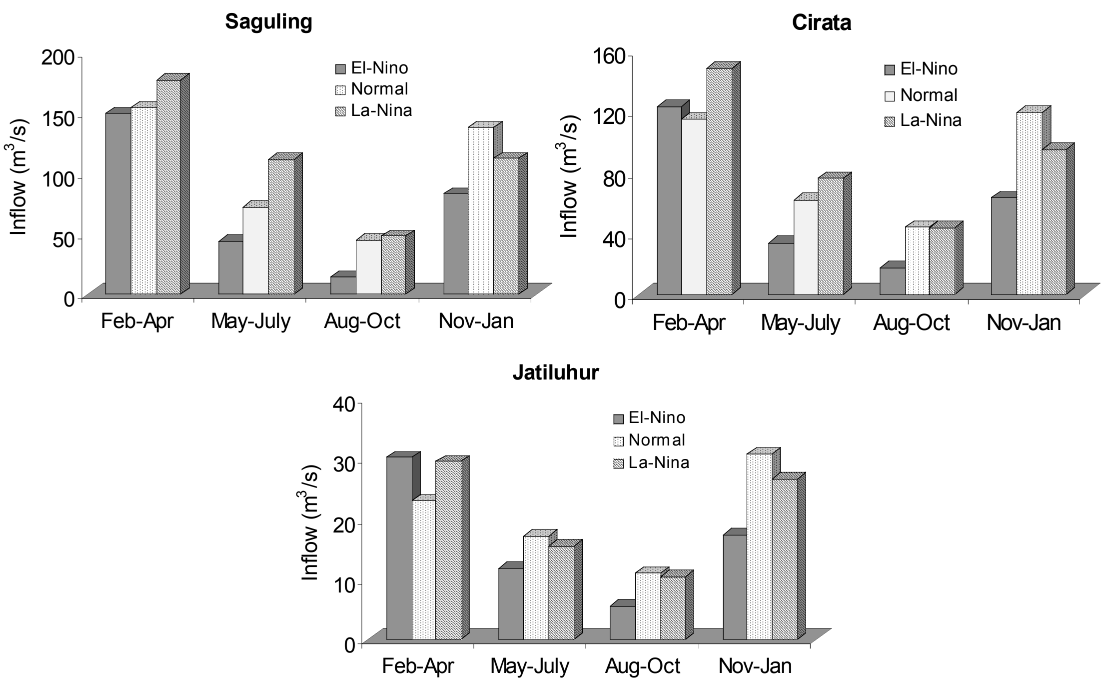


Fig. 9.1: Average inflow to the three dams during El Niño, normal and La Niña years.

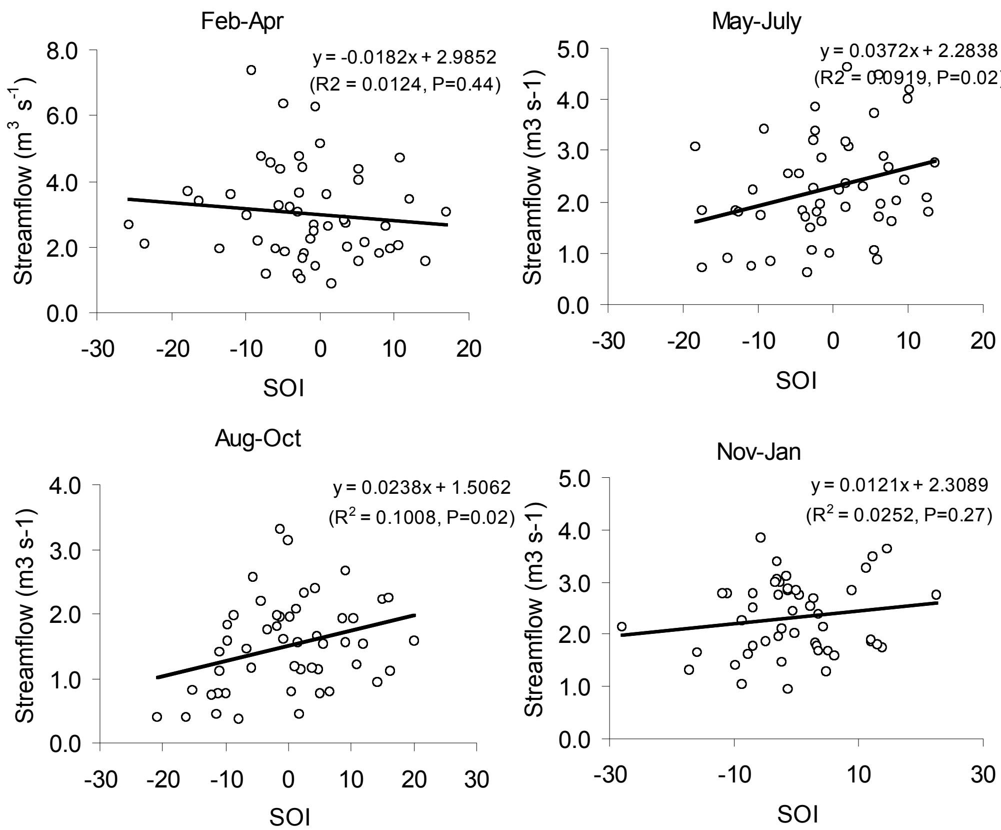


Fig. 9.2: Relationship between SOI and streamflow of Citarum Nanjung.

Seasonal streamflow distribution developed from SOI phases one month before the season start is shown in Figure 9.3. It was suggested that the August-October streamflow distribution might change when the July SOI falls rapidly or is consistently negative, or when the July SOI increases rapidly or is consistently positive. The same is true for November-January streamflow. This analysis suggests that when SOI phase of July falls rapidly or is consistently negative, the chance of high streamflow in the August-October is low. On the other hand, if the SOI phase in July increases rapidly or is consistently positive, the chance of having high streamflow in August-October will increase. Similarly for November-January streamflow, the chance of having high streamflow in this season will be low if the October SOI falls rapidly or is consistently negative. For example, the chance of having a November-January streamflow of least 2 $m^3 s^{-1}$ when the October SOI fall rapidly or consistently negative (Phase 1+3) is only 0.35, but when the October SOI increases rapidly or is consistently positive (Phase 2+4), the chance will increase to more than 0.60 (Figure 9.3).

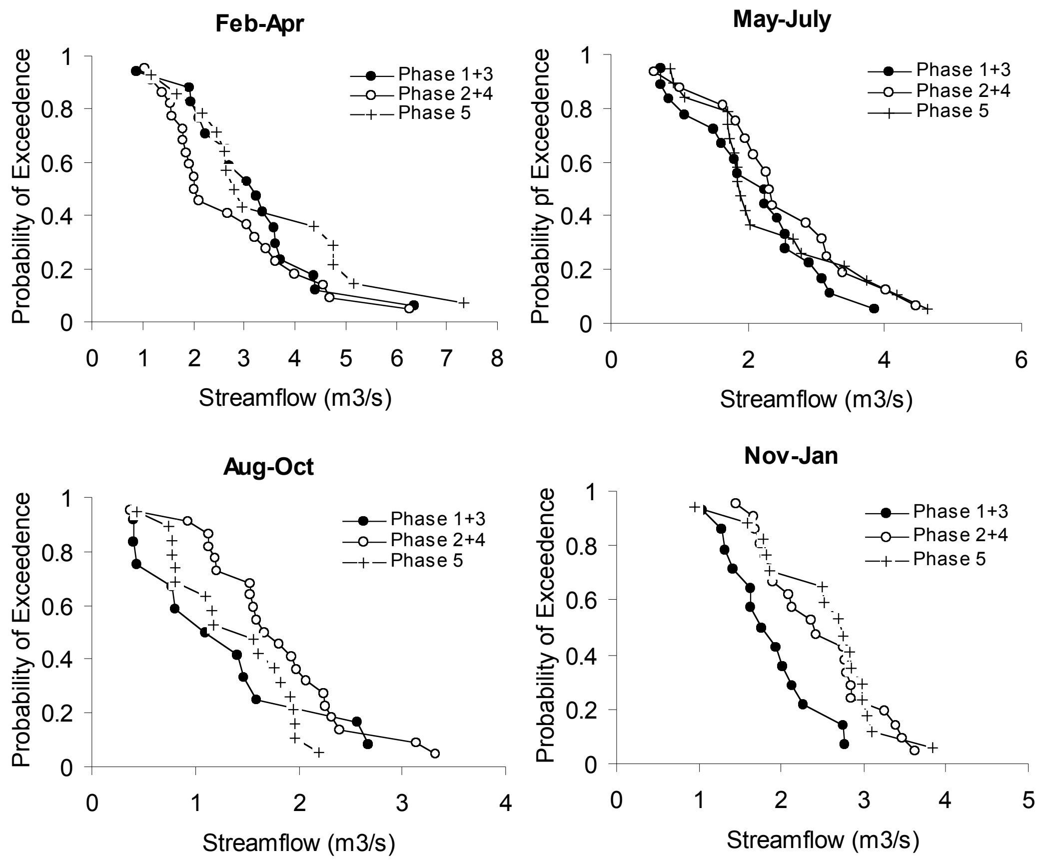


Fig. 9.3: Seasonal streamflow probability distribution for Citarum Nanjung, associated with SOI phase of the previous month.

9.3.1 Water supply

Variations in streamflow closely follow variations in rainfall. In the Citarum watershed, the relationship between annual rainfall and total annual streamflow is presented as simple linear regression equations (Figure 9.4). For the upstream area, every 1,000 mm of rainfall yields 547 mm of streamflow, for middle this is 736 mm while for lower area it is only 92 mm.

The middle and lower areas receive water not only from the local rivers but also from the dams (see the equations in Figure 6.1). The middle area receives outflow from Saguling Dam (Is), and the lower area from Cirata Dam (Ic). Outflow from Jatiluhur is used for irrigation, drinking water, industry, fishery, flushing canal, and electricity, not only districts in the watershed area, but also outside watershed area. The outflow from Saguling is about 710 mm per year (equivalent to 56 $m^3 s^{-1}$) for normal years and about 434 mm (34 $m^3 s^{-1}$) for dry years. From Cirata, the outflow is about 1,532 mm (122 $m^3 s^{-1}$) for normal years and 888 mm (71 $m^3 s^{-1}$) for dry years, and for Jatiluhur, it is about 2,505 mm (200 $m^3 s^{-1}$) for normal years and 1447 mm (116 $m^3 s^{-1}$) for dry years.

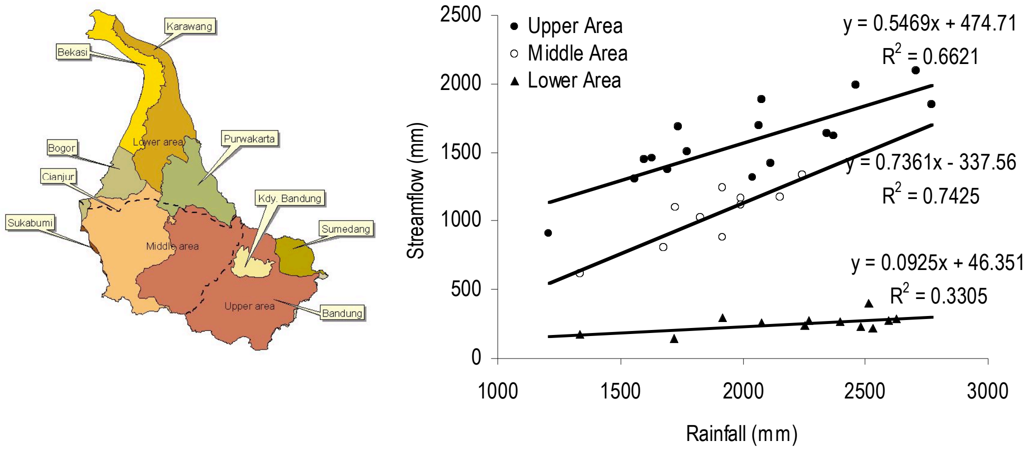


Fig. 9.4: Relationship between annual streamflow and annual rainfall in the upper (upstream), middle, and lower (downstream) areas of Citarum watershed.

9.3.2 Water balance

The water balance analysis consists of 30 scenarios: five rainfall scenarios, two water supply scenarios, and three water demand scenarios (5*2*3=30). The diagram tree of the scenarios is given in Figure 9.5.

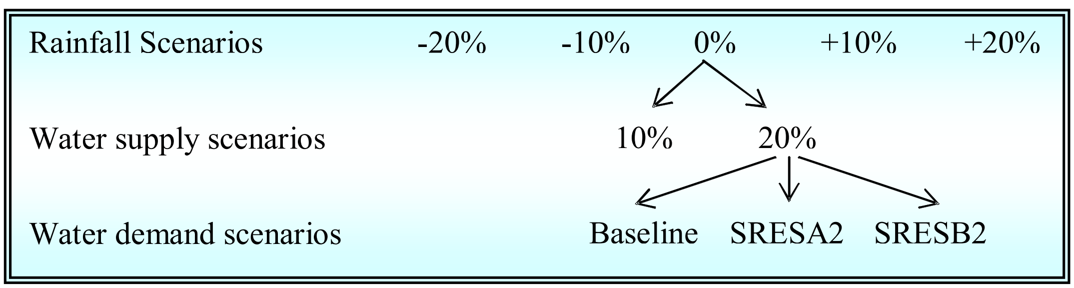


Fig. 9.5: Water balance scenarios.

9.3.2.1 No change in rainfall

Under present climate (no change in rainfall), if increases in the volume of water extracted from the streamflow were limited to 10%, all sub-districts would continue to have a water deficit problem, particularly in the lower areas of sub-districts in Kerawang, Bekasi and Purwakarta (Figure 9.6). The water deficit in these sub-districts would total more than 60 m^3 per year. In 2020, under projections of demand changes, more areas in these districts would experience severe water deficits. In 2080, the water supply for most of sub-districts in this lower area would be insufficient. Increasing the volume of water extraction by 20% would not change the water status of these sub-districts (Figure 9.7). Therefore, these sub-districts could be considered as vulnerable areas.

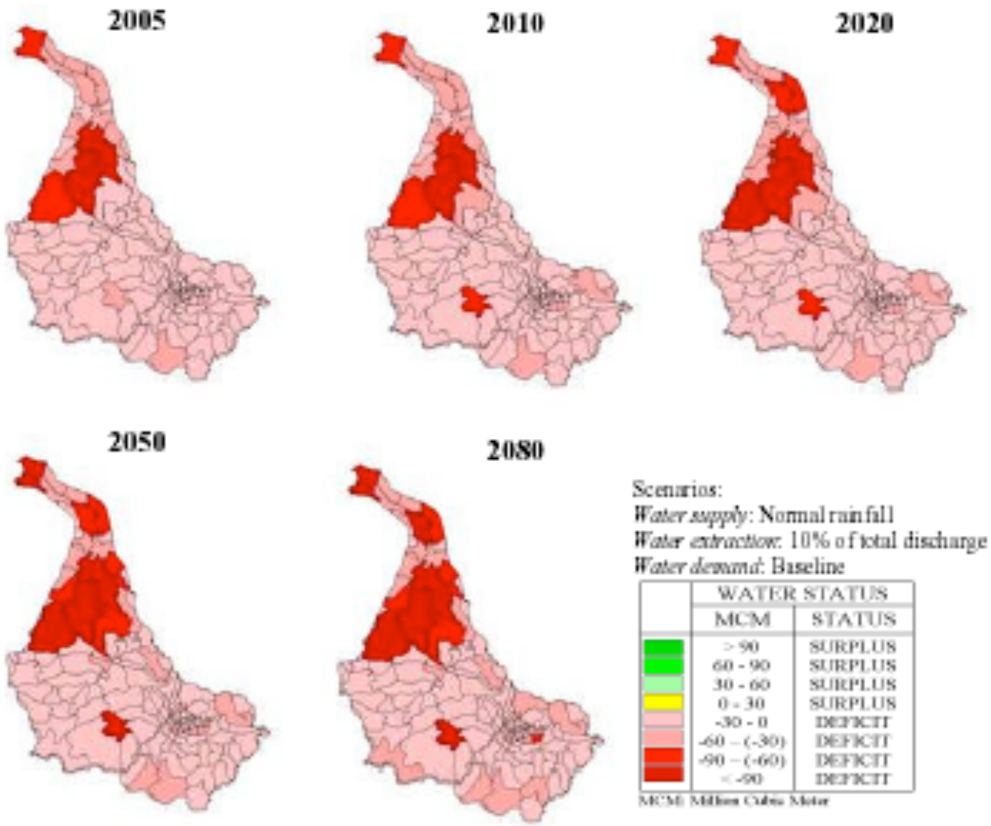


Fig. 9.6: Projection of water status by sub-district at Citarum watersheds with no change in rainfall and water extraction of 10% using baseline demand scenario.

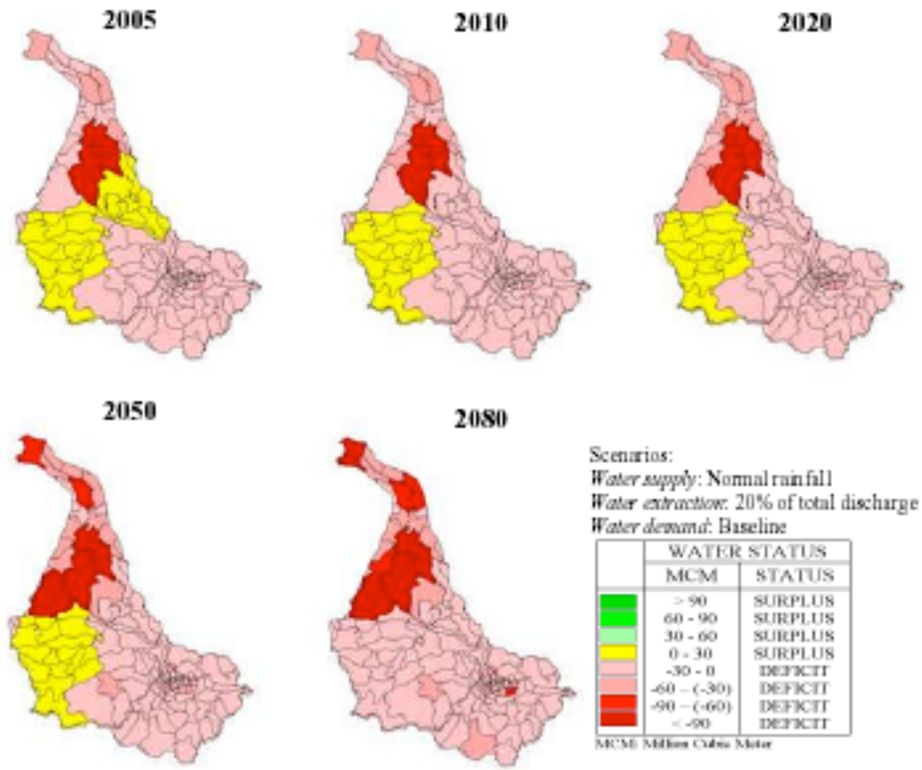


Fig. 9.7: Projected water status by sub-district of the Citarum watershed with no change in rainfall and water extraction of 20% using baseline demand scenario.

Figure 9.7 shows that by increasing level of water extraction from 10% to 20%, the status of water balance in a number of sub-districts of Sukabumi and Purwakarta would be in surplus (Figure 9.7). By changing water demand scenarios to either of SRESA2 or SRESB2, the water status of Citarum watershed remains the same as those at the baseline.

9.3.2.2 Change in rainfall

As indicated by some of GCM models, rainfall in West Java might change in magnitude by +5% to -50%. The ECHAM model projects mainly decreases in regional rainfall. The magnitude of decrease will increase with global warming from 2020 to 2080 (Table 9.6). Furthermore, rainfall decreases in the dry season are projected to be more pronounced than those in the rainy season. This feature is similar to past trends (Pawitan 2002).

Scenarios	Year	DJF	JJA
SRESA2	2020	0 to –5	-10 to –20
	2050	-5 to -10	-25 to –35
	2080	-5 to -20	-40 to –50
SRESB2	2020	+5 to –5	-10 to –20
	2050	0 to -5	-10 to –15
	2080	-5 to -10	-20 to –30

Table 9.6: Percent changes in rainfall under SRESA2 and SRESB2 suggested by ECHAM in West Java, Indonesia.

By decreasing rainfall by 10% or 20%, and increasing the level of water extraction by 20%, the sub-districts of Sukabumi would remain in surplus up to 2010 irrespective of water demand scenarios. If the increase in water extraction is kept to 10%, all sub-districts would experience deficits similar to those shown in Figure 8.1. However, if water demand scenarios followed SRESA2 and SRESB2, the number of sub-districts with a deficit of more than 60 MCM would be less. Further analysis showed that if water extraction was increase by 10%, an increase in rainfall by 10% or 20% would not change the status of water deficits in the Citarum watershed significantly, irrespective of water demand scenarios. The condition would be similar to those with no change in rainfall (see Figure 9.6).However, if the level of water extraction were increased to 20%, most of sub-districts at Citarum watershed would move to a surplus (Figure 9.8). Sub-districts at Sukabumi might be in surplus up to 2080. The CSIRO model suggests that the rainfall in West Java might increase up to 20% under global warming.

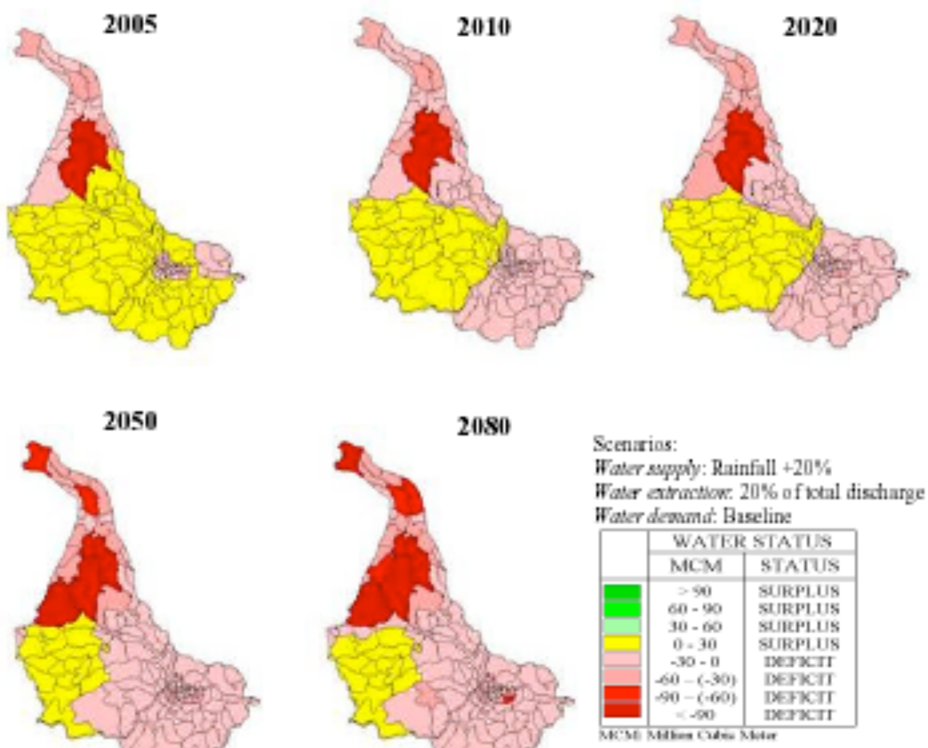


Fig. 9.8: Projection of water status by sub-district at Citarum watersheds with 20% rainfall increase and water extraction of 20% using baseline demand scenario. Water status for SRESA2 and SRESB2 were the same as the baseline.

9.4 Conclusions

The results of the analysis suggests that the Citarum watershed is very vulnerable to current climate and moreover to future climate change. The Directorate of Plant Protection (2002) reported that West Java is the most vulnerable province to drought and flood events. During El Niño years, the area suffering from drought increased dramatically, while during La Niña years, area under floods also increased significantly.

Based on observed inflow data from the three major dams (1986-2002), it was found that the change to have minimum flow of less than 10% (of the mean) was about 10% for Saguling, 15% for Cirata, and 25% for Jatiluhur. These conditions usually occurred in El Niño years. As this study suggests that if water extraction is only 10%, all sub-districts will have water deficit problem. Thus if minimum flow could not reach 10% of the mean flow, many sub-districts would have more severe water deficit problems. Under current climate, the chance to have serious deficit problem is between one to three times in every 10 years. The frequency to have this condition in the future might increase as suggested by a number of GCM models such as ECHAM and CGCM (CRU 1999) and historical trend data (Pawitan 2002; Kaimuddin 2002). From analysis of annual rainfall data of Citarum watershed which covers approximately 100 years data (1896-1994), it was shown that the annual rainfall in this watershed has decreased at a rate of 10 mm/year. In the early 1900s the mean annual rainfall was about 2,800 mm per year and in the 1990s it decreased to about 2,350 mm (Pawitan 2002).

Long-term land use strategy of Bandung District indicated that in 2010 total area of paddy field would increase from about 40 thousand to 100 thousand ha (Bapeda 2002). When this plan is implemented, agriculture demand for water would increase significantly, while the available water supply from Citarum would not change. Under this condition, conflict over water might increase. On the other hand, if programs for reforesting critical land could not be achieved as planned, the area under forest cover might decrease further increasing flood and drought risk in the future.

10 Development of Land Use Change Model at Citarum Upper Catchments

10.1 Activities Conducted

Shrinking forest due to deforestation causes degradation of land and water resources, decline of food production capability, and decreasing availability of wood for fuel, shelter and timber products. The future of world forest is therefore not just dependent on appropriate management of forest themselves but also management of conflict that forest face from outside. To understand these conflicts and learn how to deal with them, it is not enough to learn how the forest ecosystem function. It is vital to understand social system (CIFOR, 1995). This study was aimed to develop a model that can be used to predict future land use change based on changes of physical and socio-economic condition in the future.

10.2 Description of Scientific Methods and Data

Area of the study was the upper catchments area of Citarum watershed situated at 06º48'-07º07' S and 107º31'53"-107º49' E (Figure 10.1). Total area is about 1,873 km^2. Topography is quite complex with slopes ranging from 0% to 45%. This catchments area has 13 sub-watersheds with size varying from 29.7 km^2 to 281 km^2 (Ridwan, 1993).

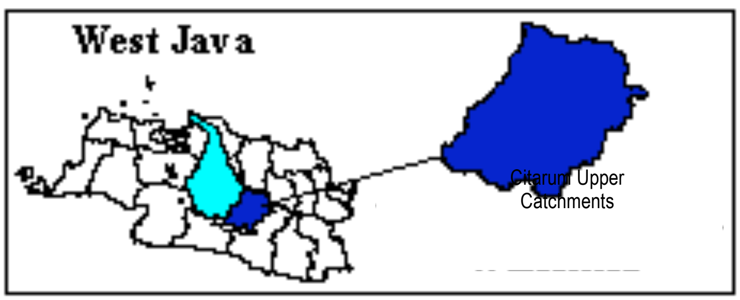


Fig. 10.1: Citarum Upper Catchments.

To assess the likely change of land use in the future, a logistic regression technique was used. The formula used is as follows (Aldrich and Nelson, 1984):

$$\text{Logit}(P_i) = a + \Sigma(b_j.x_j)$$

where P is probability of land cover change-i, an intercept a and b_j a coefficient of independent variable x_j. The relationship between P_i and Logit(P_i) is as follows:

$$P_i = e^{\text{logit}(Pi)} / (1+e^{\text{logit}(Pi)})$$

The model was developed using four satellite image data of 1989, 1993, 1999, and 2001. The independent variables used in this analysis were distance a pixel (one pixel equal to 100x100 m^2) to a center of a given land use (X_1), population density (X_2) and distance a given land use to rivers (X_3). These three variables were selected considering that land use dynamic of Citarum upper catchments may be low as most of areas already occupied and used by people, particularly for agriculture activities. Development of industries tends to be close to rivers, as rivers will use for throwing pollutants. Local community also tends to open land/forest close to the rivers for their agriculture activities. In addition, control of government to land use will be tighter.

The logistic regressions equations were developed for three periods. First period was using satellite data of 1989 and 1993. The second used data of 1993 and 1999 and third used data of 1999-2001. The population data used in developing the equation was average population data of the corresponding periods, while the distance of pixel to a given land use and to a rivers were extracted from the image data of the beginning years. For example, logistic regressions developed in the 1989-1993 period will used average population data from 1989 to 1993, while distance of pixel to a given land use and to rivers will use data of 1989.

To estimate land use change in the future, population density data was projected into the future based on historical trend. The model was run with two-year step. For example, the land use of 2010 was predicted by running the regressions equations using land use data of 2001 to estimate land use 2003, then the predicted land use of 2003 to predict land use of 2005, predicted land use 2005 for predicting land use of 2007, and finally predicted land use 2007 for predicting land use 2010. Detail procedure for performing the analysis was described in Boer *et al.* (2003). The projection of population data to 2010 was done based on historical trend.

Land use change scenarios used in this study were (i) land use scenario as suggested by the models, called as baseline, (ii) government land use scenario, and (iii) two mitigation scenarios, scenarios for land/forest rehabilitation. The second scenario was taken from Bapeda (2002), i.e. Land Use Planning for 2010 (*Rencana Umum Tata Ruang*) of Bandung District, and the last scenarios developed based on land/forest rehabilitation plan set up by Balai Pengelolaan DAS Citarum-Ciliwung (2003).

10.3 Results

Based on land use historical data, it was shown that the area of bareland and shrub land increase tremendously from 2694 ha in 1989 to 11860 ha in 2001 (Table 10.1; and Figure 10.2). While agriculture areas decreased slightly due to conversion to other uses, in particular settlement and urban/industry area. A number of small lakes have also been converted to settlement areas. Total reduction of lake from 1989 to 2001 was about 28.7% (equivalent to about 89 ha. Conversion of these lakes to other uses have cause serious problem in Bandung district. Frequency of floods has increased recently as the capacity of the lakes to store surplus rainfall water during rainy season has decreased. Local government has stated that lakes that have been converted to other uses would be restored again to its original condition.

Land Use	**Area (ha)**				**Percent change**			
	'89	**'93**	**'99**	**'01**	**89-93**	**93-99**	**99-01**	**89-01**
Bare land and shrub land	2694	5105	10469	11860	89.5	105.1	13.3	340.3
Agriculture area[1/]	126536	124755	126501	126335	-1.4	1.4	-0.1	-0.2
Forest & vegetation covers[2/]	46105	44182	34928	31951	-4.2	-20.9	-8.5	-30.7
Settlements	2639	3429	4547	5522	29.9	32.6	21.4	109.2
Urban and Industries	9030	9597	10627	11426	6.3	10.7	7.5	26.5
Dam/Lakes	312	247	243	223	-20.9	-1.5	-8.5	-28.7
TOTAL	187316	187316	187316	187316				

Note: [1/]Agriculture area consists of cropland, mosaic upland crops, mosaic upland rice, rice paddy, and plantations (tea, cocoa etc). [2/]Forest and vegetation covers include forest plantation, lowland forest, lowland logged-over forest, sub-montane forest, and montane forest.

Table 10.1: Land use change in the period of 1989, 1993, 1999, and 2001.

10.3.1 Logistic regression

For the period between 1989 and 1993, number of logistic regression equations was 13 equations, while for 1993-1999 it was only 11 equations and for 1999-2001 10 equations. The reduction number of equations the period moves forward due to disappearance a number of land use type. The coefficient determination of the equations ranged from 9% to 70% with mean of 30%. The interesting finding was that the coefficients of the regression equations for most of land use changes were quite persistent. The intercepts, and the coefficients of independence variables (X1 to X3) of land use change equations developed using image data of 1989 and 1993 were similar with those of 1993-1999 and 1999-2001 (Figure 10.3). This result suggests that the development of the logistic equations for predicting land use changes can use only two images from different years irrespective of the interval between the two years. However, this finding should be investigated further in regions using more socio-economic variables such as (GDP/income per capita, number of job seekers etc.) and in areas where land-use changes are very dynamic.

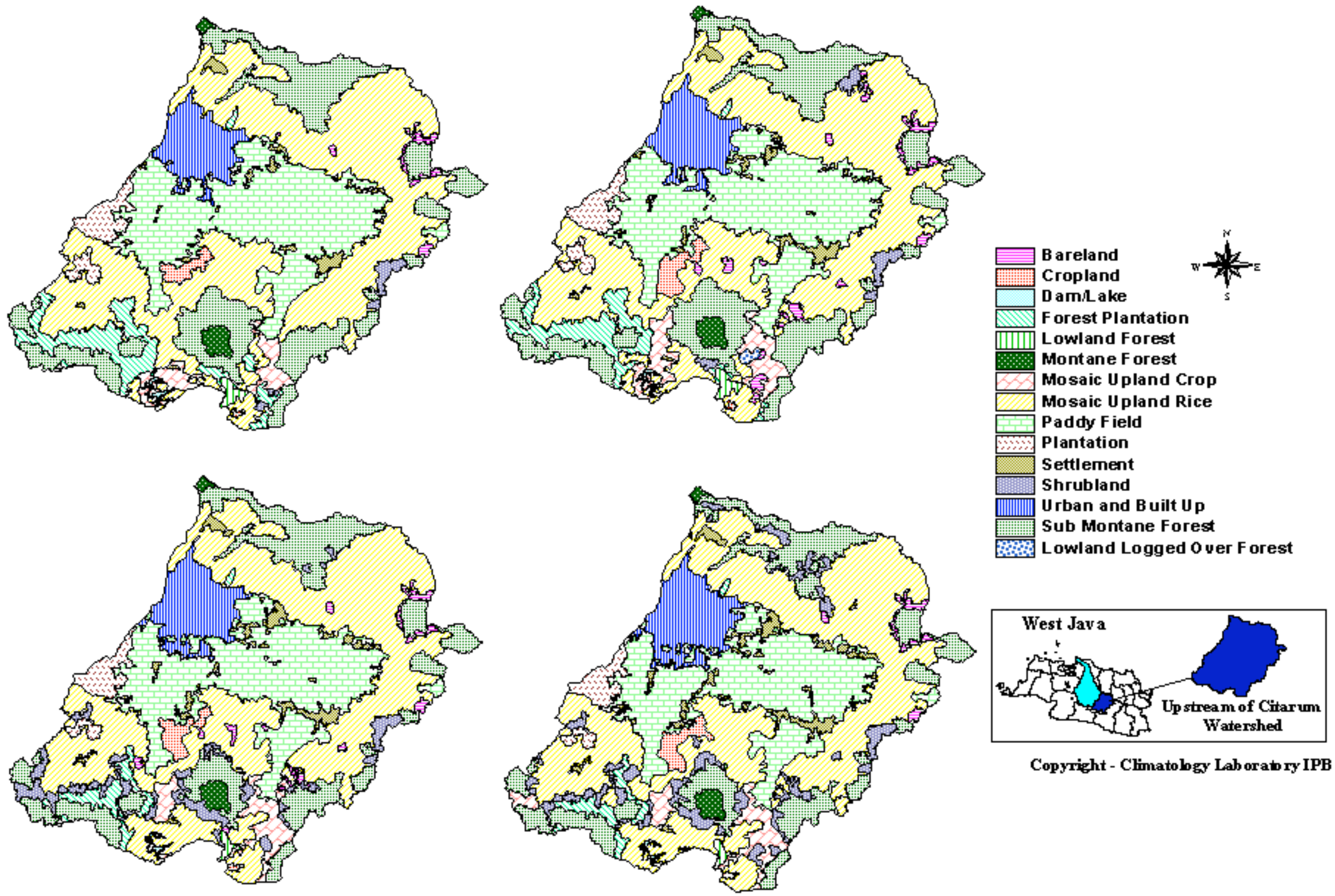


Fig. 10.2: Land use and forest cover at Citarum upper catchments in 1989, 1993, 1999 and 2001

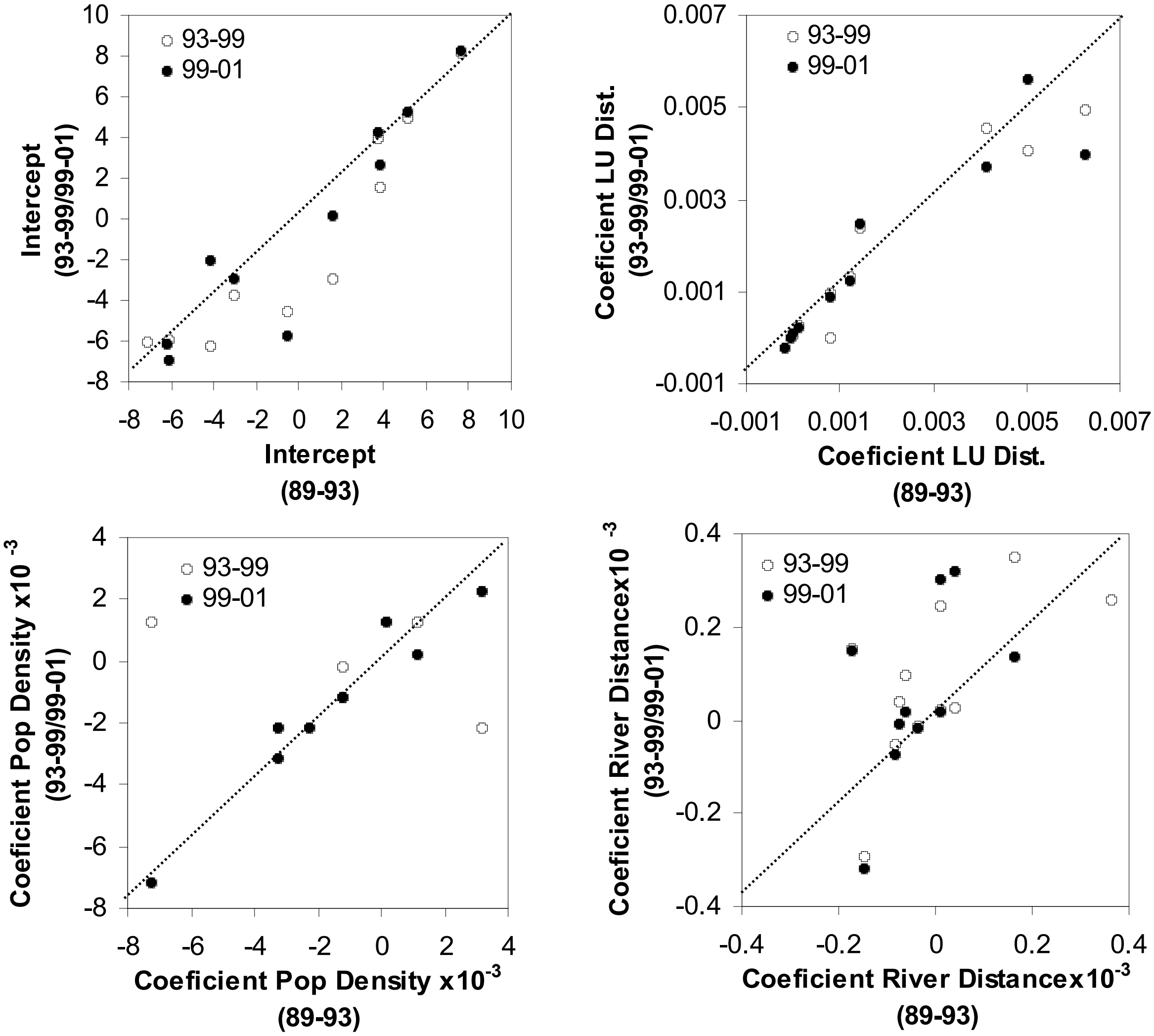


Fig. 10.3: Relationship between regression coefficients of logistic equations developed using image data of 1989-1993 and image data of 1993-1999/1999-2001.

10.3.2 Land use scenarios

By applying the logistic regression equations, land use in 2010 was predicted using land use of 2001 and population projection data. The result indicated that the land use pattern in 2010 would not change significantly from that in 2001. It implies that there may be no significant change in land use pattern in the future if no government intervention takes place.

According to government plan (Balai Pengelolaan DAS Citarum-Ciliwung, 2003), area of critical land/degraded forest in the Citarum watershed going to be reforested during 2003-2007 is about 138 thousand ha or equivalent to about 27,760 ha per year (Table 10.2). While total area of critical lands inside and outside forest area are very large, i.e. about 390 thousand ha (Table 10.3). Citarum upper catchments which is located mostly in Bandung area has critical land of about 140 thousand ha. Considering this condition, possible future government intervention on increasing forest cover in Citarum watershed realistically may be divided into two scenarios, namely mitigation scenario-1 and 2, with total reforestation area of about were 22.5 thousand ha and 45 thousand ha respectively.

Location	Area	2003	2004	2005	2006	2007	Total
Bandung	Inside	2749	1862	1695	2283	1846	10435
	Outside	7135	7135	7135	7135	7135	35675
Cianjur	Inside	1818	2066	1962	1841	1738	9425
	Outside	9616	9616	9616	9616	9616	48078
Purwakarta	Inside	5622	5622	5622	5622	5622	28110
	Outside	511	971	971	971	971	4395
Karawang	Inside	0	0	0	0	0	0
	Outside	436	436	436	436	436	2182
TOTAL		27887	27707	27437	27904	27364	138300

Source: Balai Pengelolaan DAS Citarum-Ciliwung (2003)

Table 10.2: Government plan for rehabilitation of critical land located inside and outside forest area in the period 2003-2007.

Location	Inside Forest Area			Outside Forest Area	TOTAL
	Conversion	Protection	Production		
Bandung	18994	77900	700	44728	142322
Cianjur	16893	57594	16806	80264	171557
Karawang	0	16280	7615	23807	47702
Purwakarta	2451	14005	5601	5514	27571
Kota Bandung	0	0	0	350	350
Kota Cimahi	0	0	0	175	175
TOTAL	38338	165779	30722	154838	389677

Source: Balai Pengelolaan DAS Citarum-Ciliwung (2003)

Table 10.3: Critical land at Citarum watershed in 2001.

Based on land use planning of Bandung District for 2010, most of area at Bandung district would be converted into agriculture area (in particular paddy field) and urban/industrial areas (Figure 10.4; Bapeda, 2002). Following the government land use plan for 2010, it was suggested that total area under forest cover/vegetation cover would be less than the mitigation scenario-1 and 2. Percent forest cover in the Citarum upper catchments under the mitigation scenario-1 and 2 would be about 29% and 41% of the total area while under the government land-use scenario was 19%, slightly higher than percent forest cover of 2001 (Figure 10.5).

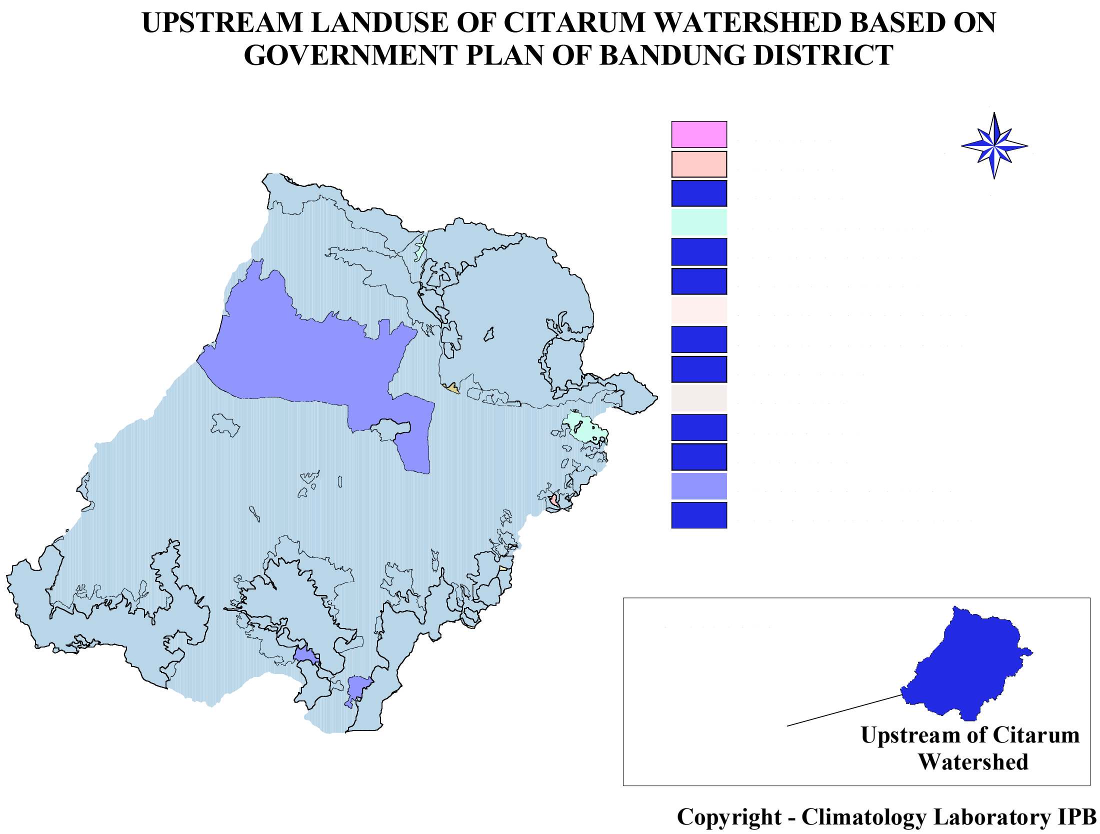


Fig. 10.4: Government land use plan for 2010 at Citarum upper catchments (Bapeda, 2002).

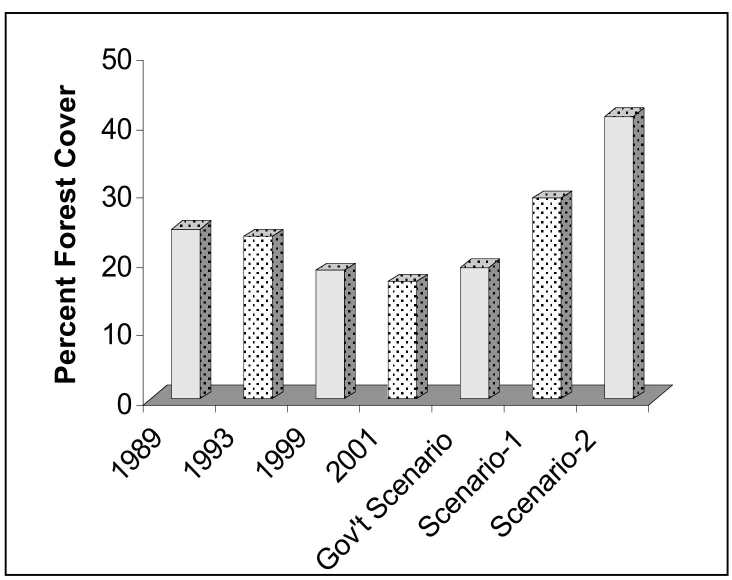


Fig. 10.5: Historical and future scenarios of percent forest cover at Citarum upper catchments area.

Forest or vegetation cover has significant impact on river flow. By increasing forest/vegetation cover, fraction of rainfall being run off will decrease, and more water will be stored in the soils and then release slowly to river. Removing forest or vegetation cover from land will increase flood risk as most of water from heavy rainfall will become run off. Whereas during dry season, river flow will be very low since amount of water that can be stored by forest will decrease. Maintaining forest cover to a certain level is important to minimized flood risk during rainy season and drought risk during dry season.

Based on historical data, it was clearly shown that fraction of annual rainfall being run off decrease with increasing forest cover. Similarly, variability of river flow also decreased with increasing forest cover (Figure 10.6). The data suggested that variability of daily river flow would decrease by about 2 $m^3 s^{-1}$ for every one percent increase in forest cover. In addition, fraction of annual rainfall being run off also decreased by about 9% with every 10% increase in forest cover. This means that the difference between peak flow in rainy season dan low flow during dry season will decrease.

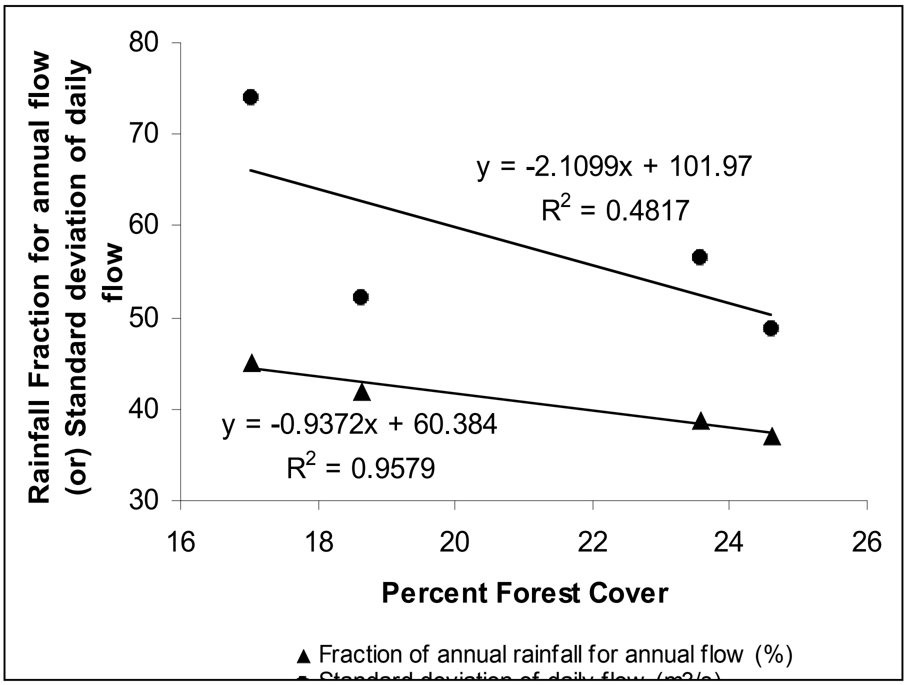


Fig. 10.6: Relationship between percent forest cover and rainfall fraction being run off as well as variability of daily river flow.

10.4 Conclusions

Land use in the Upper Citarum Watershed may not change significantly in the future unless there is government intervention through changes in land use policy. Thus in this study, the land use change scenarios were developed not based on the model but based on land use of 2001, government land use scenario for 2010, called RUTR (Bapeda, 2002), and forest rehabilitation plan (BP DAS Citarum-Ciliwung, 2003).

11 Assessing Impact of Land Use and Climate Changes on River Flow of Upper Citarum Watershed

11.1 Activities Conducted

This study was aimed to assess the impact of land use and climate changes on stream flow at the upper Citarum River. The result of the study can be used as basis in developing recommendations for local government in setting up land/forest rehabilitation program in the upper catchments of Citarum watershed so that risk of flood and drought under changing climate can be minimized. During the study, the project team has presented the results of the study to different stakeholders (electricity companies and local government).

11.2 Description of Scientific Methods and Data

To assess the impact of land use and climate change on river flow, this study used VIC-BASIN model. In the VIC-BASIN, the hydrology of regional-scale river system was modeled as a geospatially-explicit water mass balance for each grid cell (0.01=1 km^2). Model was divided into two major components, i.e. vertical and horizontal components and it separates the indirect water routing and direct water diversions. The model uses two soil layers and one vegetation layer. Land cover is classified into 13 classes where different class of vegetation has different root depth and leaf area index which affect infiltration capacity and evapotranspiration respectively.

To capture the impact of land use change using VIC-BASIN, the base flow parameter of the model have to be adjusted following the change of forest cover. In this study the VIC-BASIN model was run using the historical land use of 1989, 1993, 1999, and 2001 of Citarum watershed and historical land use of 1985 and 1994 of Sumberjaya watershed (data from ICRAF), and base flow parameter was adjusted until the outputs of the model did not significantly different from the observed ones.

As hydrology impact model requires daily climatic data inputs, while the available data of GCM model are monthly basis (see Figure 8.3), a model called CLIMGEN v1.0 developed by Boer *et al.* (2000) was used to generate daily climatic data from the monthly means. The CLIMGEN was developed based on works of Stern, and Coe (1984), Epstein (1991) and McCaskill (1990). The means of stream flow data from VIC-BASIN simulated using the generated daily climatic data was not significantly different from the observed stream flow data (Boer *et al.*, 2004). This justifies the use of CLIMGEN for the study. The step of the analysis is shown in Figure 11.1.

Land use scenarios used in this study were five scenarios (Table 11.1). The scenarios were not developed using the model but based on land use of 2001, government land use scenario for 2010, called RUTR (Bapeda, 2002), and forest rehabilitation plan (BP DAS Citarum-Ciliwung, 2003) as stated previously. The baseline scenario was land use of 2001, while other four scenarios (LUSs) were developed by changing percentage of forest cover, agriculture areas and industrial/resettlement areas. The four scenarios have higher percent forest cover than that of the baseline. By increasing forest cover, it is expected that the different between minimum and maximum stream flow could be reduced thereby reducing drought and flood risks. Thus the four land use scenarios were called as Mitigation Scenario-1 (MIT-1), Mitigation Scenario-2 (MIT-2), Mitigation Scenario-3 (MIT-3) and Mitigation Scenario-4 (Government Plan or RUTR).

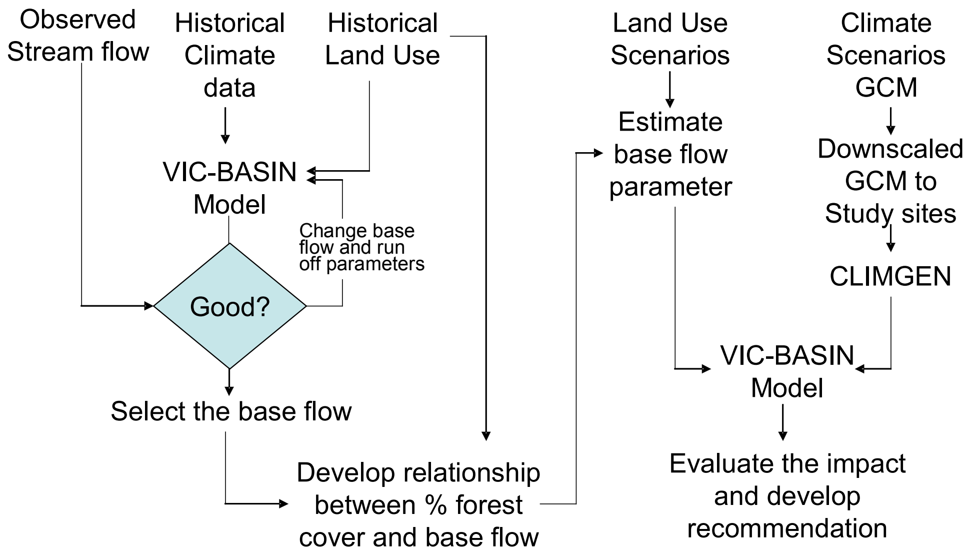


Fig. 11.1: Steps of analysis for assessing the impact of land use and climate changes on streamflow.

Land use category	**Area (ha)**				
	Baseline (LU 2001)	**MIT-1**	**MIT-2**	**MIT-3**	**RUTR**
Shrubs	11862	9578	5	0	0
Agriculture	126494	118465	124167	115736	77426
Forest/Agroforest	31825	35921	45990	54445	89426
City/Industrial areas	16912	22849	16931	16912	20016
Dam/Lakes	223	503	223	223	448
TOTAL	187316	187316	187316	187316	187316
Percent forest cover (%)	17	19	25	29	48

Note: Percent forest cover of MIT2 is similar to that of 1989 (see Table 13).

Table 11.1: Land use change scenarios.

11.3 Results

The result of study shows that the base flow parameter of VIC-BASIN was significantly correlated with changes of percent forest cover irrespective of land use pattern (Figure 11.2). The base flow parameter increases exponentially with percent forest cover. The equation in Figure 10.6 was used to estimate the parameter of base flow of the VIC BASIN for each land use scenarios.

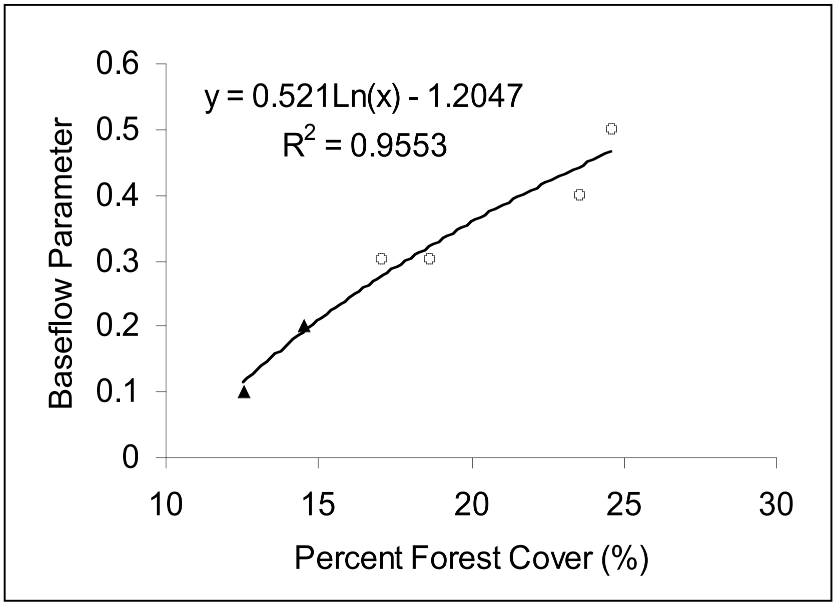


Fig. 11.2: Relationship between percent forest cover and base flow parameter of VIC Model.

(Note: The circles in the figures are base flow parameters of Citarum and black triangles from Sumberjaya).

Validation of VIC-BASIN model at Citarum watershed was done using land use data of 1989, 1993, 1999, and 2001. It was found that the suitable base flow parameter for the model under 1989 land use condition was 0.5, while for other years were 0.4, 0.3 and 0.3 respectively. The model could produce river flows data that have similar pattern with the observed ones (Figure 11.3). Statistical test using simulated monthly aggregate data suggested that there were no significance different between simulated and observed data. The use of climatic data from climate data generator model was also assessed. It was found that simulated data produced using generated rainfall data (UGCD) was similar to those using observed rainfall data and able to follow the pattern of observed river flow data (Figure 11.4).

To assess the impact of land use and climate change on stream flow, the VIC-BASIN model was run using the five land use scenarios (Table 11.1) and generated climatic data from CLIMGEN where the inputs used were the monthly rainfall data from the three climate scenarios (baseline, low and high climate scenarios, see Figure 8.3). Compare to baseline climate, the maximum flows of Nanjung River (Upper Citarum) under low climate scenario were lower but the minimum flows were higher (almost two times of the baseline) for all land use scenarios (Table 11.2). This condition is due to the different in rainfall pattern between the two scenarios. In term of total annual rainfall, the two scenarios were not very different, but the rainy season rainfall of the low climate scenarios was much lower than that of the baseline, while the dry season rainfall of the low climate scenarios was a little bit higher than that of the baseline (see Figure 8.3). Similar pattern was also observed for the high climate scenario (Table 11.2). The difference is that the increase in minimum flows was much higher (about three times of the baseline). This condition can also be explained from the rainfall pattern between the two scenarios.

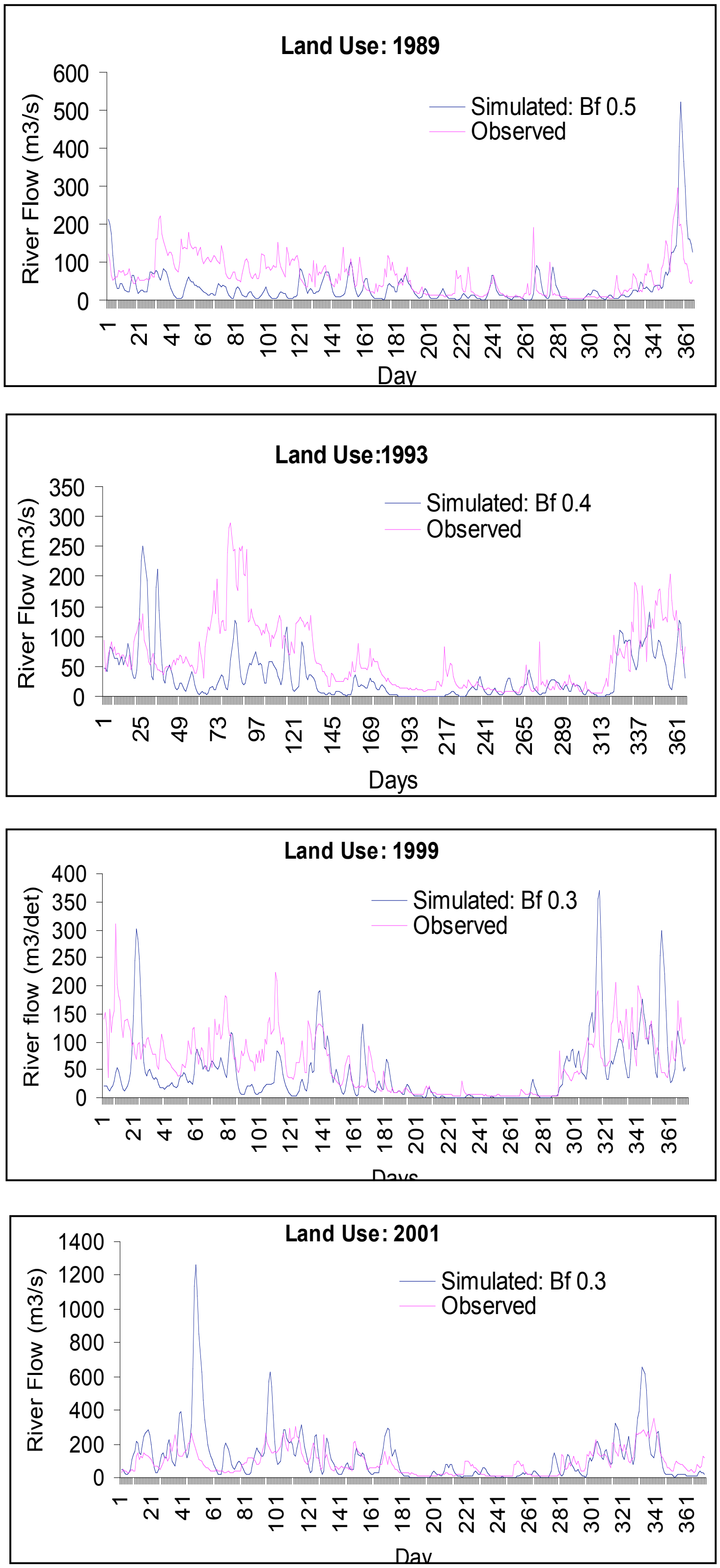


Fig. 11.3: Comparison between observed and simulated river flow from VIC-BASIN.

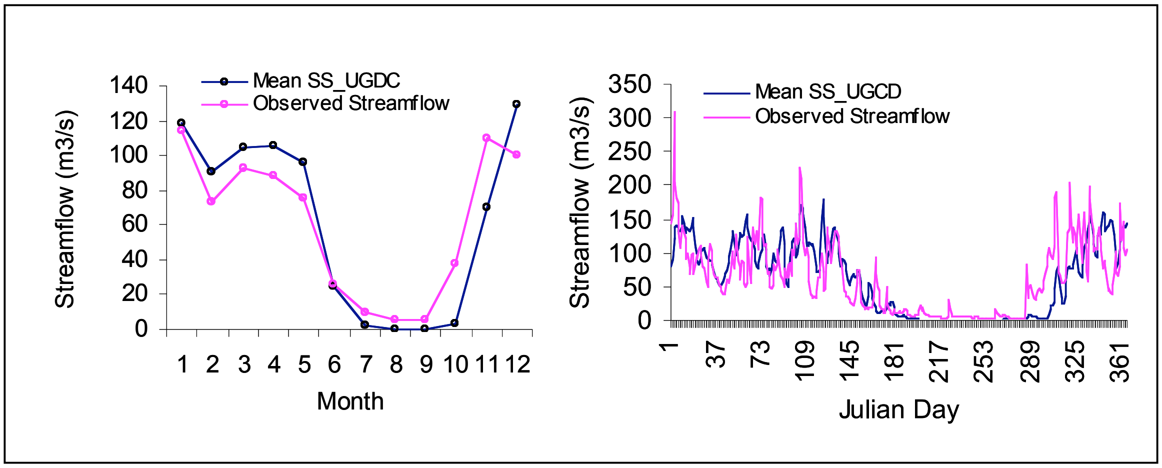


Fig. 11.4: Comparison between stream flows data simulated using generated climate data (SS_UGCD) and the observation.

	Vegetation Cover	Mean of Maximum flow	Mean of Minimum flow	Ratio Max/Min
Baseline Climate	%	**Flow (m³/s)**		
LU-2001 (Baseline)	17	289	7	43.8
MIT-1	19	329	7	50.6
MIT-2	25	151	13	12.0
MIT-3	29	226	16	13.9
RUTR	48	144	13	11.5
Low Scenario				
LU-2001(Baseline)	17	281	12	22.9
MIT-1	19	258	17	14.8
MIT-2	25	147	18	7.9
MIT-3	29	153	13	11.6
RUTR	48	136	14	9.7
High Scenario				
LU-2001(Baseline)	17	252	13	20.0
MIT-1	19	229	23	10.0
MIT-2	25	152	29	5.3
MIT-3	29	137	23	6.1
RUTR	48	169	27	6.3

Table 11.2: Maximum, minimum, mean flows and ratio maximum:minimum flow of Nanjung River under different land use and climate scenarios.

Other finding was that increasing forest cover more than 25% will reduce the maximum flow quite significant compare to the scenarios with vegetation cover of less than 20%, whereas the minimum flows will increase so that the ratio between maximum and minimum flow would decrease significantly (Table 11.2). These results suggest that minimum forest cover of about 25% should be maintained at the upper Citarum watershed in order to reduce the risk of drought and flood. To reach this percent forest cover, 14,000 ha of degraded land/forest needed to be rehabilitated.

Flows at Nanjung River have been used as indicator for flood risk at Bandung City. Data from 1990-2002 showed that floods occurred almost every years (Figure 11.5). Severe flood occurred in 1998 (La-Nina year) where total area being inundated was more than 6000 ha, and streamflow at Nanjung River went up to almost 450 m^3/s. These data suggest that if flow at Nanjung river is more than 200 m^3/s, the chance of having flood is about 75% and chance of having heavy flood increased when the flows in Nanjung River is more than 250 m^3/s. Referring to Table 11.2, it is clear that under current percent forest cover (19%), the mean of maximum flows at Nanjung Rivers is generally more than 250 $m^3 s^{-1}$ and this causes Bandung City vulnerable to floods. The mean of maximum flows of less than 250 $m^3 s^{-1}$ could be expected if the percent forest cover were more than 25% (Table 11.2).

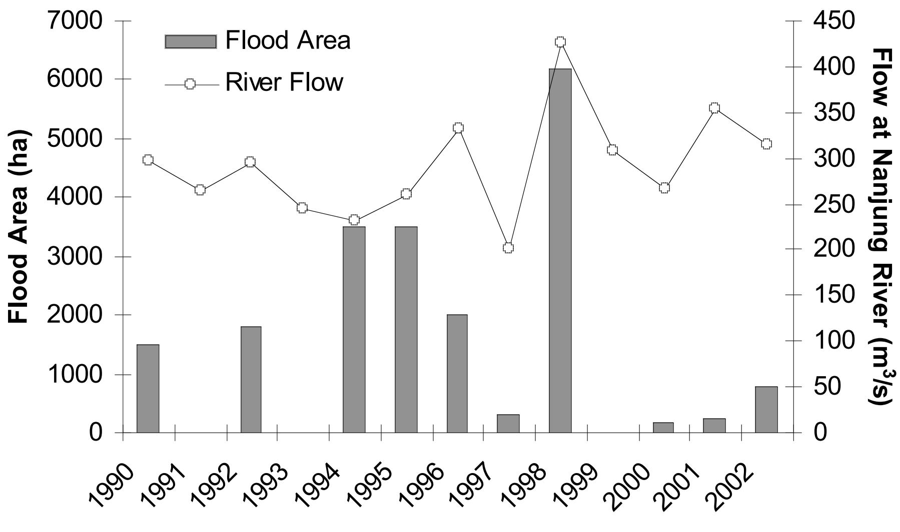


Fig. 11.5: Total area of flood at Bandung city and flow at Nanjung river from 1990-2002 (BPDAS, 2002).

Increasing forest cover will also have positive impact for electricity companies. Saguling reservoir control the outflow based on the inflow, and the outflow will determine the electricity power being produced (Figures 11.6a and 11.6b). The relationship between inflow (X) to and outflow (Y) from Saguling Reservoir can be written in the following equations:

$$Y = \begin{cases} 0.569\,X + 42 & \text{for inflow} < 140\ m^3 s^{-1} \\ 0.831\,X - 15 & \text{for inflow} > 140\ m^3 s^{-1} \end{cases}$$

This relationship suggests that when inflow to Saguling is already over 140 $m^3 s^{-1}$ the rate of outflow will be increased. The current system is that the water level at the reservoir is maintain as low as possible during the rainy season and as high as possible during dry season. This system is to ensure the reservoir could accommodate surplus water from rainfall during rainy season so that risk of flood could be reduced, and provide enough irrigation water during dry season.

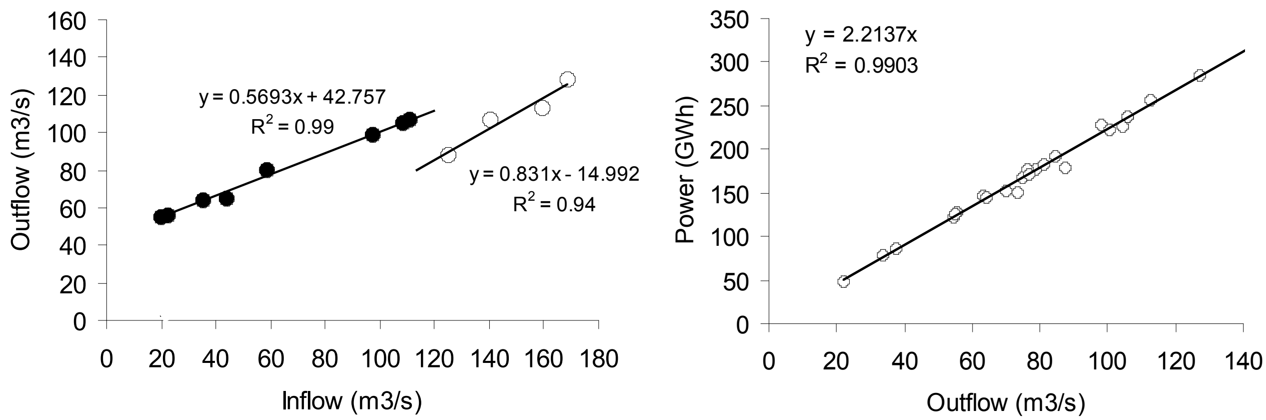


Fig. 11.6: (a) Relationship between inflow to and outflow from Saguling reservoir and (b) between outflow and electricity power generation.

Using data in Table 11.2 and equations in Figure 11.6, minimum electricity power produced by power plant under different land use and climate scenarios can be estimated. The data suggest that if the forest cover were not increased to more than 25%, the chance of produce electricity power less than 100 GWh during dry season will be high.

11.4 Conclusion

Increasing forest cover to at least 25% from the total land area at the upper Citarum watershed is required in order to reduce risk of flood and drought under current and future climate. The total degraded land/forest that needs to be rehabilitated to reach this is about 14,000 ha.

12 Assessment of Community Participation to Reduce Impact of Climate Change at Citarum Watershed, West Java Indonesia

12.1 Activities Conducted

This study was aimed to assess perception of communities to climate change and to evaluate the impact of climate hazards on upstream and downstream communities, to evaluate driving factors for deforestation at the upper Citarum watershed, to assess perception of downstream communities to the need of increasing forest cover of the upper Citarum watershed as effort to mitigate impact of climate hazards, and to assess willingness of downstream community of Citarum watershed to pay for protecting and improving forest cover at upper the Citarum. The study was conducted through intensive survey to the upstream and downstream communities at the Citarum Watershed.

12.2 Description of Scientific Methods and Data

The survey was conducted to a number of villages at the upstream and downstream areas. Villages at the upper Citarum (Mt Wayang) were: Tarumajaya, Cikembang and Cibereum. Tarumajaya locates near the Mt. Wayang while the other two are quite far from the mountain. These villages located at Kertasari Sub-District, Bandung district. Whereas, villages at the downstream selected for the survey were Ciparay dan Bojongsoang, Bandung Districts, representative of agriculture area, while cities selected were Purwakarta and Jakarta. The two cities are the cities where most of the communities get supply of drinking water from the Jatiluhur Dam at Citarum watershed through PDAM (Drinking Water State Company). All sites locate at the Citarum watershed except Jakarta (Figure 12.1).

Number of respondent being interviewed at the upper Citarum watershed was 75 respondents, which consists of 30 respondents from Tarumajaya, 20 respondent from Cikembang and 25 respondents from Cibereum. In addition, interview with villages' leaders, informal leaders and head of forest community agency was also conducted. At downstream agriculture areas, number of respondent interviewed was 20 respondents for Ciparay and 6 respondents for Bojongsoang. The questionnaire was designed to assess perception of communities to climate change, to evaluate impact of climate hazards, and to assess driving factors for deforestation and types of rewards preferred by upper watershed community for the services they provided in maintaining and protecting forests.

At Purwakarta and Jakarta number of respondent interviewed was 450 for each city. The respondents were classified into three categories following PDAM system, namely non-luxury house (*rumah sederhana*), semi-luxury house (*rumah menengah*), luxury house (*rumah mewah*). The questionnaire was designed to assess the willingness of the community to pay compensation for environmental services provided by the upper watershed community in maintaining and protecting forest.

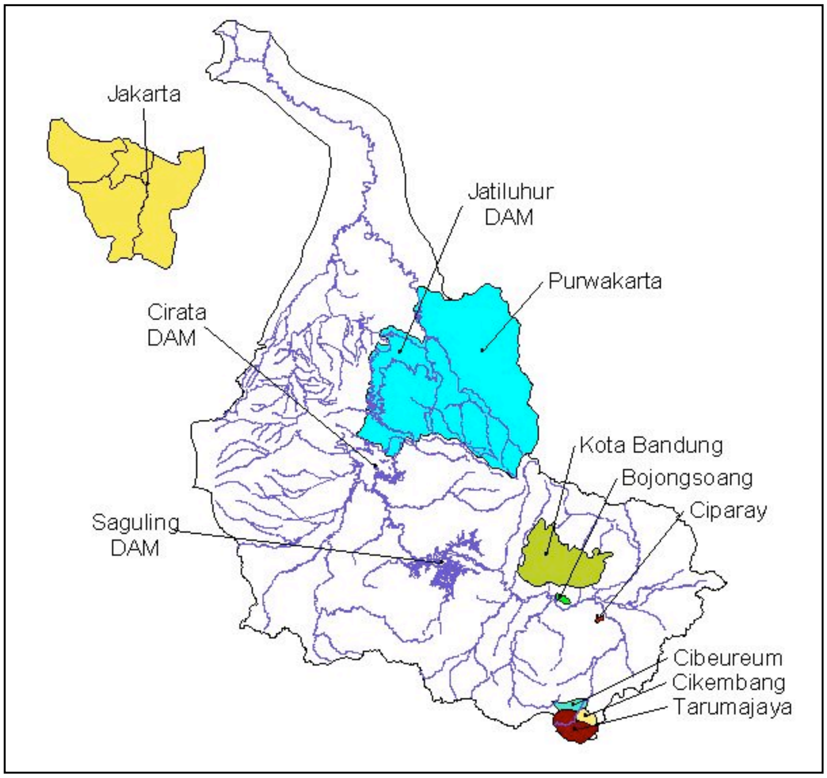


Fig. 12.1: Citarum watershed and the study sites.

Data on climate hazards, and impact collected from the survey were analyzed using descriptive statistics and qualitative assessment. Preference of upper watershed community to types of rewards provided for them in maintaining and protecting forest was analyzed using *Analytical Hierarchical Process* (AHP; Saaty, 2000), while willingness of downstream community to pay compensation for the reward provided by upper watershed community was assessed using *Contingency Valuation Method* (Hanley and Splash, 1993).

12.3 Results

Based on the result of analysis to survey data for assessing the perception of community on climate change and impact of climate hazards, it was found that about 85% of respondents stated that they felt the climate has changed. Temperature is warmer, particularly during dry season while rainfall becomes more variable. Farmers at Ciparay and Bonjongsoang said that they were more often exposed to extreme climate. Length of dry season in some seasons could extend to more than 6- 9 months. This long dry season caused drought problem. In wet season, floods also occurred quite often. Respondents said that flood occurred once every four year. Height of flood could go up to 1-2.5 m in their land and between 0.25 and 1 m in the house. However, most of respondent said that drought occurred more often than flood.

Number of properties being damage by floods is more than drought. Floods would damage their rice field, ponds, dry land crops, livestock, houses and other infrastructures, while drought only damage rice field, ponds, dry land crops, and livestock (Figure 11.2). The properties being damaged mostly by the floods were rice crops and house, while by drought were rice and upland crops. About 80% of respondent said that flood and drought would fail their crops to harvest. The crop loss due to drought valued between 300 and 2,000 USD, while due to flood was between 200 and 1,800 USD. After the hazards, to meet their needs farmers normally sold their properties such as TV etc., and work as laborer or construction workers in other villages or cities, and borrow money. During severe drought and flood, government provided aids to the affected communities in the form of seed supply, foods and medicines.

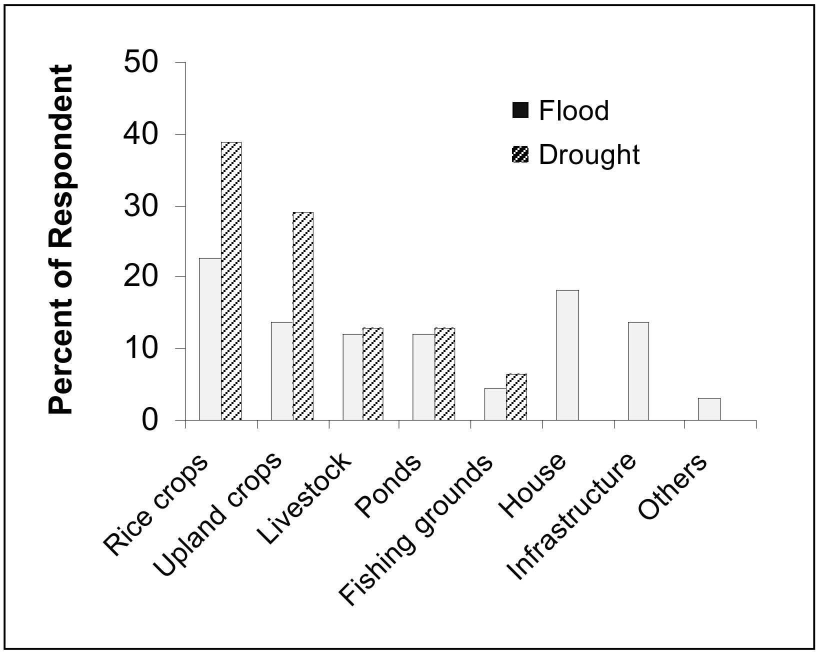


Fig. 12.2: Properties being damaged by flood and drought.

12.3.1 Perception of community to factors causing the increase of drought and flood intensity and role of forest function

About 60% of respondents at Ciparay and Bojongsoang said that they did not know factors causing the increase of drought and flood intensity. However, 50% of them said it was primarily due to the increase of rainfall intensity and occurrence, 20% said because of poor drainage system, and the remaining said because of high deforestation rate in the upper Citarum watershed. On the other hand, communities in the upper Citarum watershed (Cikembang, Cibereum and Tarumajaya) knew quite well wit forest function (its impact on water availability). More than 75% of respondents from these village understood that forests played important role in governing hydrology of the watershed. They also believed that protecting and rehabilitating forests would reduce the risk of flood and drought.

Most of respondents from Cikembang believed that the effective way to avoid deforestation was by protecting the forests, while respondents from the other two villages stated that it could achieved by establishing agroforestry, particularly at Tarumajaya (Figure 12.3). The dependency of communities at Tarumajaya on forest is much higher than the other two villages. This might explain why communities at Tarumajaya prefer to establish agroforestry than just protecting forest.

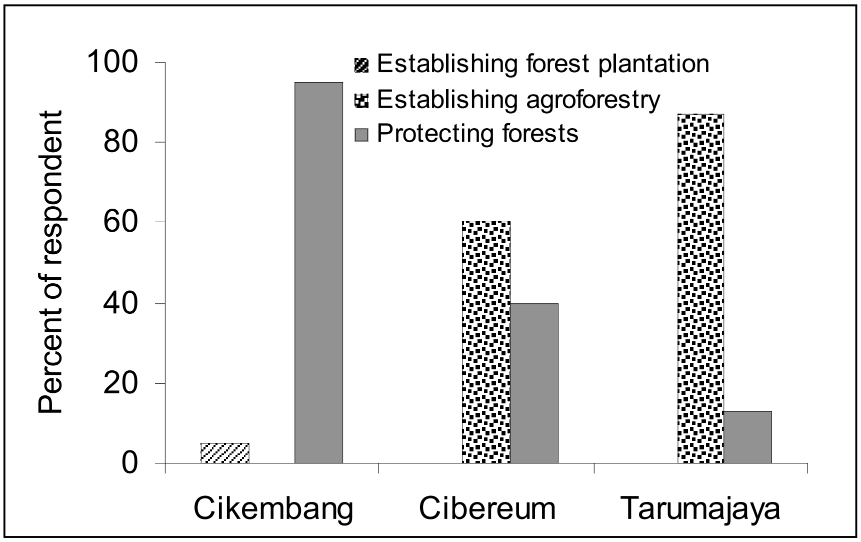


Fig. 12.3: Community perception to type of activities that can avoid deforestation.

12.3.2 Driving factors for deforestation and rewards preferred by community for protecting forest

The interesting finding at Tarumajaya is that even the communities know the important of forest function, but they still do deforestation. Based on previous study (Bina Mitra, 2000) factors that drive communities to do deforestation were: (i) lack of income sources for meeting primary needs of the household, (ii) lack of knowledge on forest function, (iii) lack of land for cultivation, (iv) lack of cooperation between village institutions in protecting forest. The result of AHP analysis indicated that the main factor that drove community to deforest was to expand their cultivation land for meeting their primary needs. Priority weights for this factor at Cikembang, Cibereum and Tarumajaya were 0.56, 0.56 and 0.71 respectively, while those for other factors were less than 0.32 (Figure 12.4). This finding is in agreement with Miller (1991) findings. He stated that this condition is quite common in rural areas of Indonesia where income from agriculture only is not enough to meet their primary needs.

Further analysis suggested that the community at Cikembang and Ciberuem is willing to stop deforestation if they can get aid from government of other entities in the form of funding support so that they could use the funding to create alternative activities other than deforestation. Respondents at Cibereum stated that if they had funds, they would use it for trading. Cibereum has a traditional market which is centre of economic activities of the three villages and has a terminal. Community at Cikembang stated that they also like to have seed aid. This is because PT. Nusantara Plantation (PTPVIII) locates in this village and the land of the PTPVIII can be used for farming by the communities. At Tarumajaya, the community preferred to get aid in the form of livestock (cows) as in this village there is a packaging milk factory called KBPS (Koperasi Bersama Pengalengan Susu) that can absorb milk production from the community.

Inconsistency ratios of the respondent in answering the question were all less than 0.1, indicating high level of consistency or certainty. The inconsistency ratios for Tarumajaya, Cikembang and Cibereum were 0.09, 0.01 and 0.08 respectively.

Rate of deforestation at Mt. Wayang by communities from Tarumajaya is quite high. Many of forest land have been converted into crop lands. Farmers use the converted forest for planting horticultural crops such as potato, cabbage, and onion. Rate of erosion is quite high and increase sediments content of Cisanti River. As the dependency of community at Terumajaya on forest is quite high, their willingness to stop deforestation, to increase forest cover through establishment of agroforestry system and to protect the forest, should be compensated by downstream community who will get benefit from these activities. International initiative to introduce RUPES (Rewarding upland poor for the environmental services that they provided) concept for managing environment is now underway (Leimona, 2004). It is expected that if the RUPES could be adopted and implemented successfully, condition of forest cover at upper Citarum watershed could be increased and maintained, and this would diminish the risk of flood and drought. The following section discusses the perception of downstream communities on the role of upstream communities in protecting forest and their willingness to pay the compensation.

12.3.3 Willingness of downstream community to pay compensation

From the interview, most of the downstream communities (Purwakarta and Jakarta) stated that the upstream communities do not play role in protecting and improving forest cover of Citarum watershed. However, they agreed that there was an urgent need to rehabilitate forest of the upper Citarum watershed as water scarcity during drought years occurred quite often and they also agreed that the upstream community could play important role to do the activities (Figure 12.5). They believed that successful implementation of the program could ensure the continuous supply of drinking water during dry season.

Furthermore, willingness to pay compensation for the rehabilitation of upstream watershed was assessed based on the perception of the community to the role of upstream community and the need of rehabilitating the forest as well as level of knowledge of the respondents on forest function. It was found that willingness to pay of respondents which have good knowledge on forest function and also understand the role of upstream communities is much higher than ones who do not have good knowledge on forest function and do not understand the role of upstream community (Figure 12.6). Similarly, willingness to pay of respondents who agreed with the importance of protecting and rehabilitating forest is also high. The willingness to pay of the respondents increases as the level of knowledge on forest function increases. In addition, age, level of education, level of income, family size, type of jobs and sex also affect the WTP (Table 12.1).

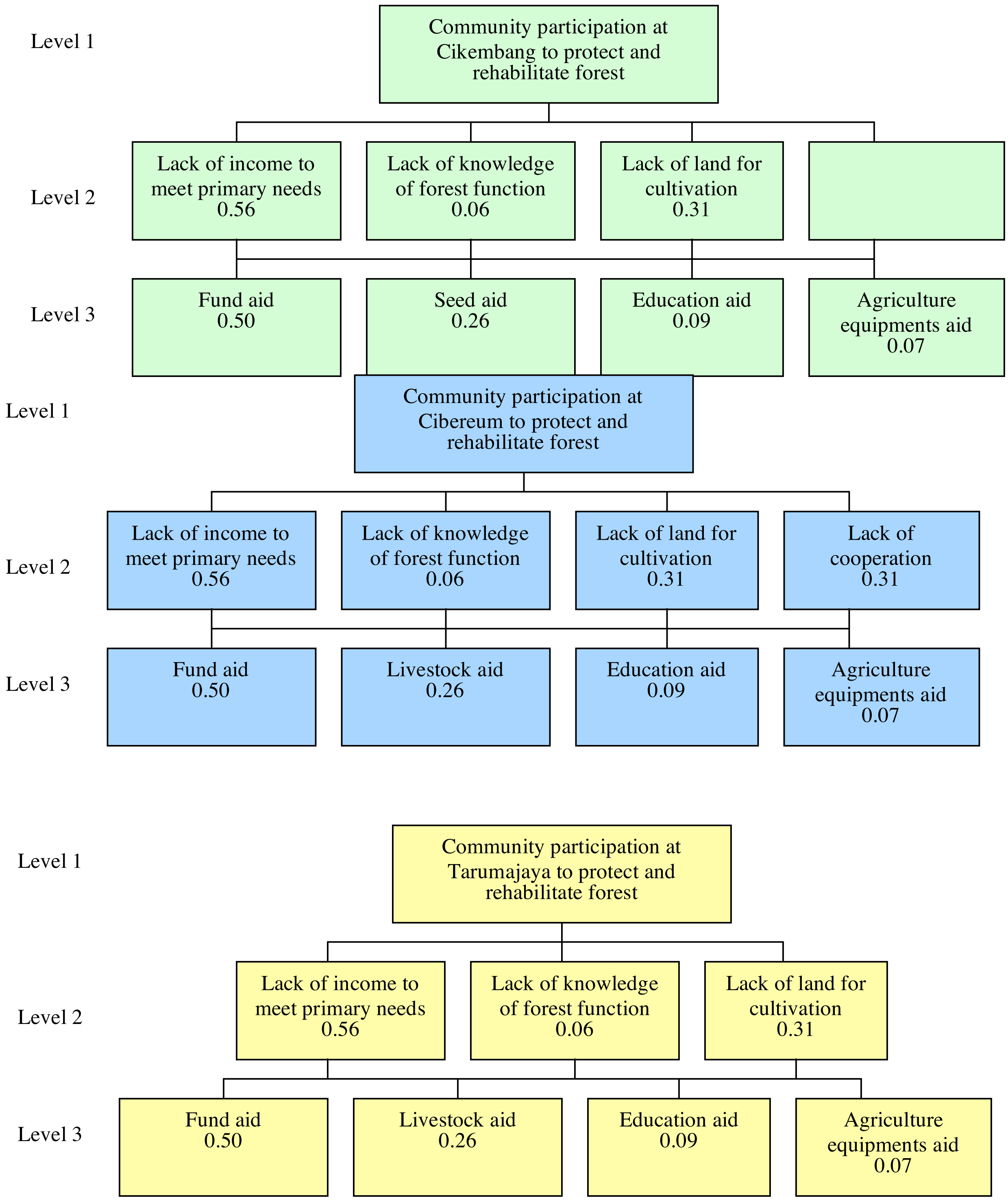


Fig. 12.4: Analytical Hierarchical Process for protecting and rehabilitating forest.

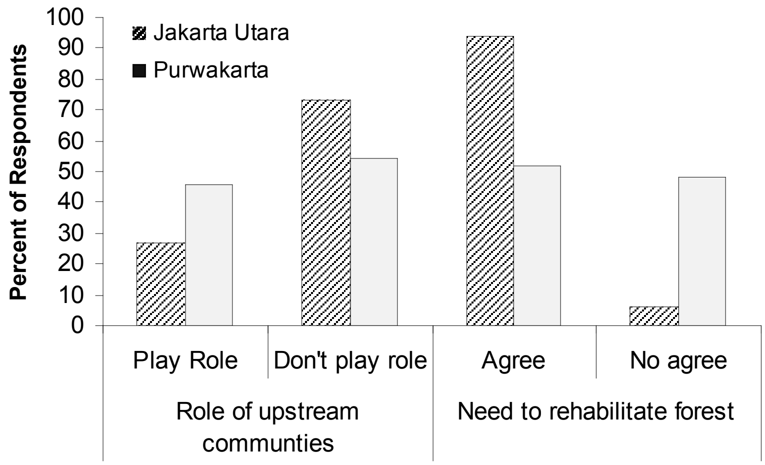


Fig. 12.5: Perception of downstream community to the role of upstream community and the need of ehabilitating the forest.

Predictors	**Purwakarta**	**North Jakarta**
Level of knowledge on forest function (X1)	2,9231** (18,60)	4,5395** 93,65
Perception on the role of upstream community (X2)	3,2223** 25,09	3,5320** 34,19
Perception on the need for rehabilitating forest (X3)	1,6396* 5,15	3,176** 23,96
Job (X4 in category)	0,5557* 1,74	1,2802* 3,60
Age (X5 in years)	0,09050** 1,09	0,11729** 1,12
Education (X6 in years)	0,14171* 1,15	0,15388** 1,17
Income (X7 in category)	1,3333* 3,79	1,3433* 3,83
Family size (X8 in number of family)	-0,7291** 0,48	-0,3771* 0,69
Sex (X9)	1,1928** 3,30	2,0481** 7,75
R^2	87.9%	97.8%

*Note: *significant at 5% level, ** significant at 1% leve1. Values in the bracket are Odd ratio. X1 use dummy variables (-1 for low, 0 for medium and 1 for good), X2 (0 not play role, 1 play role), X3 (0 not agree and 1 agree), X4 (0 government employee, 1 private), X6 (length of study, e.g. 6 years complete elementary school), X7 (-1 for low ~ 0.25 up to 1.5 million rupiahs, 0 for medium ~ 1.5 up to 3 million rupiah, and 1 for high ~ more than 3 million rupiah.*

Table 12.1: Coefficients of logistic regression for WTP for Purwakarta and North Jakarta.

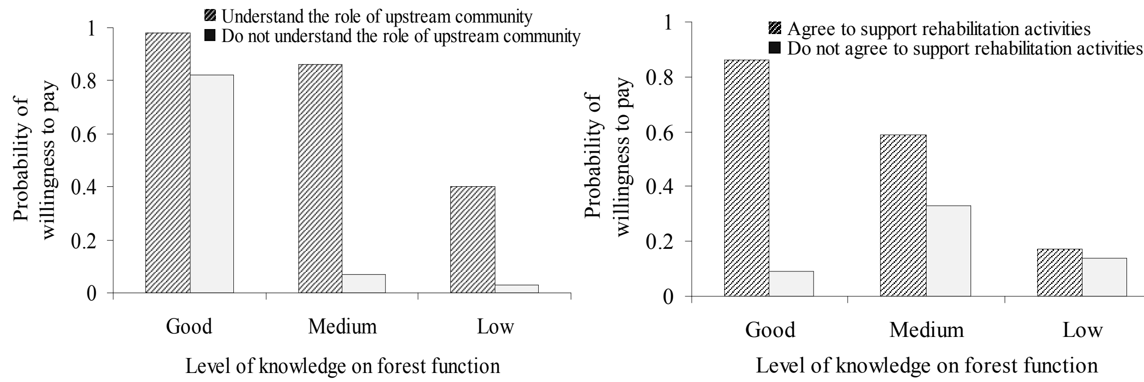


Fig. 12.6: Dependency of willingness to pay on level of knowledge on forest function and the perception of downstream community.

(Note: The higher the probability, the higher the willingness to pay)

Further analysis indicated that additional cost that the community agreed to pay from the current water price to rehabilitate upstream areas varied from Rp250,- up to Rp4000,- per m^3 of drinking water (Figure 12.7). On average, the value of WTP (*Willingness to Pay*) for Purwakarta was Rp.900,- per 10 m^3, and North Jakarta Rp.1500,00 per 10 m^3. Socio-economic condition of communities at Jakarta is better than Purwakarta.

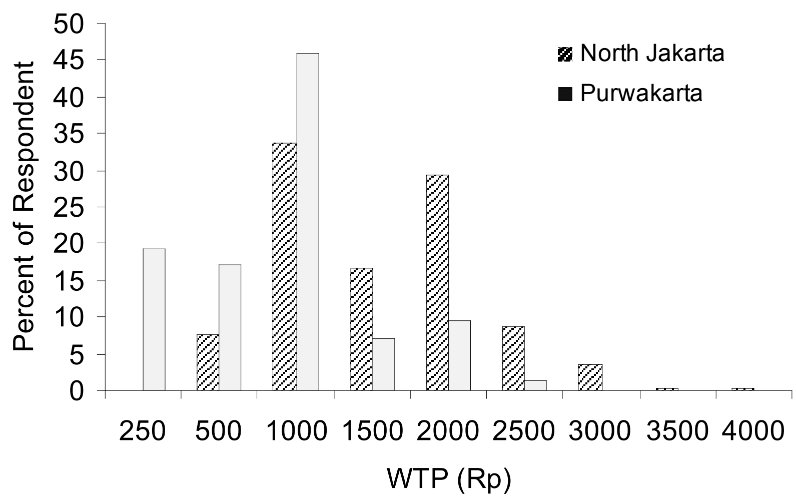


Fig. 12.7: Value of WTP for Purwakarta and North Jakarta.

The above analysis suggests that increasing awareness and understanding of the communities on the forest function (its impact on water availability) as well as its role in diminishing magnitude impact of increasing intensity and frequency of extreme climate events in the future is quite crucial. This factor determines the WTP significantly. The downstream community is willing to pay additional cost to support programs and activities for improving forest condition in the upstream areas as they believe the program could ensure the continuous supply of drinking water especially during dry season and extreme drought years. However, institutional mechanisms for collecting, transferring or distributing the payment should be established. Direct payment to upstream community may not be appropriate. In the case of dinking water, the use of PDAM as collector for the payment is recommended and institutional system for managing the reward should be arranged as such the reward is really used for achieving the objectives.

Method to quantify the impact of protecting and improving forest cover on environmental services (in this case drinking water) also needs to be developed. This is to ensure that the expectation of the downstream community could be met.

12.4 Conclusion

Most of respondents agree that the intensity and the frequency of climate hazards (drought and flood) have increased recently. The events cause significant impact on community income. Increasing forest cover is believed to diminish the impact of extreme climate events and could ensure the continuous supply of water during drought years. Establishment of agroforestry for increasing the forest cover is the preferred option.

Upstream communities may continue to do deforestation if they can not find alternative activities to meet their demand. Developing reward system for supporting upstream community to increase forest cover and to avoid deforestation may be one of the effective ways to reduce rate of deforestation. Deforestation can be avoided if the community can increase land use intensity or find suitable alternative activities to get additional income such as raising livestock and trading.

Development of reward system for environmental services provided by the upstream community is possible as the downstream communities is willing to support activities or program for maintaining and increasing forest cover of the upstream watershed by increasing price of drinking water from the current price. With the activities, it is expected that continuous supply of water during dry season and extreme drought years is ensured.

The willingness to pay (WTP) of the downstream communities highly depends on level of understanding on forest function and their perception on the role of upstream communities and the need for rehabilitating the forest. In addition level of education, level of income, and job also affect the WTP. Program for increasing understanding and awareness of community on forest function and its role in diminishing impact of extreme climate events and climate change is crucial for the successful implementation of ES reward system.

There is a need to establish institutional system for collecting, transferring or distributing the payment to the community as well as the regulation. The use of existing institutional system for collecting the reward may be effective such as PDAM for drinking water.

13 Capacity Building Outcomes and Remaining Needs

The limited capacity of developing country scientists in the Asia-Pacific region to conduct vulnerability assessment and adaptation planning is well recognized (Zakri *et al*., 2000). Thus, a key feature of this project is the enhancement of capacity of local researchers to conduct climate change impact and vulnerability assessment. By working with developed country scientists from its key partners, (ICRAF and GCTE) there were transfer of skills and know-how in modeling and assessment tools. Aside from the researchers, other stakeholders within each the Philippines and Indonesia benefited as they participate in the research process. These include staff of government agencies, NGOs and even people's organizations. Training courses and technical assistance for scientists from Indo-China (Laos, Vietnam and Cambodia) were also implemented by the project as part of its capacity building efforts in the region. Furthermore, several graduate and undergraduates students had participated actively during the implementation of the project.

13.1 Training-workshop for Indo-Chinese scientists

The training/workshop on climate change impacts, adaptation and vulnerability was held last November 25 to December 8, 2002 at the University of the Philippines at Los Baños campus. This activity was designed to capacitate scientists from Indo-China (Vietnam, Laos and Cambodia) with the necessary knowledge and skills on the research methods to assess the impacts of climate change in the natural and social systems in their respective countries, including the vulnerability and adaptation measures that need to be undertaken. As a key output of this training, the Indo-Chinese scientists were able to prepare a research proposal which was supported by AS21. The objectives of the training course were as follows:

1. Explain the research methods to be used in assessing the impacts of climate change to water resources, forest ecosystems and social systems of the watersheds in their country;
2. Assess the impacts of climate change to natural and social systems of the watersheds; and
3. Conduct integrated vulnerability assessment of natural and social systems in the watershed areas.

13.2 Training-Workshop for Bhutan Local Scientists

As part of the capacity building of the AS21 study, the project team conducted a training-workshop on Methodologies in Assessing Climate Change Impacts on Local Communities last May 3-14, 2004 at the Continuing Education Center, University of the Philippines. The training was designed to capacitate the scientists from Bhutan with the necessary knowledge and skills on the research methods that will assess the impacts of climate change in the social systems in their country, and the vulnerability and adaptation measures that need to be undertaken. The two members of the AIACC Socio-economic Team served as key resource persons on various topics discussed during the workshop dealing on vulnerability and adaptation to climate change. The different topics discussed highlighted the experience of the resource persons in conducting the AIACC project. Five (5) participants from the National Environment Commission Secretariat office, Ministry of Agriculture, and the National Statistics Bureau attended the workshop.

Furthermore, to capacitate local scientist and stakeholders in Indonesia and Philippines with different methods in assessing climate change, the following workshops and trainings were conducted

13.3 Training for Stakeholders

Training on Research Methods in Assessing Climate Change Impacts was conducted last June 18-20, 2003 to address the need raised by the stakeholders during the local stakeholders meeting held last August 29, 2002 at the Central Luzon State University, Philippines. The training was designed to train stakeholders with the necessary knowledge and skills on the research methods that will assess the impacts of climate change in the natural and social systems and the vulnerability and adaptation measures that need to be undertaken. It is hoped that after the training, stakeholders will be able to duplicate the study undertaken by the AS 21 team in other watersheds under their jurisdiction.

There are a total of eight participants who came from the local government units, National Power Corporation, Department of Environment and Natural Resources and the National Irrigation Administration.

13.4 Scenario Building Workshop

A Stakeholder's Workshop on Climate Change Impacts and Adaptation was held last March 2-3, 2004 at the National Irrigation Authority Guesthouse in Pantabangan, Nueva Ecija, Philippines. The workshop's objectives were to validate initial results of the study, conduct consultations on climate change impacts on forests, water, and land use, and to solicit feedback from various stakeholders. Thirty participants coming from different organizations within the Pantabangan-Carranglan Watershed, particularly, the National Power Corporation, National Irrigation Authority, local government units, non-government organizations, and people's organizations were able to attend the said workshop. The activity's outputs include the updated land use map of the watershed, updated assumptions for the CLUE-S model, the impacts of climate change on different land use types of the watershed, and the impacts of climate change on soil and water.

13.5 Multi-Stakeholder Workshop

A ***Multi-Stakeholder Dissemination and Validation Workshop on Adaptation to Climate Change*** was conducted last April 14-15, 2205 at the Philippine Rice Research Institute in Muñoz City, Nueva Ecijia. The workshop's objectives were to disseminate and validate initial results of the study and plan for adaptation strategies to mitigate potential climate change impacts. There were a total of forty six participants coming from different organizations within the Pantabangan-Carranglan Watershed, particularly, the National Power Corporation, National Irrigation Authority, local government units, non-government organizations, and people's organizations that were able to attend the workshop..

Similarly, ***Multi-Stakeholder Dissemination and Validation Workshop on Adaptation to Climate Change*** in Pantabangan-Carranglan Watershed Service Area was held last September 22, 2005 at Plaza Leticia, Cabanatuan City. The workshop's objective were to present and validate the results of the study; identify current adaptation measures to water shortage and flood; and identify action and agenda to improve the capacity of farmers and irrigators to adapt. A total of seventy-nine participants from Farmers' and Irrigators' Association, Provincial and Municipal Agricultural Offices, and Upper Pamapanga River Integrated Irrigation System attended the workshop.

13.6 Policy Seminar-Workshop

A ***Policy Seminar-Workshop*** was held last June 1, 2005 at Traders Hotel Manila. The objectives of the workshop were to present project's results to various stakeholders and decision makers and at the same time propose policy recommendations. Key officers from DENR, NIA, NPC, LGUs, NGOs, and POs attended the workshop. During the workshop various concerns of LGUs and NGOs regarding the watershed's condition were addressed to policy makers.

13.7 Involvement of students in the research process

As part of the capacity building approach of the project, one B.S. Forestry student (major in Forest and Natural Resource Governance) and two master students (one major in Social Forestry and one major in Remote Sensing) were recruited to conduct their thesis on the social and institutional dimensions of climate change in the Pantabangan-Carranglan Watershed. Their studies were supported by AS 21. The following are the titles of their thesis:

1. Vulnerability and Adaptation of Pantabangan-Carranglan Watershed Communities to Climate Variability and Extremes – M.S. thesis

2. Institutional Impacts and Adaption Strategies to Climate Variability and Extremes in Pantabangan-Carranglan Watershed – B.S. thesis

Moreover, a total of 14 B. S. Forestry students and one graduate student participated in the data gathering of the project through conducting interviews and surveys in the project area from April 29 to May 11, 2003 as part of their practicum work and research studies

13.8 Travels related to the project

The AIACC gave opportunities to the members of the research team to participate in various conferences, trainings, and workshops that equipped them with more knowledge in assessing climate change impacts, adaptation and vulnerability. Furthermore, some members of the research team served as resource persons in various conferences, trainings, and workshops.

13.9 Others

The project was able to create linkage with the developer of CLUE model (Dr. Peter Verlag) at Wageningen University (The Netherlands). The project was able to procure GIS software through AIACC as part of its capacity building. Furthermore, the project was featured in the AIACC exhibit in the COP-8 held in New Delhi in October 2002.

The remaining needs include:

- Disseminating massive information, education and communication (IEC) program. At the moment, the watershed is poorly protected partly because of the low levels of awareness of the local communities on the importance of the watershed.
- Strengthening the research community to help the LGUs educate the local communities with the concepts of climate change, its impacts on the forest ecosystem, water resources and communities. Concepts should be in popularized form to enable the communities to easily understand them.
- Conducting training to be conducted to help capacitate the stakeholders.

Local government units and concerned agencies should set aside a budget for the purchase of the software needed.

In Indonesia, the project has conducted a number of capacity building activities in the form of training workshops and seminars as well as supervising students and involving young scientist to work under projects. The activities were:

- Training workshop of Indonesian local scientists at Bogor. This workshop invited 11 local scientists. Participant of the workshop from South Sulawesi (University of Hasannuddin) has proposed a project on climate extreme events and climate change to Department of Education for funding. The proposal has been accepted and will get funding for year 2005-2007. Two participants from Research Agency on Hydrology and Agroclimate and from Surabaya Institute of Technology have used methodology and also tools delivered during the workshop in their research activities.
- Involving one post graduate student and three undergraduate students from Bogor Agricultural University in the project.
- Involving four young scientists (age of below 30 years). One of them has got scholarship for continuing study at University in Australia next year and another one has been accepted at Bureau of Meteorology and the experience gained from the project would be useful for their further career. The other two involved in NGO working in the area of climate variability and climate change.

- Conducting public awareness activities and contacts with a number of government and non-government agencies either during survey/dialogue, workshops or seminars.
- The project have kept climate database at Bandung districts that can be used to support future related activities.

Networking with local agencies has strengthened. Indonesian Power, one of hydropower companies at the Citarum watershed, has shown its interest to support the work of the team and will provide funding to continue the work particularly to develop strategies for encouraging and engaging communities at the upper watershed to protect and increase forest cover through development of reward mechanism. LAPAN (National Agencies for Space and Aviation) also invited the project team to do collaboration research on the impact of doubling CO_2 on Indonesia climate.

The remaining needs includes:

- Strengthening capacity of local scientists (the capacity building workshop participants) and maintaining network. The strategy is to develop joint research proposal on climate change with the local scientist to be submitted to various funding agencies.
- Continuing working with local NGOs and District Agriculture Office in increasing resilience of local communities to adapt to climate change through improving their capacity to cope with extreme climate events. The strategy is to involve or to provide inputs to local agencies in the development of their programs (such as research agenda or extension program) and to keep the partner agencies involve in other related activities.
- Institutionalizing climate (forecast) information application as steps to increase local community capacities to future climate change.

14 National Communications, Science-Policy Linkages And Stakeholder Engagements

14.1 Philippines

The AIACC project is well-positioned to contribute to the Philippine 2nd National Communication. One of the members of the research team, Ms. Joycelline Goco heads the preparation of the 2nd National Communication as chair of the Philippine Inter-agency Committee on Climate Change. Project staff was able to participate in the initial consultations leading to the preparation of the 2nd National Communication. Many of the findings of our AIACC project will feed directly to the 2nd National Communication being pioneering studies on climate change impacts and adaptation in natural ecosystems, water, and local communities. Some of these are climate projection the project team generated for the project area and the adaptation strategies used and developed by the local communities in mitigating impacts of climate change. These will be used in the disaster preparedness in the national communication. Furthermore, the project team in cooperation with the Philippines Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) will be doing climate projection for the entire Philippines. This will also be included in the national communication.

In the first six months of the project key members of the research team were involved in various capacities during the first national communication of the Philippines. As expected, their involvement greatly contributed. Also, the research team initially presented the project and its objectives through workshops to Department of Environment and Natural Resources (DENR), Local Government Units (LGUs), various stakeholders, Non-government Organizations (NGOs), and People's Organizations (POs) to ensure that they are aware of the project.

Regularly, the project updates the stakeholders and participating agencies through presentations and workshops every time the project has initial results so that they are always keep informed. Likewise, members of the research team were invited to several conferences and workshops to serve as resource person and to present results of the project.

14.2 Indonesia

During the project implementation, the Ministry of Environment (MOE), Climate Change Focal Point is in the process of preparing second national communication. The principle investigator was invited as resource person in the process of developing document on National Capacity Self Assessment (NCSA) for Global Environmental Management and also in the process of developing proposal for second national communication to be submitted to GEF-UNDP. The focus of the second national communication will be on climate change adaptation aspect. This aspect was not accommodated in the first national communication due to lack of understanding and studies on the issues. The principle investigator has also been invited to assist the MOE in preparing and designing project activities for the second national communication.

15 Outputs of the Project

15.1 Publication in Peer Reviewed Journals

'*Hydrology Balance of Citarum Watershed under Current and Future Climate*'. Authors: Rizaldi Boer, Bambang Dwi Dasanto, Perdinan, and Delon Marthinus. This paper has have been reviewed by 3 reviewers. All the reviewers have provided good comments on the paper and recommended the paper for publication

15.2 Other Outputs

1. The use of Climatic Data Generator to cope with Daily Climatic Data Scarcity in Simulation Studies. Authors: Rizaldi Boer, Perdinan, and A. Faqih. Proceeding of the 4th International Crop Science Congress in Brisbane, October 2004 (in Print)

2. Carbon Budgets of Terrestrial Ecosystems in the Pantabangan-Carranglan Watershed. Authors: Rodel D. Lasco, Florencia B. Pulhin, Rex Victor O. Cruz., Juan M. Pulhin and Sheila Sophia N. Roy. (Submitted to AIACC Working Paper Series). Below is the abstract of the paper:

    Climate change is predicted to affect forest ecosystems. One of the uncertainties yet to be resolved is the impacts of climate change on carbon budgets of forest ecosystems. This study provides baseline information on the carbon stocks of the Pantabangan-Carranglan Watershed in preparation for impacts and vulnerability studies.

    Current carbon stocks in above-ground biomass, necromass and soil were determined using field measurements and laboratory techniques. Total carbon budgets over time of natural forest ecosystem were simulated using the CO2-Fix Model.

    The study shows that natural forests have a carbon density of 300 and 563 MgC/ha in aboveground biomass and necromass using the Powerfit equation and Brown (1997) equation, respectively. Brushlands and tree plantations have lower carbon densities (generally less than 200 MgC/ha) while grasslands have less then 20 MgC/ha. Total above-ground carbon stocks of the whole watershed are estimated to range from 4,800 to 8,900 MgC depending on the biomass allometric equation used.

    The results of simulation showed that while carbon in forest biomass is increasing over time by about 50MgC per century in the PCW, the soil organic carbon was declining by roughly a similar amount. Thus, overall, the total carbon density remains stable over time after an initial decrease.

    The potential of the watershed for carbon sequestration through tree establishment in open areas is highlighted

3. Assessment of Climate Change Impacts on and Vulnerability of Forests Ecosystems in the Philippines using GIS and the Holdridge Life Zones . Authors: Rodel D. Lasco, Florencia B. Pulhin and Sheila Sophia N. Roy (Presented in the Bellagio Conference March 2005). Below is the abstract of the paper:

    Climate change is expected to affect tropical forest ecosystems of the world. To date, the potential impacts of climate change on Philippine forests has not been quantitatively assessed. Thus, the main objective of the study was to assess climate change impacts on Philippine forests ecosystems using GIS and the Holdridge Life Zones. Three synthetic scenarios each of precipitation (increase of 50%, 100% and 200%) and air temperature (increase of 1ºC, 1.5ºC and 2ºC) were used in the study. These scenarios are within the limits of GCM projections for the country.

The study showed that dry forests (more than 1 M ha) are the most vulnerable to climate change. They will be eliminated even with a 50% increase in rainfall. If rainfall doubles, even the moist forests (3.5 M ha) will be totally replaced. On the positive side, the wet and rain forest life zones will significantly expand as dry and moist forests become wetter. Thus overall, it is expected that the total area of forest in the Philippines will not decline.

It is recommended that future studies look into the impact at the species level especially on the most vulnerable forest types.

This study was designed to quantitatively assess the impact of climate change scenarios on Philippine forest ecosystems using GIS and the Holdridge Life Zones.

4. Vulnerability of Watershed Communities to Climate Variability and Extremes in the Philippines. Authors: Juan M. Pulhin, Rose Jane J. Peras, Rex Victor O. Cruz, Rodel D. Lasco, Florencia B. Pulhin, and Maricel A. Tapia (Presented in the Bellagio conference March 2005)

5. Institutional Impacts and Adaptation Strategies to Climate Variability and Extremes in Pantabangan-Carrangalan Watershed. Authors: Juan M. Pulhin, Flordeliz A. Agra, Rose Jane J. Peras, and Maricel A. Tapia (Will be presented in the October 2005 Open Meeting of the Human Dimensions of Global Environmental Change in Bonn Germany). Below is the abstract of the paper:

    The watershed ecosystem in the Philippines is predicted to be adversely affected by the occurrences of climate variability and extremes. Key watershed institutions play a critical role in developing strategies to mitigate the impacts of extreme climate events on this ecosystem. This study explores the impacts and adaptation strategies developed by institutions in the Pantabangan-Carrangalan Watershed to cope with the impacts of climate variability and extremes.

    Climate variability and extremes presented both positive and negative effects to the different institutions in the watershed. However, the adverse impacts outweighed the beneficial ones. These affected the overall aspect of operation of the institutions, particularly the delivery of major services provided by the watershed, i.e., irrigation and power generation.

    Reforestation, forest protection, IEC, and adjustments in program implementation are the major adaptation strategies performed by the PCW institutions to cope with the impacts of climate variability and extremes. While most of these practices improve the condition of the watershed and thereby the services that it provides, they do not address the operational problems faced by the institutions in times of extreme climate events.

    It is recommended to procure new equipment and adopt new technologies that could enhance their mechanism to cope with the impacts of climate variability and extremes. Though fund availability is a problem, alternative financial sources should be explored

6. An Assessment on Social Vulnerability to Climate Change in a Time of Renovation: A Case Study in Giao Thuy District, Nam Dinh Province, Vietnam.

7. Authors: Luong Quang Huy and Ngo Cam Thanh. (Working paper for the Environmental Forestry Programme, University of the Philippines Los Baños, Laguna, Philippines: www.enfor.com.ph)

8. Assessment of Climate Change Impacts, Vulnerability and Adaptation: Water Resources of Pantabangan-Carranglan Watershed

9. Rex Victor O. Cruz, Rodel D. Lasco, Juan M. Pulhin, Florencia B. Pulhin and Kristine B. Garcia (Working Paper of AIACC-AS21: www.enfor.com.ph)

10. Current and Future Rainfall Variability in Indonesia. uthors: Boer, R. and Faqih, A. (Working Paper of AIACC-AS21: www.enfor.com.ph)

11. Hydrology Balance of Citarum Watersheds under Current and Future Climate. Authors: Boer, R., Dasanto, B.D., Perdinan and Marthinus, D. (Working Paper of AIACC-AS21: www.enfor.com.ph)

12. Assessing the Impact of Land Use Change and Climate Change on River Flow at Citarum Upper Catchments. Authors: Boer, R., Perdinan, Delon and Faqih, A. (Working Paper of AIACC-AS21: www.enfor.com.ph)

15.3 User Manuals

1. Modified SEA BASIN - VIC Model Manual for PCW: The VIC Model is a semi-distributed grid-based hydrological model, which parameterizes the dominant hydro meteorological processes taking place at the land surface – atmosphere interface. A mosaic representation of land surface cover, and sub grid parameterizations for infiltration and the spatial variability of precipitation, account for sub-grid scale heterogeneities in key hydrological processes.

2. The CO2 Fix Model Manual: CO_2 Fix Version 2 is a carbon bookkeeping model that simulates stocks and fluxes of carbon in a forest ecosystem, the soil and the wood products. It is a hectare-scale model and is an improved version of CO_2 Fix version 1. Compared with version 1, this improved version: (1) has ability to simulate multi-species and uneven aged stands in multiple cohorts; (2) has ability to parametarize the growth also by stand density; (3) has ability to deal with inter cohort competition; (4) improved allocation, processing lines, and end-of life disposal of harvested wood; (5) has ability to show soil dynamics; (6) has ability to deal with a wider variety of forest types including agro-forestry systems, selective logging systems and post harvesting mortality; and (7) has output viewing charts.

3. Holdridge Life Zones Manual: The Holdridge Life Zone is an ecological classification system based on the three climatic factors, i.e. precipitation, heat (biotemperature) and moisture (potential evapotranspiration ratio).

15.4 Training Manuals

1. Training Manual on Research Methods in Assessing Climate Change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities UPLB, 25 November-6 December 2002: 'Procedure to run MAGICC/SCENGEN 2.4'. Author: Rizaldi Boer

2. Training Manual on Research Methods in Assessing Climate Change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities UPLB, 25 November-6 December 2002: 'Preparing Maps Using Surfer'. Author: Rizaldi Boer

3. Training Manual on Research Methods in Assessing Climate Change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities UPLB, 25 November-6 December 2002: '*Climatic data generator using MINITAB*'. Author: Rizaldi Boer

15.5 Training CDs

1. Training on Research Methods in Assessing Climate Change Impacts, Adaptations and Vulnerability in Watershed Areas and Communities: On November 25 to December 6, 2002, the research team conducted a training workshop in University of the Philippines at Los Baños for six scientists from Indo-China (Vietnam, Cambodia and Laos). Included in the CD are the details of the training design, resource materials, outputs, as well as the directory of participants and resource persons.

2. Training on Research Methods in Assessing Climate Change Impacts: As part of its capacity building objectives, the Philippine team conducted a training program on June 18 – 20, 2003 on research methods in assessing climate change impacts for the local governments units (LGUs) coming from the Pantabangan-Carranglan Watershed. Included in the CD are the details of the training design, resource materials, outputs, as well as the directory of participants and resource persons.

16 Policy Implications and Future Directions

16.1 Philippines

Results of the studies in the three components of the project have shown that the Pantabangan-Carranglan Watershed is vulnerable to climate change. Climate change is hardly being considered at all in the planning process of the government for forest resources. Its more urgent concern is to save the remaining forests from human exploitation which is the more imminent threat. At present, there had been little consideration of an overall climate change adaptation strategy and its various options for Philippine forest ecosystems. The 1999 Philippines Initial National Communication contains adaptation options for watershed management that partly apply to forest ecosystems. The private sector is less involved today compared to the height of logging activities in the 1950s and 1960s. However, civil society is more involved as community-based programs increase.

The projected changes in climate and the associated changes in streamflow patterns of Pantabangan-Carranglan Watershed will likely have more serious impacts on the lowland farmers in view of the absence of deliberate program to reduce the vulnerability of the lowland farmers to floods and water shortages. An ideal program for reducing the vulnerability of farmers should combine improvement of the conditions of the denuded watersheds of PCW, improvement of the physical and administrative infrastructure of UPRIIS, and enhancement of the ability of the farmers to cope with floods and water shortages. To enhance the coping capacity of the farmers in the service areas of UPRIIS, there is a need to increase the ability of the farmers: to gain access to cheaper alternative water sources, to engage in alternative cropping systems and viable alternative livelihoods, and to set in place systematic and deliberate mechanisms for providing technical and other logistical assistance to the farmers particularly designed to increase and sustain adoption of appropriate adaptation strategies.

There is a need for bottom-up assessment and planning to address vulnerability and enhance adaptive livelihood at the local and national level. Participatory action research engaging the different stakeholders should be pursued to minimize vulnerability of the poor and enhance adaptive capacity at the local level. Policies and development programs should aim at empowering the local communities to broaden their range of choices of appropriate strategies rather than making them dependent on external support. Howeve, this, should not preclude questioning the large scale structural causes of vulnerability such as poverty, inequity, institutional and economic barriers to development including the issue of power and conflict (Brooks, 2003).

The specific policy recommendations that arise out our study are the following:

- Integrate climate-related risks in watershed planning and management
- Integrate climate-related risks in community-based programs.

16.2 Indonesia

The study has shown that Citarum watershed is vulnerable to current and future climate risk. One of the programs that need to be done is increasing forest cover at the Upper Citarum Watershed for at least 25% of the total area. This study reveals that increasing forest cover in the upper watershed will reduce the maximum flow and increase minimum flows so that the risk of flood during extreme wet years or risk of drought during extreme drought years could be minimized. Thus increasing awareness of local communities on the importance of maintaining and increasing forest/vegetation cover in mitigating impact of extreme climate events and climate change is important. Creating reward system, paying compensation to community who contribute to the improvement of environmental services (improving watershed function, carbon services, biodiversity, and landscape beauty), will encourage community to actively participate in protecting and improving vegetation/forest cover. Development of such system is possible as the downstream communities is willing to pay compensation to the upstream community who maintain and improve forest cover. Thus development of institutional system for collecting, transferring or distributing the payment or the reward should be established as such the reward is really used for improving and maintaining the environment. ICRAF has conducted a pilot project called RUPES (Rewarding Upland Poor for Environmental Services that They Provide) and National Development Planning Agency has considered this program as a new approach for watershed management.

Increasing farmers' capacity to cope with extreme climate events is very important to increase their resilience to future climate risk. Their knowledge and ability in using climate forecast information in managing their farming activities and preparing adaptation and mitigation actions to the possible climate hazards should be developed. The role of extension workers in assisting local community in managing the extreme climate events or climate hazards is very important, therefore, inclusion of climate change aspects in development of training curriculum for the extensions workers is required.

Institutionalizing climate information should be the future directions. Climate information should be used properly in developing development plan. Thus there is a need to institutionalize the climate information. All agencies and stakeholders should engage in managing and copying current and future climate risks (Figure 41). Research agencies and universities will be main institutions that produce technologies for managing climate risks. Knowledge and understanding of policy makers and government officials either at local and national level to the climate information system should also be developed through science-policy forum. Good understanding to the climate information system will assist the policy makers and government officials to develop programs, policies and regulations that facilitate and assist the local communities in developing better adaptive capacity to current and future climate variability. Process of transferring climate knowledge and information to end users (farmers) is done through Field School program where the extension workers (agriculture extension, NGOs and other intermediaries) play as field facilitator. The modules of the Field School programs should be developed through collaboration of local, national, regional and international research agencies and universities based on understanding to the past, present and future climate characteristics and their impacts. Such effort has been initiated by ADPC (Asian Disaster Preparedness Centre) in collaboration with Bogor Agriculture University, Bureau of Meteorology and Geophysics, Directorate of Plant Protection and Indamayu Agriculture Office. The program is to assist rice farmers in managing climate risks (flood and Drought) through the use of climate forecast information. This approach may be worthwhile to be developed also in Bandung district.

17 References

17.1 Philippines

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18 PRA Methodology on Climate Variability and Extremes in Pantabangan-Carranglan Watershed

Materials Needed: Brown paper, colored paper cards, paper cut in three sizes (small, medium, large) and shapes (circles and triangles), paste, masking tape, colored pens, tape recorder, camera.

Participants: Ten (10) to fifteen (15) participants from the different barangays with ages 40 and above, at least half of which are women.

Methodology:

1. Historical Events of Climate Variability and Extremes

    a. Ask the participants the natural occurrences in their area that reflect climate variability and extremes (e.g., over the last 50 years or so).

    b. Following the format below, record in Table 1 the major events that relate to climate variability and extremes such as:

        i. Delay on the onset of rainy season

        ii. Early onset of rainy season

        iii. Prolonged rain

        iv. Drought

        v. Flood

        vi. Forest Fires

        vii. Destructive typhoon

Year	**Description of climate variability and extremes**
1950s?	
.	
.	
.	
.	
.	
200n	

Table 18.1: Major climate variability and climate extremes

2. Impacts of climate variability and extremes on watershed communities

    a. Based on the climate-related events recorded, identify the different impacts of climate variability and extremes to local communities.

b. Record the impacts of climate variability and extremes to local communities in Table 2. Such impacts could include food availability, crop yield, water availability (domestic and irrigation), livelihood, health, other impacts.

Event	**Impacts to Local Communities**						
	Food availability	**Crop yield**	**Water availability**	**Livelihood**	**Health**	**Local ecosystem**	**Others, please specify**

Table 18.2: Impacts of climate variability and extremes on local communities

3. Identification of the different socio-economic groups affected by climate variability and extremes

   a. Ask the FGD participants to identify the different socio-economic groups and institutions in their area that are affected by climate variability and extremes.

   b. List the different socioeconomic groups and institutions in the first column of Table 3 and the impacts of climate variability and extremes to each group in the second column.

   c. Using colored paper cards cut into circles of three sizes (small, medium and large), ask the participants to determine the degree of negative impacts of climate variability and extremes to the different groups by pasting these cards in the third column opposite the group. NOTE: The size of the circles corresponds to the degree of negative impact of climate variability and extremes to the specific group, that is, small circle means small negative impact and so on.

   d. Ask the participants the reason for their choice of the degree of impacts and record this in the fourth column of Table 3.

Socioeconomic groups/Institutions	Impacts of climate variability and extremes	Degree of negative impacts of climate variability and extremes	Reason for the choice of the degree of impacts

Table 18.3: Socioecomic groups and institutions affected by climate variability and extremes

4. Identification and Mapping of Vulnerable Groups and Places

    a. Ask the FGD participants to draw a barangay map indicating the major physical features such as roads, river systems, settlement areas and purok locations.

    b. With Table 3 as reference, ask the participants to indicate in the map the location of different socioeconomic groups in the barangay by pasting the different circles/triangles of various sizes.

    c. Using the same map, request the participants to indicate in the map the location of vulnerable places in their barangays. Request them to explain why they have identified these places as vulnerable (e.g. steep slope therefore highly erosive area, grassland frequently subjected to forest fires, etc.)

5. Local Groups and Institutions Adaptation Strategies

    a. Ask the FGD participants to identify the different adaptation strategies mechanisms of the different socioeconomic groups/institutions to cope with climate variability and extremes.

    b. Request the participants to explain if they find these strategies to be effective and why?

    c. Request the participants to recommend strategies for the different groups to improve coping mechanisms and for the different institutions to be able to better support the local people to cope with future climate variability and extremes.

    d. Record all the answers in Table 4/

Socioeconomic groups/Institutions	**Adaptation strategies**	**Perception of Adaptation strategies (Effective or Not Effective- indicate the reason/s why)**	**Recommendations to Improve adaptation strategies**
Socioeconomic groups			
Institutions			

Table 18.4: Adaptation strategies of different socioeconomic groups and institutions

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