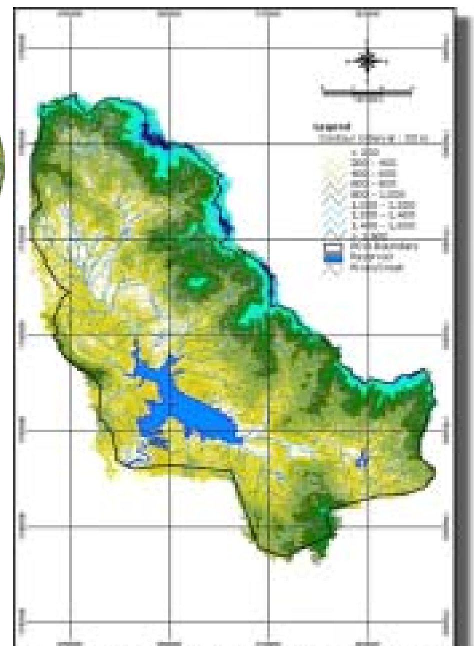
An Integrated Assessment of Climate Change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities in Southeast Asia (AIACC AS21)



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SEMI-ANNUAL REPORT 2003
(July to December)

INTEGRATED ASSESSMENT OF CLIMATE CHANGE IMPACTS, ADAPTATION AND VULNERABILITY IN WATERSHED AREAS AND COMMUNITIES IN SOUTHEAST ASIA (AIACC AS21)

SEMI-ANNUAL REPORT

(July – December 2003)

A. SUMMARY

From July to December 2003, the Philippine and Indonesian AS21 teams were able to produce five working papers for review. These papers covered topics on carbon budgets of terrestrial ecosystems, social vulnerability, and hydrology balance.

Through participatory rural appraisal (PRA), the impacts of climate change were elicited from local communities within the watershed. This would serve as bases in the creation of programs aimed at minimizing the adverse impacts of climate extremes.

PART 1: PHILIPPINES

Research team:

Environmental Forestry Programme (ENFOR)
CFNR, University of the Philippines at Los Baños

Rodel D. Lasco, PhD (Principal Investigator)
Rex Victor O. Cruz. PhD
Juan M. Pulhin, PhD
Florencia B. Pulhin, PhD
Sheila Sophia N. Roy, MIT (ongoing)

B. DESCRIPTION OF TASKS PERFORMED AND OUTPUTS PRODUCED

1. Working Paper Produced

One working paper completed during the second half of 2003 entitled “Carbon Budgets of Terrestrial Ecosystems in the Pantabangan-Carranglan Watershed” (see Annex A). The abstract of the paper is below.

> 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 was 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 is 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.

2. Completion of PRA

The last five (5) focus group discussions using the various Participatory Rural Appraisal (PRA) tools developed by the project were conducted in November, 2003. The barangays covered were Bgys. Salazar, R.A. Padilla and General Luna from the municipality of Carranglan; Bgys. Galintuja and San Juan of Ma. Aurora; and Bgys. Galintuja, Abuyo and Lublub of Alfonso-Castañeda. The targeted four (4) barangays were not covered during the last FGD due to non-availability of participants during the trip which is the timing for harvesting rice. These barangays are: Bantug, San Agustin, and T.L. Padilla of the municipality of Carranglan; and Bgy. Conversion of Pantabangan.

Every after focus group discussions (FGDs), the team made it a point to have a GPS reading of vulnerable sites identified by the participants.

3. Encoding survey questionnaire completed

Encoding of survey questionnaire ended in November, 2003. Data is currently being processed using the Statistical Package for Social Sciences. The following information will be generated from the analysis of the household survey: 1) socio-economic characteristics of the watershed communities; 2) incidence of climate variabilities and extremes in the watershed area as experienced and recalled by the respondents; and 3) household vulnerability index in terms of food and water availability, livelihood, health, and ecosystem condition.

4. Presentation of the Initial PRA Results at the Open 2003 IHDP Meeting

Preliminary analysis has been done from the qualitative information generated through the series of PRA exercises conducted with the members of the different watershed communities. Output of the analysis was presented during the 2003 Open Meeting of the International Human Dimension Program (IHDP) held in Montreal, Canada from 16-18 October 2003. The presentation focuses on the impacts of climate variabilities and extremes to the local households in terms of water availability, crop yield, water availability, livelihood, health, and infrastructure. It also analyses the effects of climate variabilities and extremes to various socioeconomic groups in the community as well as the adaptation strategies of these groups to minimize the adverse impacts of these extreme climatic events. Sample tables **(Tables 1-3)** and figures **(Figure1)** that synthesize the initial findings presented in the IHDP Open meeting is shown below.

Table 1. Impacts of climate variability and extremes to watershed communities.

General Impacts	**↑ Decline, ↓ Increase**
Food availability	↑
Crop yield	↑↓
Water availability	↑↓
Livelihood	↑
Health	↓
Local ecosystem	↓
Infrastructure	↓

Table 2. Effects of climate variability and extremes to various socioeconomic groups.

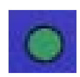
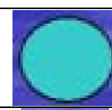
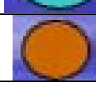
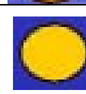
Groups	**Effects**	**Degree of Effects**	**Remarks**
Better-off farmers	↓ production & income; ↔ food, livelihood, health		Better coping mechanism
“Little” farmers	↓ production, food, livelihood, health; more debt		Poor coping mechanism
Employees	↑ price of commodities		“Average” coping mechanism
Business-persons (small-scale)	↓ in sales		“Average” coping mechanism

Figure 1. Location of vulnerable people and vulnerable places in Brgy. D.L. Maglanoc, Carranglan

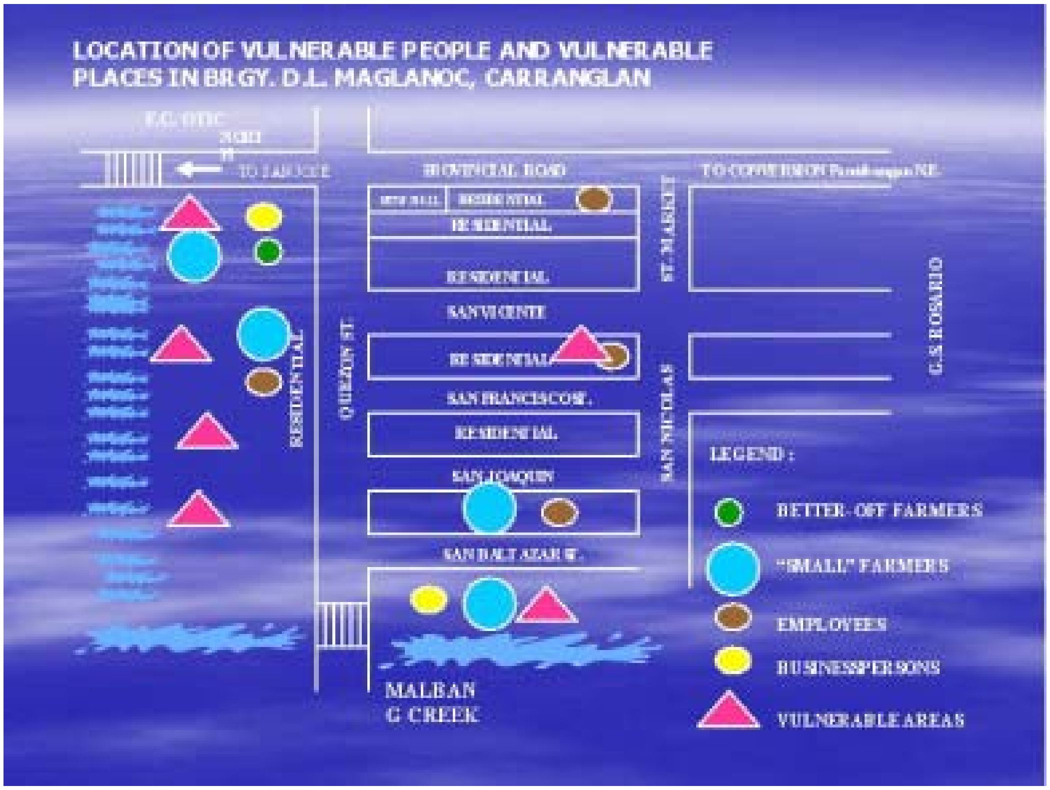


Table 3. Adaptation Strategies

Groups	**Strategies**	**Effectiveness**	**Recommendations**
Better-off farmers	Store food and farm inputs	Effective	
“Little” farmers	“5-6” loan; borrow from relatives; plant vegetables along river; work in nearby town; seek overseas employment; engage in other jobs	Some effective; others not	Livelihood project; estab. Factory; coop development; financial assistance; estab. of Grain Agency accessible to the poor
Employees	Avail of loan; backyard project (e.g. piggery)	Effective	
Business-persons (small-scale)	Store food supply and other farm inputs	Effective	“Price watch” to regulate prices

1. Land Use and Cover Change Modeling

The team was able to conduct a dry run of the CLUE-S model using hypothetical assumptions. A scenario building activity will be conducted through focus group discussion. The scenarios that will be generated from this activity will be used in running the model.

2. Travels related to the project

Three of the team members, Drs. Juan M. Pulhin, Dr. Florencia B. Pulhin, and Ms. Sheila Sophia N. Roy were accepted for the 2003 Open Meeting of the Human Dimensions of Global Environmental Change, held in Montreal, Canada last 16-18 October 2003. Through this activity, much has been learned regarding human dimensions issues, as well as, key linkages have been established. On July 27 to August 10, 2003, Dr. Rex Victor O. Cruz attended a workshop on Stanford Energy Modeling Forum at Snowmass, Colorado. It's purpose was to advance integration across the many research areas related to climate change, such as social and economic drivers of greenhouse gas emissions, atmospheric chemistry and radiative forcing, climate system behavior, biophysical and social impacts of climate change, adaptation and mitigation. Moreover, Dr. Lasco attended an AIACC workshop held in Milan, Italy last December 7-11, 2003. July 27 to August 10, 2003

3. Other accomplishments

The Vietnam scientists, who were trained on research methods in assessing climate change impacts, have also come up with a working paper through a small grant from AIACC. The paper assessed the changes in social vulnerability and resilience under the effects of economic renovation in Vietnam and the implications for local society coping with the impacts of climate and weather extremes in Giao Thuy district, Nam Dinh province in the north of Vietnam **(Annex B)**.

C. DIFFICULTIES ENCOUNTERED AND LESSONS LEARNED

There were no difficulties encountered during the second half of 2003.

D. THE PROJECT AND THE PHILIPPINE NATIONAL COMMUNICATION

The results of the research will be timely for the preparation of 2nd National Communication. The head of the Philippine InterAgency Committee on Climate Change (IACCC). Ms. Joyceline Goco, is now one of the members of the research team. This will help facilitate involvement of researchers in the forthcoming 2nd National Communication.

E. TASKS FOR THE NEXT EIGHT-MONTH PERIOD

For the biophysical component, the main activities are:

- Assessment of climate change impacts on forest ecosystems at the national and watershed scale using Holdridge life zones and GIS tools.

- Vulnerability assessment and identification of adaptation strategies for the forest ecosystems and water resources.
- Calculation of impacts of climate change on carbon budgets of forest lands.
- Computer modeling and validation of landuse change and cover change in the PCW watershed.

For the socio-economic component of the study, the major tasks to be performed from January to June 2004 include the following:

1. Processing and analysis of household survey using SPSS
2. Taking of GPS readings on vulnerable areas identified by the local communities during FGDs
3. Final analysis of FGD results and institutional study
4. Completion of working paper on the vulnerability and adaptation of watershed communities to climate variabilities and extremes.
5. Validation of findings with the concerned stakeholders
6. If time and resources will allow, in-depth case study of two to three carefully selected barangays to have a deeper understanding of the impacts of climate variability and extremes and the local people's present vulnerability and adaptation strategies in these areas.
7. Final report writing and publication of research results

F. ANTICIPATED DIFFICULTIES

None.

PART 2: INDONESIA

Research Team:

Climatology Laboratory, Department of Geophysics and Meteorology, Bogor Agricultural University (Labklim-IPB)

Dr. Rizaldi Boer
Dr. Ekawati S. Wahyuni
Ir.Bambang Dwi Dasanto, SU
Ir. Rini Hidayati, MS
Perdinan, SSi
Raden Maris Karima Rahadiyan, SSi
Dr. Ahmad Parhan, MS

Key Partner: ICRAF (*International Centre for Research in Agroforestry*)
Dr. Meine van Noordwijk

B. DESCRIPTION OF TASKS PERFORMED AND OUTPUTS PRODUCED

The Indonesia team has achieved most of target defined in the Mid-Annual Progress Report 2003. Three technical papers have been developed. The title of the technical papers were:

1. *Current and future rainfall variability in Indonesia*. This paper describes the climate variability under present climate as well as historical trend of long-term rainfall data and future climate condition in Indonesia suggested by a number of GCM models **(Annex C)**.
2. Hydrology Balance of Citarum Watersheds under Current and Future Climate. This technical paper describes impact on climate changes on hydrology balance of Citarum watershed under three different water demand scenarios. Two of the water demand scenarios were developed following SRESA2 and SRSB2 of the IPCC scenarios **(Annex D)**.
3. Assessing the Impact of Land Use Change and Climate Change on River Flow at Citarum Upper Catchments. This paper describes an assessment of impact of changing land use policies and climate change on river flows at Citarum upper area. This report actually summarizing all works that have been done by Indonesian team. Some of the chapters in the report could be expanded to a number of publication papers, such as statistical downscaling technique, climatic data generator model, impact of land use change and climate change on streamflow using downscaled GCM **(Annex E)**.

These technical papers may need refinement before submitting for publication. Training workshop for local scientist could not be done in 2003. It will be postpone to early 2004.

C. DIFFICULTIES ENCOUNTERED AND LESSONS LEARNED

Up to now, there is no significant technical problem encountered. One of research team member, Maris K. Rahadiyan, has resigned from the IPB.

D. TASKS TO BE PERFORMED FROM JULY TO DECEMBER 2003

In 2004, Indonesia team will do the following activities:

- Conducting training workshop on Adaptation and Impact Assessment on Climate Change for local scientists
- Conducting capacity building workshop for Cambodia team in Indonesia in early 2004. Participant of the workshop will be two trainees from Cambodia who participated in the UPLB-AIACC training workshop last 2002.
- Continuing the development of downscaling GCM model for Citarum watershed.
- Focusing work with local stakeholders, in particular, with NGO and government agencies. Focus of work will be on the social-aspects of climate change (social dimension of climate change) and strengthened synergy with on-going works at Citarum Watershed. It is planned in mid 2004, Indonesian team in collaboration with National Water Resource Agencies (Balai Sumber Daya Air) to conduct national workshop on ‘Citarum watershed and Climate Change’. The workshop is designed for disseminating the result of AIACC studies as well as other relevant works conducted by other stakeholders in relation to climate and watershed management.
- Refining technical papers-1 and technical paper-2 for publication and developing two or three other technical papers from Technical paper-3.

E. ANTICIPATED DIFFICULTIES

For developing downscaling GCM model, one statistician will be recruited in 2004.

LIST OF ANNEXES

ANNEXES

CARBON BUDGETS OF TERRESTRIAL ECOSYSTEMS IN THE PANTABANGAN-CARRANGLAN WATERSHED

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ABSTRACT

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 was 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 is 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.

1. INTRODUCTION

Climate change is one of the primary concerns of humanity today. The most recent IPCC assessment report concludes that there is strong evidence that human activities have affected the world's climate (IPCC, 2001). The rise in global temperatures has been attributed to emission of greenhouse gasses, notably CO_2 (Schimell *et al*., 1996).

There is great interest on the role of terrestrial ecosystems in the global carbon cycle. It is estimated that about 60 Pg C is exchanged between terrestrial ecosystems and the atmosphere every year, with a net terrestrial uptake of 0.7 ±1.0 Pg C (Schimel *et al*., 1996). The world's tropical forests which cover 17.6 M km^2 contain 428 Pg C in vegetation and soils (Watson *et al*., 2000). However, land use change and forestry

(LUCF) activities, mainly tropical deforestation, are significant net sources of CO2, accounting for 1.6 Pg/yr out of the total anthropogenic emissions of 6.3 Pg/yr (Houghton *et al*., 1996; Watson *et al*., 2000).

Philippine forest ecosystems have likewise been a source and sink of carbon. From the 1500s to the modern era, it is estimated that deforestation has contributed 3.7 Gt C to the atmosphere (Lasco, 1998). Of this amount, 70% (2.6 Gt) was released this century alone. However, present land-use cover also absorbs carbon through regenerating forests and planted trees. The vast areas of degraded land in the Philippines in fact offer great potential for carbon sequestration through rehabilitation activities such as reforestation and agroforestry.

In the last five years, several studies have investigated the carbon stocks of forest ecosystems and other land cover types in the Philippines (e.g. Lasco *et al*., 2001, Lasco *et al*., 2000). However, the carbon stocks in the Pantabangan-Carranglan Watershed (PCW) have not been adequately characterized. Thus the main objectives of this study is to quantify the carbon stocks of the various land cover types in the Pantabangan watershed. Specifically, the study aimed to:

- Determine the biomass and carbon density of the forest ecosystems and other land cover types in the Pantanbangan-Carranglan Watershed;
- Simulate the carbon stocks of natural forest ecosystems using the CO_2-Fix model.
- Assess the capacity of the watershed to mitigate climate change through carbon sequestration.

2. METHODS

2.1 Site Description

This site description of the study site below was partly based on the “Watershed Atlas of Philippine Watersheds” (Bantayan *et al*., 2000) as well as our own primary data collection activities.

(a) Geographical location

The Pantabangan-Carranglan Watershed lies between 15º 44’ to 16º 88’ north latitude and 120º 36’ to 122º 00’ east longitude (**Fig. 1**). It is bounded in the north, northwest and northeast by the Caraballo Mountain Ranges while the Sierra Madre Ranges bound the south, southeast and southwest portions.

The Municipality of Pantabangan is about 176 km away from Manila, about 59 km away from Cabanatuan City, which is the capital of Nueva Ecija and about 38 km away from the nearby City of San Jose.

(b) Climate

The Pantabangan-Carranglan Watershed belongs to Philippine Climatic Type I. This type has two pronounced seasons - dry from December to April and wet during the rest of the year. A small part of the watershed, especially those that are near the boundary of the sub-province of Aurora falls under Climatic Type II which is characterized by having no dry season with very pronounced maximum rainfall from November to January. Total annual rainfall from four rainfall stations range from 1777mm to 2271mm.

Air temperature in Pantabangan - Carranglan Watershed from 1961 - 1999 is fairly uniform. The mean monthly temperature ranges from 25.7º C to 29.5º C. The lowest and highest temperature in the watershed occurred in January 1963 at 23.8º C and May 1970 at 30.6º C, respectively.

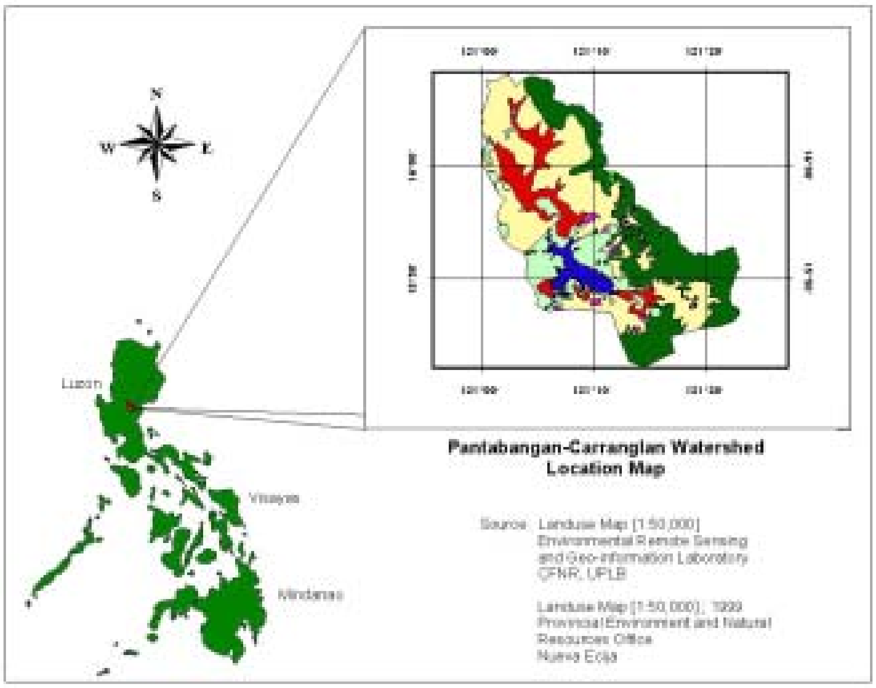

Fig. 1 Location map of the Pantabangan-Carrranglan Watershed

Dominant wind direction occurring in the watershed is east to northeast with a speed of 2 meters per second (mps). The area experiences windy days from December to February. The watershed is within the typhoon belt with most typhoons occurring between September to October.

(c) Topography and geology

The PCW has a complex land configuration. Topography ranges from nearly level, undulating and sloping to steep hilly and rugged mountain landscapes. The highest peaks are 1,650 and 1,410 masl, respectively. The PCW has a mean slope of 40%.

Rocks generally derived from intrusive and extrusive rocks of igneous type and from sedimentary rock materials underlie areas on the surrounding upland, hills and mountains within the watershed limit. The diorite and quartz materials that belong to the middle and upper miocene age extend to the northwestern edge and extending towards the Canili-Diayao watershed.

Metavolcanic minerals comprise the Caraballo Mountain and Mt. Deugonog areas. On the northwestern part of the watershed extending towards the south and southeastern part, including Mt. Carranglan, Maluyan and Pantabangan, consolidated conglomerates with interlayer of sandstone, mudstone and shade of upper Miocene age to Pliocene age can be found.

(d) Soil

Soils at PCW are derived mostly from weathered products of metavolcanic activities and diorite. Surface soil textures are silty clay loam, clay loam to clay. Soils in the watershed are classified into four types, namely: the Annam, Bunga, Guimbaloan, and Mahipon. The Annam soil type is primarily a mountain soil derived from weathered igneous rocks. It is moderately deep from 50 to 130 centimeters. The dominant soil color is brown and clayey. This soil type is recommended for tree and forest crops. At the start of the plantation, this soil may not need liming but eventually will develop higher acidity if nitrogen fertilizer is applied.

Guimbaloan soil occurs on moderately sloping or undulating and generally on hilly to steep hilly and mountainous relief. This type of soil is derived from basalt and metavolcanic materials. It is predominantly clayey with about 50 cm deep and well drained. The surface soil is dark clay to dark grayish brown with manganese concentrations.

The Bunga soil type on the other hand occurs on a level to nearly collu-alluvial landscapes. The dominant color is dark gray brown with strong brown and light gray mattles. It has a clayey texture, with a depth of 147 to 155 cm and moderately well drained.

Mahipon which usually occurs on level to nearly level collu-alluvial landscape is derived from quartenary (one million) alluvial/tallus deposits and terrace gravels. The soil is clayey in texture but has a restricted internal drainage. It is moderately acidic.

(e) Land cover and land use

As of 1999, the major land cover types in the PCW are natural forests (secondary), grasslands, reforestation areas, and A and D (alienable and disposable) lands (**Fig. 2**). Of these, the grasslands occupy the largest portion followed by secondary forests (**Fig. 3**). The forest cover in the watershed is predominantly secondary forest. Grazing and reforestation activities are conducted in open and grassland areas covered with cogon (*Imperatra cylindrica*) as predominant vegetation.

Rice, vegetables, corn, cassava, onion and other agricultural crops are grown on cultivated lands (A and D; ISF, and occasionally, grassland areas). 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 rainfed. Water pumped from well and run-of-the-river irrigate some areas for rice production. Other crops like banana, cassava, sweet potato and corn are normally grown on swidden farms.

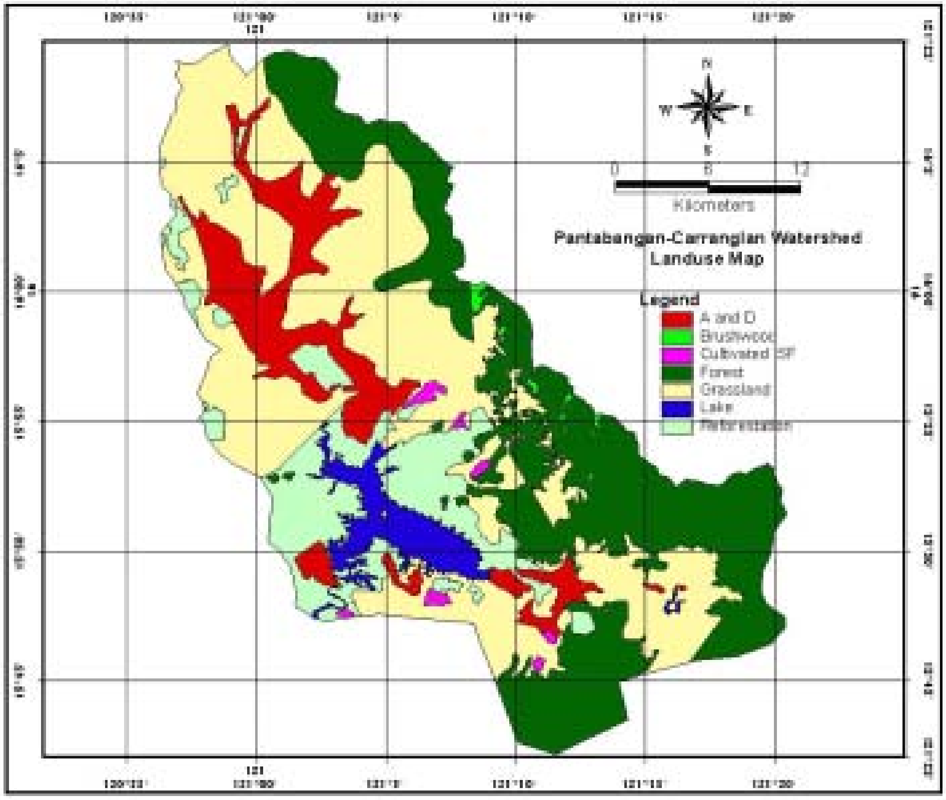

Fig. 2 Land use map of the Pantabangan-Carranglan Watershed, Philippines

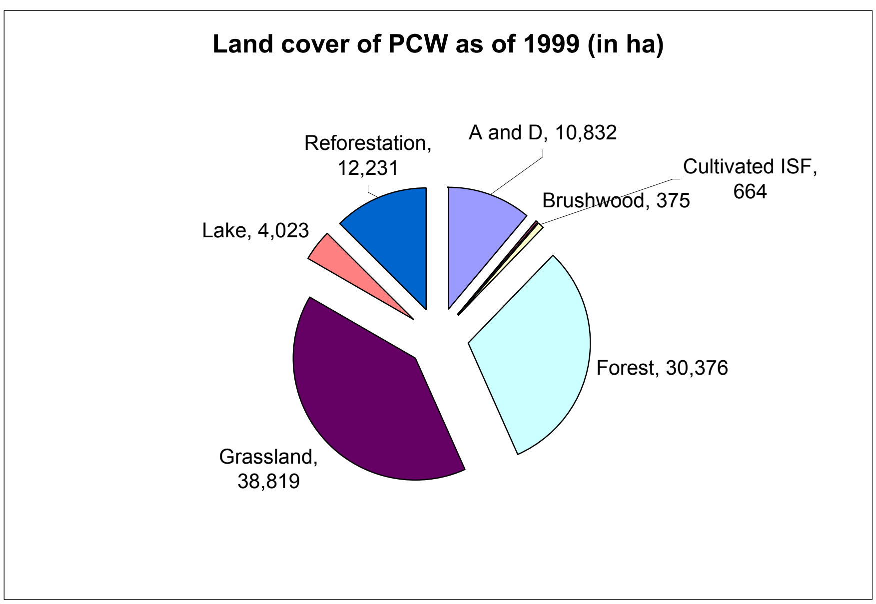

Fig. 3 Area of each land cover in the Pantabangan-Carralnglan Watershed, Philippines

2.2 Field Measurements of Biomass and Carbon Analysis

G. 2.2.1 Sampling plots and field measurements

H. 1. Natural forests

The method used was the point-centered quarter method. The point-centered quarter method is a plotless method of sampling that is designed to determine the number of trees per unit area that can be calculated from the average distance between the trees.

Four parallel lines were randomly laid out. Each parallel line comprised of five sampling points with a 50 meter distance from each other. In each point, two lines formed a cross. One of the lines is the compass direction and the other is the line perpendicular to it and passing through the sampling point. The distance to the midpoint of the nearest tree inside each quadrat with a diameter at breast height of ≥ 10 cm was measured and identified.

2. Brushland areas

For the brushland areas, ten transects measuring 10m x 10m were established.

I. 3. Tree plantations

The method used in plantation areas is transect method. Two 5m x 40 m plots were established in each plantation type. If trees with dbh > 50 cm are present whether they are included in the sample plots or not, an additional sample of 20m x 100 m was established. In plots measuring 5m x 40m, all trees with dbh of >5 cm are measured and identified while in plots 20m x 100m, only trees with a diameter >30 cm are measured.

2.2.2 Understorey and herbaceous vegetation

Four frames measuring 1m x 1m was randomly laid-out near the sampling points. All herbaceous and woody vegetation (less than 5 cm dbh) inside the frame were collected. Fresh weight of the samples was determined after which samples were oven dried.

2.2.3 Standing litter crop

Inside the same sampling frames used for measuring understorey and herbaceous vegetation, a 0.5 m x 0.5 m transect was established for litter collection. Total fresh weight of all the samples were taken after which about 300 grams was reserved for air- and oven drying. Samples were dried inside the oven with a temperature of ± 102°C for at least 48 hours or until weights of the samples become constant.

Coarse litter was collected in the 0.5 x 0.5 m quadrat within the understorey sample plot. Similar to understorey, sub-sample of about 300 g was taken for oven drying and carbon content analysis.

2.2.4 Grassland

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

2.2.5 Soil organic carbon

Soil samples were collected within the sample plots of second growth, brushland and grassland areas at 30 cm depth. Samples were air dried and were taken to the Soils Laboratory of the Soil Science Department of the College of Agriculture, University of the Philippines Los Banos for analysis.

For bulk density determination, samples were collected using a ring metal with height of 10 cm and diameter of 3 cm at 20-30 cm depth.

2.2.6 Biomass calculation

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

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

Biomass values for litter, understorey and grass were calculated using the following formula:

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

where,

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

Table 1. Characteristics of study plots in natural forests

Study Plot	Location	Elevation (masl)	No. of Species	Dbh range (cm)	Total Height (m)
STRIP 1			9	10-59	12-27
STRIP 2			13	4-20	11-27
STRIP 3			17	12-51	14-25
STRIP 4			13	10-38	10-23

Table 2. Characteristics of study plots in brushland areas

Study Plot	Location	Elevation (masl)	No. of Species	Dbh range (cm)	Total Height (m)
BR-1			1	8-9	5
BR-2			1	7	4
BR-3			2	5-9	4-5
BR-4			2	5-8	3-6
BR-5			2	5-6	3-5
BR-6			1	20	7
BR-7			2	14-18	3-4
BR-8			1	9	4
BR-9			3	7-10	4-5
BR-10			1	7-15	3-4

Table 3. Characteristics of study plots in plantation areas

Study Plot	Location	Elevation (masl)	No. of Species	Dbh range (cm)	Total Height (m)
Narra	N15°48'43.8"	**412**			
20 x 100	E121°03'14.2		2	30-43	17-25
5 x 40			5	5-29	1-20
5 x 40			2	5-27	4-22
Mixed Plantation					
20 x 100			3	30-67	7-24
5 x 40			7	5-25	4-18
5 x 40			5	8-29	1-18
Mahogany					
5 x 40			2	5-26	2-15
5 x 40			2	5-26	4-12
Ipil-ipil					
5 x 40			2	5-24	5-17
5 x 40			2	5-19	6-13
Gmelina					
20 x 100			2	30-52	7-31
5 x 40			2	10-29	6-10
Eucalyptus					
20 x 100			2	31-33	7-13
5 x 40			2	14-28	3-12
5 x 40			1	11-19	2-12
Benguet					

Pine 5 x 40 5 x 40			1 4	5-23 39-74	3-18 6-15
Acacia 5 x 40 5 x 40	N 15°45'44" E121°04'19.8	567	 5 4	 6-29 5-28	 4-24 4-26

2.3 Computer Simulation Using CO2-Fix Model

The carbon density of the various land cover types over time will be simulated using the CO_2 Fix model which has been used in previous studies (Nabuurs *et al.*, 2001). It is a tool, which quantifies the carbon stocks and fluxes in the forest, soil organic matter compartment and the resulting wood products at the hectare scale. The latest version of the model was improved to include the following features (ref??):

- the ability to simulate multi-species and uneven aged stands in multiple cohorts (defined as group of individual trees or group of species which are assumed to exhibit similar growth and which maybe treated as single entities within the model)
- the ability to parameterize the growth also by stand density;
- the ability to deal with inter cohort competition;
- allocation, processing lines, and end-of-life disposal of harvested wood;
- soil dynamics;
- the ability to deal with a wider variety of forest types including agroforestry systems, selective logging systems and post harvesting mortality;
- output viewing charts

In modeling the growth of the stand, two basic approaches could be used:

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

Described below are the main components of the model from xxx (xxx).

1. Biomass Components

The model had been parameterized to Pantabangan condition. Where the age of the stand is known, biomass growth is in the form of current annual increment (CAI) of stemwood volume, in m^3 ha^{-1} yr^{-1}. Moreover, biomass of other stand components such as branches, foliage and roots was also calculated as an additional fraction to the growth rate of the tree biomass. The carbon content of the wood components and wood density of the sample species were inputed.

2. Turnover rate

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

3. Interactions (Competitions)

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

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

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

4. Parameterising the Soil

The model required inputs on the mean annual temperature of the soil (˚C), precipitation in the growing season (PREC, mm) and Potential Evapotranspiration in the growing season (PET, mm). PREC and MAT data can be found at www.worldclimate.com or mean monthly temperatures can be computed using 'PET.xls' file installed in the CO2FIX installer. Values of litter in the soil were also inputed.

3. RESULTS AND DISCUSSION

3.1 Above-ground Biomass and carbon density

Field measurements coupled with the use of allometric equation showed a wide range of biomass density in the various land cover in the PCW (**Tables 4 and 5**). Two estimates are presented here, one using the allometric equation from Brown (1997) and the other using the Power Fit developed at the Environmental Forestry Programme (Banaticla, 2002). It will be noted that Brown's equation gave about 50% higher biomass estimate than the Power fit equation which is also the same trend in other Philippines studies (Banaticla, 2002). Without site-specific biomass equations for the PCW, these two estimates can be used as a high and low estimate for the biomass in the watershed.

Among all the land cover types, secondary forests have the highest above-ground biomass density while grasslands have the lowest. Secondary forests form the only remaining natural forest cover in the watershed. The original forest cover has been slowly decimated over the years as result of timber cutting and shifting cultivation activities. After years of repeated cultivation and burning, grasslands become the dominant vegetative cover.

In attempt to revegetate the denuded areas, there have been several attempts to reforest the watershed. The various reforestation species have biomass density values (about 70 Mg on the average using Power Fit equation) that are lower than natural forests but much higher than grassland areas. This implies that reforestation activities are helping increase the biomass of denuded areas. However, their biomass is typically lower than natural forests.

The results of the study are consistent with above-ground biomass density values obtained in other parts of the country using the Brown (1997) equation (Lasco and Pulhin, 2003; Lasco *et at*., 2002; Lasco *et al*., 2000; Kawahara *et al*., 1981). For example, a secondary forest in Makiling Forest was found to have 547 Mg/ha (Lasco *et a*l., 2001) while in Leyte a similar forest type has 446 Mg/ha (Lasco *et al*., 2002). The results of the study are also consistent with the IPCC default values for natural forests in the Philippines which is 370-520 Mg/ha (Houghton *et al*., 1997). Similarly, the biomass density is within the range of other forest types in SE Asia (Lasco, 2002).

It will be noted that except for grassland areas, most of the above-ground biomass are stored in trees. This is consistent with findings from other studies where more than 90% of biomass is commonly found in the bigger trees (Lasco *et al*., 1999; Guilespie *et al*., 1992).

The plantation species have differing biomass density. This could be due to a number of reasons such as age differences between and among species. In addition, it could also be due to the uneven site conditions obtaining in the PCW.

Table 4. Biomass of various land uses in Pantabangan-Carranglan watershed using allometric equation of Brown (1997)

LAND USE	BIOMASS DENSITY (Mg/ha)			
	Tree	Herbaceous/ Understorey	Litter	TOTAL
Second Growth	546.6	0.16	16.53	563.29
Brushland	113.35	0.42	7.57	121.34
Grassland		17.15		17.15
Acacia auriculiformis	286.01	0.04	0.62	286.67
Benguet Pine	181.22	0.42	0.83	182.47
Eucalyptus	54.29	0.22	0.72	55.23
Gmelina	108.97	0.15	0.66	109.78
Ipil-ipil	82.55	0.24	0.39	83.18
Mahogany	152.56	0.08	0.41	153.05
Mixed species	87.19	0.4	2.99	90.58
Narra	145.24	0.33	0.72	146.29

Table 5. Biomass of various land uses in Pantabangan-Carranglan watershed using the Power Fit equation

LAND USE	BIOMASS DENSITY (Mg/ha)			
	Tree	Herbaceous/ Understorey	Litter	TOTAL
Second Growth	282.91	0.16	16.53	299.60
Brushland	72.38	0.42	7.57	80.37
Grassland		17.15		17.15

Acacia auriculiformis	120	0.04	0.62	120.66
Benguet Pine	95.67	0.42	0.83	96.92
Eucalyptus	28.47	0.22	0.72	29.41
Gmelina	55.66	0.15	0.66	56.47
Ipil-ipil	42.95	0.24	0.39	43.58
Mahogany	80.43	0.08	0.41	80.92
Mixed species	45.38	0.4	2.99	48.77
Narra	76.09	0.33	0.72	77.14
Ave for tree plantations	68.08	0.24	0.92	69.23

As expected, the carbon density values of the various land cover follow the trend of biomass density (**Fig. 4**). Similarly, the area distribution of carbon density is a reflection of the land cover types of the watershed (**Fig. 5**).

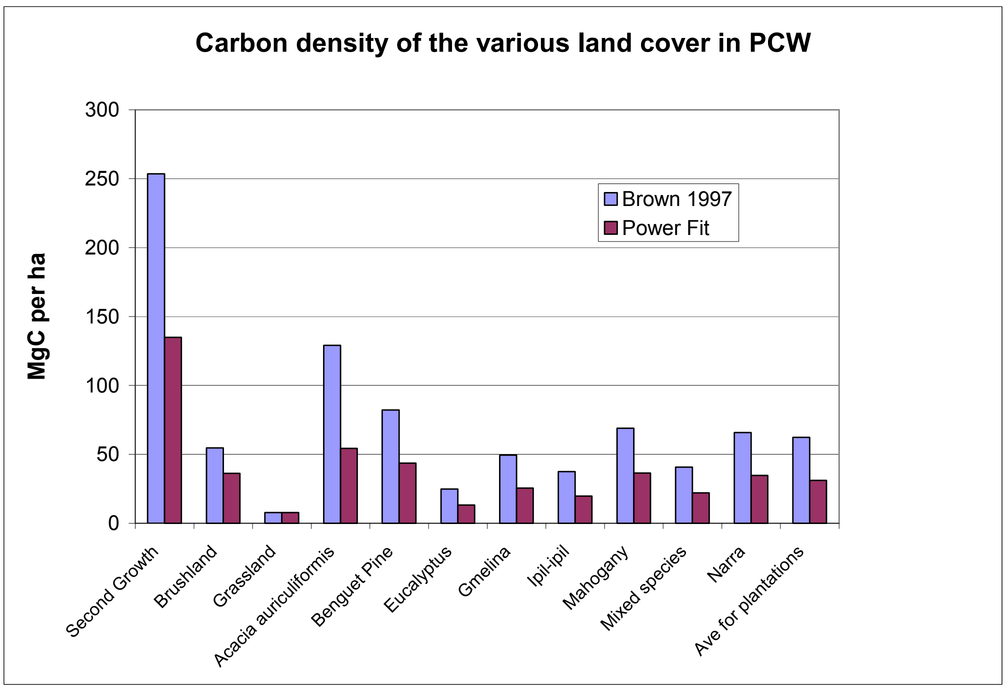

Fig. 4 Carbon density of land cover types in Pantabangan-Carranglan Watershed, Philippines
(Note: carbon content of biomass= 44%)

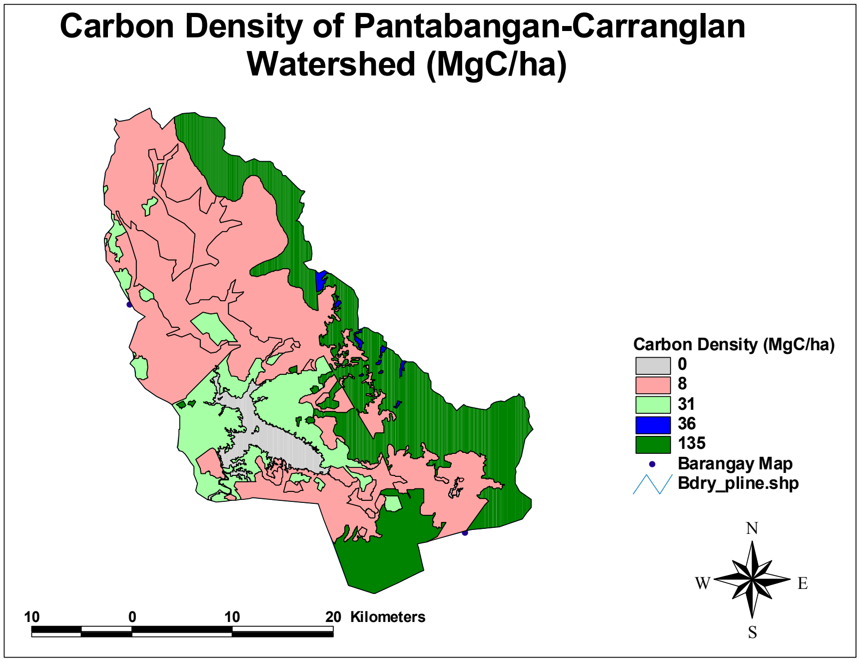

Fig. 5 Distribution of carbon density of the Pantabangan-Carranglan Watershed, Philippines

On the basis of the carbon density values, the entire watershed is estimated to contain 4,878 GgC (Power Fit) to 8,870 GgC (Brown) in above ground biomass and necromass. As expected, most of these are contained in the natural forests (**Fig. 6**).

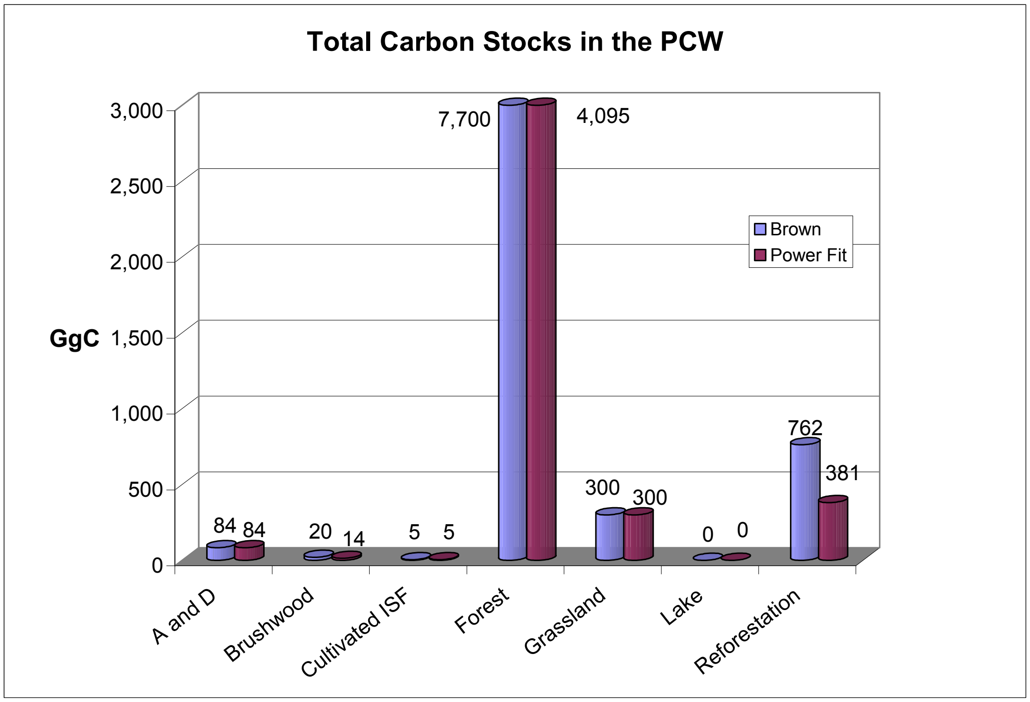

Fig. 6 Total carbon stocks of the Pantabangan-Carangglan Watershed, Philippines

3.2 Simulation of carbon budgets using CO2-Fix v2.0

Three modules in the CO2 Fix v.2.0 were parameterized using local data where available, viz., general, biomass and soil parameters. Since there was no harvesting, the products module was not used.

The following are the values inputed to the model:

1. General parameters

- Simulation length= 100yrs
- Maximum biomass= 400 Mg (roughly the average of the high and low estimate in Tables 1 and 2)
- Cohorts: Upper storey, understorey
- Cohorts age= 20 years

2. Biomass parameters

<u>*Upperstorey:*</u>

- Carbon content= 45% (from Lasco and Pulhin, 2003)
- Wood density= 0.57 (Brown, 1997)
- Initial carbon= 100 MgC/ha
- Stem growth rate:

The stem growth rate of the forest was estimated using the following logistic equation of a dipterocarp plantation in the Philippines:

Logistic Model: y=a/(1+b*exp(cx))
Where:
a = 260.9623
b = 204.2171
c = 0.14702
r= 0.998 R^2= 0.996
Equation generated using Curve Expert 1.3

The estimated total biomass and CAI are shown in **Table 6** and **7**.

Table 6 Estimated total biomass of a dipterocarp plantation in a good site in the Philippines

Age	Merchantable Volume[1]	Biomass	MAI Biomass
20	8	5	3
25	60	34	18
30	111	63	10
35	165	94	8
40	223	127	8
45	271	154	6
50	308	176	4
55	330	188	2
60	348	198	3
70[2]		199	0
80		200	0
90		200	0
100		200	0

[1]Merchantable volume data for ages 20 to 60 from PCARDD (1985)
[2]Biomass for ages 70 to 100 were extrapolated from the logistic equation

Table 7 CAI used for stem in the CO2 Fix Model (estimated based on the logistic equation)

Biomass/Maximum Biomass	CAI (m3/ha/yr)
0.10	0.7
0.20	3.5
0.30	9.2
0.40	12.2
0.50	12.7
0.60	10.8
0.70	7.6
0.80	4.5
0.90	1.6
1.00	0.5

- Default values were used for foliage, branches and roots
- Mortality and competition were assumed to be zero.

Understorey

- Carbon content= 45%
- Wood density= 0.57
- Initial carbon= 10 MgC/ha

- Default values for potential species were used in the other parameters.

3. Soil Parameters

- Annual mean temperature= 27.6°C for Cabanatuan station (www.worldclimate.com)
- Precipitation in growing season = 2000mm
- PET in growing season= 1848 from (mean monthly temperature from www.worldclimate.com)

Calibration of initial soil carbon

Total litter fall= 10 t/ha/yr (8 upper; 2 under)
Upper (3 leaves; 2stems; 1 branch; 2 roots)
Under (0.5 leaves; 0.5 stems; 0.5 branch; 0.5 roots

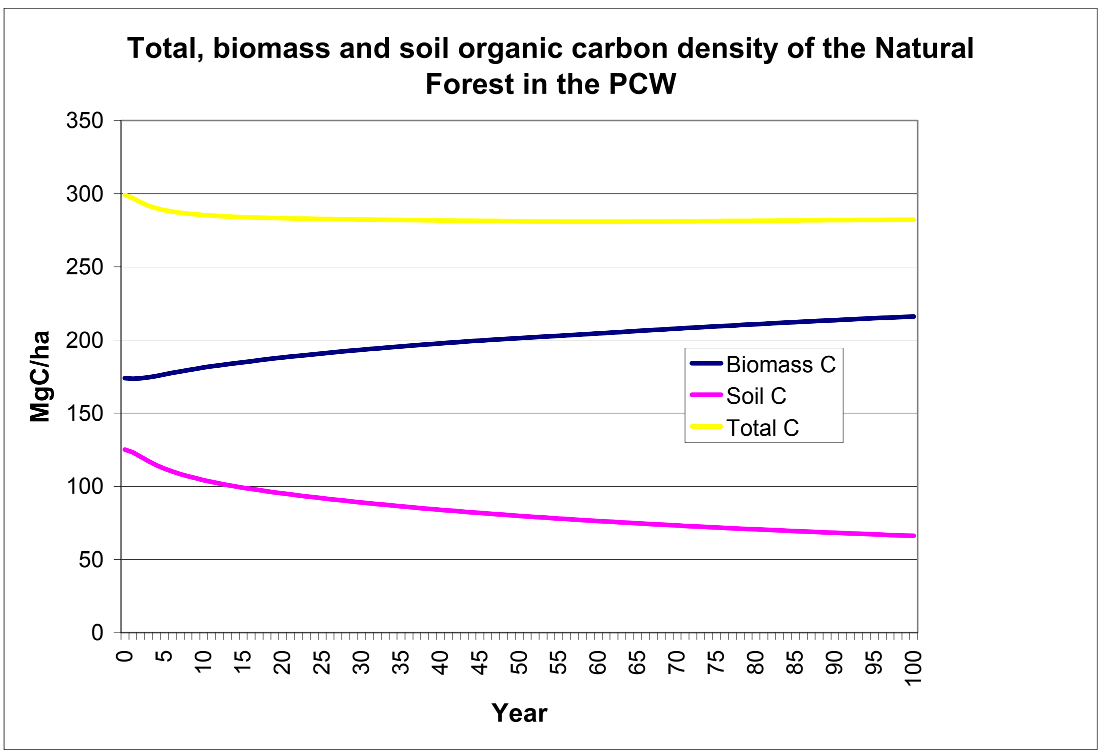

Fig. 7 Total, biomass and soil carbon density in the natural forest of PCW for 100 years as simulated by CO2 Fix v2.0

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 similar amount. Thus, overall, the total carbon density remains stable over time after an initial decrease.

3.4 Potential for Carbon Sequestration

Open areas in the watershed mainly grasslands and brushwood have some potential to sequester carbon through tree planting and agroforestry. Because of the harsh and sub-marginal conditions in grassland areas, the rate of carbon sequestration is estimated to be generally less than 4 Mg/ha/yr (**Table 6**). This is low compared to the IPCC default for tropical plantations (IPCC, 1996) as well previous findings in other part of the country like the Makling Forest Reserve and Leyte where conditions are much better (Lasco and Pulhin, 2003; Lasco *et al*., 2002; Lasco *et al*., 2001). However, given the large open area in the watershed, there is some potential for caron sequestration through natural and/or artificial regeneration.

Table 6 Biomass and C density and MAI in Nueva Ecija, Philippines (from Lasco, 2001)

Species	Age (yr)	Ave dbh (cm)	Biomass Mg/ha	MAI Mg/ha/yr	C density Mg/ha	MAI Mg/ha/yr
Acacia auriculiformis 1	6	5.68	7.39	1.23	3.33	0.55
A. auriculiformis 2	6	6.46	9.97	1.66	4.49	0.75
A. auriculiformis 3	9	9.62	42.51	4.72	19.13	2.13
A. auriculiformis 4	9	8.71	32.00	3.56	14.40	1.60
A. auriculiformis 5	9	10.47	46.11	5.12	20.75	2.31
A. auriculiformis 6	9	8.73	39.73	4.41	17.88	1.99
Tectona grandis 1	13	5.50	8.70	0.67	3.92	0.30
T. grandis 2	13	7.36	22.30	1.72	10.04	0.77
Gmelina arborea 1	6	7.33	17.22	2.87	7.75	1.29
G. arborea 2	6	6.80	7.71	1.29	3.47	0.58
Pinus kesiya	13	12.53	107.83	8.29	48.52	3.73
P. kesiya + broadleaf spp.	13	10.10	83.24	6.40	37.46	2.88

Note: age and dbh data from Sakurai *et al*., 1994; biomass computed using the equation Biomass/tree in kg= 21.297-6.953*dbh+0.74dbh^2 for broadeaf species and Biomass/tree= EXP-1.17+ 2.119*LN(dbh) for conifers (from Brown, 1997); %C in biomass= 45% (based on Lasco and Pulhin, 2000)

4. CONCLUSIONS AND RECOMMENDATIONS

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 is estimated to range from 4,800 to 8,900 MgC depending on the biomass allometric equation used.

The results of simulation using CO2 Fix model 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 similar amount. Thus, overall, the total carbon density remains stable over time after an initial decrease.

The watershed has great potential for carbon sequestration through tree establishment in open areas.

Literature Cited

Bantayan, N. *et al*. 2000. Philippine Watershed Atlas. College of Forestry and Natural Resources, University of the Philippines, College, Laguna, Philippines.

Brown, S. 1997. Estimating biomass and biomass change of tropical forest: A primer. Forestry paper 134, FAO. Rome.

Gillespie, A.J.R., S. Brown and A.E. Lugo. 1992. Tropical forest biomass estimation from truncated stand tables. *For Ecol and Mgt* 48: 69-87.

Houghton, J.T., Meira Filho, L.G., Lim, B., Treanton, K., Mamaty, I., Bonduki, Y., Griggs, D.J. and Callander, B.A. (eds). 1997, , Greenhouse Gas Inventory Workbook, Intergovernmental Panel on Climate Change (IPCC), Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA), Paris, France, pp. 5.1-5.54.

IPCC. 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. Summary for Policy Makers and Technical Summary of the Working Group II Report. World Meteorological Organization (WMO), Geneva, Switzerland and UN Environmental Programme (UNEP), Nairobi, Kenya. 89pp.

Kawahara, T. Y. Kanazawa and S. Sakurai. 1981. Biomass and net production of man-made forests in the Philippines. *J Jap For Sci* 63(9): 320-327.

Lasco, R.D. 2002. Forest carbon budgets in Southeast Asia following harvesting and land cover change. *Science in China* 45: 55-64.

Lasco, R.D. 1998. Management of tropical forests in the Philippines: implications to global warming. *World Resource Review* 10(3): 410-418.

Lasco, R.D. and F.B. Pulhin. 2003. Philippine forest ecosystems and climate change: Carbon stocks, rate of sequestration and the Kyoto Protocol. *Annals of Tropical Research* (in press).

Lasco, R.D. and F.B. Pulhin. 2000. Forest land-use change in the Philippines and climate change mitigation. *Mitigation and Adaptation Strategies to Global Change Journal* 5: 81-97.

Lasco, R.D., J.S. Lales, M.T. Arnuevo, I.Q. Guillermo, A.C. de Jesus, R. Medrano, O.F. Bajar, and C.V. Mendoza. 2002. Carbon dioxide (CO_2) storage and sequstration of land cover in the Leyte Geothermal Reservation. *Renewable Energy* 25: 307-315.

Lasco, R.D., I.Q. Guillermo, R.V.O. Cruz, N.C. Bantayan, and F.B. Pulhin. 2001a. Carbon stocks assessment of a tropical secondary forest in Mt. Makiling, Philippines. *J of Tropical Forest Sci*. (in press).

Nabuurs, G.J., J.F. Garza-Caligaris, M. Kanninen, T. Karjalainen, T. Lapvetelainen, J. Liski, O. Masera, G.M.J. Mohren, A. Pussinen, M.J. Schelhaas. 2001. CO2FIX V2.0 – manual of a model for quantifying carbon sequestration in forest ecosystems and wood products. ALTERRA Report xx. Wageningen The Netherlands x p.

The Philippines Recommends for Dipeterocarp Production. 1985. PCARDD Technical Bulletin Series No. 58. Philippine Council for Agriculture and Resources Research and Development. Los Baños, Laguna, Philippines. 96p.

Sakurai, S., R.S.B. Ragil and L.U. de la Cruz. 1994. Tree growth and productivity in degraded forest land. In Rehabilitation of Degraded Lands in the Tropics. JIRCAS International Symposium Series No. 1, Japan International Research Center for Agricultural Sciences (JIRCAS), Tsukuba, Japan. Pp.64- 71.

Schimmel, D., Enting, I.G., Heimann, M., Wigley, T.M.L., Rayneud, D., Alves, D. and Seigenthler, U.: 1996, ‘CO2 and the carbon cycle’, in J.T. Houghton, L.G. Meira Filho, J. Bruce, H. Lee, B.A. Callander, E. Haites, N. Harris, and K. Maskell (eds), Climate Change 1994: Radiative Forcing of Climate Change and an Evaluation of the IPCC IS92 Emision Scenarios, Published for the IPCC, Cambridge University Press, pp. 35-71.

Watson, R.T., I.R. Noble, B. Bolin, N.H. Ravindranath, D.J. Verado and D.J. Dokken (eds): 2000, Land Use, Land-use Change, and Forestry, Published for the Intergovermental Panel for Climate Change, Cambridge University Press, 377pp.

Annex B

AN ASSESSMENT ON SOCIAL VULNERABILITY TO CLIMATE CHANGE IN A TIME OF RENOVATION

A Case Study in Giao Thuy district, Nam Dinh province, Vietnam

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Executive Summary

Understanding the capacity of a society to cope with global environmental change is critical, especially in a developing and vulnerable country like Vietnam. The study aims to assess the changes in social vulnerability and resilience under the effects of economic renovation in Vietnam and the implications for local society coping with the impacts of climate and weather extremes in Giao Thuy district, Nam Dinh province in the north of Vietnam. A set of vulnerability indicators has been selected and tested in the study.

The economic renovation – *doi moi* - promulgated in Vietnam since the mid 1980s has affected the rural society. Social livelihoods have changed, of which aquaculture shows a fast rate of development since the introduction of *doi moi*. The newly-introduced livelihoods have increased the level of income and of welfare inequality within the local community. Though these newly-introduced livelihoods have richened the community, only the better-off, who can afford to invest in the new livelihoods, can gain the major benefits.

Income and welfare inequality has led to some consequences, spontaneous migration and labour reallocation. Increasing demands for manual works in urban areas has attracted men from the local region. This trend has increased the remittance income and limited the loss of resilience associated with greater level of inequality. However, along with spontaneous migration, labour reallocation has also caused a lack of local employment and weakened the social structure. This has not improved the level of social resilience. Under these consequences, the coping capacity of local community to deal with climate and weather extremes has been altered. An analysis of how the different groups cope with climatic change shows the imbalance amongst the groups within the community.

Giao Thuy area is also an important conservation site. Giao Thuy district is the only Ramsar site in Vietnam established in 1989. This area is officially acknowledged as the internationally important wetland by the Ramsar Convention (Ramsar, 1971). The establishment of Ramsar site narrowed the access to the mangrove, which used to be free and the main income of the locals. This was considered as reducing the capacity of community as a whole. The research is also to identify the impacts of *doi moi* and Ramsar designation alongside the impacts of climate extremes on social livelihoods and the way local people respond and recover from these changes.

Statistical techniques have been used in parallel with qualitative assessment. Techniques, including bivariate analysis, have been undertaken to provide a quantitative proof for the analysis. Due to the complication of livelihoods in the region, relevant parameters were chosen such as economic, labour force, economic loss caused by climatic extremes, speed of recovery. Linkages among them were also examined from which various possible socio-economic scenarios developed. Applicable indicators were chosen to consider the future trends and sensitivity of different important sectors in the region to institutional changes and climatic extremes. Especially, eco-tourism – a potential and fast developing sector in the local area – is taken into account.

The study has also analysed and tested a set of indicators reflecting the level of social vulnerability and resilience of different groups within the community. Results showed a complexity in effects and local response. From these findings, policy implications to promote greater resilience have been proposed. Further research opportunities are also discussed.

Introduction

The way a society adapts to the uncertain impacts of future climate change remains one of the key environmental issues of a global nature. The issue is increasingly highlighted both in international scientific assessments and in the Intergovernmental Panel for Climate Change Assessment (IPCC, 2001:5). Adaptive options for vulnerable societies must be identified on the basis of vulnerability assessment to potential impacts. Vulnerability assessment is especially meaningful in the countries like the developing countries. These countries, according to the Third Assessment Report of the IPCC, are more vulnerable to climate change than the developed countries caused by the transition in economy. How social vulnerability and resilience change under the impacts of climate change still remain uncertain.

In order to assess the level of vulnerability to environmental stresses, approaches considering both internal and external influences on level of vulnerability are necessary. Internal influences refer to changes within a country, a society or a group of people such as formal and informal institutional changes. External influences, in contrast, refer to stresses caused by outside factors such as environmental change. Two approaches applied in Vietnam are discussed:

Adger (1997) developed a conceptual model and set of indicators to examine the relative vulnerability of any given set of individuals or social situation, applied in case study level in Vietnam. Adger (1997:1) argued that in rural Vietnam evidences of changes derived from economic renovation have been partially exposed by inequality in income and are usually explained as being directly related to changes in the structure of ownership of land. This trend was observed in many countries such as China, Pakistan, Cameroon, Burkinafaso, Kenya, South Africa and Mexico (see Hussain *et al.*, 1994; Adams, 1995; Ruitenbeck, 1996; Reardon and Taylor, 1996; Francis and Hoddinott, 1993; Leibbrandt, 1996 and Stark *et al.*, 1986). Adger *et al.* (2001:92) concluded that vulnerability is created and resilience is undermined by the rising levels of inequality caused by gains and losses from the new commercialism and privatisation after economic renovation in Vietnam.

Another approach which considers the way in which institutional trends shape livelihood resilience has been developed by Luttrell (2001) and also applied in the coastal zone of Northern and Southern Vietnam. Luttrell defines social resilience as 'the ability to adapt to changing circumstances and thus ensure security of livelihoods'. Subsequently, Luttrell (2001) applied the approach in two different coastal communes in the North and South of Vietnam considering the changes in social livelihoods under the formation of institutions. The major finding of the study concerned the effects on access rights of the recent institutional reforms in Vietnam associated with economic renovation. Privatisation of resource use was the main factor along with other formal institutional changes such as land reform, the dismantling of the cooperatives, forest enterprise reform and policies encouraging aquacultural expansion. These have caused shifts in access and required individuals to adapt their livelihoods to these changes.

Though both of the above-mentioned approaches have assessed the level of social vulnerability and resilience in Vietnam, the question raised is that whether there is any possibility to go further in analysing social vulnerability. Luttrell's approach (2001) is mainly based on qualitative analyses with major indicators developed from institutional changes to assess the way institutions shape the livelihood resilience. Luttrell's assessment of livelihood resilience, as the name implies, mostly concerned the local livelihoods, which are affected by institutional changes. From the changes in livelihood patterns, Luttrell has drawn out in the interactions between institutions and livelihoods, which are the basis for resilience assessment. In contrast, Adger's approach is more quantitative. Basic indicators in Adger's approaches are the levels of income and land inequality and the formal institutional changes. Though both of the approaches have similar conclusions on the changes of various social livelihoods, interactions of socio-economic factors, institutions and climatic effects are not examined thoroughly. Therefore, an integrated approach incorporating factors from a broader context, including both institutional and economic changes, is a critical need.

The need to understand the complex of the impacts on social vulnerability of both institutional and economic changes is important. These impacts are not consistent over time, especially in a developing country like Vietnam. An enhanced understanding of the process by which social vulnerability varies and its implications will inform both the scientific community and policy makers regarding the causes of vulnerability. The causes will be observed in different aspects of society, particularly economic and institutional. These underlying causes of vulnerability will be the basis for potential policy for reducing vulnerability and enhancing resilience.

The objective of this project is to assess the changes in social vulnerability and resilience under the effects of economic renovation and the implications for local society coping with the impacts of climate and weather extremes in a coastal district in Northern Vietnam: Giao Thuy district, Nam Dinh province. To obtain the objectives of the project, indicators to assess the changes in social vulnerability under the effects of economic renovation in Vietnam with implications to the impacts of climate and weather extremes are selected and tested.

The study is designed with the following sequence. Chapter 2 provides an overview of definitions and arguments on social vulnerability and resilience, access to natural resources and related concerns to the objectives of the project. Detailed objectives, analyses and selected indicators, which have been used in this study, are also discussed in this chapter. Chapter 3 deals with the data collection, methods and techniques applied during the study. Potential difficulties and limitations of this study are also stated in this chapter. Chapter 4 discusses the indications of social vulnerability under the effects of economic renovation with the changes in income and welfare inequality which has led to changes in social structure, particularly labour reallocation in the community and access to natural resources. Chapter 5 tested the changes in social vulnerability by considering the impacts of climate and weather extremes and the way different local groups cope with the impacts. Chapter 6 summarises the findings in a scenarios based analysis which gives a means to the policy makers an overview of sensitivity of various sectors in the local area. Finally, conclusions and recommendations from the study are drawn in Chapter 7. Policy implications and opportunities for further research are also discussed in this chapter.

Literature review
The origin of the terms "vulnerability" and "resilience"

The concept of vulnerability originally emerges from consideration of food scarcity and natural hazards (Adger and Kelly, 2001:21). The term is closely related to the concern of poverty alleviation in which food security and natural hazards are the major components. Watts and Bohle (1993) discussed social vulnerability to food scarcity as exposure to crises and stresses caused by the lack of sufficient capacity to cope with these stresses, the consequences of these stresses and slow recovery that incurred related possible risks. From the natural hazards context, vulnerability is defined as "the capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (Blaikie *et al.*, 1994). This perspective has been recognised at different scales, from local to global. Vulnerability to risk, as Doornkamp (1998) argues in a study on coastal flooding caused by global warming and environment management, is increased by the inability to grasp the true scale and the ways in which environmental change can increase either the magnitude or the frequency of the flood hazard.

Resilience, in contrast to vulnerability, is commonly found in ecological contexts. The term, as demonstrated by Timmerman (1981), originates from the Latin meaning 'invulnerable' or 'not woundable'. Definitions of resilience in traditional ecological theory can be classified into two categories. The first emphasises resilience as a return to a normal state of the ecosystem. The other focuses on the magnitude of change a system can absorb. These definitions reveal a steady state, though presumed, and emphasise resistance to a turbulence or disturbance in returning to the equilibrium point of a system (Margaleff, 1969; Connel and Sousa, 1983). Therefore, resilience implies that the maintenance of the functions under stress or while recovering from stress, and the notion of returning to a set of baseline conditions (Dow, 1992:420). Adger (2000) argues that the difference among definitions of resilience lies in the emphasis placed on the speed of recovery from a disturbance, highlighting the difference between resilience and resistance, which is the extent disturbance is actually translated into impacts.

The significance of social vulnerability and resilience to managing human-environment interactions

Recently, Adger (1997:11) develops these concepts further by examining the notion of 'social resilience'. He defines "ecological resilience" as 'characteristics of ecosystems to maintain themselves in the face of disturbance' then relates social resilience to ecological resilience (see also Zimmerer, 1994; Gunderson *et al.*, 1995 and Levin *et al.*, 1998). The term social resilience itself has many roots in the literature on stability and criticality (Kasperson *et al.*, 1996) and notions of coping and adaptation. Adger (1997) emphasised that the important role of social resilience is in the way in which individuals and social groups adapt to environmental change. There are two important factors from which social resilience is formed, allocation of the natural resources and property rights. These factors, in many cases, are vital components of social resilience. Changes in social stability and criticality are also closely attached with the altered states of resource allocation and property rights. By looking at the characteristics of the resources system and social property rights, the ability of a community to absorb changes can engage with ideas of new ecology (Adger, 2000:347-359).

Luttrell (2001:14) came up with the concept of “livelihood resilience” which may involve the maintenance of a current livelihood situation as it is, or moving to a new and resilient stage. Such a definition of resilience includes the undesirable process and the utilisation of a changing situation for one’s own benefit as a sign of resilience (Blaikie and Brookfield, 1987). There is a stream of thought that improving the performance of natural resource systems requires an emphasis on institutions and property rights. This is a human-oriented approach focusing on the resource user rather than on the resource itself: as Berkes and Folke (1998:2) argued, “resource management is people management”. With this perspective, social resilience, from the livelihood outlook, can be referred to dealing with both natural and human resource allocation.

The recognition of social resilience is that communities are constantly changing and the focus on their capacity to deal with external stresses. If communities are resilient to the changes and hold an accessible resource base and a dynamic range of potential livelihoods and responsive institutions, they will be able to absorb these shocks and even respond positively to them. In contrast, if communities are less resilient, or more vulnerable, maybe because their resource base is inaccessible or frequently damaged, their livelihoods are not stable, or their institutions are inflexible or when external stresses are changing rapidly, significant rebalance may occur. This leads to the structural changes of social capital, natural resources, and newly-introduced livelihood options. The key element here is the dynamic nature of these processes.

Social resilience, more precisely, can be considered as the adaptive capacity of a community to external stresses without significant structural changes. In the relation with the environment, social resilience is revealed clearly in the use of the natural resources and dependence on them. Therefore, it is formed by the dynamic structure of livelihoods, which is dependent on natural resources, access to resources and social institutions, both formal and informal. External changes or stresses, including government policies, civil strive, environmental disasters, result in changes in social structure, livelihoods and alter resources. When managing human-environment interactions, the term resilience should be developed and applied to communities dependent on natural resources from which the causal links between human and the environment can be emerged and proved. Adaptive capacity can be considered as a function of social welfare. As social welfare is improved, the capacity to adapt to external changes is also enhanced.

A person’s welfare is an aggregate of its constituents: utility (Dasgupta, 1993:70). Dasgupta also suggests that an assessment of welfare is not only an issue of income a person can earn but also covers a wide range of welfare features. Therefore, it is unwise to conclude that the higher income a community can gain the higher resilience level there. Indeed, Sen (1981, 1984) pointed out that a social welfare must include full employment, which enables to provide the basic needs for them. Therefore, welfare must be considered from a broad outlook based on specific cases, regions, political regimes, socio-economic conditions and so on. In an agrarian and developing country like Vietnam, welfare is often referred to the combination of land, labour and financial output. This thinking was applied to the well-being analysis theory by Dasgupta (1993:475) in different countries of decentralised market economy.

Though social vulnerability, resilience and welfare can be defined and examined in different ways, their relevance to a sustainable human-environmental interaction can be summarised in the following:

- Social resilience has been seen as the capacity of a society to return to its equilibrium under the effects of external shocks. Communities that are highly resilient can even benefit from the external shocks.
- The vulnerability and resilience properties of a specific community can be incorporated within the management system of its location to develop and support a long-term adaptation strategy.
- Social resilience is closely related to social welfare, which reflects the way a community use and benefit from their natural, financial and human resources.
- The level of social vulnerability and resilience of a community is related to the way in which people respond to, cope with and benefit from institutional regimes.
- An integrated approach to assess social resilience incorporating economics, politics, sociology, anthropology and natural sciences needs to be applied. From such a comprehensive approach, interactions between the human system and the environment can be addressed in a systematic fashion and effective policies can be developed.

In this study, as Giao Thuy is a typical egalitarian area in the North of Vietnam, social resilience must be examined on the basis of agriculture system which includes income from different agro-economic sectors and labour allocation in these sectors. Changes of these factors will vary the level of social resilience. It is important to note that social resilience of a specific community must be assessed considering institutional changes. Institution has overall effects on the use of the natural resources. Social trends are occurring under these effects and use of natural resources is shaped by the changes of livelihood options. Social trends act to reinforce existing inequalities and some types of social capital are exclusionary in nature (Adger, 2000). Stresses, such as climate and weather extremes, may amplify the level of vulnerability of some groups, or communities while at the same time providing potential opportunities for groups or communities advancement. From this perspective, a set of indicators (Moss *et al.*, 2000) to assess social vulnerability is selected and tested during the study. This set of indicators allows considering a wide range of factors affecting the level of social vulnerability and is consistent with the purpose of the study.

Table 2.1. Indicators selected for assessing social vulnerability

	Vulnerability indicators	**Proxy variables**	**Proxy for**
1	Ecosystem sensitivity	Land managed	Degree of human intrusion into the natural landscape and land fragmentation
2	Economic capacity	GDP (market per capita, Gini coefficient	Distribution of access to markets, different kinds of capital and other resources useful for adaptation
3	Human resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs
4	Institution	Employment	The rate of employment available in

	Empowerment	different economic sectors Participatory status of people to decision making

Sources: adapted from Moss *et al.*, 2000

This set of indicators is also supported by the IPCC (IPCC, 2001). It is, therefore, extremely valuable to test their effectiveness. The first indicator, ecosystem sensitivity indicator, refers to the way local people obtain and manage their land. As *doi moi* process has some particular effects on the land management, the coping capacity of society is also altered. In Giao Thuy district, the mangrove ecosystem plays an important part in social livelihoods, particularly aquaculture. Inland management and mangrove forest are the focus of this indicator. The second indicator, economic capacity, refers to the level of income individuals, groups or society can earn as well as access to the market and other resources that can be used to adapt to climate change. This indicator includes GDP (market) per capita as one of the proxies for economic capacity. Unequal distribution of wealth within the society is examined by conducting Gini coefficient analyses. The third indicator, human resources, is also a component of coping capacity. This includes the labour force, skill and social structure of the households that determine how flexible individuals may be in adapting to new employment opportunities or shifts in living patterns brought about by external changes such as the *doi moi.* Finally, the fourth indicator, institution, is the components of *doi moi* itself and has the overall effects on the society. This indicator includes the status of employment and empowerment of local society to cope with and to adapt to changes. This set of indicators has been tested in this project in order to obtain the following objectives.

Aquaculture and the use of natural resources

Recently, Huitric *et al.* (2001) considered the development and government policies of the shrimp farming industry in Thailand in relation to mangrove ecosystems. Similar to Vietnam and other developing countries in the Southeast Asin, intensive shrimp farming arrived in Thailand during the 1980s and developed virtually unregulated until 1987. The industry has been subsidised by Thailand government and it quickly became an important export industry. Thailand has been the world's largest producer of tiger shrimp since 1991. Huitric's studies revealed that the development of the shrimp farming industry in Thailand over the last 20 years in relation to its use of mangrove ecosystems is an example of sequential exploitation of natural resources witnessed through the shift in farm development from one region to another. The use of coastal zone for shrimp farming, particularly intensive farming, has caused widespread degradation of mangrove ecosystems. It is argued that the benefits of the industry may be less than perceived as a result of subsidies and environmental and social impacts. Huitric also showed that the development of legislation has not followed the same pace as the development of the industry, neither temporally, nor in content nor implementation, and contradictory policies have arisen.

More comprehensive, the UK Department for International Development, in cooperation with different research institutions, has carried out a policy review in relation to coastal zone management in Bangladesh. The study attempted to track the evolution of policies on coastal zone management with particular reference to Bangladesh. It then discusses the linkages between coastal management and livelihood issues that predicate the necessity for an integrated coastal zone management (ICZM) approach. The study also examined the inter-sectoral policy linkages and discussed how institutions and policy initiatives have dealt with, and might in future strengthen, the overall policy framework and implementation. This is an important work for less-developed countries like Bangladesh where poverty alleviation is a priority. As coastal zone is a massive resource where a large part of population depends on, an effective solution to integrate governmental policy to managing coastal zone and related environmental issues is a necessity. The development of coastal policies and programmes in Bangladesh are both important in their own right, affecting many millions of the poorest and most vulnerable people in the world, and in relation to wider processes of change in governance, policy and programme modalities in Bangladesh. Such a study will help to reduce the level of vulnerability and enhance social resilience among the poor to cope with institutional changes and other environmental and resources issues.

Another study which considered shrimp farming and environmental issues in the coastal zone was conducted by Hernandez-Cornejo and Ruiz-Luna (2000) in Mexico. Shrimp farming development in southern Sinaloa and its effects on coastal environments were analysed by municipalities and by region. This study is to analyse shrimp aquaculture from a regional view, evaluating the contribution of this activity to the changes in land use and estimating its trend in growth over time. In the last 20 years, development of shrimp farming has been rapidly increasing due to its high net benefit in all over the world. The study showed that if development of this industry maintains the same rate of expansion, it is imperative to determine the real growth potential for this activity. The study proposed an assessment, which is based on the characterisation of the systems that shrimp farming depends on in term of supply and drainage. On the other hand, the evaluating not just water-quality variables but also the effects of change in land use on the lagoon systems, because the impact can be major and irreversible. Moreover, the development of this activity must be regulated, taking into account characteristics of the estuarine systems, and must incorporate a regional view, including some other interacting activities such as agriculture and fishing, to evaluate its growth potential.

The Giao Thuy area is also an internationally important conservation site. Giao Thuy district is the only Ramsar site in Vietnam; it was established in 1989. This area is thus officially acknowledged as the internationally important wetland by the Ramsar Convention (Ramsar, 1971). With the establishment of this site, conservation activities have been stimulated by both the national government and the international communities. Birdlife International and International Union for Conservation of Nature (IUCN) have been conducting different projects on habitat and wildlife conservation for the site (see Pedersen *et al.*, 1996 and Buckton *et al.*, 1999). These projects are mainly focusing on conservation of the wildlife and habitat in the local region. Though there is communal development research, including poverty alleviation strategy for the areas, the major output is still for the purpose of conservation.

Since the economic renovation in the late 1980s and during the 1990s, the system of governance and property laws has changed dramatically and part of the trend has resulted in the effective privatisation of productive assets such as agricultural land, forest and marine resources (Adger *et al.*, 2001:79). The most influential change reform is land reform, which changed the property rights of the peasant regarding their land and the use of natural resources in the area. From this land reform policy, both economic and conservation activities in the area have changed to cope with the new scheme of property rights (Adger *et al.*, 2001:259). Economic activities, however, are still the most important concern of the managemental system at the local level.

In Giao Thuy district, along with economic activities, the local authority has had to deal with an equally important concern – natural conservation. However, in spite of its high profile within Vietnam and internationally, conservation management at the site is still weak, and management practices are currently being implemented that threaten habitats in the nature reserve, and, thereby, reduce the biodiversity value of the site (Birdlife, 2001). As the mangrove system for generations is the living sources of local people, conflicts between economic development and conservation purpose have been emerging rapidly. These above mentioned issues lie into mangrove conversion to be agricultural or aquacultural activities. The functions and services provided by mangroves, and wetlands in general, do have positive economic value and this point is often ignored in the ongoing process of mangrove conversion (Barbier, 1993; Ruitenbeek, 1994; and Swallow, 1994). This poses the local authority as well as international concerns many issues to deal with.

The changes in both formal and informal institutions since the economic renovation have challenged the local authorities in both economic development and environmental conservation purposes. Furthermore, local livelihoods associated with the mangrove are endangered by climatic related extremes happened annually and the frequency of these events are increasing rapidly as the results of global change. Therefore, the local people have to create their own capacity to cope with the impacts of climatic extremes, which are increasing rapidly. As mentioned in the previous section, Adger *et al.* (2001), Huy *et al.* (2000) and Lutrell (2001) have conducted different research on both physical and social vulnerability to both climate change and institutional reforms. These studies have development different approaches to assess social vulnerability and livelihood resilience (Adger, 1997 and Luttrell, 2001). Applications have been conducted in Giao Thuy district and compared with different case studies in the South of Vietnam. The common conclusion is that there is a complex relationship amongst the impacts of climate change and institutional reform to social vulnerability and adaptive capacity of local people.

However, these studies were not focusing in social adaptive capacity that plays an important part in shaping livelihood resilience to local people and taking effects on social vulnerability. A better understanding on how does local authority deal with both internal and external changes to manage use of the coastal resource is essential. This is critical because of the difference in political and legislature schemes. Besides, the effects of climate change on social livelihoods are varied. This complexity is not consistent overtime. An assessment on how the local livelihoods and responses and recovery to disturbance can be used in coming management scheme.

Eco-tourism – a potential and challenge

With two major objectives as discussed above, tourism has become a promising idea for the local authority. As Giao Thuy is the first and only Ramsar site in Vietnam with a long coastline, which can be converted to be leisure beach, tourism is being a potential for the economic development strategy of not only the local region but also the vicinity. By developing the tourism sector in the local area, local authority expects to reduce the increasing rate of unemployment in agriculture by attracting a number of young labourers working in the business. Having realised that aquaculture is being a highly inequalising effects on the local society, local authority also expects tourism an equalising factor for the coming future. From that perspective, tourism is mentioned as one of the important developments in the local region.

The question is that how does this new trend affect the local capacity to cope with the changes of institution and the impact of climatic extremes? Tourism in developing countries often face problems like rapid population growth, workforce-pressure, lack of capital and foreign debts, which lead to over-exploitation of wild living resources, expansion of agriculture, forestry and aquaculture, and - with mounting pressure on the remaining habitats - to loss of biodiversity (Burgess, 1993). In Vietnam, ecotourism represents a small segment of nature-tourism in comparison to conventional tourism which has also been flourishing since the introduction of economic renovation. Since Giao Thuy is facing two different, sometimes conflicting, issues of economic development and natural conservation. Ecotourism has become a solution the local authority has been considering. As argued by Gössling (1999), ecotourism can contribute to safeguard biodiversity and ecosystem functions in developing countries. The research has also examined the possibility of ecotourim in the local area and its possible effects on local resilience. A picture of possible future of ecotourism along with other economic sector will be drawn to consider the possibility of this potential and challenging trend.

The objectives of the project

The objective of this project is to assess the changes in social vulnerability and resilience under the effects of economic renovation in Vietnam with implications of local society to cope with the impacts of climate and weather extremes and to test a proposed set of indicators. From this emerged the following specific questions:

1. What are the changes of local society under the effects of economic renovation and consequences from these changes? And how is the local society responding to the consequences?
2. What are the impacts of climate and weather extremes on social livelihoods? And how are these livelihoods recovering from the impacts?
3. How is the level of social vulnerability and resilience revealed and varied since the economic renovation?
4. How effective are the chosen indicators in addressing understanding the processes that influence level of vulnerability?

In order to answer the questions defined above, the following tasks will be undertaken to test the indicators and answer the above questions:

(a) Identify social livelihoods changes under the effects of economic renovation and analyse the increase of income and welfare inequality caused by newly-introduced livelihoods,
(b) Examine responses of local people to income and welfare inequality by immediate actions such as migration, labour allocation, etc.
(c) Examine the relationship between the limitation of access to resources caused by Ramsar designation and local livelihoods and how it has changed the level of resilience to both climatic extremes and external socio-economic changes.
(d) Identify the impacts of climatic related extremes to economic activities and analyse the way different social groups respond and recover from the impacts,
(e) Analyse changes in the level of social resilience of different social groups since the economic renovation by considering the implications to cope the impacts of climate and weather extremes,
(f) And finally, the policy implications in order to enhance social resilience for a long-term adaptation strategy are considered. Further research opportunities and an integrated set of indicators for a comprehensive assessment are discussed.

The indicators of ecosystem sensitivity, financial and human capacity, and the role of institution are tested during the implementation of tasks (a) and (b) from which implications to cope with climatic related extremes are identified and analysed by undertaking task (c and d). Findings of tasks (a), (b), (c) and (d) are the basis for argument implemented during task (e) and (f). Tasks (a), (b), (c), and (d) includes the following assessments and analyses.

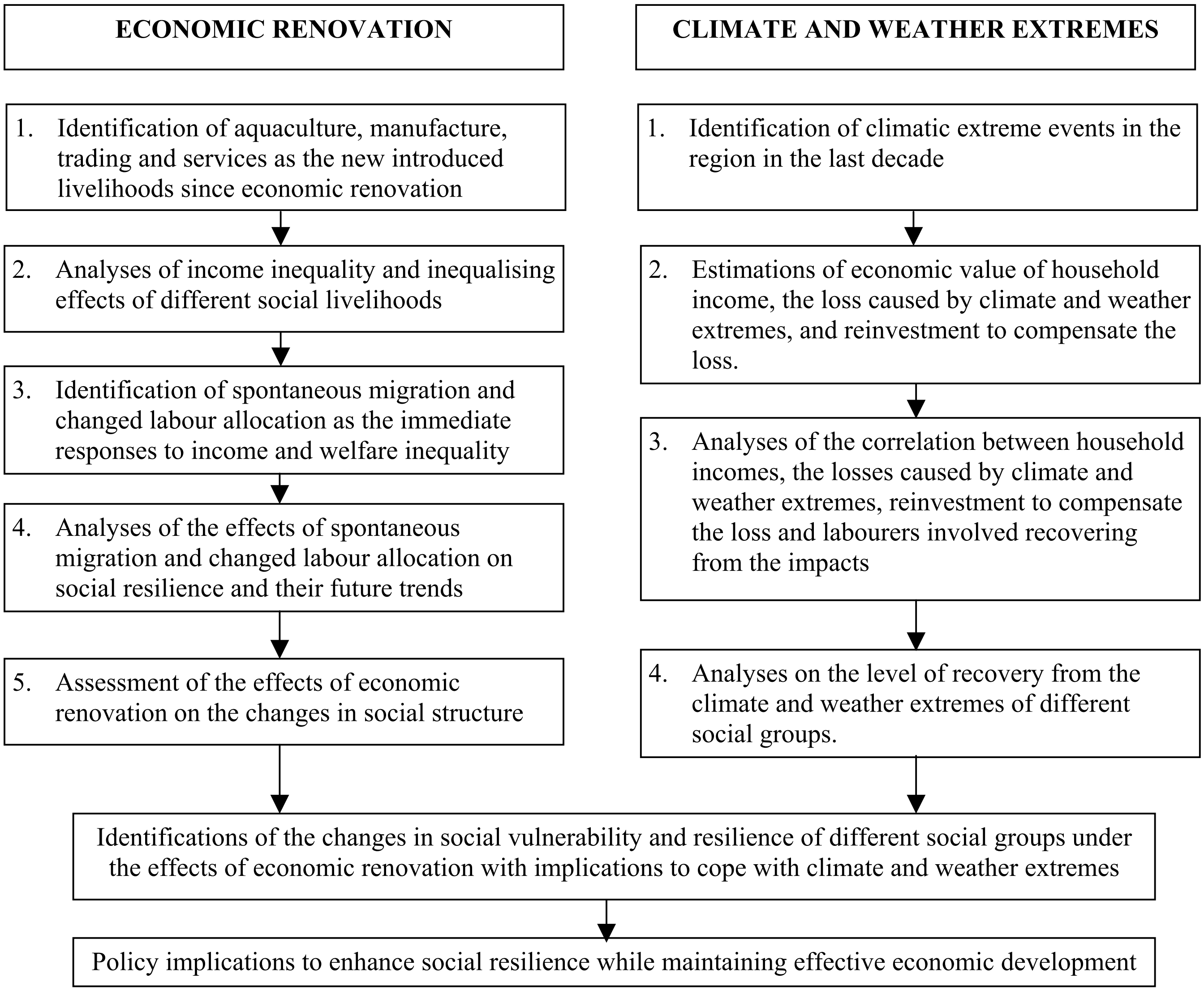


Figure 2.1. Framework for analyses

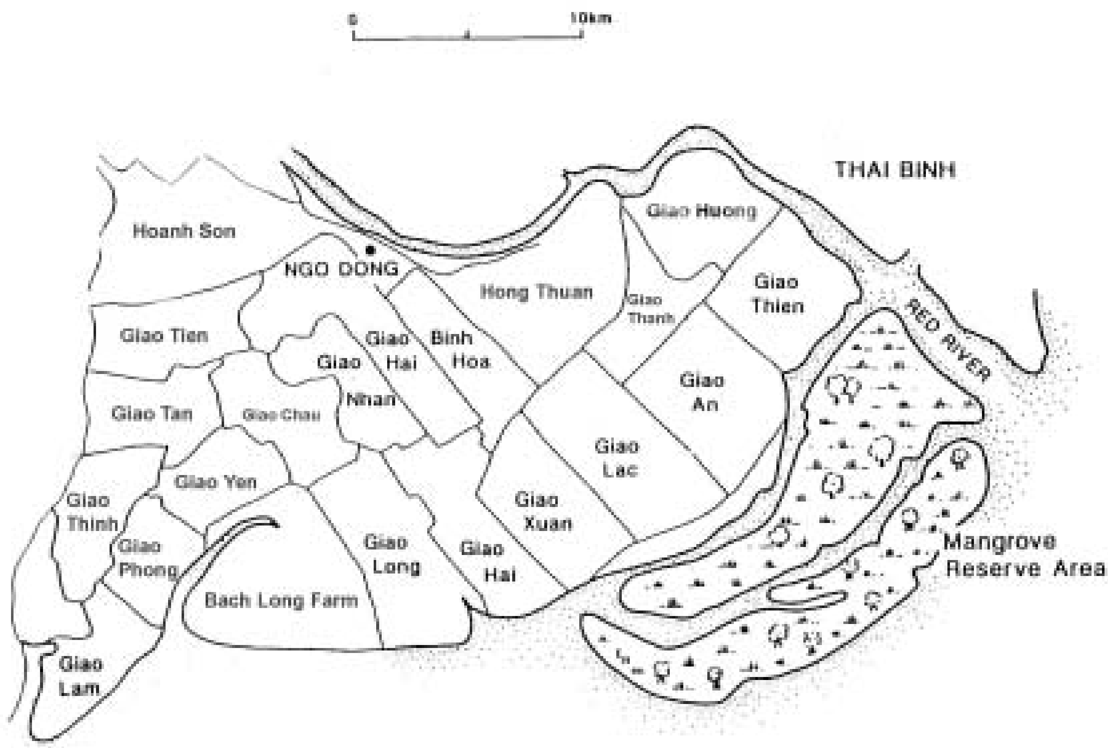
These assessments and analyses have been conducted in Giao Thuy district in North Vietnam. Data sources and methods for this study are discussed in the following chapter.

Data and methods

This section provides background and discussion of the methodology and techniques used in the study. Data used in this study has been collected during the period of 2000-2001 within the Red River Delta / Global Change Programme (Huy *et al.*, 2000).

Case study and data collection

In order to answer the research question as identified above, data for a case study in Giao Thuy district, Nam Dinh province, Vietnam (see figure 3.1) have been used. The area was selected on the basis of statistical and social representativeness that provides a typical account of the social structure. This selection allows a theoretical, analytical and descriptive basis to obtain a high level of insights and thoroughness.



Figur

The choice of study site was important for exploring the varying effects of both climate and weather extremes and diversity of institutions. Giao Thuy district is a resource-dependent community which has been affected significantly by institutional changes. Annual climate and weather extremes are given special considerations in local policy making as local livelihoods are strongly dependent on environmental condition. The impacts of both institutional changes under economic renovation and climatic related events have altered the social structure and adaptive capacity of the local area afterwards. The choice of Giao Thuy district allows a wide range of indicators to be investigated.

Giao Thuy district is one of the three coastal districts of Nam Dinh province. The population of the district was 196,761 people by the end of 1999 (see Table 3.1) and expected to increase by 1.58% per year (Giao Thuy Archive Office, 1999). There are 22 administrative communes in the district of which nine communes are located along the coastal line. Most of the inland communes are depending on agricultural activities, particularly rice production and some subsistence crops such as vegetable and cereals. The coastal communes, different from inland communes, are specialising in aquacultural activities such as shrimp farming, clam farming and salt production.

Table 3.1. Some socio-economic features of Giao Thuy district

Population	Population	196,761
	Labourers	96,953
	Growth rate	1.58%
Land-use	Cultivated area	19,674 ha
	Rice area	16,049 ha
	Shrimp pond areas	2,000 ha
Productivity	Rice productivity	12,993 / ha
	Rice yield per capita	540 kg
	Marine product yield	4,580 tons
	Fish	2,800 tons
	Shrimp	250 tons

Source: Giao Thuy Archive Office, 1999

The district holds of an area of mangrove of more than 12,000 ha covering on two accreted islands near the Red River mouth of which 2,000 ha has been converted to shrimp farms (Birdlife, 2001). The shrimp farming area is located near three communes, Giao Thien, Giao An and Giao Lac (see Figure 3.1) giving people in these commune the best opportunity to access the resources. Besides, a clam farming area has also been developed in the area on the open sea, which plays a considerable part in the livelihood diversity of the local people.

The case study was undertaken during the year 2000 (Huy *et al.*, 2000). Household surveys covered 171 households of which 28 households were involved in aquaculture and 143 households where there was at least a migrant. 40 shrimp ponds and 25 clam farms were sampled and interviewed. A summary of the number of households and individuals interviewed is given below.

Table 3.2. Description of the sample in the case study

	Interviews	Usable surveys
Household surveys	171	171
Individual interviews in household surveys	258	225
Shrimp pond surveys	40	40
Individuals interviews in shrimp pond surveys	72	62
Clam pond owner surveys	25	25

Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA), participant observations, elite interviews and collection of relevant documents were used in this case study. In addition, formal interviews with the local authorities were also undertaken. Relevant offices in the local District People's Committee were selected and interviewed including the (i) administrative division, (ii) agricultural division, (iii) aquacultural division, (iv) irrigation division, and (v) archive office.

Methods
Documentary analysis

Documentary analysis was conducted to achieve a contextual understanding of the policy and practice environment at the national and local level. Relevant documents, such as policy statements, technical reports, regulations and reports, related to the economic renovation in Vietnam were selected and analysed. Documents from both international and national institutions such as assessments by the World Bank, UNDP and Vietnam governmental reports were consulted to obtain subjective and objective opinions on the issues concerned.

Qualitative analyses

Qualitative analysis consists of any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification (Strauss and Corbin, 1990:17). This method is suitable to the purposes of the project as it provides a basis to consider causal links, predictions, and generalisation of findings from information obtained. Qualitative analysis results in a different type of knowledge than does quantitative analysis. Strauss and Corbin (1990) also argued that qualitative methods can be used to understand any phenomenon about which little is yet known. In this research, social vulnerability cannot be analysed using quantitative methods alone as mentioned in the previous chapter using qualitative method supports in-depth information that may be difficult to convey quantitatively. Qualitative methods are used to identify relevant variables that were later to be tested quantitatively.

Information used for qualitative methods was obtained by conducting RRA and PRA practices in which structured and semi-structured interviews played the most important role. Structured interviews were performed with ready-prepared questionnaires in which the detailed data and information will be gained. Although this is a leading interview it provides a basis for examining hypotheses developed in the study. Semi-structured interviews are non-standardized, less-structured, non-directive interviews, implemented in the field to encourage the local people to talk about their opinions on concerned issues.

Quantitative analyses

The analysis was engaged after variables and their relationships were identified by quantitative analysis. Quality of data and information were also tested during the qualitative analysis by using statistical analyses. This supports the use of quantitative data to statistically test the hypothesis set in the study. There were two main quantitative methods used in this project, income inequality analysis and correlation analysis.

Inequality assessment

Inequality assessment is undertaken to test the indicators of financial capacity within the community. Along with simple summary statistics, Gini coefficient analysis has been applied. The Gini coefficient is defined as the ratio of the area between the Lorenz curve for a distribution and the diagonal of equality to the total area between the diagonal of equality and the horizontal axis (Atkinson, 1970; Sen, 1973 and Cowell, 1977).

The Gini coefficient is calculated as:

$$G = 1 + \frac{1}{n} - \frac{2}{n^2 \mu}(ny_1 + (n-1)y_2 + (n-2)_3 + ... + 2y_{n-1} + y_n)$$

Where y_i = income of individual *i* in rank *i* ($y_1 \leq y_2 \leq .... \leq y_n$)

μ = mean income of sampled surveys

The first step for calculating the Gini coefficient using aggregated data is to sort the sampled units by the income variable from the poorest to the richest (Adger, 1997). The rates are then transformed into continuous variables and the cumulative proportion is calculated for both variables. The graph showing the cumulative proportion for the income variable (Y axis) and the cumulative proportion of the population is then prepared, and the Gini coefficient can be calculated as the absolute value of the result of the given formula.

Variable correlation analysis

The correlation between two variables reflects the degree to which the variables are related. The most common measure of correlation is the Pearson Correlation. Pearson correlation reflects the degree of linear relationship between two variables. It ranges from +1 to -1. A correlation of +1 means that there is a perfect positive linear relationship between variables. A correlation of -1 means that there is a perfect negative linear relationship between variables (Mendenhall *et al.*, 1993). This analysis reflects the significance in relationships between relevant variables in quantitative analysis conducted by the project.

Potential difficulties

The first problem the study may encounter was that "stated amount" in response to any given questions on economic activities of the local people maybe different from the "actual amount" they lost or gained. This could happen if the respondents are not committed in any social or financial obligations for answering the questions. This problem was minimised by careful research design and double-checking with a similar approach in the ready-made questionnaires. Furthermore, analysis the similarity among the samples helped reduce the unusable samples if there was any missing or inaccurate data.

Due to the potential inconsistency of data and information during the period of previous studies and this project, there were some conflicts in data collected that gave different results in the overall quantitative analysis. This has been taken into account during implementation of the study. Inconsistency has been eliminated by selecting homogenous sources of data and information for the analysis.

Finally, a problem could be happened of relationships concerned by the study is too complex to reveal using the data available. This will require a more comprehensive set of indicators to be tested. During this study, the effectiveness of the chosen indicators is discussed and a broader set of indicators is also proposed.

Indications of vulnerability and resilience under the effects of economic renovation

This chapter aims to test the indicators set in the Chapter 2. The chapter starts with an introduction of the economic renovation – *Doi moi* – followed by its effects on local livelihoods. Changes in land management which leads to higher productivity, income inequality caused by the newly-introduced economic sectors, spontaneous migration and labour reallocation are examined in this chapter. Finally, the possible future trend of the most significant feature – spontaneous migration – is discussed. The underlying issue in this chapter is whether the various indicators used can capture the processes affecting trends in vulnerability and resilience

Economic renovation – *Doi Moi*

The significance of *doi moi* in Vietnam during the mid 1980s lies in the promotion of major economic reforms from the communist regime which lasted for almost 50 years to a market-oriented economic development (UNDP, 2001). Tracing back to the history of this remarkable process, early attempts to turn the former centrally planned economy to an open-market economy were begun in the early 1980s. Evidence emerged from the introduction of market-based incentives structures, such as policies which allocated land contracts to agricultural households all over the country. However, the landmark was in the Sixth Party Congress in December 1986 with the adoption of the term *doi moi* (a *renovation* strategy), which promoted the will to reform both domestic economic towards a more market-oriented economy, and the tendency to "open the door" to international community. Three main orientations of *doi moi* process are a move from a centrally planned economy to market economy, a democratisation of social relations and the opening up of doors to non-socialist countries (Vietnam Communist Party, 1991:147).

In Giao Thuy district, formal institutional changes which are associated with the governmental policies in economic development have a marked effect on access rights and are raising several social issues. The Law on Land-use, along with other formal policy changes, has had an important effect on the level of social vulnerability and resilience. It has improved food security, productivity and access to credit. Besides, though there are increasing welfare inequalities as a result of the development of land markets and misapplication of the policies.

Based on documentary analysis and case study interviews and survey data, the most significant policies are the Law on Land-use and changes in cooperatives system. The Law on Land-use has conducted reallocation and privatisation of agricultural land. The reallocation process has been implemented on the basis of population and agricultural land available at time of implementation. The Law on Land-use have given the property rights to use, transfer, sell, buy, inherit, mortgage the land which encourages the land users the motive to get the optimum benefits from their land. The achievements of the new Law on Land-use have improved security, productivity and access to credit in rural area. However, income inequalities have been observed as a considerable raise along with the consequences of the development of land markets and misapplication of the policy. The dismantling of cooperative system has lessened restrictions on markets and supplies of agricultural inputs giving the land users different alternatives to utilise their land. This has improved the crop management and agricultural service system in the whole country and particularly significant in rice production. The dismantling of cooperative system has also increased various potentials for agricultural profit and local vulnerability amongst the poorest.

Table 4.1. Policy changes and its effects on social livelihoods

Policies	Context of formal policies
Land reform	Allocation and privatisation of agricultural land. Allocation is based on population and agricultural land available at time of implementation Property rights to use, transfer, sell, buy, inherit, mortgage the land
Dismantling of the cooperative system	Lessening of restriction on markets and supplies of agricultural inputs Improve the crop management and agricultural services
Open market of employment	Removal of governmental guaranteed employment
Agriculture mechanisation	Changed agricultural practices

Source: adapted from Luttrell, 2001

Income inequality has also been increased by the development of aquaculture and extensive fishing in the area. Having given the natural resources for exploiting the marine products on the mudflat, shrimp and clam farming have become most beneficial businesses in the region. These new-introduced livelihoods have only been flourishing under the encouragement of the economic renovation. Open market to other countries in the region allows the marine products being exported with high profit. Higher demand of marine products from urban areas in Vietnam is also an advantage for the development of aquaculture. Besides, the local authority has also addressed the importance of aquaculture and fishing in poverty alleviation in the region. These are the basis for the rapid increase in investment and production of aquaculture and fishing in the area. However, these are also increasing inequalising effects across the community.

Table 4.2. Formal policies of the economic renovation process in the last two decades

	Date of promulgation	What does the policy involve?
Instruction 100	January 1981	Reallocation of cultivated land to agricultural household and specific responsibility of household to the agricultural system of the local region
Decision 10	April 1988	Passing the rights of agricultural land-use to the households Contracting the agricultural activities with the labour and groups Changing to agricultural contracts between the government and household Acknowledging the rights to transfer these facilities in the market.
Decision 5	June 1993	Changing agricultural structure to be multi-sectoral agricultural system

		Reallocating cultivated land and passing rights of land-use to the households Acknowledging the rights of households in changing, transfer, leasing, hiring, inheriting and mortgaging land Changing the rural economics in combination with industrial and service development. Changing seed and breed structure to increase the effectiveness and utilize the labour-force in agricultural system, promote non-agricultural sectors such as forestry, aquaculture and to stimulate household economics in cooperation with cooperative
Land Law	January 1997	Rights to inherit, mortgage, transfer, exchange and lease land

Source: UNDP, 1999 and Vietnam Government Report, 1995.

Evidence from Giao Thuy district has revealed several issues covered by the project. Firstly, income and welfare equality has been increasing ever since the economic renovation. This is caused by the newly-introduced livelihoods along with the increased economic diversity of the area. Specifically, extensive and semi-intensive[1] aquacultural activities have made the whole population better off but the benefits have not been distributed equally. Secondly, along with the income inequality, changes in social structure, labour allocation led to a part of population migrate to other areas to find jobs. This situation has left an unbalanced distribution in labour allocation in agricultural sector. Loss of skills in agricultural activities and unbalanced diversity of income sources have posed the local population a new challenge to cope with both institution and environmental effects. These trends are now discussed in the following section.

The relevance of the indicators and influence of formal policies on livelihoods

As mentioned above, the four major changes of the economic renovation process have a number of effects which are reflected by the level of inequalising effects. These changes are evidenced by the framework of indicators set in the Chapter 2.

The study first examined the indicator of land managed by the community. How has the economic renovation affected rice production through the Law on Land-use? In rice production, the economic renovation process has reallocated and privatised rice production land on the basis of the available population at the time of implementation. The changes in the agricultural cooperative system have left the peasant the decision-maker in rice production. The peasants now are able to plan and cultivate their land to optimise the productivity of arable land allocated. Agricultural materials have been supplied from different sources. The supply, in response, has developed a positive competition for quality and price. The role of the agricultural cooperatives now lies into the general planning and services for timing and irrigation system for the production. Both of these changes in land use and in the cooperative system have lead to a remarkable increase in productivity and quality of rice production in the area (Figure 4.1).

[1] In Vietnam, extensive shrimp farming is based on the natural resources without any addition of agricultural products introduced to the practice. Semi-intensive shrimp farming is basically similar to extensive shrimp farming with the introduction of some agricultural products such as feed, and aims to raise tiger shrimp for higher income output (Anon, 1994b).

This is a significant achievement of the economic renovation giving every rural household stable employment and relatively high productivity. The productivity increase since the early 1990s is given in the following figure.

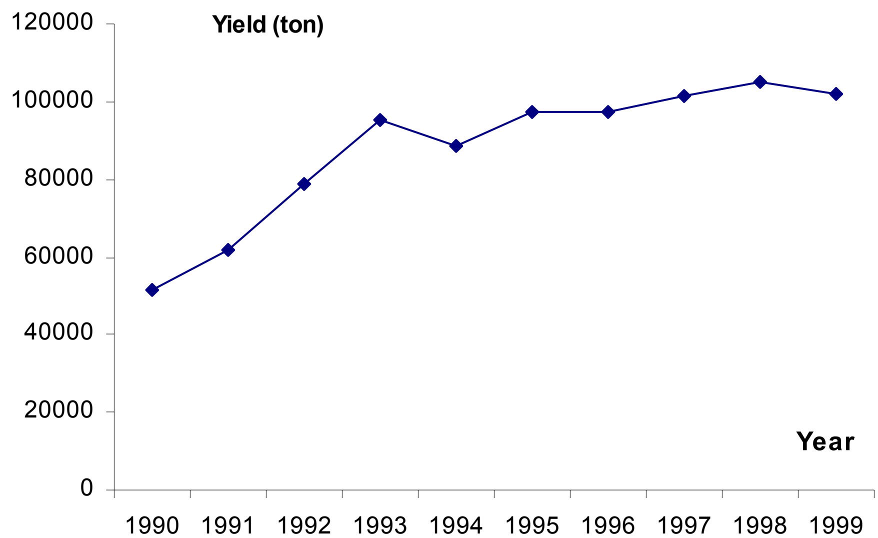


Figure 4.1. Rice yield in the area during the implementation of economic reform
Source: Giao Thuy Archives Office, 2000

There have been also some down sides concerning the level of social vulnerability. The Law on Land-use, which reallocated the land equally on the basis of the population at the time of implementation, has also give the right to use, transfer, sell, buy, inherit and mortgage land. This influential policy gives an open opportunity to the development of a land market. This informal market, however, may well increase inequality in land ownership though the production of the reallocated land per capita remains stable. Land inequality has not been emerged during the study, as the land market in the research site has not been developed. However, this remains a concern for the management of land in the future that poses the local authority a challenge for years to come.

The formal policies in dismantling and changing the structure and functions of agricultural cooperative have also revealed both positive and negative sides to the rice production and other related agricultural activities such as household breeding or agricultural paid jobs. The cooperatives have been promoting the capacity of land and crop management and providing agricultural services to the household level. This has resulted in the increased potential profit and increase in productivity of rice production as mentioned previously (see Figure 4.1). However, these changes have turned the agricultural cooperatives from an institution providing subsidies in rice production and related agricultural activities to a form of service company. This has also eventually established a form of market of agricultural materials in the local area. Priorities and better products have given to the population which obtains of a stable and sufficient financial capital for the crops. At the time of study, the operation of cooperatives has not been extensive, partly because weak management remained from the centrally planned regime, so that products and services have been allocated relatively equal to the local population. However, as the nature of market-oriented economy develops, the operation of agricultural cooperatives will be expanded and more priorities in product supply and services will be given to the better off. This will increase the inequality amongst the poorest and the disadvantaged of the population.

The indicator of human capacity is explored by considering labour reallocation in the region. Under the centrally planned economy, agricultural paid jobs had been allocated by the cooperative. The work done was recorded and salary was given in the form of rice to the household. This was another form of the subsidised system under the former economic regime along with subsidies in rice production operated by the cooperative. Since the introduction of economic renovation, these subsidies have been removed and the open market is developing rapidly giving the agricultural labourers opportunities to work in their extra time. By the early 1990s, this open market contributed a more effective labour use in rice production and contributed significantly to the increase of rice production. However, as a result of productivity increases, the overall income in the region has been lifted dramatically. The consequence is agricultural mechanisation which has been introduced in rice production activities in the last few years. Agricultural paid jobs have become scarcer in the local area. This led to an immediate effect. The unneeded labourers have to seek for jobs to cover the extra time and earn more income to cope with the increasing living cost. The response is spontaneous migration to other areas to look for jobs.

By looking at the changes in income inequalising effects, the indicator of financial capacity has been analysed and tested. The newly-introduced livelihoods, aquacultural practices, registered fishing, manufacturing and services in the local area, have justifiably placed a strong inequalising effect on the society. The increasing development of aquacultural group has altered the balance of financial capacity within the community. Aquacultural activities have been developing rapidly since the introduction of new policies brought about by the economic renovation. The study particularly concerns to the way in which institutional changes have shaped these new livelihoods.

Aquacultural activities, which include shrimp culture and clam farming, were first introduced to the area in the early 1980s and have been developing rapidly ever since. During the 1980s, aquaculture was based on extensive farming methods with relatively high productivity from a number of shrimp ponds managed by the governmental office. When the land policy was implemented in the local area, the shrimp-farming area was reallocated and privatised to the households who were able to get hold of a specific area of the shrimp ponds. As the land policy encourages the farmer to optimise the profit from the land, shrimp pond owners have expanded shrimp farming during the late 1980s and early 1990s. The process of economic renovation is also indirectly encouraging the development of shrimp farming. By implementing an open-market economy to the international community, products from Vietnam can be exported bringing a large amount of foreign currency to the country. Marine products are also being exported to China, Taiwan, Japan and some other countries in the region. In short, the economic renovation has encouraged and promoted the high-income production in the local area bringing very high profit to the shrimp and clam farmers (see Table 4.2).

Table 4.2. Summary statistics of Giao Thuy sample surveys

	Household information	
1	Family size (people in the household)	4.64
2	Rice cultivated land (ha)	0.24

3	Income per capita (000vnd)	4,256
	In UDS	304
	Breaking down by income sources (%)	
1	Rice income	25.16
2	Income from other plantations	1.84
3	Income from household breeding	23.09
4	Income from aquacultural activities	17.23
5	Income from fishing	19.01
6	Income from trading, services, handicraft	5.69
7	Wages	3.56
8	Remittance income	4.42

The development of aquaculture in Giao Thuy, however, has some negative effects on both the environment and society. The expansion of extensive shrimp farming in the early 1990s led to a very apparent consequence. Mangrove has been cut down. Along with this was the decrease of productivity of natural products such as natural prawn and fish, which are also harvested products of the shrimp farm areas. Adverse changes in irrigation system and wave activity caused by the degradation of mangrove has also emerged clearly (Anon, 1994). This poses the local authority an immediate problem.

As the habitat of natural shrimp was being degraded, productivity of extensive shrimp farming was going down dramatically during the early 1990s. The solution was to change to modified extensive[2] and semi-intensive shrimp farming which appears to be more sustainable. The introduction of black tiger shrimp also took place during this time to compensate the loss of natural prawn productivity. Meanwhile, along with shrimp farming, clam farming in the open sea along the coast of the district has been also developing and attracted a number of farmers investing in the business. Though the investment is high, the high return and simpler techniques in comparison to the shrimp farming have been the basis for clam farming development in the area.

Though there are various rewards from aquacultural activities, the local welfare inequality implications of this trend have gradually emerged. The beneficiaries from shrimp and clam farming in the local area are the households who are able to obtain of a considerable financial capital. This has led to marked inequalising effects on the society.

Both of these aquacultural practices have engaged a part of the population and numerous labourers The return has drawn a network of services around the shrimp and clam farm. These services involved supplying of seed, feed and materials for aquacultural practices as well as consumption of the harvested products. The development of the employment market has also opened a number of opportunities to work on the farms as well as other associated works. However, these opportunities are limited while the need for employment is increasing.

[2] Modified extensive is large ponds where mangroves and intertidal areas are enclosed by dikes. The enclosed mangrove forest usually dies after three to five years. This system is dependent on both natural and artificial stocking with crab, shrimp and fish. This method uses fish and the shellfish for supplementary feeding (Anon, 1994b).

The changes in both traditional and newly-introduced livelihoods have led to the same trend in the society, spontaneous migration. Spontaneous migration has emerged clearly after the economic renovation. The migrants are mostly men who are the main labourers (men aged from 16-45) in the households. The absence of men has taken agricultural skills away from the rice production and weakened the social structure in the local area. These significant changes in the local social structure and labour allocation system have a number of effects on the level of social resilience. This trend is expected to increase in the next decade as a result of on-going consequences of economic renovation as well as population growth. An in-depth analysis of income and welfare inequality, local labour allocation and spontaneous migration is now undertaken.

Income and welfare equity

Figure 4.2, based on the 171 household surveys in Giao An commune, clearly shows the way aquaculture contributes to the level of inequality within this coastal community. The Lorenz curves show the distribution of income across the population with the straight line indicating pure equality of income. The solid curve shows that the households investing in aquaculture are all amongst the richest (have the highest income) in the community. This means that the curve showing the income distribution for all households is further away from the equality line than the curve showing income distribution for non-aquaculture households. Aquaculture is a major contributor much to income inequality.

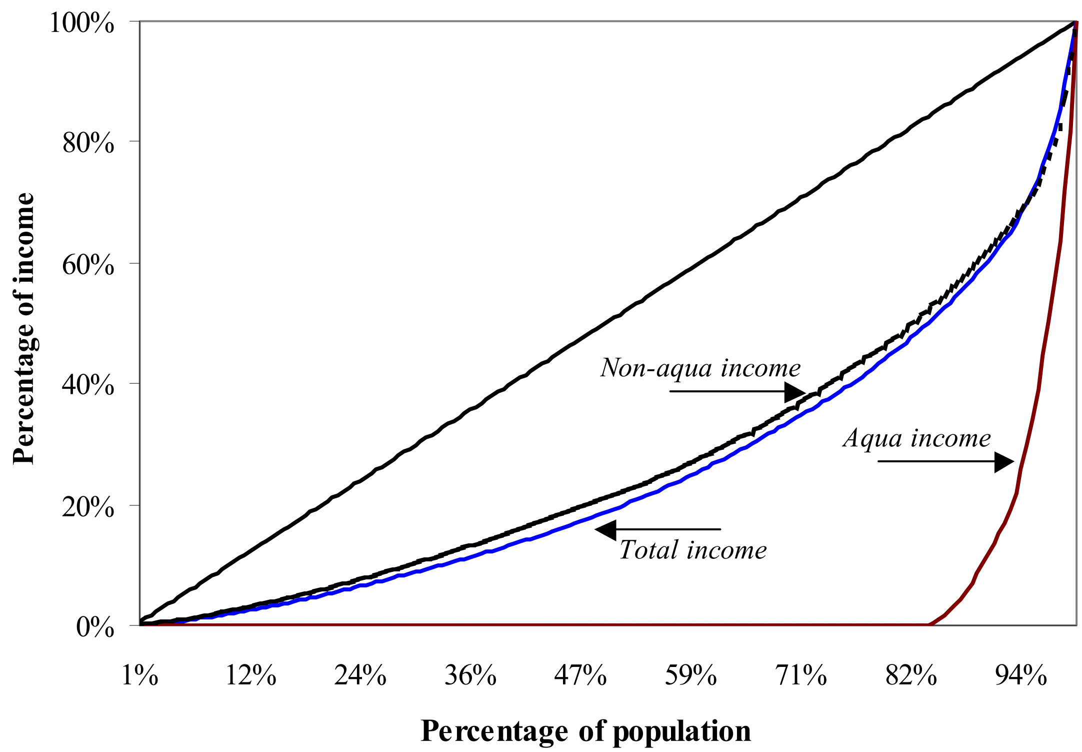


Figure 4.2. Lorenz curves for measurement and decomposition of inequality in Giao Thuy

This result is confirmed by an analysis of Pseudo Gini Coefficients[3]. The Gini Coefficient measures the departure between the observed income distribution and the equal distribution of income across the community and is an indicator of income inequality across all income sources. Pseudo Gini Coefficients decompose the contribution of separate income sources to income inequality.

Table 4.3. Decomposition of per-capita income inequality

	Overall	Aquaculture*	Non-aquaculture**
Gini coefficients	0.196	0.343	0.164
Income per capita(795 individuals)	4,287	765	3,523
Income per household (171 hhs)	19,933	3,555	16,378
% share income		17.83%	82.17%
Contribution to inequality (%)		31.17%	68.83%
Inequalising effects		+	-

Table 4.3 shows a calculation of inequality decomposition with only two sub-groups (i) aquaculture and (ii) non-aquaculture. The result shows that income share of aquacultural activities over the total communal income is only 18% but the contribution to inequality is over 31%. The final row shows the inequalising effect of the income source which is either negative **(-)** signifying that the subgroup of income contributes less to inequality than its share of income; or positive **(+)** signifying that the income source contributes more to inequality than its share of income.

Based on the contribution to inequality decomposed by income sources as highlighted above, not only income from aquaculture have been contributing greatly to the overall inequality but also, generally, aquacultural community is one of the population portion causing inequality in the area. The assessment, however, is undertaken only a single subgroup. The question set above is not completely answered as the other subgroups and their specific contribution to inequality is needed for an integrated assessment. The following is more detailed inequality decomposition with assessment based on the range of income sources of the sample community.

Table 4.4. Decomposition of per-capita income inequality by different income sources

	Income sources	Pseudo Gini coefficients	Share of income	Contribution to inequality	Inequalising effect
1	Rice income	0.031	25.1%	4.0%	-
2	Other plantations	0.416	1.8%	3.9%	+
3	Breeding	0.114	23.1%	13.4%	-
4	Aquaculture	0.343	17.8%	31.2%	+
5	Fishing	0.371	18.9%	35.4%	+
6	Manufacture and service	0.457	5.6%	13.3%	+
7	Wages	0.148	3.5%	2.7%	-

[3] Pseudo-Gini's coefficient measures the disparity between income groups by arranging income in order and applying the same computation method as Gini's coefficient.

8	Remittance income	-0.175	4.2%	-3.9%	-
	Overall Gini	0.196			

Note: **(+)** Income source contributes **more** to inequality than share of income
(-) Income source contributes **less** to inequality than share of income

The detailed decomposition has found that not only is aquaculture contributing to inequality but also fishing (35.4%) and manufacture (13.3%) have been contributing to the overall trend in inequality. Income from other plantations also takes its portion to contributing to overall inequality but it is not considerable, only 3.9%. It is assumed that the contribution to inequality caused by plantations is the result of several households who are planting cereal crops in the reclaimed land of the district. This can be considered as one of the new economic sectors in the district.

From this analysis, some initial conclusions can be drawn:

- Rice cultivation, breeding and wages which are "conventional occupations" of the rural area contribute less to inequality
- New occupations, aquaculture, registered fishing and manufacture and services of which the first two are the two major sectors contributing much to overall income inequality, also emerge as main income sources of the community.

Further on the analysis of the resource use and the impact of conversation purposes, an assessment on the introduction of the protected area – Ramsar site – on the economic and social conditions of the area, especially the access to natural resources is now undertaken.

Ramsar designation and access to natural resources
Ramsar establishment and the threats to conservation

The only Ramsar site in Vietnam, Xuan Thuy Natural Wetland Reserve is located in Giao Thuy district. The site was designated in 1988 and established officially a year later. This estuary contains the last significant remnant of mangrove and mudflat habitat along the coast of Viet Nam. These mangroves are undoubtedly of considerable importance in maintaining fisheries production in the area. The estuary provides critical habitat for large numbers of migratory waterbirds. According to Ramsar Convention (1992), there are at least eight Red Data Book species of waterbirds (*Pelecanus crispus*, *Egretta eulophotes*, *Platalea minor*, *Tringa guttifer*, *Limnodromus semipalmatus*, *Eurynorhynchus pygmeus* and *Larus saundersi*).

Before the 1990s, the site was heavily exploited and overused by local residents. Activities such as fishing, land conversion to aquaculture (cutting mangroves) and then to agricultural fields were being practiced extensively. Another activity was collection of natural products and hunting of shorebirds which also jeopardised the reserve. After the establishment of the Ramsar site, 6,000 ha of the area was strictly protected from these activities (see Figure 4.3). However exploitation outside the strictly protected area proceeded unchecked. Under the pressure of population growth and land limitation, the local government had established a settlement area, which later becomes an administrative commune of the district, during the 1990s to include a plan to settle 400 households on the area. The designation also scaled down the area of former development plans that tended to converse the area into rice paddies and settlements. There are 6,000 ha strict nature reserve acknowledged covering all of Con Lu island and a part of Con Ngan island (see Figure 4.3). According to the Ramsar Information Centre (1992), market hunting of shorebirds was terminated, and an area of 750 ha was replanted in *Kandelia candel* mangroves.

There are several considerable threats to the conservation purposes of the site. Construction of sea dykes and reclamation of mangroves and mudflats for aquaculture ponds and agricultural land are the major issues concerned by conservationists. This has also been part of a local government policy. Shrimp pond construction started in 1982 and by 1989 almost all mature mangrove stands on the mainland and on Con Ngan had been cut down and cleared for shrimp production (Birdlife International, 2001). Many extensive farming shrimp ponds were converted to rush fields, and a small commune developed. During this period of time the area was becoming apparent that the extensive shrimp farming was not sustainable. Even honey production from the mangrove forests fell dramatically. A strict nature reserve was established over part of the site and this alleviated some pressures on this part. There continue to be difficulties in managing Xuan Thuy Wetland Reserve because no institutional management framework has been identified or established.

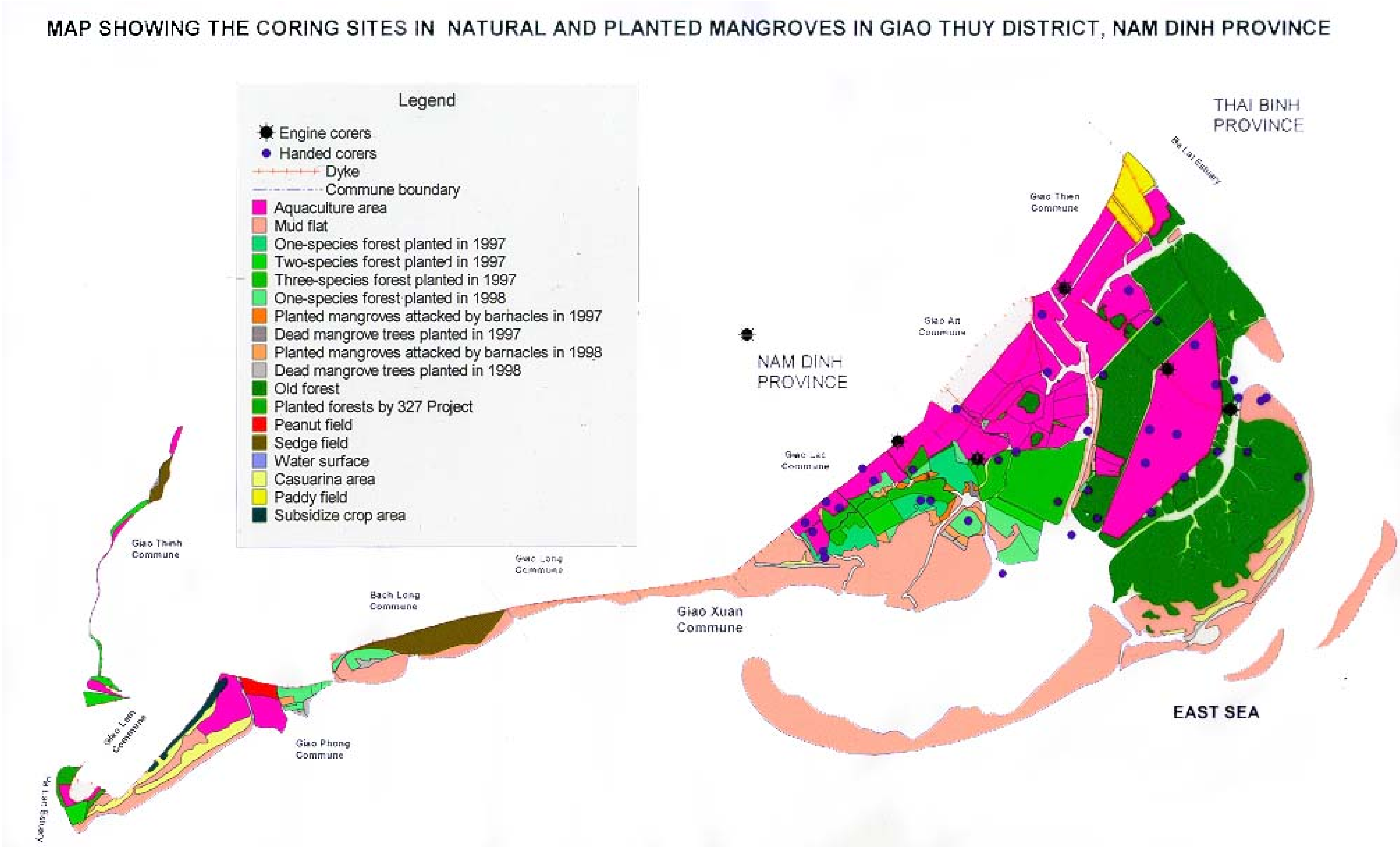


Figure 4.3. The coring sites in natural and plated mangroves in Giao Thuy district, Nam Dinh province

Conservation, institutions and access to natural resources

The effects of the evolving institutional framework ion Vietnam and the designation of Ramsar site in the local region are now analysed based on documentary sources and interviews.

Having committed to conserve the site, there are different ministries responsible to the management and use of the site. The Ministry of Agriculture and Rural Development (MARD) has responsibility for the management and development of forests, including mangrove. Forestation, which has taken place in the coastal zone, has been within different programmes such as Programme 327. However, the Ministry of Fisheries (MoF) extends to the management of marine resources found in mangroves and the intertidal area (Birdlife, 2001). The protected area system is managed by MARD, while responsibility for administration of the Ramsar Convention is of the Ministry of Science, Technology and the Environment (MOSTE). Furthermore, nature reserves are a category of special-use forest according to the management regulations issued by the Ministry of Forestry. Under these regulations, it is prohibited to "change the landscape, introduce grazing domestic animals, introduce any plant or animal species and to engage in activities affecting wildlife" (MoF, 1987).

Although the entire nature reserve is zoned as strictly protected, the rights of local people to engage in aquaculture, collect marine products and graze domestic animals within its boundaries with unrestricted access and with impunity remain a consideration. The impact of these activities on wildlife remains unquantified. Competition may exist for shellfish between shorebirds and local people. As the specified management system is clearly not being implemented, it appeared to be more appropriate to try and regulate human resource-use by zoning the protected area to ensure that particularly important habitats and roosting and feeding areas for birds are managed in accordance with the area's primary purpose and in line with IUCN guidelines (IUCN, 1994). In aquaculture, during the period of 1989 and 1994, there was a 130% increase in the number of aquacultural ponds on Con Ngan and Con Lu islands (Nguyen Hoang Tri, 1996). These trends have appeared to be continued rapidly.

Table 4.5. Status of local access to natural resources before and after Doi Moi and Ramsar designation

	Before Doi Moi and Ramsar designation	**Current time (as time of research by the year 2000)**	**Effects on the level of social resilience**
Formal regulations by Ramsar managemen t board	Not available	6000 ha is under strict protection	Limited access lead to decrease the number of locals who totally depend on mangrove. On the other hand, it increased inequality in whole community which shrimp pond owners gain
Formal policies over use and access	Free access to the mangrove in the area. There was no regulations or	Environmental protection: water resources and soil quality	Increase social resilience by higher productivity and stability of rice production. Loss of resilience by

to the natural resources	economic tool to control the exploitation of the area.	Protection forest: maintaining the natural balance and the ecosystem, serving the need of scientific study and protecting the historical vestiges Production forest: exploiting timber and forest products including special animals.	limited employment, loss of skills and changes in social structure due to changes in labour allocation and new trends, such as spontaneous migrations.

The regulation set by the commitment of conservation by the Vietnamese government has changed the number of beneficiaries to the natural resources in the local area. As free access had been given before the designation of the Ramsar site, the local residents had benefited from the mudflat area by collecting marine products such as shellfish, crabs, seaweed, etc. These products have taken a large portion of income source of the households in the district. Since the designation of the Ramsar site, though the rights to access and use of local resources, apart from the strictly protected area, remain unchanged, the number of beneficiaries has changed dramatically. The analysis of the beneficiaries of 171 households before and after the designation is given below:

Table 4.6. Beneficiaries before and after the designation of Ramsar site

	Before the designation and economic renovation (late 1980s)	**After the designation (2000)**
Number of household benefiting from the mudflat	171	52
Individuals collecting marine products from the mudflat	208	76
Mean income gained from the mudflat per month	200 kg of rice* (171 households)	< 50 kg of rice or 150,000 VND (52 households)
Percentage of income from mudflat out of total income of the household	12.48% (171 households)	<5% (52 households)

Note:
* The research used rice as a measure for the value of marine products collected by the households as marine products were not marketed before the designation of Ramsar site

A substantial decrease in access to the natural resource is emerged after the economic renovation and Ramsar site designation. This has a number of hypotheses for this decrease. Firstly, the restriction of Ramsar site has scaled down the area local people can have access to for collection of marine products. Secondly, aquacultural area has been privatised for shrimp and clam farm owners. This also reveals the inequality in access to the natural resources along with income inequality discussed in the former section. Thirdly, changes in labour allocation, free market of employment and diversity of local livelihoods have also drawn a large number of labourers to different works. Collection of marine products in the mudflat has changed from one of the main income source to a minor work during extra time of the households. This is a considerable loss for the local area, which has posed a challenge for the authority to benefit local residents from their own natural resources. To consider further and test the hypothesis we have developed above, an in-depth analysis is now undertaken.

Table 4.7. Access to the natural resources in local area before and after the Ramsar designation and economic renovation.

		Before the designation and economic renovation (late 1980s)	After the designation (2000)
	AGRICULTURE		
1	Area of cultivated land	10,681 ha	10,856 ha
2	Number of land-plots per households	2.8	3.2
3	Cultivated land per capita	1,200m^2	1,000m^2
4	Productivity per capita	231 kg	538 kg
5	Labourers per households	3.4	3.1
6	Labourers working in agriculture	3.4	1.9
7	Mean agriculture income per capita (VND)	n/a	766,000
	In USD	n/a	54.7
	AQUACUTLTURE		
8	Area of aquacultural ponds	250 ha	2,158 ha
9	Number of aquacultural ponds	5	65
10	Number of labourers involved to aquaculture	25	452
11	Mean aquacultural income per capita	1,800,000	1,289,000
	In USD	200	92
	FISHING AND FREE PRODUCT COLLECTION		
12	Local area with free access to natural resources	12,000 ha	4,202 ha
13	Number of beneficiaries who have been using the free access area	20,000 (approx. 22% of the whole community)	12,000 (approx. 12% of the whole community)
14	Mean working hours in free access area per month	110	50
15	Mean income per capita from fishing and free collection	approx. 200 kg of rice	Approx. 50 kg of rice

The designation of Ramsar site has placed a pressure on the collector community. The area the collectors in the local area have been exploiting the marine products has been narrowed. Ramsar regulation has designated 6,000 ha of protected area. This area is mostly situated on the Lu island which is the habitat of internationally important waterfowl. The ecosystem of mangrove system on this island is also relatively untouched. All activities including collecting marine products have been halted. The area is under control of both Ramsar management board and local authority. This has left the local community around 6,000 ha, mostly on the area Ngan island, for local livelihoods such as shrimp farming, fishing and marine products collection. However, since the land policy has been issued, shrimp farming is also privatised giving the shrimp pond owner the right to manage their shrimp farm. The area of shrimp farming on Ngan island covers more than a third of this area, 2,158 ha. That is to say, there is only around 4,202 ha free access area left for marine product collection. As the development of aquaculture and clam farming is expected to increase rapidly, this free access area will also be scaled downed.

Both the regulations of Ramsar site and development of aquaculture have contributed to the welfare inequality in the area. Welfare inequality here not only refers to the income the local residents can earn but also the natural resources they have access to. Development of aquaculture, which has shown a highly inequalising effect in income inequality as discussed in the previous part, has also contributed to the inequality in access to the natural resources. This trend is expected to increase in the coming future. Profit gained by the development of aquaculture may richen the area as a whole from which poverty alleviation strategy of the local region is proceeding. However, amongst the poor, less access to the natural resources will weaken financial capacity as well as the ability to get hold of full employment of the disadvantaged. The result is a decrease in the level of social resilience to cope with institutional changes and climatic extremes of the poor.

In short, the economic renovation process and designation of Ramsar site have a number of effects on the society as a whole

- Both the economic renovation and Ramsar site designation have benefited the community as a whole by raising the development of aquaculture, which helps proceed the poverty alleviation strategy. However, the beneficiaries are amongst the aquacultural community only.
- The rest of population, which include a large number of marine product collectors and rice farmers, has been in difficulty in access to the natural resources.
- Economic renovation has changed the agricultural management system, which has lessened the labourers required for rice production, by changing the function of cooperative and agricultural mechanisation.
- Non-aquacultural community has to seek for a solution to find more jobs and income.

Spontaneous migration has become a popular trend that has a number of effects on the level of social resilience. Its trends in the future are also of important consideration.

Human resources allocation and spontaneous migration
Use of labour force in local society

The level of inequality is not only revealed in the income output from different economic sectors. Under the changes of Law on Land-use and agricultural mechanisation, labour allocation within the local community has changed along with the trend of livelihoods diversity. The study considers the second factor of welfare inequality within the area by examining the labour distribution in aquaculture and non-aquaculture subgroups. As discussed above, aquaculture has been proved to be the major economic sector that contributes to income inequality. The question is if the labour input is also concentrated in this sector with effects on the overall welfare inequality within the region.

The study examined labour allocation in two different groups: aquaculture and non-aquaculture, which refer to the households who are and are not involved in aquaculture, respectively. Main labourers who are working on shrimp farming and agricultural activities are the main concern along with the work hours spending in different economic sectors. A statistical summary is given below from the household surveys.

Table 4.8. Labour allocation in two subgroups: aquaculture and non-aquaculture communities

		Aqua community	Non-aqua community
1	Mean of number of people in the households	4.64	4.65

2	Mean of total cultivated land (m^2)	2,490.86	2,359.47
3	Mean of number of major laborers	2.64	2.71
4	Mean of number dependents	2.00	1.95
5	Aquacultural community		
	a. Main aquaculture labourers	2.25	-
	b. Main labourers for agriculture and other livelihood	0.40	-
6	Non-aquacultural community		
	a. Main labourers for agriculture	-	1.75
	b. Main labourers for other livelihoods	-	0.95
7	Work hours in aquaculture per week	47.5	-
8	Work hours in agriculture per week	28.4	27.6

From the summary, there is slight difference in the mean number of people in a household as well as the number of main labourers and dependents. Main labourers here refer to the people who are in the age of 18-55 and working on a daily basis in different economic sectors in the area.

The main difference between the aquaculture and non-aquaculture groups lies into the number of main labourers involving to aquaculture and agriculture and particularly the work hours spent in aquacultural activities. In the aquaculture group, there is a substantial difference between the number of labourers working on shrimp farming while the number of main labourers working on agriculture and other livelihoods, such as trading or services, is very limited. The attraction of greater income in aquaculture draws the labour force to the business. In contrast, within the non-aquacultural group, the main labourers are concentrated on agricultural activities such as rice production and breeding. The results show a clear picture of differences between labour allocation, which reflects the unbalanced situation between aquaculture and agriculture. This situation is further proved by the work hours spending on aquaculture and agriculture, which is calculated on the basis of all main labourers available in the households. While the work hour in agriculture of both groups is very much similar, working time spent for aquacultural activities is substantially more than agriculture.

The fact that the work hours spent for aquaculture is much more than agricultural activities may partly be a result of agricultural mechanisation developed in the area. There is 47 working hours gap between the non-aquaculture and aquaculture groups (Table 4.8, lines 7,8). This showed the aquaculture group has sufficiently used their available labour force working in both agriculture and aquaculture. However, the question is: where and how are a part of labourers in agricultural group working on? Therefore, another trend in the area is observed – spontaneous migration.

Although the community as a whole may become richer because of the development of aquaculture (though, profits from aquaculture are rarely invested in the local community), the trend towards greater inequality amplifies the pressures on the poorer households caused by population growth and land availability, the rising cost of living and other factors such as loss of jobs caused by agricultural mechanisation. The response of many households to these pressures is spontaneous migration, a response only possible since the start of *doi moi.*

Labour allocation and relation with spontaneous migration

Seasonal and temporary migration began to develop in the early 1990s when economic renovation, *doi moi,* was implemented in the urban areas, expanding service industries and creating new opportunities and increased benefits for those in the towns and cities. Such was the need for, and relatively high income from, service work in urban areas that these industries attracted a remarkable number of laborers from the provinces. Seasonal migration in the district is distributed evenly in terms of labour age, from 16 to 45. Men and women in the age range 16 - 45 constitute the main labour force of the district.

Table 4.9. Occupations of spontaneous migrants

Men laborers	Women laborers
Construction: workers for construction works	*Waste collection and recycling*: mostly concentrated on the urban areas, working in interval time between crops
Transportation: passenger bike, cyclo, tractor, etc.	*Small trading*: centered on the province and the vicinity, marine products and consumer goods are the main products.
Carpenters: mainly employed by carpentry workshops.	*Manual works*: working for restaurants, hotels, hairdressers, etc.
Manual works: working in restaurants, hotels, etc.	

Sources: Interviews, Giao Thuy 2000

There are many driving forces behind spontaneous migration: 'push' factors such as population pressure, the rising cost of living, lost access to resources, and so on; and the 'pull' factors, often associated with economic reform, such as the opportunity to compensate for adverse trends in the local community and the possibility of income diversification or simply wider employment/life options. The main concern here is the immediate consequences of this form of migration:

- Changing gender roles – as women must take greater responsibility for management of the family's agricultural crops;
- Loss of skills and efficiency in the agricultural workforce as minor laborers must be used such as children and old people as well as causal laborers;
- Weakening family structure because older members of the family are absent; and,
- Loss of social capital as members of community are absent.

Considering the labour allocation in agricultural sector in relation with spontaneous migration, the migrants may be classified to two patterns according to labour structure

(i) *Migrants working in agriculture*: These labourers make up only 25% of the migrants in Giao Thuy and mainly are women who work as employees in towns at the period of agricultural leisure time. These people do not influence the agricultural labour structure in the area.

(ii) *Migrants not working in agriculture*: This number makes up most of labour force who involve in occupations such as transportation service (passenger bike, cyclo, small truck), aquaculture, construction and so on. Most of them are men at the age of 16 - 45. These people are household heads who make decision in production at household level. During the survey, more than 60% of households involved in these occupations. Therefore, the decrease of agriculture labour force partly affects the structure of production, investment, and agriculture development.

Household heads and young men are the major migrants leaving others to handle agricultural and household tasks. The labour allocation is given in the following chart:

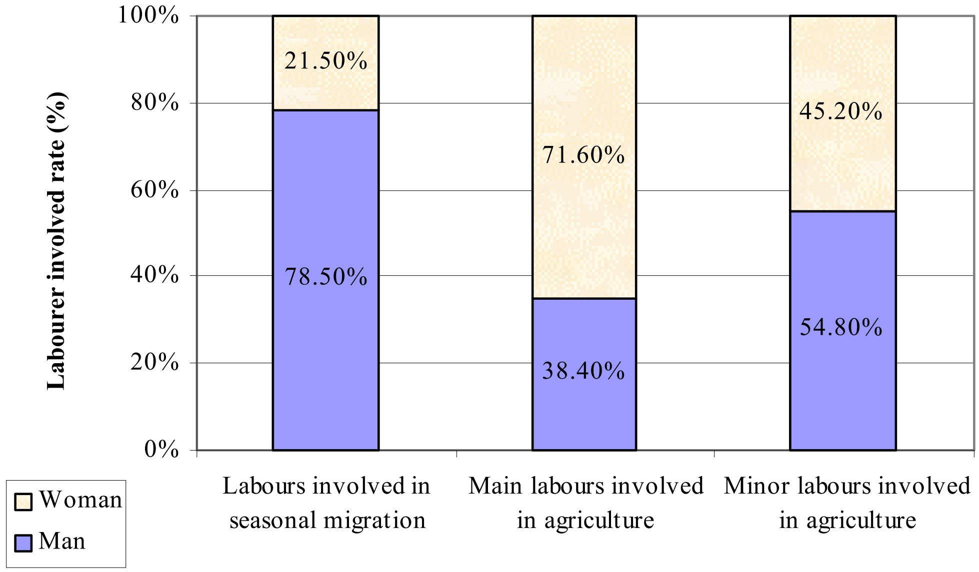


Figure 4.3. Labour force allocation in relationship with spontaneous migration.
Source: Archival Statistics of Giao Thuy District.
Note: Minor laborers are women and children who work part time in production.

Most of the agricultural and household works are now done by women and children, and sometimes by the elderly.

> Since my husband and the my first son, who is 21 years old, have left home to go to Hanoi for cyclo, I and my second daughter have to cover all the works in rice field and breeding at home. Sometimes my husband's mother (who is 74 years old) helps some works at home as well.... It is really hard but we have no choice, if my husband and my son did not go there, we would not have enough money to live, let alone build this house. (*Interview with a woman in Giao An commune, Giao Thuy district, 2000*)

Migration is also degrading the capacity of the society to cope with the institutional changes in the area. The heads of household, who are men, are more aware of changes in law, regulations and women and the elderly in the society. Since they are absent, difficulties to cope with new policies of both governmental and local level have been emerged in the household level.

> My husband and his brothers have gone to Hanoi for 4 years and they just come back home every 3-4 months. There are many changes in land reallocation and crop management I don't know. So I have to follow my neighbors, but it seems to me they don't even know what is best for them as well. (*Interview with a woman in Giao An commune, Giao Thuy district,1996*)

Before the economic renovation, migration was organised by the government to move a part of local population to another place for reclamation. This was also a governmental policy to reduce the local population in some high-density population areas in the Red River Delta region. Popular destinations were the mountainous area in the North or the central highland in the South of Vietnam (Locke *et al.*, 2000). The migration plan of the local government at that time was to move a group of households with every member to the new area. This did not allow the member of the families to go back and work during the crop season or any other business at their homeland.

This is significantly different from spontaneous migration at the current time. Planned migration did not break the household structure. Labour allocation for rice production and household tasks in Giao Thuy stayed stable and agricultural practices were implemented with participation of both men and women. This did not affect the level of inequality amongst the households of the community, as rice production at that time was the only significant income source of the society.

A comparison between the current time and the time before economic renovation has revealed the effect of migration on the level of social resilience. To further analyse this issue, another income assessment of different subgroups in the community is undertaken.

Table 4.10. Summary statistics of family membership, rice cultivated land and income sources of decomposed groups in the community.

		Non-migrant households	**Migrant households**	**Aquacultural households**
1	Family size (people in hhs)	4.7	4.3	4.8
	a. Major laborers per households	2.6	3.4	2.5
	b. Dependents per households	2.2	0.9	2.2
2	Rice cultivated land (m2)	2,345.1	2,572.6	2,225.2
3	Income per capita (vnd)	4,309,262	4,316,911	7,157,385
	in usd	307.8	308.4	511.2
4	Income per main laborer (vnd)	8,428,472	5,119,196	14,075,455
	in usd	602.0	365.7	1,005.4
5	Rice income per main laborer (vnd)	1.946.655	1.447.152	1.866.315
	in usd	139.0	103.4	133.3
	By income sources (%)			
1	Rice income	24.3	31.0	14.4
2	Income from other plantations	2.0	0.9	1.3
3	Income from breeding	23.8	18.5	20.4
4	Income from aquacultural activities	19.2	3.5	57.7
5	Income from fishing	21.7	0.6	1.9
6	Income from trading, services, handicraft	6.0	3.7	1.8
7	Wages	3.1	7.1	2.6
8	Remittance income	0.00	34.8	0.00

Table 4.10 shows key characteristics of non-migrant, migrant and aquaculture households in Giao An commune. Migrant households have more major laborers than the other households. (Major laborers are defined by age and labor allocation in the households and partially from the rural tradition that considers men the main laborers.) This shows that limited employment opportunities locally forces household members to migrate. Fewer dependents in these households show that grown children are migrating in search of work. Remittance income replaces income from fishing and aquaculture (line 4,5 and 8). (The loss of fishing income is partly the results of conversion of mangrove to aquaculture.) As noted above, migration affects

directly rice cultivation, the effectiveness of the agricultural labor force. Rice income per main laborers is US$103 and US$139 for migrant non-migrant households respectively. Equal income between migrant and non-migrant households shows that remittance income is simply compensating for lack of work locally rather than significant increasing income and creating opportunities for investment. This is confirmed by information about uses of remittance income.

Average remittance in the whole area is about 400,000 VND/month/person (30 USD), excluding expenses for each migrant. The use to which remittances are put is normally decided by the head of households and remittances were invested in a number of different sectors. Priorities are given in Table 4.11. The results show that saving money is the highest priority but, according to interviewees, savings are commonly invested in agriculture and breeding in the coming years.

Table 4.11. Amount and number of households in use of remittance income

Categories	Percentage of amount invested	Percentage of household invested
Health care	1.0	3.1
Education	5.4	5.2
Necessities	5.9	16.5
Food	7.7	12.4
Breeding	7.8	16.5
Construction	12.7	3.1
Agriculture	15.4	20.6
Saving*	44.1	22.7

The use of remittance income reveals a popular trend of investment of the migrant community. Most of remittance income is reinvested in traditional livelihoods, particularly rice production, breeding or for long-term investment such as construction or saving. There is no investment to aquaculture using remittance income. The effects of spontaneous migration on the level of social vulnerability and resilience are now analysed.

The effects of spontaneous migration to the level of social resilience

The study has now discussed differential aspects of the effect of economic renovation process – *doi moi*. First of all, income inequality has been increasing under the effects of development of aquacultural activities, particularly shrimp and clam farming. This has a considerable financial benefit for the whole society in general but the main beneficiaries are a small part of the population only. Secondly, income inequality has another trend, created an unbalanced allocation of labour by changing a stable labour force in agriculture. Agricultural practices are now being undertaken mostly by minor labourers such as women, the elderly and children. The situation has also led to a popular trend after the economic renovation, spontaneous migration, which have some immediate consequences as discussed above.

Spontaneous migration has both positive and negative effects on the society. On the positive side, it has brought about opportunities to work and earn extra money for the migrant community, which later benefits the community as a whole. However, though the remittance income earned by the migrant represents a considerable portion of the household income sources, remittance income is simply reinvested in existing agricultural activities or being saved for infrastructure development such as construction of houses. It limits the loss of resilience caused by the development of aquaculture and other recent trends, but it is not enhancing the level of resilience by diversifying livelihoods in the local (sending) community. Furthermore, loss of skills by the absence of most major workers in agriculture caused by migration has also decreased the level of resilience of the community.

This led us to an unavoidable conclusion about spontaneous migration at the current time that the migrants, in one sense at least, are running away to stand still. Having said that, it is essential to stress the complexity of the effects rather than simply concluding that any particular development has a positive or negative effect on the level of resilience and adaptive capacity of the society.

Possible future trend of spontaneous migration

As spontaneous migration has considerable effects on the local society as a whole as well as the level of resilience to cope with different changes caused by the economic renovation, it is essential to consider how the trend might develop in the future.

Spontaneous migration from Giao Thuy in particular and other rural areas to the urban area can be called rural-urban mobility which has been affected by different demographic and structural changes since the introduction of economic renovation. Surveys and interviews suggested four factors that seem to be especially important in shaping spontaneous migration. They are (i) a large gap (inequality) between urban and rural incomes; (ii) agricultural market reform, including the dismantling of cooperative system and the development of the household own right to manage their crop; 3) the development of industry, trading and services in rural areas; and 4) a very large surplus labor in agriculture. These factors play the most significant role in the decision to migrate and expected to develop in the coming future. These changing trends are also observed in different developing countries with economies in transition, particularly China (Seeborg *et al.*, 2000).

Most the migrants from Giao Thuy are now working as self-employed and often underemployed in the informal sector in every urban area in Vietnam, mostly in the big cities in the North and the South. Unemployment sometimes happens to the rural-urban spontaneous migrants. Though it is not possible to accurately estimate the levels of unemployment within a large population of these cities, the level of unemployment within the informal market appears small. There are various opportunities to find a job in the informal market. However, as the number of spontaneous migrants is rapidly increasing, different sectors the migrants involve to may be rapidly developed in the near future.

It is relevant to view the potential migrant as assessing the probability to work in the informal market and how much they can earn in this market. When compared to opportunities in the rural sector, the choice would determine whether rural-urban migration occurs. However, when the demand in informal market become overwhelming and migration is the only option to earn extra income, the migrant will look at other employment sectors. There are two other market sectors which can cover the needs of the migrant. They are state-owned enterprises and the non-SOE contract wage sectors. With the development of urbanisation and modernisation, the need for manual and trained workers will be emerged increasingly in both of these sectors. And again, what interests the migrant is the expected permanent income gain from the migration. The expected permanent income gain from the move depends on three main factors: (i) the length of time of the anticipated period of migration in the urban area, (ii) opportunity to be employed in each of theses two sectors over the anticipated period, and (iii) the anticipated paid rate in each sector over the anticipated period.

With the encouragement of the government in the development of industrial, manufacturing, trading and services sectors within the economic renovation process, theses two factors will be increasingly established giving the migrant many opportunities to be employed in the urban area. Though these sectors require higher trained workers but with more attractive paid rate, the trend of rural-urban spontaneous migration is expected to increase in the coming future. This will pose the sending area, such as Giao Thuy district, more challenges to cope with the structural and dynamic changes in the future caused by migration. Along with the development of aquaculture, migration will place a considerable effect on the level of social vulnerability in the future.

Summary

The chapter has discussed the impacts of economic renovations on the socio-economic structure in the local area. The effects vary in different economic sectors and have some particular consequences on the population.

- Agricultural diversification has imposed the community an increasing rate of income inequality across the economic sectors.
- The whole community has been richer but considerable reward has placed on a part of the population only, aquacultural households. Fishing is also a prime contributor to the income inequality in the district, especially in some coastal communes within the district.
- Immediate effects of income inequality have emerged in the form of spontaneous migration, which has been rapidly increased after the economic renovation.
- The effects of Ramsar designation which limited the access to the natural resources of the local people and later affected the level of social capacity in enhancing their own economic condition and ability to diversify their livelihoods.
- Spontaneous migration has affected the level of social vulnerability by altering the stable structure of labour allocation in agriculture.
- Though remittance income enhances the economic capacity of the migrant community, the trend of spontaneous migration may not be the efficient solution to enhance the level of social resilience to cope with climate and weather extremes.

The set of indicators has proved useful in developing an account of these trends and has suggested implications for social vulnerability and resilience. But is there hard evidence of effects on vulnerability and resilience? The impacts of any response to recent extremes events, typhoons strikes, are now considered.

The effects of climatic extreme and local response

This chapter examines the ability of local society to cope with the impacts of climate and weather extremes. By considering how the aquacultural, non-aquacultural, migrant and non-migrant communities coped with typhoon strikes, findings from testing the indicators in the previous chapter are applied to examine trends in the level of social vulnerability. Analyses covered the income from different sources at household level, loss caused by the extremes, reinvestment (recovering expenses) and the workforce available and involved to recover from the extreme events. The most recent and serious typhoon strikes occurred in the region in 1992, 1996 and 1998.

The impacts of climate and weather extremes in Giao Thuy

Giao Thuy district, located in the mouth of Red River, frequently suffers from natural disasters. An integrated assessment of the Disaster Management Unit of the United Nations Development Programme in Vietnam (DMU) (2001) reported that in June 1992, typhoon Chuck landed to Haiphong and Quangninh provinces, northern part of Vietnam. This storm had serious effects on the estuarine area of the Red River Delta. Aquaculture and agriculture in Giao Thuy district was also seriously damaged. By the same month during the storm season in June 1996, typhoon Frankie hit northern part of Vietnam affecting most of the provinces along the coast including Nam Dinh, Thai Binh and Ninh Binh provinces of which Nam Dinh was the most effected province. In September 1998, the centre of a tropical depression was situated approximately at offshore from the Central of Vietnam. Many provinces in the northern part of Vietnam were seriously affected by the impact of this depression. The community of Giao Thuy district, again, had to deal with the damage caused by this storm.

The impacts of typhoon strikes in the three years of effects, 1992, 1996 and 1998 were estimated on the basis of income and loss associated with the events. Total income was estimated based on the income accrued from different sources of the households. Loss caused by climate and weather extremes referred to direct loss from crops, farming and infrastructure loss. Summary statistics are given below.

Table 5.1. Loss, reinvestment and labour allocation to recover from typhoon strikes in the last decade in Giao Thuy.

	Year	Overall	Non-aquacultural community	Aquacultural community	Migrant community	Non-migrant community
Mean total income	1992	7,303,111	6,320,000	12,324,000	6,036,548	13,020,464
	1996	13,810,441	11,690,672	24,636,404	13,169,262	20,219,094
	1998	14,883,684	12,850,000	25,270,000	14,550,750	22,830,670
Mean income loss	1992	3,178,480	1,264,000	12,956,000	1,454,627	14,770,314
	1996	4,849,450	1,595,854	21,466,030	1,721,388	23,039,382
	1998	7,220,117	3,680,000	25,300,000	4,260,820	23,174,560

Note: Data have been converted to the value of the year 1998 using inflation rates (IMF, 2000)

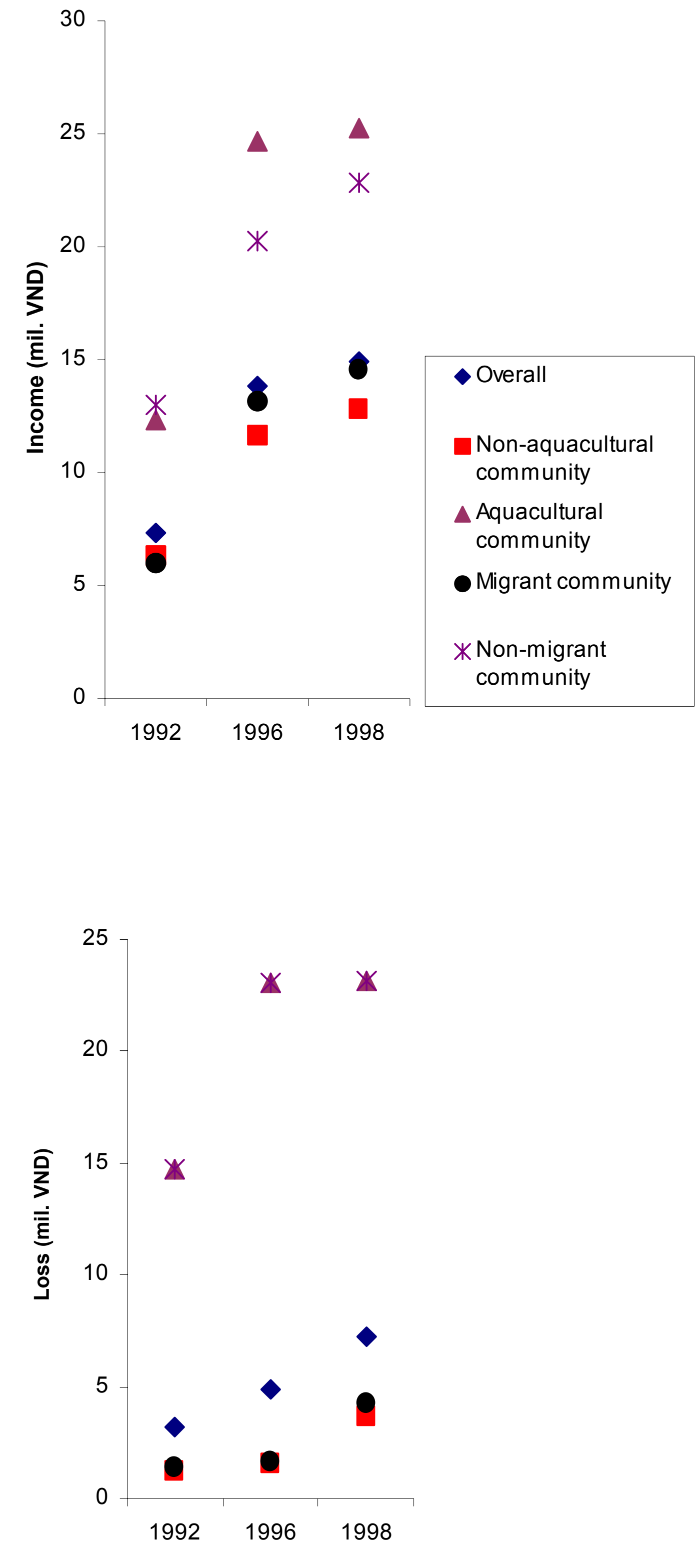


Figure 5.1. Increases of income and loss caused by typhoon strikes in Giao Thuy during the period 1992-1998

The analysis shows a dramatic increase in both income and loss caused by climate and weather extremes in the last decade in the area. Though the community as a whole become richer, especially the aquacultural group, the losses also increase corresponding to the income they gained from local livelihoods (Figure 5.1). Higher investment in both agriculture and aquaculture has resulted in greater financial benefit giving the household a better capacity to cope with climate and weather extremes. However, as an egalitarian community strongly dependent on the environment, the more investment in the land, the more vulnerable they have become.

Recovery from climate and weather extremes

The households have to use their own financial and human capacity to reinvest in their land in the year after the damage. An analysis of this activity is now undertaken.

Table 5.2. Reinvestment and labourers involved recovering from typhoon strikes

	Year	Overall	Non-aquacultural community	Aquacultural community	Migrant community	Non-migrant community
Mean income loss	**1992**	3,178,480	1,264,000	12,956,000	1,454,627	14,770,314
	1996	4,849,450	1,595,854	21,466,030	1,721,388	23,039,382
	1998	7,220,117	3,680,000	25,300,000	4,260,820	23,174,560
Mean Reinvestment	**1993**	3,878,731	1,467,030	16,195,632	1,950,510	19,909,106
	1997	7,557,713	2,920,255	31,241,876	3,141,855	28,026,224
	2000	12,747,544	5,673,450	48,875,950	6,875,450	45,682,520
Mean labouers involved	**1992**	3.15	3.20	2.89	3.12	3.00
	1996	2.82	2.61	3.89	2.24	3.56
	1998	2.70	2.48	3.85	2.34	3.92

Note: Data have been converted to the value of the year 1998 using inflation rates (IMF, 2000)

From the analysis, there is a substantial difference between non-aquaculture, aquaculture non-migrant and migrant groups in income, loss, investment and labourers used to recover from the extremes. The losses of the non-aquacultural groups are the rice crops and infrastructure in the household. The loss of this group has not taken a large part of the income accrued from the households. However, they did have to invest a considerable amount to recover from the loss which is accounted for a large part of income the household gained in the year (approximately 25%) (Tables 5.1 and 5.2). In contrast, the aquacultural group had a very serious loss in comparison to their mean income (approximately 40%) of the income. This group also has to invest in their shrimp or clam farming with a large amount of money which was more than the income they obtained for the last year. This showed the economic capacity of this group is much higher than the others. The labour used also reflects the difference in coping capacity of two groups in recovering from the events. The rate of labourers used in aquacultural groups is much higher then than non-aquacultural groups.

This discussion is further checked by Pearson correlation analyses that show the correlation between different variables of the analysis. The reason to undertake this analysis is if the more loss the households experienced, the more investment and labour forced they are able to use. The analysis use income losses as the dependent variable while the other as dependent variables.

Table 5.3. Pearson correlation using loss as the dependent variables.

1992	Overall	Non-aquacultural community	Aquacultural community	Migrant community	Non-migrant community
Loss and Income	0.57	-0.04*	0.75	0.62	-0.15*
Loss and Investment	0.73	0.77	0.82	0.75	0.79
Loss and Labour used to recover	0.73	-0.03*	0.76	0.85	-0.18*
1996					
Loss and Income	0.46	-0.03*	0.87	0.52	-0.07*
Loss and Investment	0.89	0.84	0.82	0.82	0.84
Loss and Labour used to recover	0.64	-0.01*	0.87	0.87	-0.01*
1998					
Loss and Income	0.59	-0.19*	0.78	0.49	-0.29*
Loss and Investment	0.79	0.79	0.85	0.78	0.75
Loss and Labour used to recover	0.68	-0.06*	0.69	0.68	-0.05*

Note: * not significant at 5% level

The analyses included three pairs of variables of which the loss caused by typhoon strikes played the independent variables whilst the others were independent variables. Firstly, income and loss variable were examined to consider if the more income the households earned from agriculture and aquaculture, the more loss caused by typhoon strikes. Similar relationship was set for investment and loss variables. This analysis showed the way different groups in the society use their financial capacity to compensate the loss. This also examined the second indicator set in the Chapter 2. The last pair of variables also aimed to test the third indicator, human capacity. This included loss and labour force variables to consider the way different groups employ their labour force to recover from typhoon strikes.

The results show a strong relationship between loss and reinvestment variables of both groups but very weak relationship between loss and income and labourers used of the non-aquacultural group. The difference the study discovered from this analysis is the strong relationship between loss and reinvestment and labourers used of the aquacultural groups. This proved the stronger coping capacity in both economic grounds and labour allocation of this group. Though the non-aquacultural group has achieved successes in their livelihoods, such as agricultural mechanisation, increased productivity and extra income from trading and services, remittance income from migration, but the economic capacity and labour force to cope with loss caused by typhoon strikes is not increasing as fast as in the aquacultural sector. A similar result is also found in the other two subgroups of migrant and non-migrant community. This has clarified that though both economic capacity and livelihood diversity are increasing considerably after the economic renovation, the level of social resilience of a large part of the population is not improving to the same extent.

Summary

Considering the implications to cope with typhoon strikes, changes in the social vulnerability and resilience of different groups in the community have emerged. The analyses showed that the local community has responded and recovered from typhoon strikes. Different groups have revealed different level of social resilience. IT can be concluded that:

- The aquacultural community is the most sensitive and dependent economic sector on the environment. Damages caused by typhoon strikes are the most serious in comparison to other economic sectors. Though the level of vulnerability to extreme events of this group has increased, the higher financial capacity allows them to recover from the loss in a shorter time. Their capacity to use available labour force for both agriculture and aquaculture is also higher then the other groups.
- In contrast, the non-aquacultural group is the most vulnerable to typhoon strikes. The impacts of typhoon strikes have lead to the loss of most or whole crop. Reinvestment IN the crop after the damage also requires a large amount of financial capital. This reinvestment, though not as much as aquaculture, takes a large portion of income of the agricultural households.
- Excess labour in the non-aquacultural group has led to another trend – spontaneous migration. Spontaneous migration has also had some complex effects on the changes in the level of social vulnerability. This community, representing for non-aquacultural group, has had a positive effect to limit the level of social resilience by remittance income. However, this group has also experienced the loss in labour force, skills and social structure at the household level as discussed in Chapter 4. Remittance income is not invested in sector which enhances the level of social resilience. In general, though being more capable of reinvestment to the loss caused by typhoon strikes, the group has lost their human capacity in coping with the damage.

The key findings of this chapter are clear evidence of the changes in the level of social vulnerability and resilience as measured by the level of income, loss, investment, and labour force to recover from typhoon strikes. The comparison between non-aquaculture and aquaculture groups showed two trends. First is the increase in financial capacity of aquacultural group, which supports their capacity to recover from typhoon strikes. Second is the use of labour to recover of which aquacultural groups also showed a higher level of social resilience to cope with the impacts of typhoons strikes. These indications confirm the findings of Chapter 4. Specifically:

- The level of social resilience of aquacultural group has increased though this group remains vulnerable to typhoon strikes. The loss caused by the extreme events has increased dramatically in the last decade, from VND13 – 26 million during the period 1992-1998. It is also due to the higher investment for the semi-intensive farming method. The cost for reinvestment after the damage has also heightened from VND16-49 million. These increases have revealed a higher level of vulnerability to typhoon strike of the aquacultural group. This group, however, with the increasing benefit from the business has managed to recover from the loss by using their financial capital and labour force available. The labour force used to recover from the loss of this group also increased from 2.9-3.9 laborers per household per year during that period. In short, though being more vulnerable to the extreme events, the level of social resilience of this group has been enhanced by the increase of internal capacity of finance and labour force to recover from the damage.

- In agriculture, in contrast, has experienced a complex effect on the level of social vulnerability and resilience to cope with typhoon strikes. Higher productivity brought about by the changes in formal policies has enhanced financial capacity for the group through which social resilience has increased. The agricultural group is still highly vulnerable to typhoon strikes. The loss has rapidly increased from VND1.2-3.7 million per household. Though the loss is not as much as the aquacultural group, reinvestments to compensate the loss have taken a large part of their income (25-40% during the period of 1992-1998). This showed the group has been more vulnerable to typhoon strikes. Furthermore, available labour force has not been used effectively to recover from the loss. Though having a labour force similar to the aquacultural group (Table 4.5), a decrease in using available labour force to cope with the damage has emerged in this group, from 3.2-2.5 labourers per household. This situation has been caused mostly by the increasing trend of spontaneous migration.

Scenarios for the next two decades

In order to explore stakeholders' responses on how their group/organisation cope with the different changes of the society and economic background in the next two decades, different prototype summary sheets of the scenarios developed for the 2020s have been presented in addition with the possibility of environmental stresses. The future scenarios proposed have been based on the actual conditions and possible trends of both national and locale levels. The research team developed future scenarios with time horizons up to 2020.

Table 6.1. Summary of the scenarios with indicators of the future portrayal to 2020

	National Market (NM)	**Local Economics (LS)**	**Regional Sustainability (SS)**	**Local stewardships (LS)**
Values	Consumerists	Communist and Individualist	Conservationists	Communists/Privatisation
Governance	Nationalised, strong	Regional, strong	Nationalised, strong	Regional/local, moderate
Annual GDP*	7.4%	10.9%	8.8%	8.5%
Population growth**	1.7%	1.2%	1.4%	1.6%
Population dynamics	Natural	Natural	Natural/physical	Natural/physical
Adaptive capacity to extreme events	Moderate	Increased	Increased	Increased
Policies and promotions for sectoral development	Increased	Increased	Increased	Increased
Fast growing sectors	Industry, Services, Manufacturing, Education, Health care, High technology	Intensive aquaculture, Services, Manufacturing, Handicraft, Health care, Education, Tourism, Industry	Industry, Services, Manufacturing, Education, Health care, High technology	Intensive aquaculture, Services, Manufacturing, Handicraft, Health care, Education, Tourism, Industry, Private financial services
Declining sectors	Agriculture	Resource extensive agriculture and aquaculture	Agriculture	Resource extensive agriculture and aquaculture.
Equality	Increased	Increased	Increased	Increased
Air quality	Improved	Improved	Improved	Improved
Water quality	Improved	Improved	Improved	Improved
Biodiversity	Highly Increasing pressure	High pressure	High pressure	High pressure
Environmental Extreme Events	Increased	Increased	Increased	Increased

* Annual GDP was estimated for the duration of 1996-1999
** Population growth was estimated for the duration of 1990-1999

These trends are illustrated in the following prototype sheet.

2020

Nationalisation

Governance

NATIONAL MARKET

- Effects on provincial level under market forces
- Fast growing sectors: Industry, Services, Manufacturing, Education, Health care, High technology
- Declining: Agriculture
- Annual GDP: high 7.4%++

- Environmental condition improvement
- Increased emission / better emission control
- More serious environmental extreme events
- High adaptive capacity

REGIONAL SUSTAINABILITY

- Effects on local level under by national government
- Fast growing sectors: Industry, Services, Manufacturing, Education, Health care, High technology
- Declining: Agriculture
- Annual GDP: very high 8.8% ++

- Better environmental condition
- Increased and controlled emission
- More serious environmental extreme events
- Highly increased adaptive capacity

Consumerism

Community

Value

Conservation

LOCAL ECONOMICS

- Effects on household/group and individual level
- Fast growing sectors: Intensive aquaculture, Services, Manufacturing, Handicraft, Health care, Education, Tourism, Industry
- Declining: Resource extensive agriculture and aquaculture
- Annual GDP: very high 10.9%++

- Better environmental condition
- Decreased emission
- More environmental extreme events
- Highly increased adaptive capacity

LOCAL STEWARDSHIPS

- Effects on associated/collective level
- Fast growing sectors: Intensive aquaculture, Services, Manufacturing, Handicraft, Health care, Education, Tourism, Industry, Private financial services
- Declining: Resource extensive agriculture and aquaculture
- Annual GDP: very high 8.5% ++

- Improved environmental condition
- Improved environmental management
- Increased emission
- More environmental extreme events
- Highly increased adaptive capacity

Localisation

Figure 6.1. Prototype sheet for future portrayal to 2020

Findings of Giao Thuy case study

The main informational needs emerged though the interviews are:

- 100% of the stakeholders are using socio-economic data in different contexts related to their specialty for future planning.
- Most of the stakeholders (83%) expect to get more socio-economic data, especially social trends of the national level in addition to their planning for the near future.
- The economic sectors such as agriculture and aquaculture and tourism (45.8%) are eager to get information and data related to future programme in economic zoning, planning of the national and provincial levels in order to invest and develop their business planning.
- Details revealed in the future scenarios, as bewared by the respondents should be clearer and should be relatively accurate predictions as they expected to get more information of the trends and strategy of the government in the coming future.

There are different ways to deal with this issue but the most effective solution is to coordinate the local authorities and communities in planning the future including proposing their own ways to cope with changes of both economic sectors, social aspects and environmental changes.

Future scenarios also reflect the resilience and adaptive capacity of the society in a short-term assessment. In this case study, the time horizon identified and used in the future scenarios is for 20 years in order to develop an initial assessment with major focus on the resilience level and adaptive capacity of the local community. The terms resilience and adaptive capacity ate defined as below:

The resilience of a community to global environmental change - its ability to cope with, recover from and if necessary adapt to stress - depends on a number of factors, not least the varied societal trends that can reduce or enhance vulnerability (Adger and Kelly, 2001).

Adaptive capacity arises from the ability of the local community in general and the important stakeholders who are representatives for the whole community to respond to environmental stresses. In this research, environmental stresses refer to extreme climatic changes and changes in use of natural resources that lead degradation and destruction of available resources. Adaptive capacity of a community has two sides, positive and negative, which depends on how the analysts regard. For the Giao Thuy case study, the positive side of adaptive capacity is communal ability to cope with the changes while the other normally abandons the possibility to recover from the changes.

The interviews revealed different patterns of resilience and adaptive capacity of local community. These patterns vary in different sectors which identifies as sensitive to the environmental stresses. An integration of sensitivity to environmental stresses is given as below:

Table 6.2. Sensitivity of different social and economic sectors in Giao Thuy case study

Sectors in Giao Thuy case study	Sensitivity to environmental stresses
Natural environment	***
Agriculture	***
Aquaculture	***
Fishing	***
Trading and service	**
Health care	N/a
Education	N/a
Institutional sector	**
Tourism and recreation	***
Manufacture	*
Coastal region	***
Water resources management (irrigation, water supply)	***
Financial sector	*
Construction (including irrigation works)	***
National economy	N/a

**** Highly sensitive to environmental stresses*
*** Relatively sensitive to environmental stresses*
** Sensitivity to environmental stresses is unclear*
N/a not available

Eco-tourism, is that a highly resilient and sustainable trend?

There is a rapid developing and potential trend in the region which has been observed during the implementation of this project, eco-tourism. With the advantage of the country's first and only Ramsar site, the area is internationally known for the habitat of migrating waterfowls. There are also nice beaches along the district and the adjacent area. The transport system from big city, such as Hanoi and Hai Phong is good enough for a convenient access to the area. Besides, tourism is also a major economic factor the local government intends to promote in the coming future. Tourism is also expected to bring highly valuable currency to the economy of the local region. With all of these advantages, tourism shows a bright future. However, as discussed above, under the effects of economic renovation, there are complex effects of different trends to the level of social resilience to cope with institutional changes and climatic extremes. Therefore, though addressed as one of the major developments in the coming future, tourism may well have various effects on the level of social resilience, which have also been affected and changed by existing trends.

Current development of conventional tourism

The changes in social livelihoods under the effects of economic renovation and Ramsar site designation have significant effects on the development of ecotourism. At the current time, conventional tourism has formed in some communes along the coastline of the district. This beginning stage has started with the establishment of various guesthouses, hotels, restaurant and services along the beach of the district. Though the government has not officially invested to the development of tourism in the area, local community has begun investing in conventional tourism with the financial capital from their own non-tourism businesses.

The success of aquaculture and trading and services has contributed most in the development of tourism. With the stable and excess financial capital from shrimp and clam farming as well as profit from trading and services, tourism has been invested in household level. This has shown the collective effects of the future development on this economic sector. Household investment on the tourism has also revealed welfare inequality amongst the subgroups of the community. Similar to the development of aquaculture, labour allocation of conventional tourism has also formed in the way in which aquaculture is using the labour force in the area. This has separated the better off and the poor by the use of financial and human capacity.

Current developing tourism will have a number of effects on the social resilience to cope with the impact of institutions and climatic extremes if the trend remains unmanaged by the government.

- The level of income inequality will increase along with the development of tourism. The gap between the rich and the poor in the community will be extended. Or will the tourism; unmanaged tourism development will create an unbalanced development amongst the tourism community. As tourism is a highly competitive business, an open market of tourism will be formed giving the well-managed households a chance to develop the business while the rest will face difficulties, which may lead to the loss of financial standing and human capacity.
- Labour allocation amongst the tourism community will also be affected by the development of tourism. With higher paid rate of tourism, labourers will be attracted to the business, which will leave the community a more unbalanced allocation of labour across different economic sectors.
- Use of the natural resources will also affected by the increasing rate of tourists, transportation, operations of hotels, restaurants, etc and the development of services associated with tourism development.

Under these possible effects of unmanaged conventional tourism, the solution is to operate a system of ecotourism. However, ecotourism is also affected by the changes of other economic sectors similarly to the conventional tourism. The research developed a scenario of development for ecotourism to be considered by the local authority.

Future trend of ecotourism

As discussed above, ecotourism is a collective level, which will be affected by various impacts of the economic development and Ramsar site designation. These impacts will be determining factors to the development of ecotourism. There are fast growing sectors: Intensive aquaculture, Services, Manufacturing, Handicraft, Health care, Education, Tourism, Industry, Private financial services. Each of these sectors has different effects on the ecotourism development. The research is now considering the impacts of these factors.

Development of intensive aquaculture will give the aquacultural community a stable and increasing financial capacity, which will be a source of private credit. Income inequality will be increased in the community if there is no investment using the profit of aquaculture. However, profit from the aquaculture will partly invested to tourism which may well raise the profit for the community as a whole while giving the rest of the community an opportunity to lessen the gap of the rich and the poor. This will stop the loss of resilience in the whole community and enhance the resilience of the poor by mobilising the financial capacity from aquaculture community and human capacity of their own.

Extensive aquaculture will be decreased, or even eliminated giving the ecotourism a basis for landscape tourism as its nature. This will also ensure the sustainability of intensive aquaculture and development of ecotourism. There will not be compromised solution between aquaculture and tourism. Profit will be gained by both businesses while assuring the stability of the mangrove in particular and natural resources in general.

The Ramsar site management system will be taking part in operating ecotourism. This has a number of advantages to the purpose of conservation. Awareness in the importance of natural conservation in the area will be widened and acknowledged. This will also give the site an opportunity to get hold of financial support for the purpose of research and capacity building for the staff and local residents. These advantages will be the site's own capacity to maintain and widen the site for a long-term conservation strategy as committed by the government to the Ramsar convention.

Development of trading, manufacturing and services will be associated with the development of tourism. This will mobilise a considerable number of labourers working in the area while at the same time maintaining the labour force in other traditional livelihoods such as rice production. By developing these sectors along with aquaculture and tourism, both are local businesses, the community will stop the loss of skills and breakdown of social structure while increasing the employment rate and financial capacity of the disadvantaged.

Other developing trends within the community such as health care, education, industry will lift the living standard to a better level. Profit from aquaculture, tourism, trading and services will ensure the stability of these sectors. This will also be an advantage of local community in diversifying social livelihoods under the effects of economic renovations. This will also a basis for the services supplied by future ecotourism.

These are the positive effects of economic renovation and Ramsar site designation on the development of ecotourism. However, there are several side effects, which may reveal during the operation of ecotourism.

- Although ecotourism and recreation are considered to be clean industries, they can have significant impacts on the environment. The increase number of tourism coming to acknowledge the unique of the site takes advantage of this extensive coastline. The areas that are particularly appealing to tourists are often places with high biodiversity. However, tourists make noise; disturb the environment and need services such as accommodation, food, transport, fuel and waste disposal. All this can result in the destruction of the qualities of an area that attracted tourists in the first place.

- Changes made to the environment, even if it seems insignificant, can have an effect on biodiversity. For example, in some areas within the site the appearance of tourists will reduce the number of migrating waterfowls. Consequently, the balance of ecosystem will be jeopadised. In the long-term, if this is not taken into account, the nature of ecotourism will not be effective in the area.
- There are many ways resorts, hotels and other recreational facilities can decrease the biodiversity of surrounding natural areas. As argued by Wearing and Neil (1999), recreational tourism will increase the amount of food scraps and wastewater, which add unwanted nutrients to waterways; facilities encroach on and destroy habitats. Visitors can disturb feeding and breeding behaviour of native animals. Soil, beaches and dunes are eroded by vehicles. Reefs are trampled by snorklers; intertidal plants and animals are collected; wildlife and fisheries are depleted; seabeds are damaged by boat anchors and moorings; and pollution and vandalism have adversely affected many natural areas.

In response to the negative effects of tourism and recreation, people have developed a type of tourism called 'ecotourism', which is sensitive to the environment. The demand for ecotourism is increasing, suggesting more people are recognising the value of ecologically sensitive, nature-based holidays and recreational activities. While ecotourism is not yet strictly regulated (almost anyone can call themselves an "ecotour operator", and not all travel services adhere to minimum impact guidelines), some countries are beginning to recognise its values and are contributing some of the revenue gained from natural resources into the management of those resources. However, the challenge remains to design and implement systems that will link the growth of tourism with the conservation of biodiversity.

Conclusions and recommendations

This chapter summarises the findings from examining the indicators of social trends, under the effects of *doi moi* and considering implications with regard to cope with climate extremes. Policy implications to support trends which enhance social resilience are also proposed. Further research opportunities and a wider set of indicators are also discussed.

The study has assessed the changes in social vulnerability and resilience under the effects of economic renovation in Vietnam and the implications for local society coping with the impacts of climate and weather extremes, It has tested a proposed set of indicators. The result showed the following:

1. The first indicator, ecosystem sensitivity, has been tested by considering land management under various influences. The Law on Land-use, dismantling of the cooperative system and associated informal changes under the effects of the economic renovation have improved the land and crop management in the local area. In agriculture, rice and other agricultural products' productivity have been increasing rapidly since the introduction of *doi moi*. This has also improved the capacity to manage the agricultural land within the population. In aquaculture, the mangrove land has been used for shrimp and clam farming. Since the economic renovation, awareness on the importance of the mangrove has improved. The introduction of semi-intensive shrimp farming has maintained sustainability for the mangrove while assuring the benefit from shrimp farming. In both of these economic sectors, the implications showed an increase in the level of social resilience in both the aquaculture and the non-aquaculture groups.

2. The second indicator, economic or financial capacity, has been statistically tested. Findings of the study showed the most significant implication is the increase in income inequality between the aquaculture and the non-aquaculture groups. Aquaculture is increasing the financial capacity of coastal communities but the main beneficiaries are the aquacultural community. The implications found from testing this indicator showed that though the financial capacity of the whole community has increased, from which the level of social vulnerability in general has reduced, but pressures on the rest of the population are increasing. Therefore, the non-aquacultural groups still face a loss of social resilience caused by the development of aquaculture.

3. The third indicator, human capacity, has shown the negative effects of *doi moi*. Findings from examining this indicator have revealed to two different trends, labour reallocation and spontaneous migration. This first trend has given the aquaculture group the capacity to use their available labour force for both agriculture and aquaculture. The non-aquaculture group, however, have a large amount of excess labour. This led to the second trend. Spontaneous migration, with remittance income, has limited the loss of resilience but it is not improving coping capacity by diversifying livelihoods in the local community as remittance income is simply being invested in traditional activities or saved. Absence of migrants has caused the loss of skills in the rural society and changed the gender role on agricultural works, leading to further loss of social resilience. Again, the effects of economic renovation are shown to be different in the changes of the level of social resilience between various groups in the community.

4. The last indicator, formal policies of the *doi moi*, showed the overall implications of the effects of *doi moi* on the changes in the level of social resilience to cope with the extreme events, typhoon strikes. The aquacultural community is the most sensitive and dependent economic sector to the environment but the level of social resilience has enhanced considerably by the improved financial and human capacities. Non-aquaculture group, though less dependent on the environment than aquaculture, but is the most vulnerable to the climate and weather extremes.

The implications for the level of social vulnerability that have emerged by examining the indicators can be summarised in the following table.

Table 7.1. Summary of indicators' implications

Indicators	**The effects of economic renovation**	**Changes in the level of social resilience to extreme events**	
		Aquaculture group	**Non-aquaculture group**
1. Land management	Improved land and crop management	↗	↗
2. Financial capacity	Inequality between groups	↗	↙
3. Human capacity	Imbalance labour reallocation, spontaneous migration	↗	↙
4. Institution	Favour the aquaculture group Complex negative effects on non aquacultural group	↗	↙

Considering the impacts of typhoons strikes to different groups, actual hard evidence of the changes in social vulnerability and resilience have emerged. There are two trends revealed from comparison between the aquacultural and non-aquaculture groups. The increase in financial benefit of the aquaculture group has supported the increase their capacity to recover from typhoon strikes. The use of labour force to recover from the damage is also higher in the aquacultural group than the non-aquacultural group.

- The aquacultural group remains vulnerable to typhoon strikes but their resilience has increased during the last decade. Both loss caused by typhoon strikes and reinvestment have increased dramatically which showed the increase in the level of vulnerability to the damage. With the higher financial benefit from shrimp and clam farming, aquacultural group is capable of reinvesting in their farms after the loss. Besides, this group has also effectively used their available labour force for both agriculture and aquaculture to recover from the damage caused by typhoons strikes. These implications show an increase in the level of social resilience of the aquacultural groups.

- In agriculture has experienced a complex effect on the level of social vulnerability and resilience to typhoon strikes. Higher productivity influenced by the changes in formal policies has enhanced financial capacity for the group through which social resilience has increased. This group is still highly vulnerable to typhoon strikes. The loss has rapidly increased though it is not as much as the aquacultural group. Reinvestments to compensate the loss have taken a large part of their income. This showed that the agricultural group has been more vulnerable to typhoon strikes. Furthermore, available labour force has not been used effectively to recover from the loss though having a labour force similar to the aquacultural group. A decrease in using available labour force to cope with the damage has emerged in this group. This situation has been caused mostly by the increasing trend of spontaneous migration.

These implications from considering different groups also suggest the future trends of the community. Aquaculture will be developing with the introduction of intensive farming method. This method will maintain both financial benefit and mangrove within the farming area. Coping capacity of this group to typhoon strikes will also be heightened. In agriculture, intensive crop management, agricultural mechanisation, better supplies will increase productivity. Agricultural production will also move towards a commodity market with rice is the major product. This will increase the level of social resilience for agriculture group. However, with such the advantages, unemployment rate in agriculture will be increased caused mostly by agricultural mechanisation and population growth. This will pose the agricultural group difficulties in using labour force to recover from typhoon strikes. That excess labour force is the spontaneous migrant community. The migrant, though providing increasing remittance income, but also increases income inequality within the migrant community. The agricultural group, which also represents the migrant group, is facing complex changes in the level of social resilience in the future.

The implications found by examining the indicators have revealed complex effects of institutions and social interactions between the groups. At the local level, social capital, which includes the networks of institutions, social relationships, and norms, (Coleman, 1988 and Collier, 1998) play important roles in shaping adaptive capacity and take parts in enhancing social resilience. Moser (1998) argued that social capital is not static and that it is affected by changing circumstances. Taking social capital into vulnerability assessment becomes a critical need. In a society depending on the environment like the coastal zone, social capital is also closely related to the capacity to access to natural resources and facility to cope with climate and weather extremes. Local settlement and the sensitivity of infrastructure have become important to recover from the damage. Within this study, these indicators of social capital and settlement and infrastructure sensitivity have not been directly considered. That is the limitation of the study as they cover an important part in altering social resilience.

Having said that, a wider set of indicators is now proposed allows a comparative analysis in assessing social vulnerability and resilience assessment.

Table 7.2. Indicators selected for assessing social vulnerability

Vulnerability indicators	Proxy variables	Proxy for
Ecosystem sensitivity	Land managed	Degree of human intrusion into the natural landscape and land fragmentation
Economic capacity	GDP (market per capita Gini coefficient	Distribution of access to markets, different kinds of capital and other resources useful for adaptation
Human resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs
Institution	Employment Empowerment	The rate of employment available in different economic sectors Participatory status of people to decision making
Settlements/infrastructure	Population at risk	Potential extent of disruption

sensitivity	Population with no access to natural resources	Access of population to basic services to buffer against climate variability and change
Social capital	Institutions, social relationships, social cohesion, norms, trusts.	Reciprocal networks of trust and norms embedded in the social organization of communities

Source: Moss et al. (2000) and Moser (1998)

This set of comprehensive indicators allows considerations of a wider range of social interactions within the community and between the community and the environment.

These changes in the level of social vulnerability and resilience in various sectors have raised the local authority an important question. How and in which sector the government should promote to obtain both economic development and enhance the level of social resilience to cope with the extreme events? The study has proposed some of the possible actions which can be undertaken.

- Policy makers must find means of reducing adverse effects on social vulnerability and resilience and promoting positive consequences. As discussed above, there are income and welfare inequality caused by aquaculture, labour allocation, spontaneous migration and climate and weather extremes to be considered by the local authority.
- Poverty reduction must be a priority to protect the disadvantaged. Supports such as agricultural extensions, crop management should be allocated to the non-aquacultural community, especially households who are relying on rice production only. Agricultural extension workers should address the change in gender roles and changing skills in the workforce caused by migration.
- Creation of local employment is also an important priority. Spontaneous migration has a tendency towards non-SOEs and SOEs in urban areas, diversifying local livelihoods by establishing non-SOEs and SOEs in the local area will optimise the local capacity of labour force. This will also enhance the local resilience, stabilise and balance the gap between the rich and the poor.
- It is proved that aquaculture has contributed significantly to poverty alleviation in the local region. Its high inequalising effects would be decreased by supporting the development and diversification of other livelihoods in the local area.
- Conventional tourism should be strictly controlled by the local authority in cooperation with Ramsar site management board. Ecotourism should be considered and master-planned to drive the business to a sustainable manner, taken the development of aquaculture and fishing into account. This action will help maintain the local livelihoods and increase employment and profit for the region.
- Similar to agricultural product market, aquacultural products, which has shown a considerable potential, should be marketed under the control of local authority in order to avoid negative competition and monopoly in product consumption.
- Commodity market for agricultural products should be established and controlled by the government. This action will help and encourage intensive agricultural production giving the poor a stable and long-term investment in household level.
- Supports should be given to vulnerable livelihoods. Forecast and assistance should be placed on aquaculture and agriculture sectors. Local participation in forecasting and coping with climate and weather extremes should be implemented under the instruction of local authority.

These actions are aiming towards a higher resilience level of the local community to cope with stresses and climate and weather extremes.

There are many other actions that could be taken into account. A future action to enhance the social capacity is to diversify local livelihoods. Diversification of local livelihoods will, by the same time, improve local financial capacity, attract local employment and finally provide a means to cope with climate and weather extremes.

References

Adams, R. H. (1995) *Agricultural income, cash crops and inequality in rural Pakistan*. Economic Development and Cultural Change, Vol. 43, pp. 467-491.

Adger, W.N and Kelly, P.M. (2001), *Social vulnerability and resilience*, in Adger, W.N; Kelly; P.M and Nguyen Huu Ninh (eds) (2001) Living with Environment, Routledge, London.

Adger, W.N. (1997) *Social vulnerability in Vietnam*, Thesis submitted for the degree of Doctor of Philosophy, School of Environmental Sciences, University of East Anglia, Norwich.

Adger, W.N.; Kelly, P.M., Ninh, N.H and Thanh, N.C. (2001) *Property rights, institutional and resource management: coastal resources under doi moi,* in Adger, W.N; Kelly; P.M and Nguyen Huu Ninh (eds) (2001) *Living with Environment*, Routledge, London.

Adger, W.N.; Kelly, P.M.; and Tri, N.H. (2001) *Costs and Benefits of mangrove conversion and restoration*, in Adger, W.N; Kelly; P.M and Nguyen Huu Ninh (eds) (2001), Living with Environment, Routledge, London.

Anon. (1993) *Management plan for Xuan Thuy Nature Reserve, situated in Xuan Thuy district, Nam Ha province*. Unofficial translation by BirdLife International.

Anon. (1994a) *Biodiversity action plan for Vietnam*. Hanoi: Government of the Socialist Republic of Vietnam and the Global Environment Facility.

Anon. (1994b) *Red River Delta master plan. Background report 1: fisheries.* Hanoi: MOSTE in association with UNDP and the World Bank.

Atkinson, A.B. (1970) *On the measurement of inequality*. Journal of Economic Theory, Vol. 2, pp. 244-263.

Barbier, E. (1993) *Sustainable use of wetlands valuing tropical wetland benefits: economic methodologies and application*, Geographical Journal, Vol. 159, pp. 22-32.

Berkes, F. and Folke, C. (1998) *Linking social and ecological system: Management practices and social mechanism for building resilience*. Cambridge University Press, Cambridge.

Birdlife International (2001) *BirdLife International Vietnam Programme Quarterly Report* (November to December, 2001), Hanoi, Vietnam.

Birdlife International (2001) *Sourcebook of Existing and Proposed Protected Areas in Vietnam*, Unofficial update of the Birdlife International office in Vietnam, Hanoi, Vietnam.

Blaikie, P. and Brookfield, H. (1987) (eds) *Land degradation and society*, Methuen, London.

Blaikie, P., Cannon, T, Davis, I. and Wisner, B. (1994) *At Risk: Natural Hazards, People's Vulnerability and Disasters*, Routledge, London.

Buckton, S. T., Nguyen Cu, Nguyen Duc Tu and Ha Quy Quynh. (1999) *The Conservation of Key Wetlands in the Mekong Delta*, Birdlife International in Vietnam, Hanoi.

Burgess, J.C. (1993) *Timber production, timber trade and tropical deforestation*. Ambio, Vol. 22 (2–3), pp. 136–143.

Caroline Moser, C (1998) *Asset Vulnerability Framework: Reassessing Urban Poverty Reduction Strategies*, World Development, Vol. 26 (1), pp. 1-19.

Coleman, James (1988) *Social Capital in the Creation of Human Capital,* American Journal of Sociology, Vol. 94, pp. 95-120.

Collier, P. (1998) *Social Capital and Poverty*. World Bank, Washington, D.C.

Connel, J.H. and Sousa, W.P. (1983) *On the evidence needed to judge ecological stability or persistence*. American Naturalists, Vol. 21(6), pp. 789-824.

Cowell, F.A. (1977) *Measuring Inequality.* Oxford, Philip Allan.

Crabtree, B.F. & Miller, W.L. (1991). *A qualitative approach to primary care research: The long interview.* Family Medicine, Vol. 23 (2), pp. 145–151.

Dasgupta, P. (1993) *An Inquiry into Well-Being and Destitution*, Oxford University Press, Oxford.

DFID (2001) *Integrated Coastal Zone Management in Bangladesh*, A policy review, the Department for International Development, London.

Disaster Management Unit (DMU) (2001) *Disaster events in Vietnam*, Disaster management unit, United Nations Development Programme in Vietnam, Hanoi, Vietnam.

DMU (2001) *Reports on annual disaster in Vietnam*, United Nation Development Programme, Disaster Management Unit and Ministry of Agriculture and Rural Development, Hanoi, Vietnam.

Doornkamp, J. C. (1998) *Coastal flooding, global warming and environmental management*, Journal of Environmental Management, Vol. 52, pp. 327–333.

Dow, K. (1992) *Exploring differences in our common future(s): the meaning of vulnerability to global environmental change*, Geoforum. Vol. 23(3), pp. 417-436.

Francis, E. and Hoddinott, J. (1993) *Migration and differentiation in Western Kenya: a tale of two sub-locations*, Journal of Development Studies, Vol. 30, pp. 1115-145.

Giao Thuy People Committee (1999) *Economic development report, 1999*, Giao Thuy, Nam Dinh.

Gössling, S (1999) *Ecotourism: a means to safeguard biodiversity and ecosystem functions?,* Ecological Economics, Volume 29 (2), pp. 303-320.

Gunderson, L.; Holling, C.S. and Light, S. (1995) (eds) *Barriers and Bridges to the Renewal of Ecosystems and Institutions.* Columbia University Press, New York.

Hernandez-Cornejo, R., Ruiz-Luna, A (2000) *Development of shrimp farming in the coastal zone of southern Sinaloa (Mexico): operating characteristics, environmental issues, and perspectives*, Ocean & Coastal Management, Vol. 43, pp. 597-607.

Huitric, M., Folke, C. and Kautsky, N. (2001) *Development and government policies of the shrimp farming industry in Thailand in relation to mangrove ecosystems*, Ecological Economics, in press.

Hussain, A. and Zhuang, J. (1994) *Impact of reform on wage and employment determination in Chinese state enterprises*, 1986-1991, Programme of Research into Economic Transformation and Public Science, STICERD, London School of Economics, London.

Huy, L. Q., Ninh, N. H. and Kelly, P. M. (2001) *Migration, resilience and global change in the coastal zone*. Paper presented at the Global Change and Sustainable Development in Southeast Asia: A Regional Science-Policy Conference, Chiang Mai, Thailand, February 17-19, 2001.

IMF (International Monetary Fund) (1999) *Vietnam – Selected issues and Statistical Index*, IMF, Washington D.C.

IPCC (2001) *Climate Change 2001: Impacts, Adaptation and Vulnerability*, The Assessment Report of the Working Group II of the IPCC, Cambridge University Press, Cambridge.

IPCC (2001) *Summary for Policymakers, The Impacts, Adaptation and Vulnerability*, The Third Assessment of the Working Group II, Cambridge University Press, Cambridge.

Kasperson, J.X.; Kasperson, R.E.; Turner, B.L. (1996) *Regions at risk: exploring environment criticality*. Environment, Vol. 38 (10), pp. 4-29.

Kay, R. and Alder, J. (1999) Coastal Planning and Management, E&FN Spon, London.

Leibbrandt, M.L., Woolard, C.D. and Woolard, I.D. (1996) *The contribution of income components to income inequality in South Africa: a decomposable Gini analysis*, World Bank Living Standards Measurement Study Working Paper 125.

Levin, S.; Barrett, S; Aniyar, S; Baumol, W; Bliss, C; Bolin, C; Dasgupta, P; Ehrlich, P.; Folke,; Gren, I.M.; Holling, C.S; Jansoon, A.M; Janson, B.O; Maler, K.G.; Martin, D; Perrings, C.; and Sheshinski, E; (1998) *Resilience in natural and socio-economic systems*. Environment and Development Economics, Vol. 3, pp. 222-235.

Liverman, D.M. (1989) *Vulnerability of Global Environmental Change*. Paper presented to International Workshop on Understanding Global Environmental Change, Clark University, Center for Technology, Environment and Development, 11-13 October.

Locke, C., Adger, W.N. and Kelly, P.M. (2000) *Changing places: Migration's social and environmental consequences*. Environment, Vol. 42, pp. 24–35.

Lorenzoni, I.; Jordan, A.; O'Riordan, T.; Turner, R.K and Hulme, M. (2000) *A co-evolutionary approach to climate change impact assessment — Part II: A scenario-based case study in East Anglia (UK)*, Global Environmental Change, Vol. 10 (2), pp. 145-155.

Lorenzoni, I.; Jordan, A.; O'Riordan, T.; Turner, R.K and Hulme, M. (2000) *A co-evolutionary approach to climate change impact assessment — Part I. Integrating socio-economic and climate change scenarios*, Global Environmental Change, Vol. 10 (2), pp. 145-155.

Luttrell, C. (2001) *An institutional approach to livelihood resilience in Vietnam*, Thesis submitted for the degree of Doctor of Philosophy, School of Environmental Scieneces, University of East Anglia, Norwich.

M. Martýnez, M. C., Fournier, R.(1999) *EcoPlata: an Uruguayan multi-institutional approach to integrated coastal zone management*, Ocean & Coastal Management, Vol.43, pp 165-185.

Margalef, R. (1969) *Diversity and stability: a practical proposal and model of interdependence: In Diversity and Stability in Ecological Systems*. Brookhaven Symposia on Biology 22, Brookhaven National Laboratory, Upton.

McCracken, C. (1988). *The long interview,* Newbury Park, CA: Sage.

Mendenhall, W., Reinmuth, J.E. and Beaver, R.J. (1993) *Statistics for management and economics*, Duxbury Press, New York.

Moss, R., Brenkert, A. and Malone, E.L. (2000) *Vulnerability assessment: A trial indicator set*, Pacific Northwest National Laboratory, Richland, Washington.

O'Riodan, T. and Vellinga, P. (1993) *Integrated coastal zone management: the next steps*, in Beukenkamp, P.; Gunther, P.; Klein, R. *et al.* (eds) World Coast '93, pp. 409-413, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, The Netherlands.

P. Encontre, (1999) *The vulnerability and resilience of small island developing states in the context of globalization*, Natural Resources Forum Vol. 23 (3) pp. 261-270.

Patton, M. & Westby, C. (1992). *Ethnography and research: A qualitative view.* Topics in Language Disorders, Vol. 12(3), pp. 1–14.

Pedersen, A., Nguyen Huy Thang, Vu Van Dung, Hoang Trong Tri and Eames, J. C. (1996) *The Conservation of Key Coastal Sites in the Red River Delta*, Birdlife International in Vietnam, Hanoi.

R.K. Turner, W.N. Adger, S. Crooks, I. Lorenzoni, L. Ledoux, (1999) *Sustainable coastal resources management: principles and practice*, Natural Resources Forum Vol. 23 (4), pp. 275-286.

Ramsar (1971) *Ramsar Convention on Wetlands*, Ramsar, Iran.

Reardon, T. and Taylor, J.E. (1996) *'Agroclimate shocks, income inequality and poverty: evidence from Burkinafaso'*, World Development, Vol. 24, pp. 901-24.

Robert, K. and Alder, J. (1999) *Coastal Planning and Management*, E & FN Spon, London.

Ruitenbeek, H.J. (1994) *Modelling economic ecology linkages in mangroves: economic evidence for promoting conservation in Bintuni Bay*, Indonesia. Ecological Economics, Vol. 10, pp. 133-24.

Ruitenbeek, H.J. (1996) *Valuation and distribution of ecological entitlements in the forest zone of Cameroon: Implications for economic and environmental security*. Ecological Economics, Vol. 17, pp. 49-64.

Seeborg, M.C. Jin, Z. and Zhu, Y. (2000) *The new rural-urban labor mobility in China: Causes and implications*, Journal of Socio-Economics, Vol. 29 (2000), pp. 39–56.

Sen A. (1973) *On Economic Inequality.* Oxford, Oxford University Press.

Sen, A. (1981) *Poverty and Famines: an Essay on Entitlement and Deprivation*, Clarendon, Oxford.

Sen, A. (1984) *Resources, Values and Development*, Blackwell, Oxford.

Shi, C., Hutchinson, S.M., Yu, L., Xu, S. (2001) *Towards a sustainable coast: an integrated coastal zone management framework for Shanghai, People's Republic of China, Ocean & Coastal Management*, Vol 44, pp 411-427.

Stark, O., Taylor, J.E., Yitzhaki, S. (1986) *Labour migration, income inequality and remittances: a case study of Mexico*, Development Research Department, World Bank, Washington D.C.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications, Inc.

Swallow, S.K. (1994) *Renewable and non-renewable resource theory applied to coastal agriculture, forest, wetland and fishery linkages*. Marine Resource Economics, Vol. 9, pp. 291-310.

Timmerman, P. (1981) *Vulnerability, Resilience and the Collapse of Society: A Review of Models and Possible Climatic Applications*. Institute for Environmental Studies, Environmental Monograph, Vol.1. University of Toronto, Canada: Institute for Environmental Studies.

UNDP (1999) *Vietnam Development and Cooperation Report - 1999*, UNDP Vietnam, Hanoi.

Vietnam Government Report (1995) *Government of Socialist Republic of Vietnam, Socio-economic development ad investment requirements for the five years 1996-2000*. Government report to the Consultive Group Meeting, Paris, 30th November – 1st December.

Vietnam Government Report (1995) *Government of Socialist Republic of Vietnam, Socio-economic development ad investment requirements for the five years*

1996-2000. Government report to the Consultive Group Meeting, Paris, 30th November – 1st December.

Watts, M.J. and Bohle, H.G. (1993) *The space of vulnerability: the causal structure of hunger and famine*, Progress in Human Geology, Vol.17, pp. 43-67.

Wearing, S. and Neil, J. (1999) *Ecotourism: impacts, potentials and possibilities,* Tourism Management, Volume 22(5), pp. 576-578.

Zimmerer, K. (1994) *Human geography and the 'New Ecology': The prospect and promise of integration*. Annals of the Association of American Geographers, Vol. 84 (1), pp.108-125.

Annex C

CURRENT AND FUTURE RAINFALL VARIABILITY IN INDONESIA

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ABSTRACT

Current and future rainfall variability in Indonesia was described. From historical data, it was suggested that seasonal rainfall in some regions tended to increase while in other region tended to decrease. Based on spatial analysis on monthly rainfall means over 210 stations throughout Indonesia which are divide into two periods, i.e. 1931-1960 and 1961-1990, it was shown that 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. 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. For the sourthern 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.

Many of extreme climate events in Indonesia were often associated with ENSO phenomena, i.e. La-Nina and El-Nino. El-Nino was normally associated with drought (rainfall decrease), while La-Nina was associated with flood (rainfall increase). However, the effect of La-Nina on rainfall increase was not as strong as the effect of El-Nino on rainfall decrease. The effect of the ENSO events was strong in regions strongly influenced by monsoon system, weak in regions that have equatorial system and not clear in regions that have local system. Rainfall pattern strongly influenced by monsoon system is uni-modal (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. Rainfall pattern in regions strongly influenced by the equatorial system is bi-modal (two peaks of rainy season, normally occurs in March and in October). And rainfall pattern in regions strongly influenced by local system also has uni-modal rainfall but the pattern is the opposite of the monsoonal type. A number of studies suggested that how global warming would affect ENSO were not clear.

Based on analysis to a number of GCM models outputs from two scenarios, i.e. high (SRESA2) and low scenarios (SRESB2), it was suggested that the under changing climate means of Indonesian temperature will increase at a rate of about 0.0344 ^{o}C per year for SRESA2 and about 0.0211^{o}C per year for SRESB2. The impact on rainfall varied between GCM models 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 (Sep-Nov) rainfall. Whereas, for ECHAM4 and CGCM1, the rainfall would decrease consistently while for HadCM3, the impact was not consistent. For example the DJF (Dec-Feb) 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. In regions with decreasing rainfall might be exposed to high drought risk (long dry spell), while those with increasing rainfall might be exposed to high flood risk. The return period of such extreme events might also increase. This study indicates that the impact of global warming on rainfall in Indonesia could not be generalized.

Key words: rainfall variability, El-Nino, La-Nina, rainfall change and GCM,

I. INTRODUCTION

The increase of greenhouse gases concentration in the atmosphere will increase global temperature or cause global warming as these gases can absorb infrared radition. Many studies indicated that the global warming might have a significant impact on global climate. A study conducted by LAPAN-Indonesia indicated that under elevated CO_2, the intensity and the frequency of El-Nino Southern Oscillation (ENSO) events would increase (Ratag *et al.*, 1998). At present conditions ($1xCO_2$), the frequency of ENSO occurrence is once every 3-7 years, while under $2xCO_2$ it increased to once every 2-5 years, and under $3xCO_2$ it increased to once every 2-3 years. However, other studies gave different results. Global warming only caused a little change or a small increase in amplitude for El Nino events over the next 100 years (Trenberth and Houghton, 1996). The question that arises regarding global warming and its relation with ENSO events is that of the confidence of projections. Irrespective of that confidence, with little or no change in El Nino amplitude, global warming is likely to lead to greater extremes of drying and heavy rainfall and increase the risk of droughts and floods that occur with El Nino events in many different regions.

One of simple analysis to assess the climate change is by doing trend analysis to long historical data. Trend analysis to annual rainfall data of Citarum watershed which covering approximately 100 years data (1896-1994) showed that the annual rainfall in this watershed has decreased at a rate of 10 mm/year. In the early 1900’s the mean annual rainfall was about 2800 mm per year and in the 1990s it decresed to about 2350 mm (Pawitan, 2002). In other sites, the trend may not be significant or it might be positive. Spatial analysis to see the direction of change in rainfall from the past to present condition is important for climate change study as it can be used as a basis in developing climate change scenarios.

General Circulation Models (GCMs) – mathematical representations of atmosphere, ocean, and land surface processes based on the law of physics – has been commonly used for assessing global climate change due to increasing GHG concentration in the atmosphere. The models estimate changes of dozens of meteorological variables in regional climates in grid boxes that are typically 250 km in width and 600 km in length or 3^o or 4^o up to 10^o (latitude and longitude). As the resolution of these models is very low, their ability to represent local/regional climate is low. Their use for impact studies in small regions may not be appropriate. Therefore techniques to downscale the GCM outputs into local level are required.

This technical report describes (i) the spatial change of seasonal rainfall in Indonesia regions in the period of 1930-1990, (ii) ENSO influence on Indonesian rainfall, (iii) impact of global warming on Indonesian climate, and (iv) approach to downscale GCM output into local rainfall.

II. Rainfall Trend Over Indonesia

Analysis of spatial change of Indonesian rainfall in 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 1). Further analysis on seasonal rainfall 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. For the sourthern 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 (Figure 2 and 3).

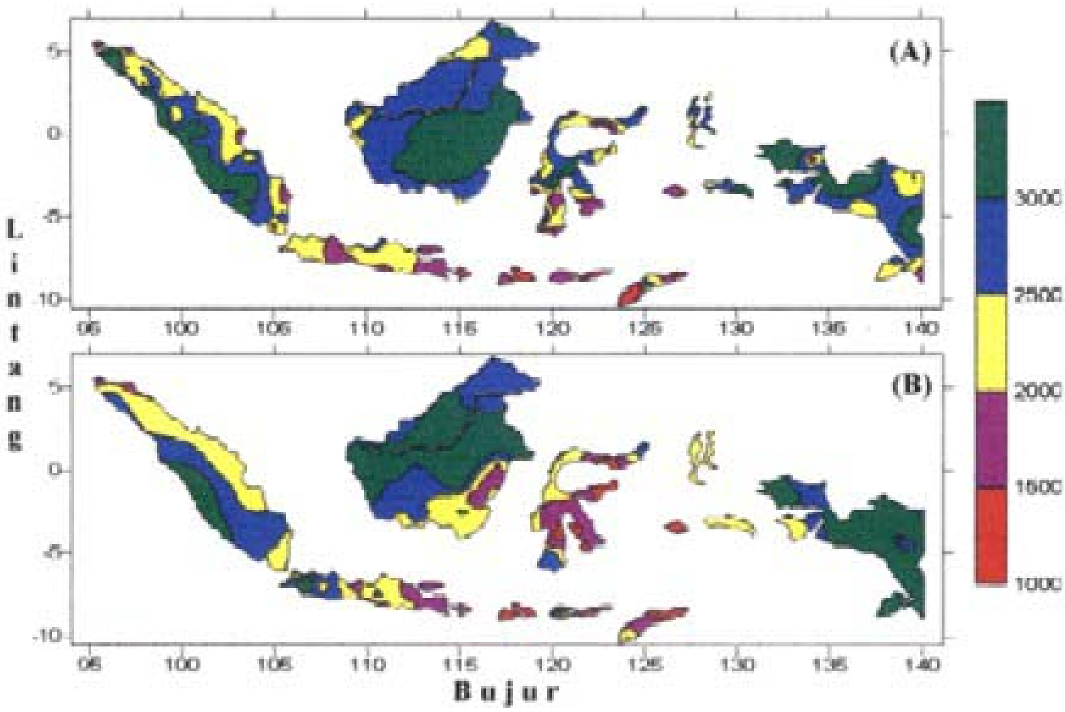


Figure 1. Mean annual rainfall in the periods of (A) 1931-1960 and (B) 1961-1900 (Kaimudin, 2002)

In order to see rainfall trend over a number of decades, rainfall data series from four stations that have about 80 to 100 years of record were selected. The four selected stations have different rainfall patterns, i.e. Kupang, Jakarta, Maulaboh and Ambon (Table 1). Rainfall patterns in Jakarta and Kupang are strongly influenced by monsoon system. They have 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. Rainfall in Maulaboh is strongly influenced by equatorial system. It is characterized by bi-modal rainfall pattern (two peaks of rainy season, normally occurs in March and in October). Rainfall in Ambon is strongly influenced by local system. It also has uni-modal rainfall but the pattern is the opposite of the monsoonal type.

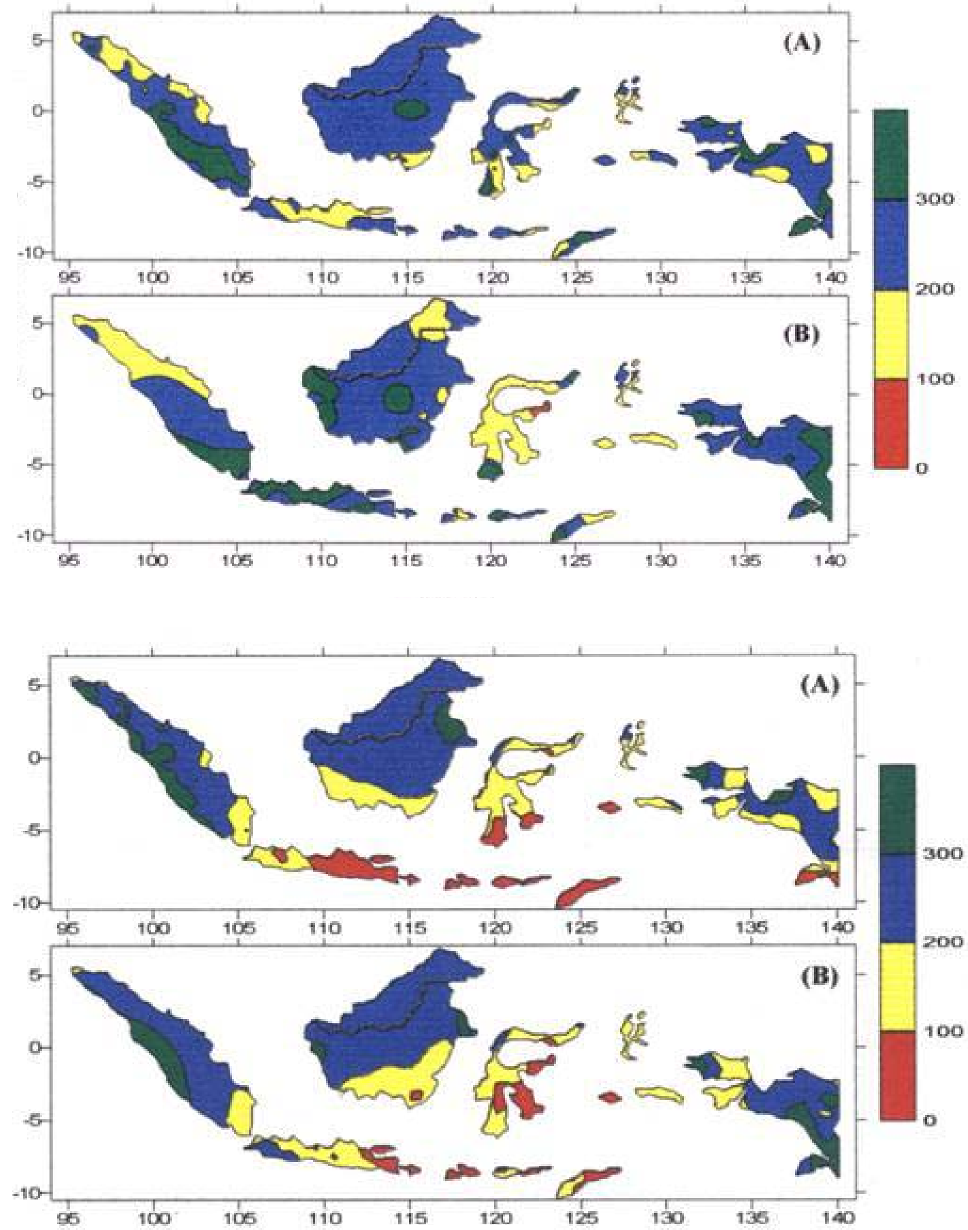


Figure 2. September-November (top) and December-February rainfalls (bottom) in the periods of (A) 1931-1960 and (B) 1961-1990 (Kaimuddin, 2002)

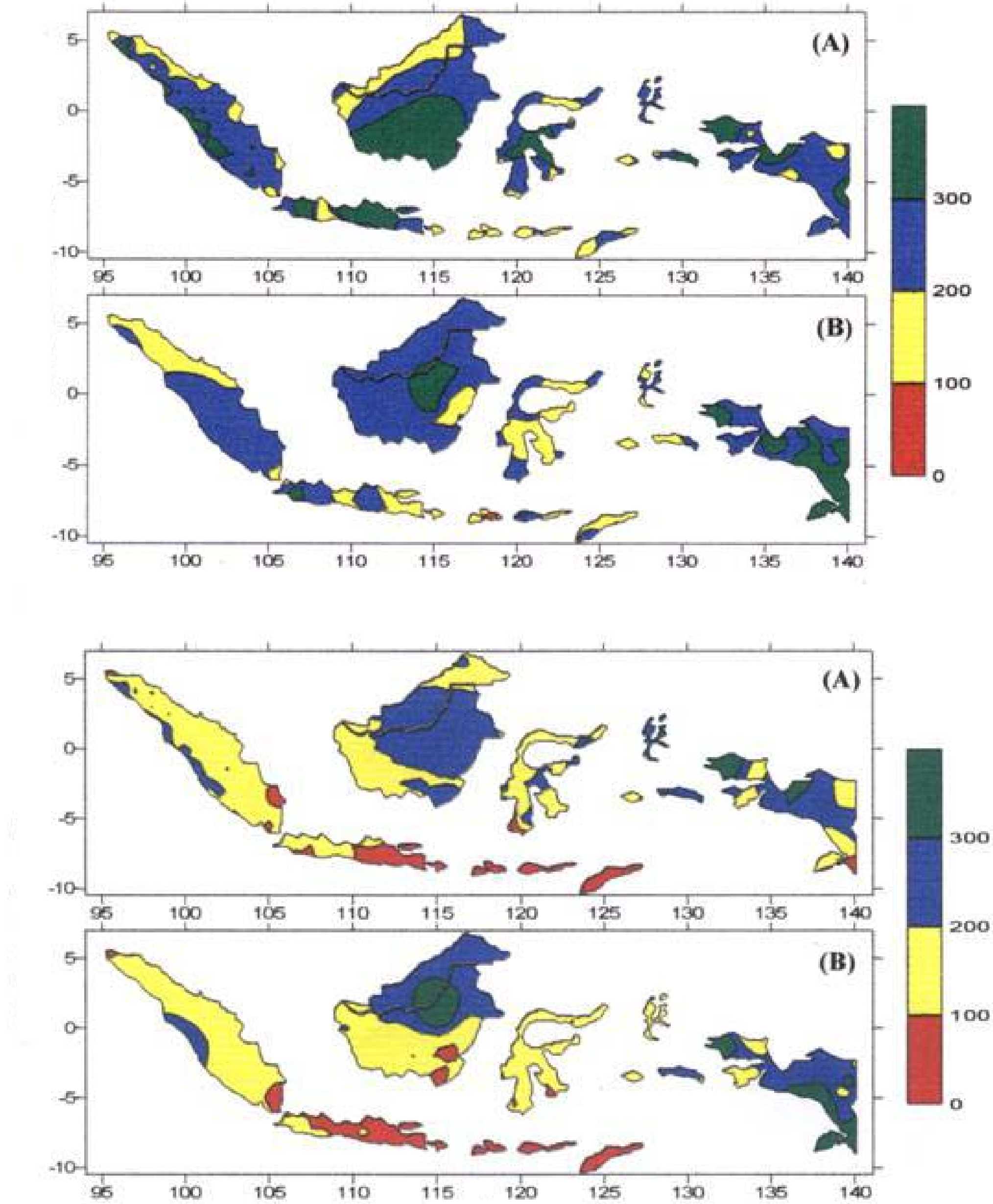
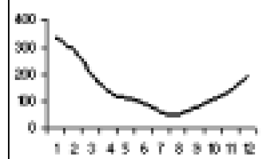
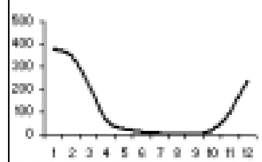
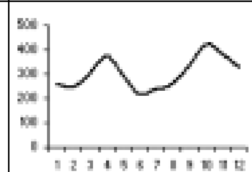
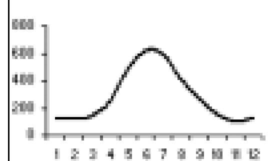


Figure 3. March-May (top) and June-August rainfalls (bottom) in the periods of (A) 1931-1960 and (B) 1961-1990 (Kaimuddin, 2002)

Table 1. Geographical position, length of record and, rainfall pattern of the four rainfall stations

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. 128°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	

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 (Figure 2). In Ambon, dry season rainfall tended to decrease while wet season rainfall relatively constant over the 100 years period. In Maulaboh, either wet or dry season rainfall both tended to decrease, in particular wet season rainfall (Figure 2). 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. The rainfall variability tended to follow the rainfall means, i.e. the variability increased as the mean of rainfall increased (Figure 2). Secondly, 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 raindfall before it decreased again in early 1950s. Different from monsoonal types, the rainfall variability generally decreased as the mean of rainfall increased. Thirdly, in Ambon (local type) the change of the pattern was in the opposite direction of the moonsonal types, in particular for dry season rainfall. 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. The change in rainfall variability was similar to that of equatorial type, i.e. the rainfall variability decreased with rainfall means. These findings might suggest that the impact of global warming on rainfall in Indonesia could not be generalized.

III. ENSO Influence on Indonesian Rainfall

El-Nino and Southern Oscillation (ENSO) phenomena has been found to be one of important factor that affect rainfall variability in Indonesia. Extreme events such as drought and flood are often associated with these events. Having better understanding on these events would be useful as a basis to assess the future climate risk in Indonesia. Even though some studies suggested that behavior of El-Nino events were not always well-presented in climate models, so that it would be difficult to predict how these events would change due to global warming (CRU, 1999; Trenberth and Hoar, 1996), but extreme climate events were very likely to increase in the future. Extreme climate events associated ENSO could be used as an analog.

Irawan (2002) has 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. Sumatra, Java and Sulawesi consistently showed a decrease of seasonal rainfall (Figure 3), 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 2).

Table 2. Percent change of rainfall relative to normal rainfall by provinces

	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)

Different from El-Nino, La-Nina events caused rainfall increase. However, the effect of La-Nina on rainfall increase was not as strong as the effect of El-Nino on rainfall decrease (ADPC, 2000; Las et al., 1999). Furthermore, Tjasyono (1997) stated that the effect of these events was strong in regions strongly influenced by monsoon system, weak in regions that have equatorial system and not clear in regions that have local system. In order to further assess the impact of these events, long rainfall data series from six stations were selected for analysis, i.e. Bukittinggi (equatorial system), Ambon (local system), and Kendari, Bandung, Jogya, and Semarang (monsoon system). The analysis was performed by studying the relationship between SOI and monthly rainfall anomaly (Figure 4 and 5). The data confirm that the effect of El-Nino on rainfall were stronger and more consistent than the that of La-Nina. Further analysis showed that when SOIs were strongly negative (El-Nino), the probability of having negative rainfall anomalies were mostly less than 50%, whereas when SOIs were strongly positif (La-Nina), the probability of having positive rainfall anomalies were much higher (more than 65%), in particular for areas strongly influenced by monsoon system (Table 3), except for Bandung station as this station locates in a valley where the local effect may reduce the ENSO influence.

Table 3. Chance of having positive rainfall anomaly during strong positive SOI, and negative anomaly rainfall during strong negative SOI

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).

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 4), 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).

Table 4. Onset of dry season and wet season in West Java based on decadal data (1951-1998)

	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.

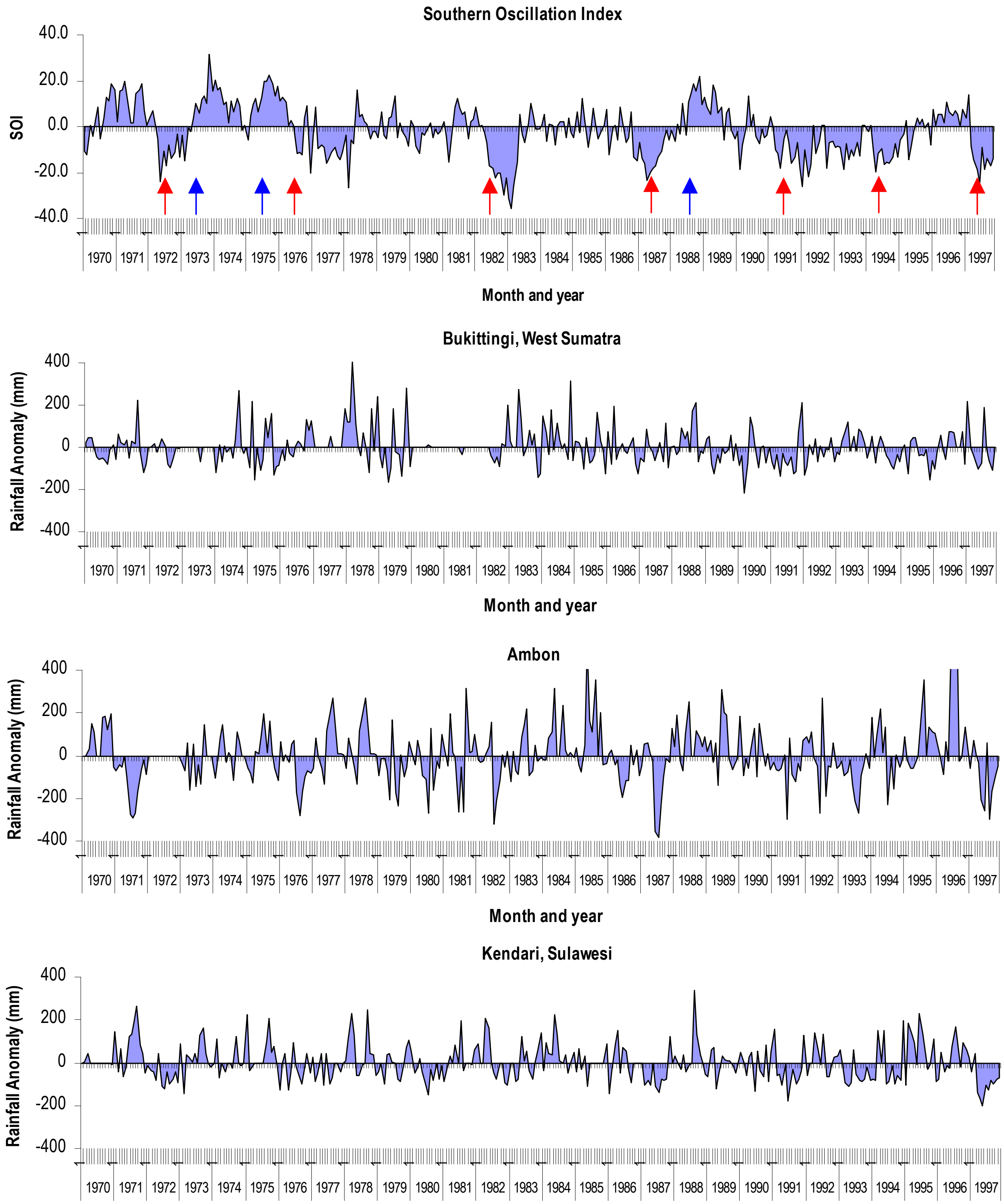


Figure 4. Sea surface temperature anomaly at Nino3.4 and rainfall anomaly in Bukittinggi (Equatorial Type), Ambon (Local Type), and Kendari (Monsoonal Type). Red arrows indicate El-Nino years and Blue arrows indicate La-Nina years

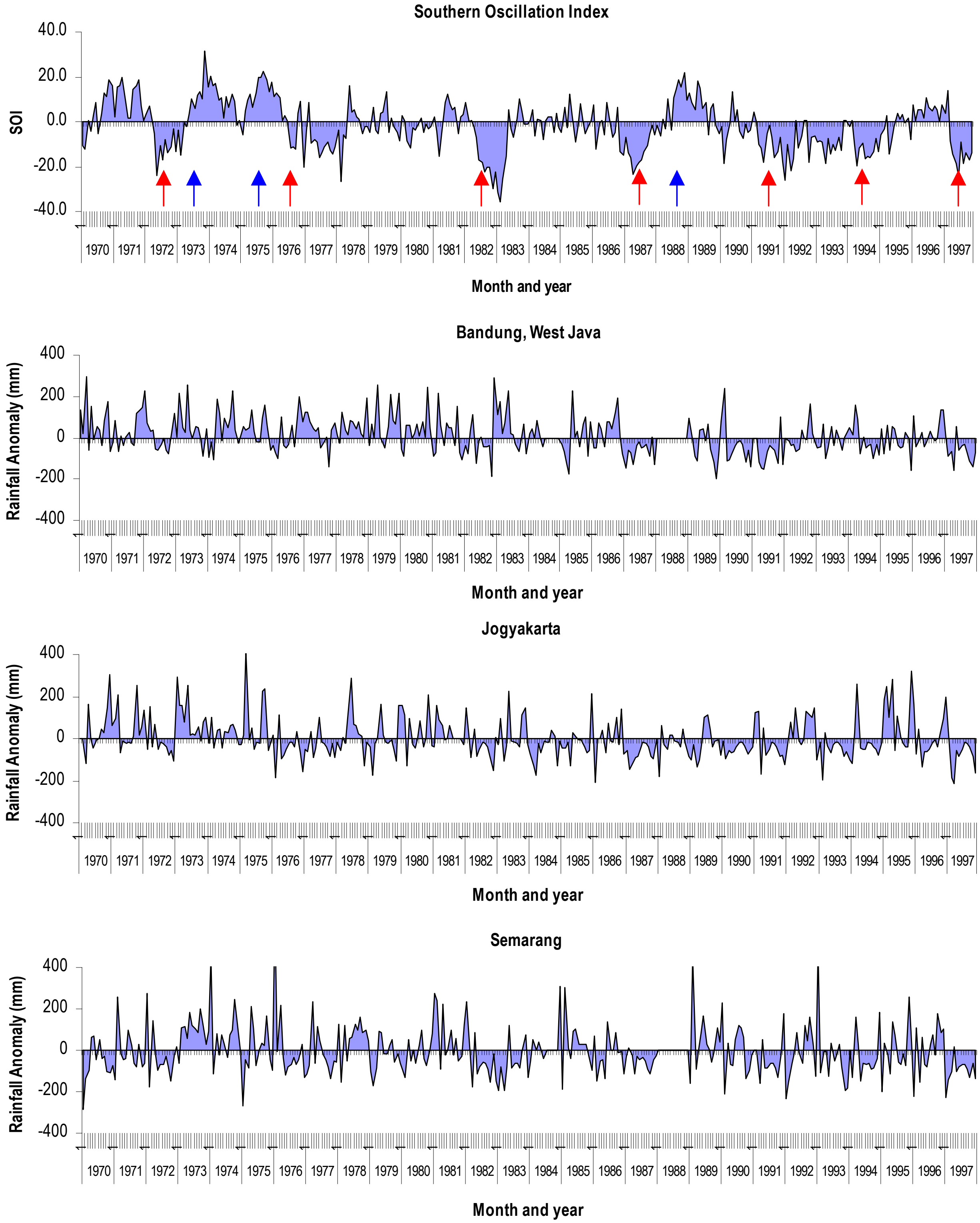


Figure 5. Sea surface temperature anomaly at Nino3.4 and rainfall anomaly in Bandung, Jogyakarta, and Semarang (Monsoonal Types). Red arrows indicate El-Nino years and Blue arrows indicate La-Nina years

IV. Impact of Global Warming on Indonesian Climate

4.1 Emission Scenarios

Many scientific evidences showed that global warming phenomena is occurring due to rapid increase in greenhouse gases consentration in the atmosphere. In the period of 1950 to 1998, it was estimated that about 270 ($\pm$30) Gt of carbon has been released to the atmosphere. About 40% of the carbon emission came from human activities such as burning fossil fuels, industry activities and deforestation, and 60% from natural process that is aboserbed again by ocean and treestrial ecosystem. Therefore, due to the increase in human activities in consuming energy and forest conversion, the concentration of greenhouse gases in the atmosphere will continuously increase. Table 5 shows the changes in GHGs concentration in the atmosphere from pre-industrial era to 1994.

Table 5. Concentration of GHGs and lifetime since pre-industrial industry and 1994

	CO_2	CH_4	N_2O	CFC-11	HCFC-22
Concentration					
At the beginning on industry revolution	~280 ppmv	~700 ppbv	~275 ppbv	0	0
In 1994	358 ppmv	1720 ppbv	312 ppbv	268 pptv	110 pptv
Rate of change					
- ppmv per annum	1,5	10	0,8	10	5
- % per annum	0,4	0,6	0,25	0	5
Lifetime (year)	50-200	12	120	50	12

Source: IPCC (1996)

The main problem in assessing future climate change is how to estimate the likely change in greenhouse gases emissions in the future. Many possibilities might occur as the level of emissions is closely related to population growth, socio-economic development, and technology changes. Implementation of climate policy or GHG emission targets by developed countries as stated in the Kyoto Protocol may also affect the rate of the GHG emissions. Therefore, in estimating future emissions the IPCC has developed a number of scenarios (IPCC 2000) using several assumptions of the driving forces. The scenarios provide alternative images of how the future might unfold and are an appropriate tool with which to analyze how the driving forces may influence future emission outcomes and to assess associated uncertainties.

The emission scenarios developed by IPCC six IS92 scenarios: IS92a up to IS92f, and four SRES scenarios: SRESA1, SRESA2, SRESB1 and SRESB2 (IPCC, 2000). In this analysis new IPCC scenarios were used, SRESA2 and SRESB2. These two scenarios may 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. 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. Quantitavely, the growth of population, income per capita, and GDP and level of energy consumption under the two scenarios is presented in Table 6, while the GHGs concentration, global temperature increase, and sea level rise in Table 7.

Table 6. Assumption used in developing SRESA2, and SRESB2 scenarios

Key assumption/Scenario	1990	2020	2050	2100
Population (billion)				
SRESA2	5.3	8.2	11.3	15.1
SRESB2	5.3	7.6	9.3	10.4
GDP-World (10^{12} 1990 USD/year)				
SRESA2	21	41	82	243
SRESB2	21	51	110	235
Ratio of income per cap between developed & non-developed countries				
SRESA2	16.1	9.4	6.6	4.2
SRESB2	16.1	7.7	4	3
Energy Consumption (10^{18} J/year)				
SRESA2	351	595	971	1717
SRESB2	351	566	869	1357
Contribution of coal consumption to total energy (%)				
SRESA2	24	22	30	53
SRESB2	24	17	10	22
Contribution of non-carbon energy to total energy (%)				
SRESA2	18	18	18	28
SRESB2	18	18	30	49

Source: IPCC (2000)

Table 7. Concentration of GHGs, and global temperature increase, and sea level rise relative to 1990

J. Year	2000	2025	2050	2100
CO_2 concentration (ppmv)				
SRESA2: Estimation	370	440	535	825
: Range	370	430-450	515-555	760-890
SRESB2: Estimation	370	425	480	600
: Range	370	415-435	460-500	560-640
CH_4 concentration (ppbv)				
SRESA2: Estimation	1600	2250	2850	4300
: Range	1600	2200-2300	2700-3000	3800-4800
SRESB2: Estimation	1600	2245	2650	2700
: Range	1600	2150-2260	2550-2750	2500-2900
N_2O concentration (ppbv)				
SRESA2: Estimation	316	344	375	452
SRESB2: Estimation	316	335	349	361
Global temperature increase (^oC):				
SRESA2: Estimation	0.2	0.50	1.20	2.9
: Range	0.15-0.25	0.30-0.70	0.80-1.60	2.0-4.1

SRESB2: Estimation	0.2	0.52	1.35	2.3
: Range	0.15-0.25	0.5-0.7	1.00-1.75	1.6-3.3
Sea level rise (cm)				
SRESA2: Estimation	2	10	21	60
: Range	0-4.0	4.0-20	9.0-41	25-112
SRESB2: Estimation	2	10	22	50
: Range	0-4.0	4.0-20	9.0-43	20-88

Source: MAGIC-SCENGEN (NCSP, 2000)

4.2 Impact of Global Warming on Indonesian Climate

The increase in GHG concentration under the two scenarios will affect Indonesian climate. The assessment of global warming impact on Indonesian climate was conducted based on five GCMs, i.e. GCMs, CCSR-NIESS, CGCM1, CSIRO, ECHAM4 and HadCM3. The montly data of the GCMs outputs 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 8).

Table 8. Resolution of the five GCMs and the coverage area for the analysis

	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

The impact of increasing GHGs concentration in the atmosphere will increase means of Indonesian temperature at a rate of about 0.0344 ^{o}C per year under SRESA2 scenario and about 0.0211^{o}C per year under SRESB2 scenario. The impact on rainfall varied between GCM models 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 6). 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 6). 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 (Figure 6).

Based on change in spatial pattern of seasonal rainfall, it was found that Under ECHAM model, the intensity of changes for wet season rainfall (DJF) would be greater in the northern part of Indonesia and less in the southern part, while for dry season rainfall (JJA), it would be greater in the southern part and less in the northern part (Figure 7 and 8). Under CSIRO model, the intensity of changes would get stronger as the areas get closer to the equator (Figure 9 and 10). High decrease in dry season rainfall will expose the Indonesian region to high drought risk while high increase in wet season rainfall will increase flood risks. These findings imply that no generalization could be made on the impact of global warming on rainfall and level of exposure to climate risk in Indonesia.

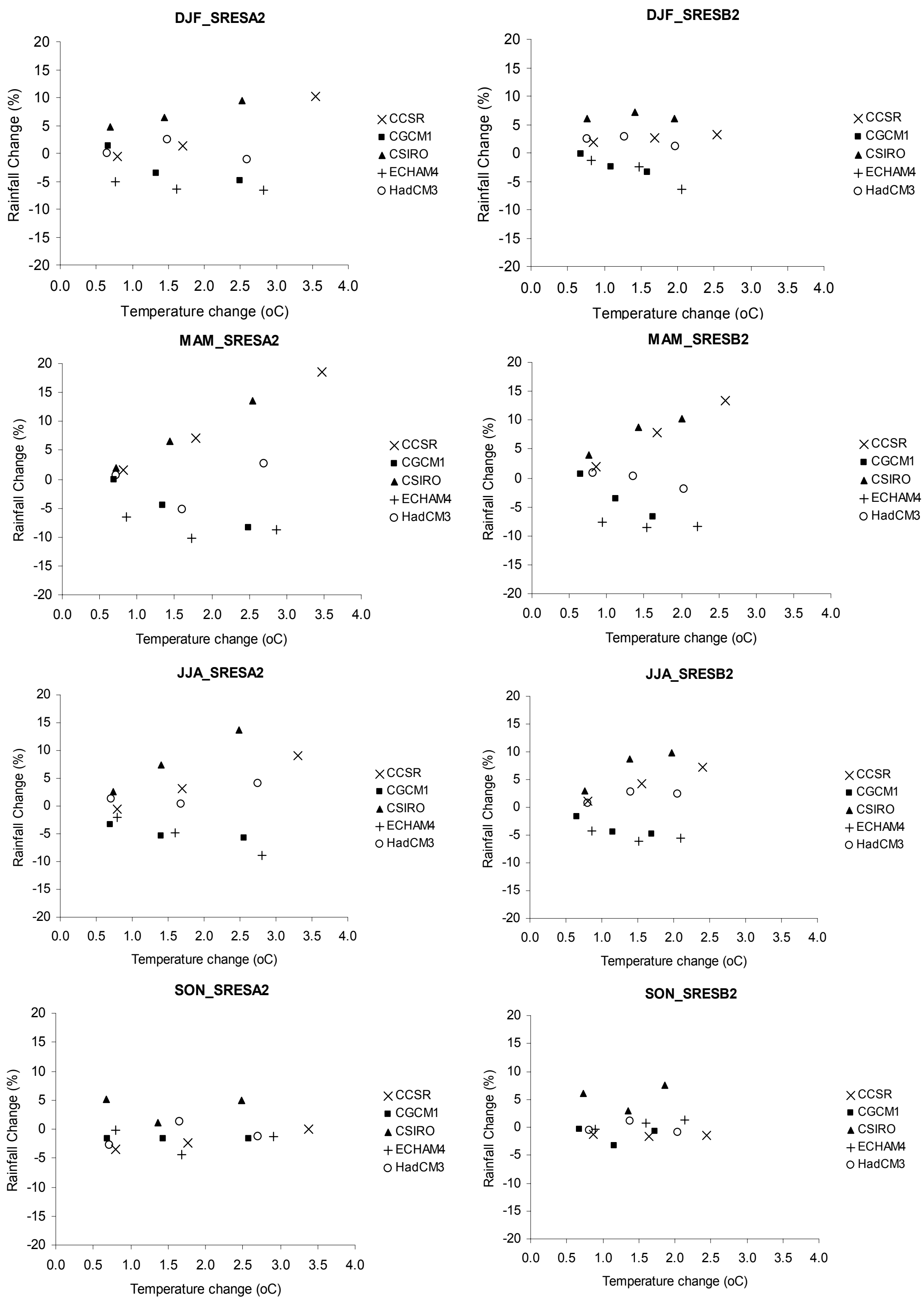


Figure 6. The change in mean temperature and seasonal rainfall in Indonesia under the two emission scenarios for the five GCM models. The data points in the left represent data for 2020, the middle for 2050 and the right for 2080

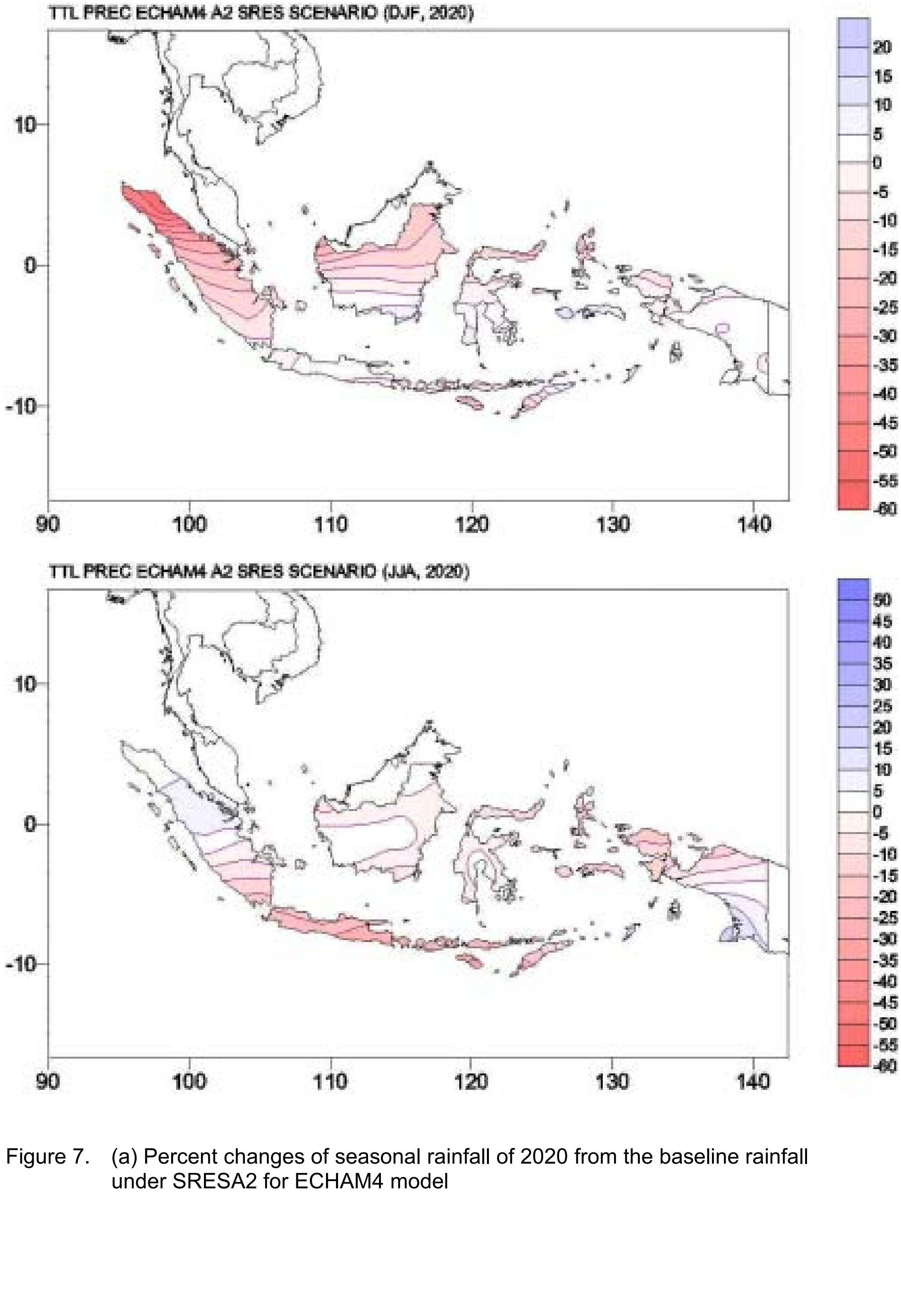


Figure 7. (a) Percent changes of seasonal rainfall of 2020 from the baseline rainfall under SRESA2 for ECHAM4 model

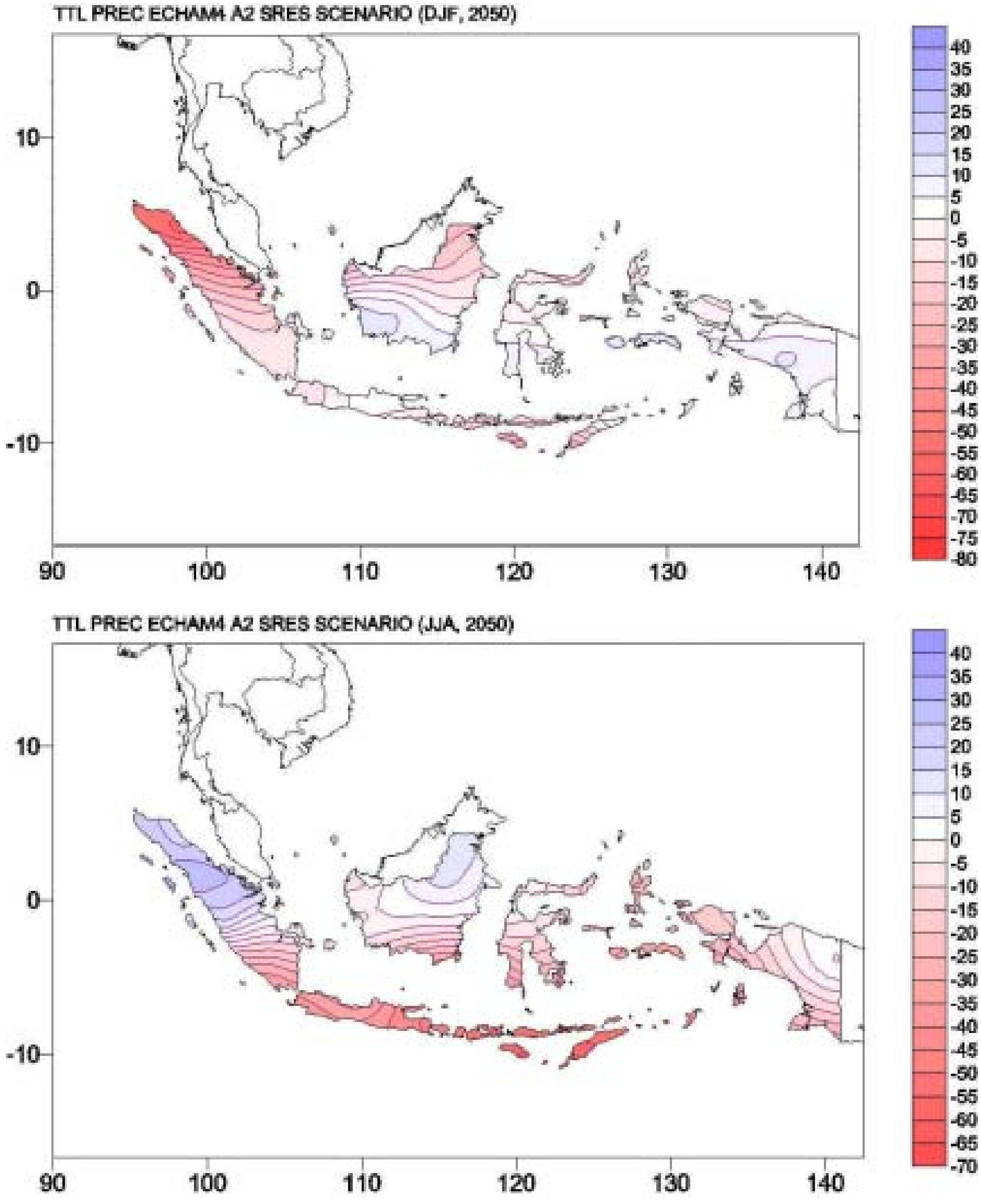


Figure 7. (b) Percent changes of seasonal rainfall of 2050 from the baseline rainfall under SRESA2 for ECHAM4 model

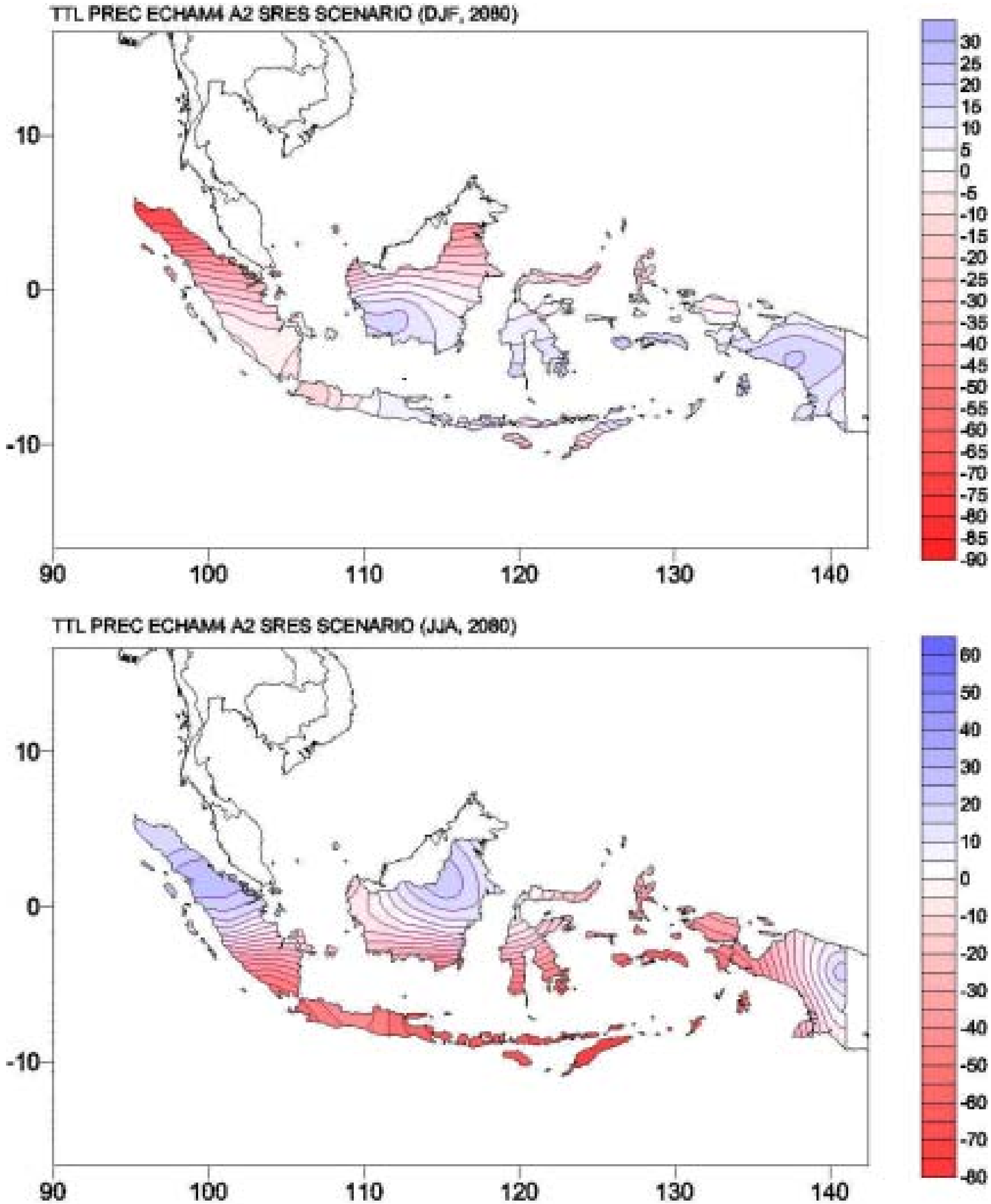


Figure 7. (c) Percent changes of seasonal rainfall of 2080 from the baseline rainfall under SRESA2 for ECHAM4 model

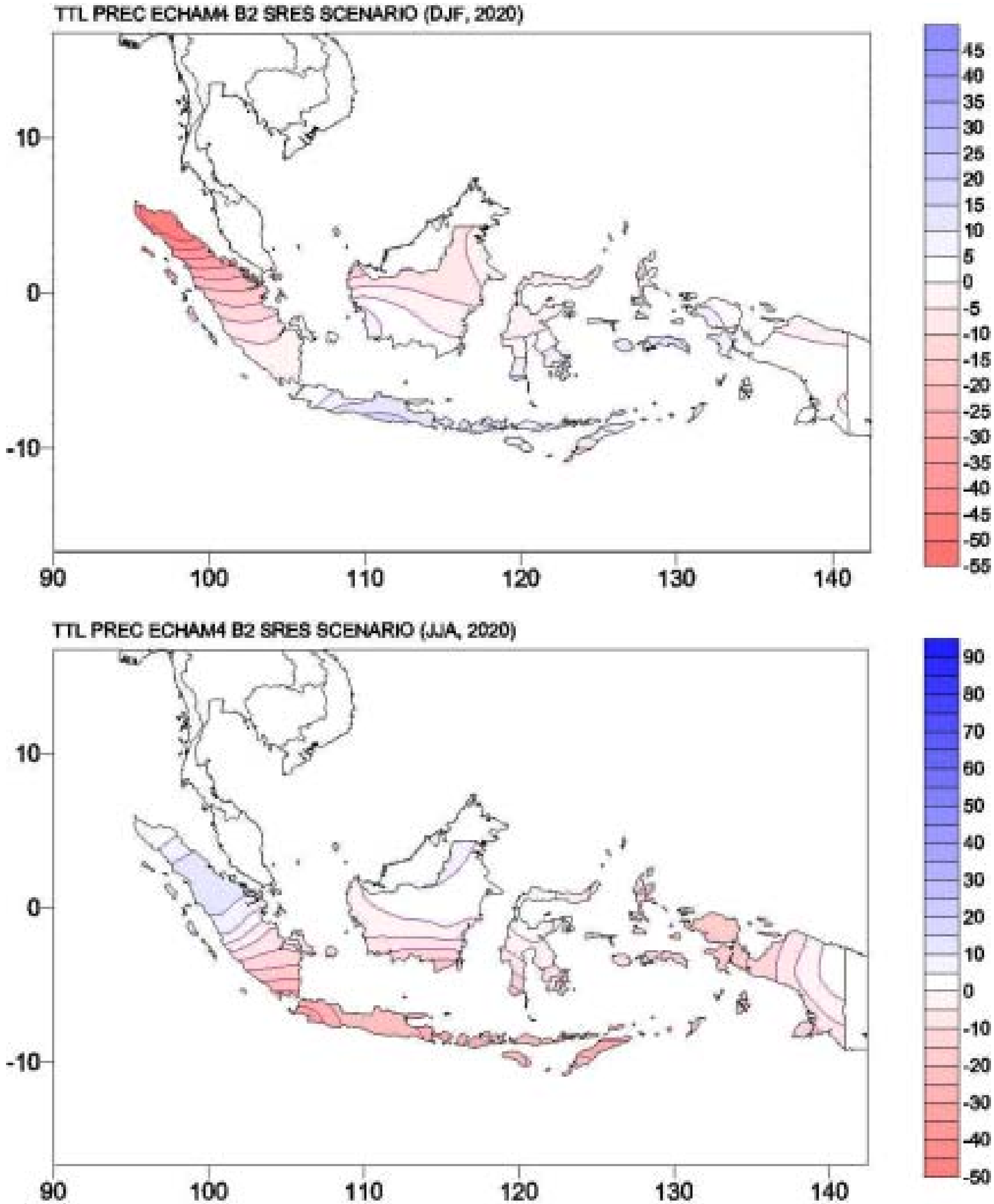
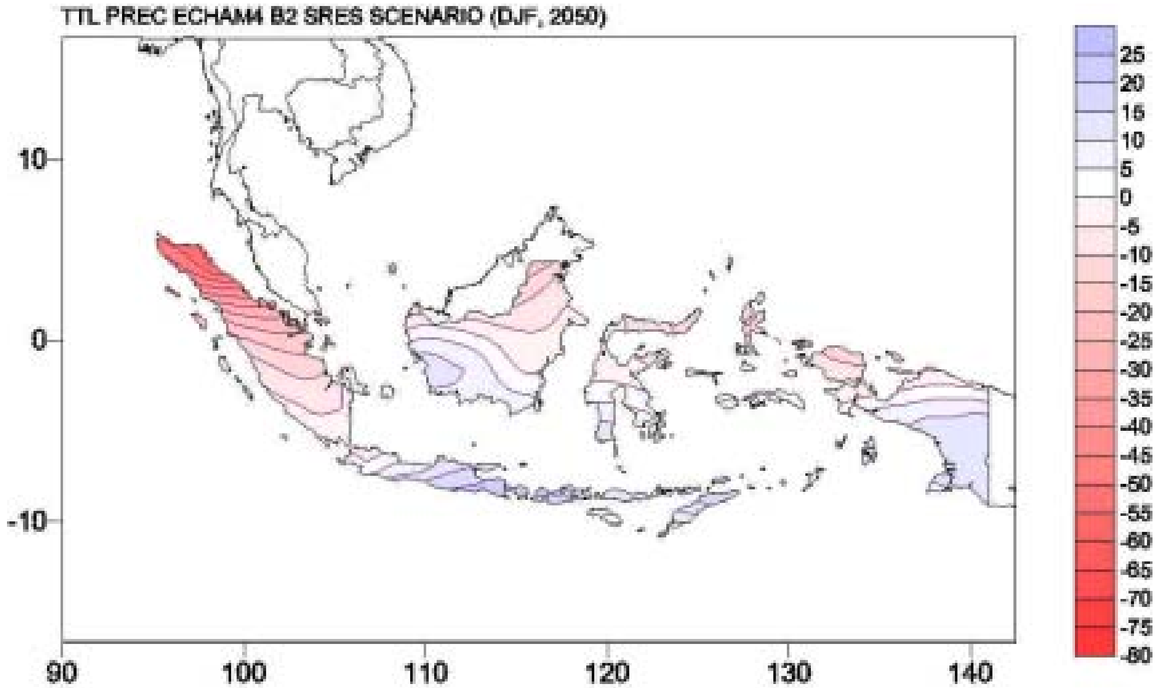


Figure 8. (a) Percent changes of seasonal rainfall of 2020 from the baseline rainfall under SRESB2 for ECHAM4 model



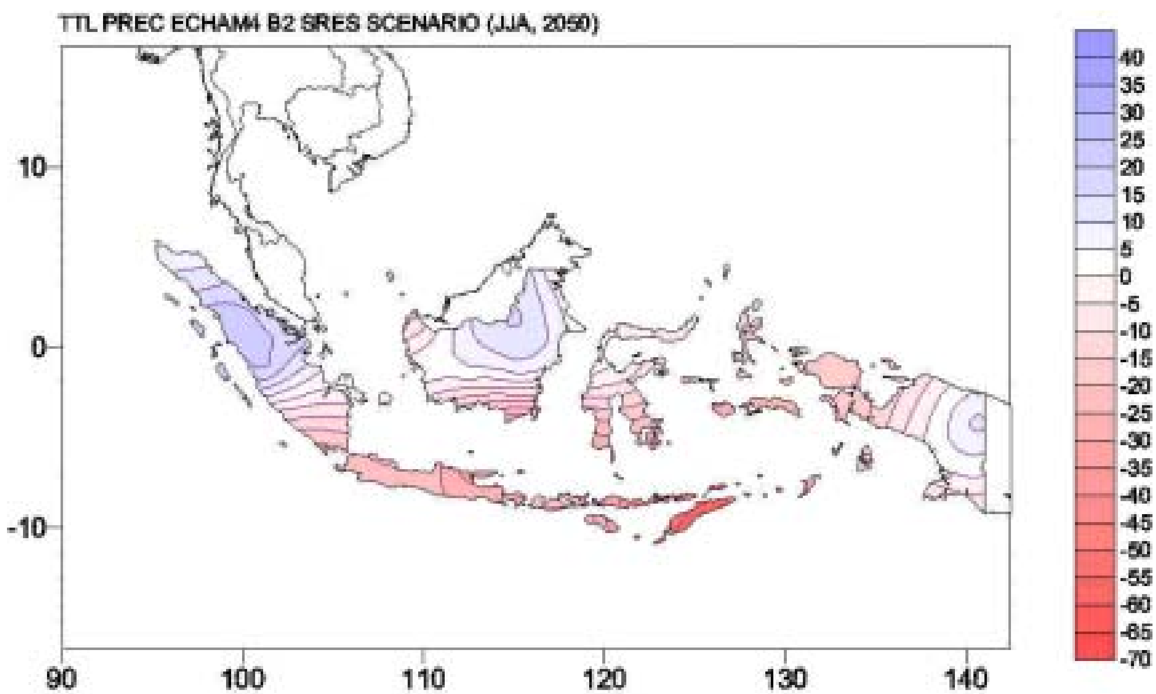


Figure 8. (b) Percent changes of seasonal rainfall of 2050 from the baseline rainfall under SRESB2 for ECHAM4 model

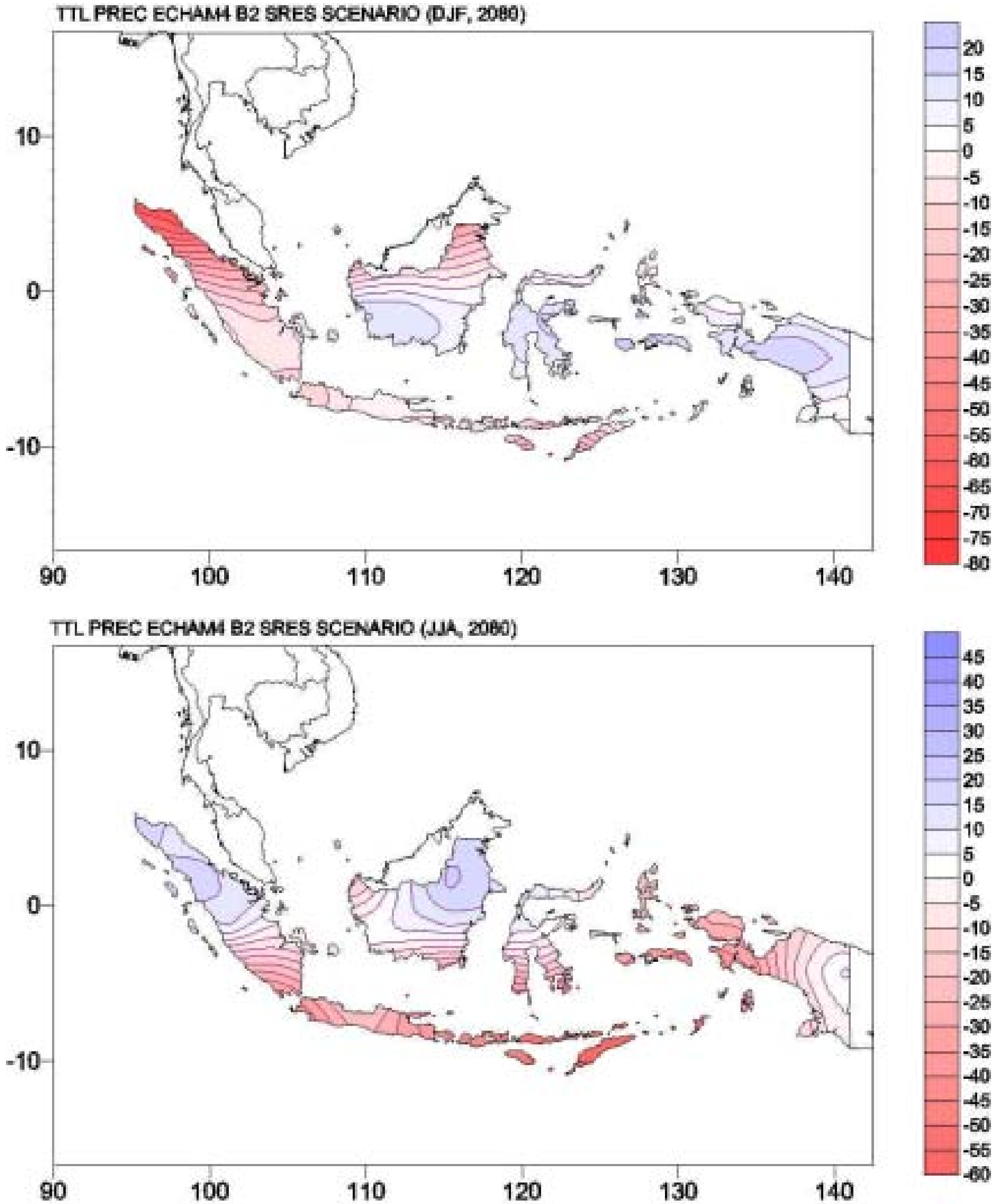


Figure 8. (c) Percent changes of seasonal rainfall of 2080 from the baseline rainfall under SRESB2 for ECHAM4 model

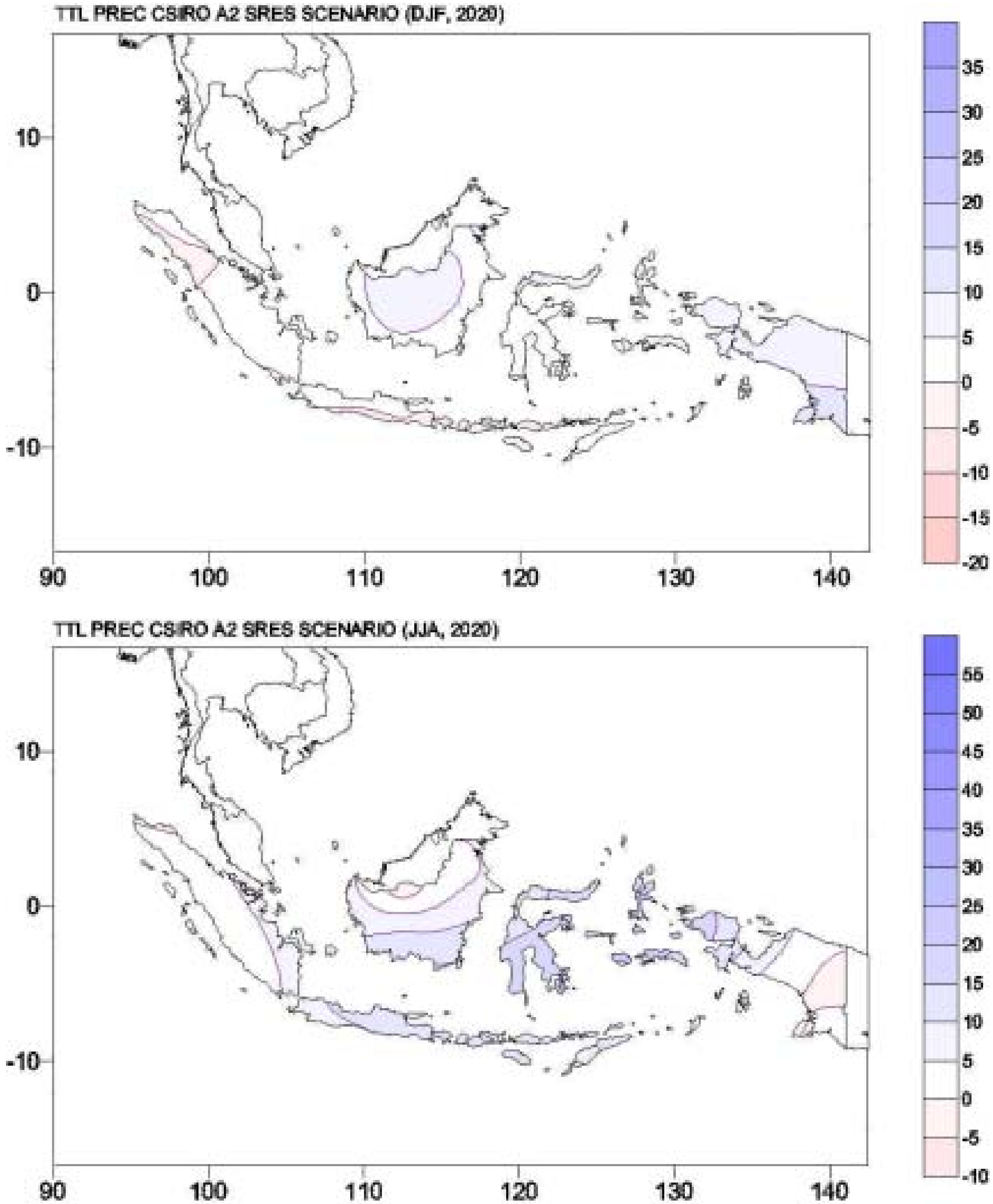


Figure 9. (a) Percent changes of seasonal rainfall of 2020 from the baseline rainfall under SRESA2 for CSIRO model

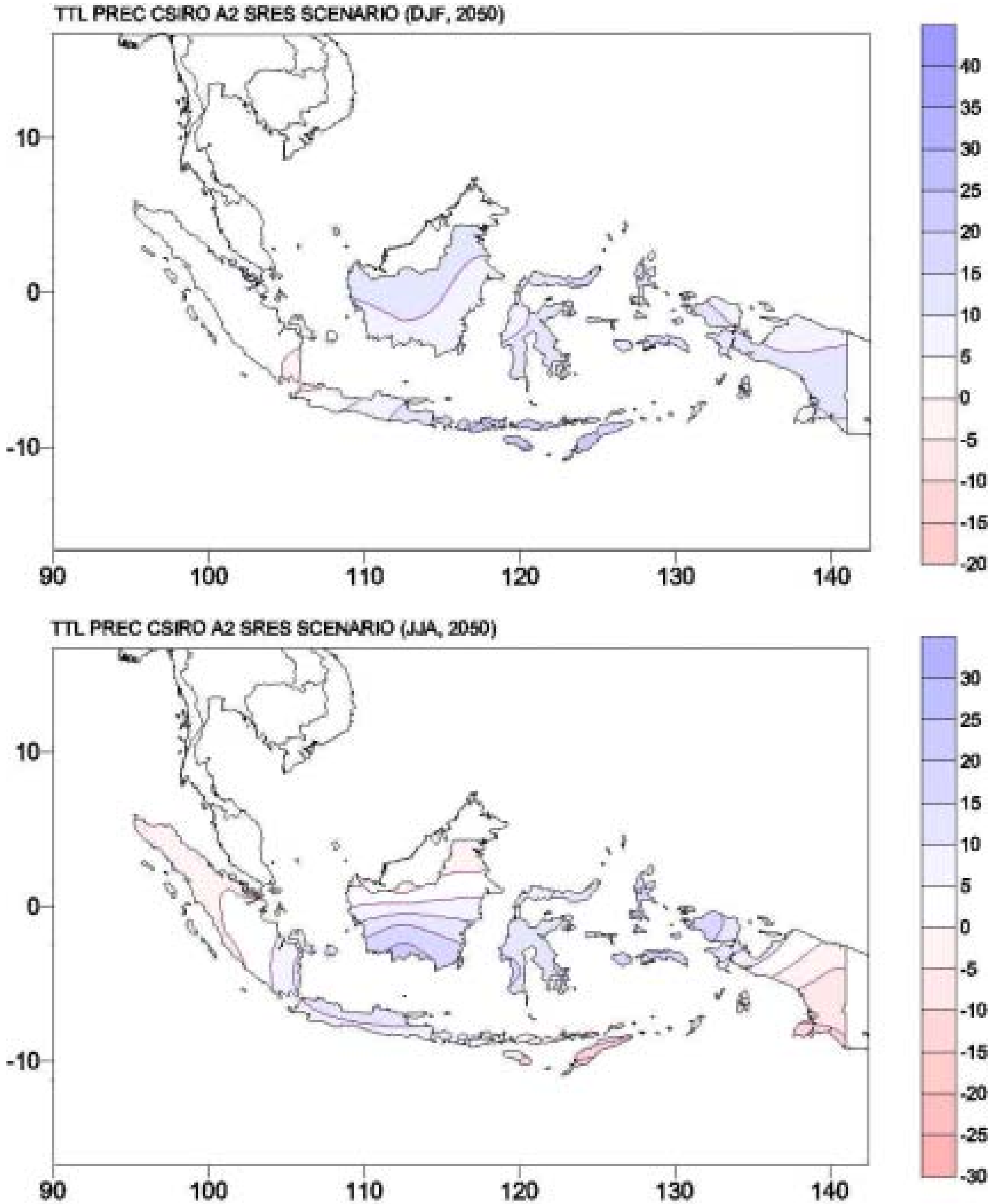
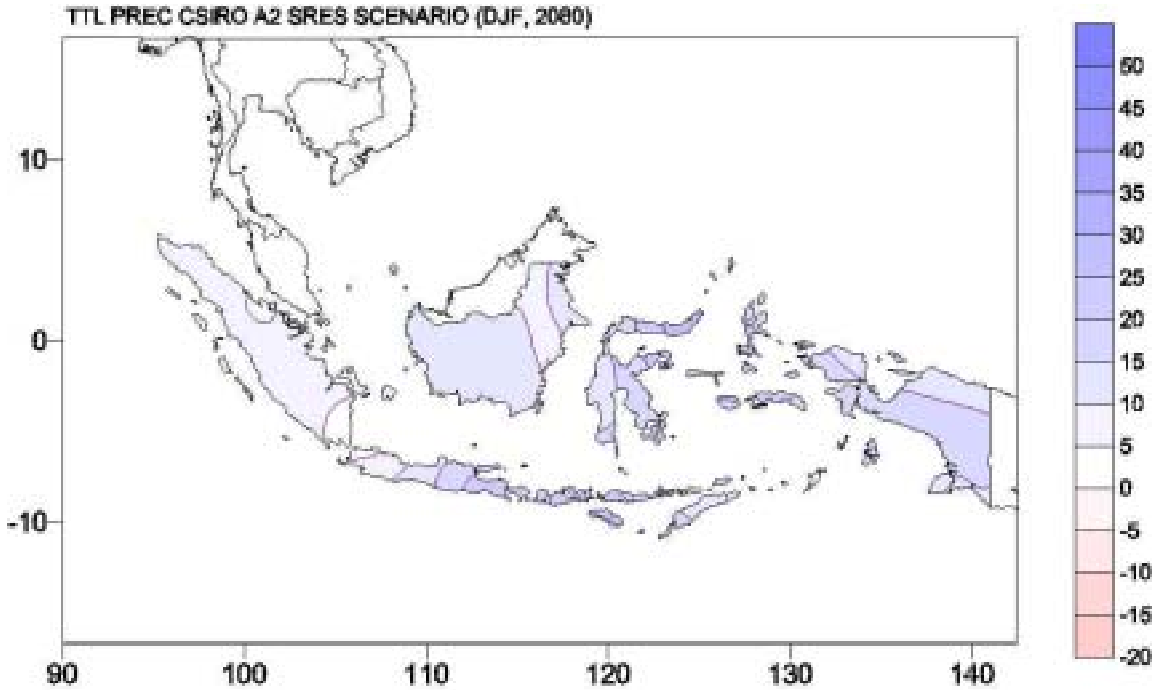


Figure 9. (b) Percent changes of seasonal rainfall of 2050 from the baseline rainfall under SRESA2 for CSIRO model



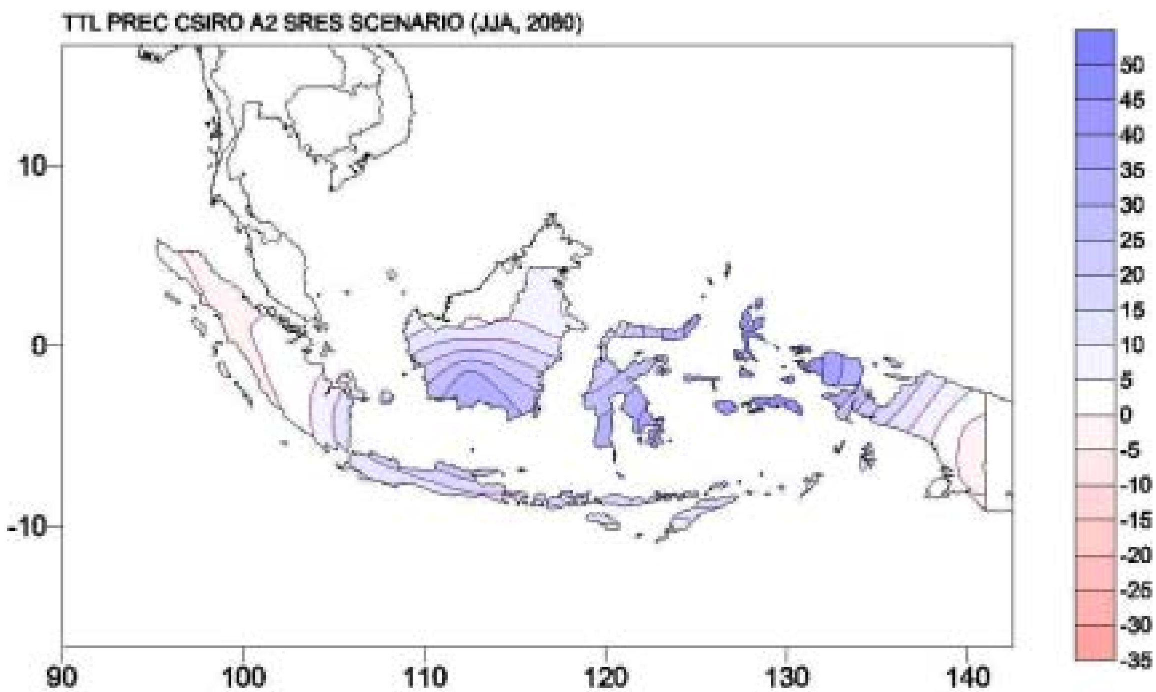


Figure 9. (c) Percent changes of seasonal rainfall of 2080 from the baseline rainfall under SRESA2 for CSIRO model

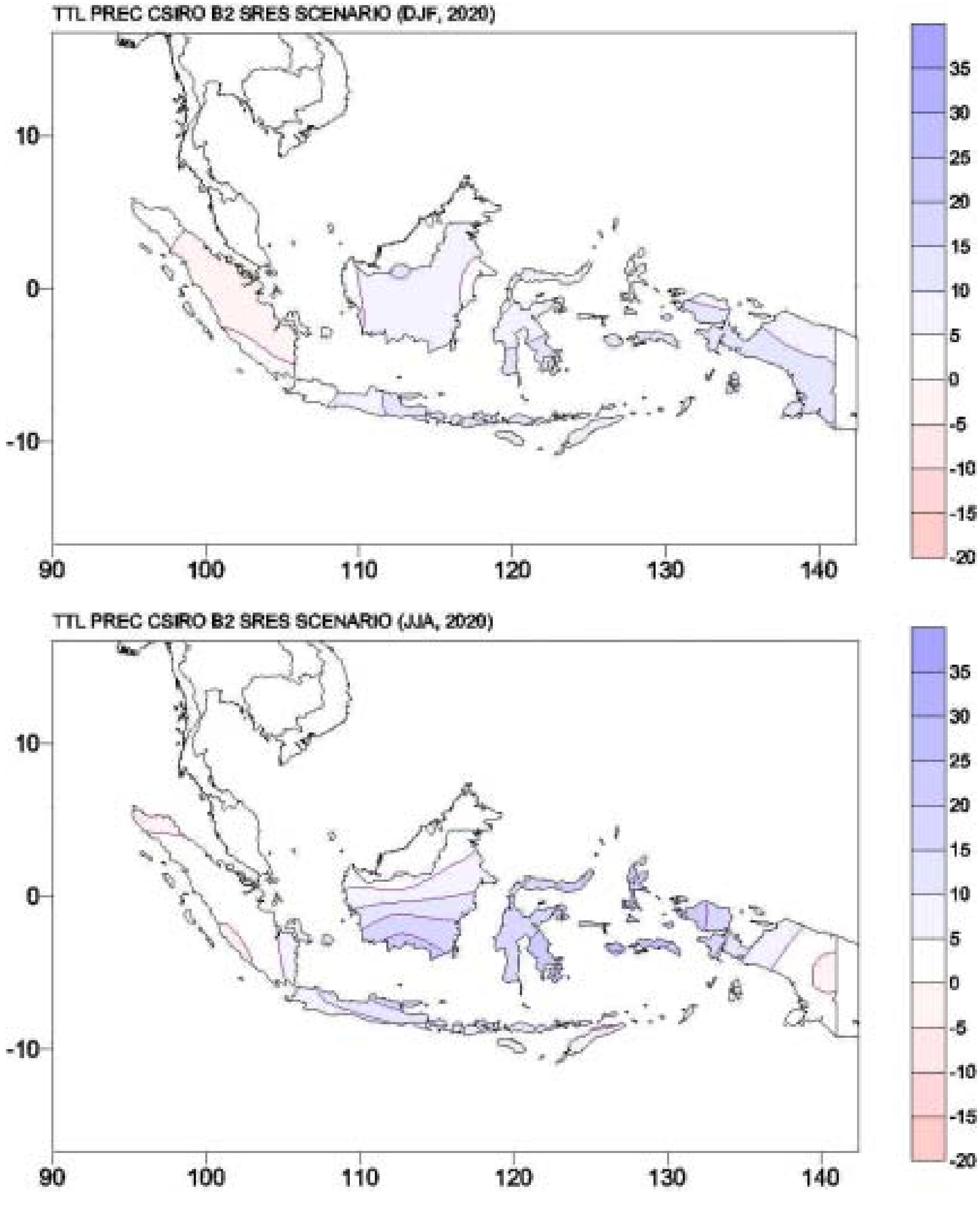


Figure 10. (a) Percent changes of seasonal rainfall of 2020 from the baseline rainfall under SRESB2 for CSIRO model

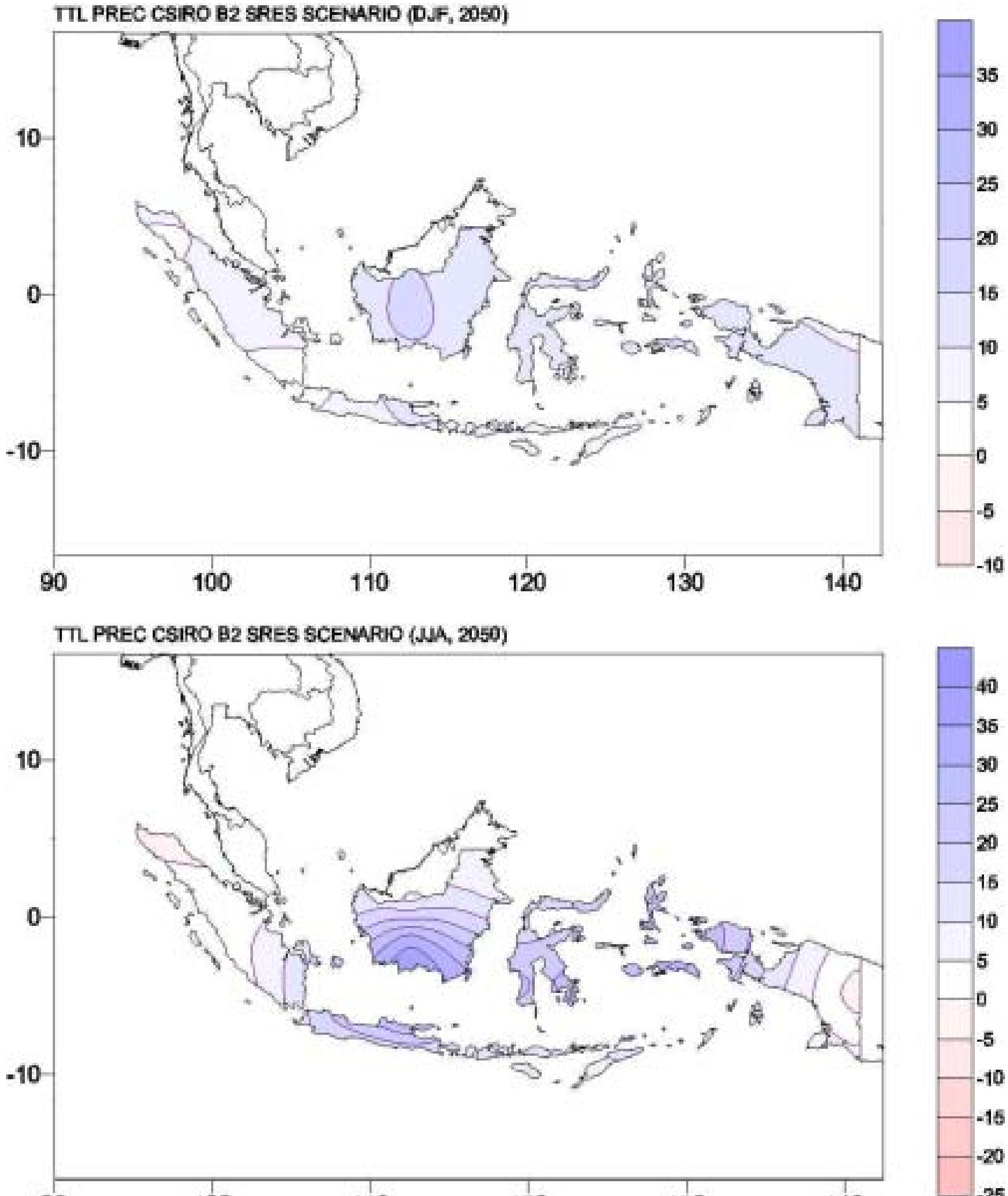


Figure 10. (b) Percent changes of seasonal rainfall of 2050 from the baseline rainfall under SRESB2 for CSIRO model

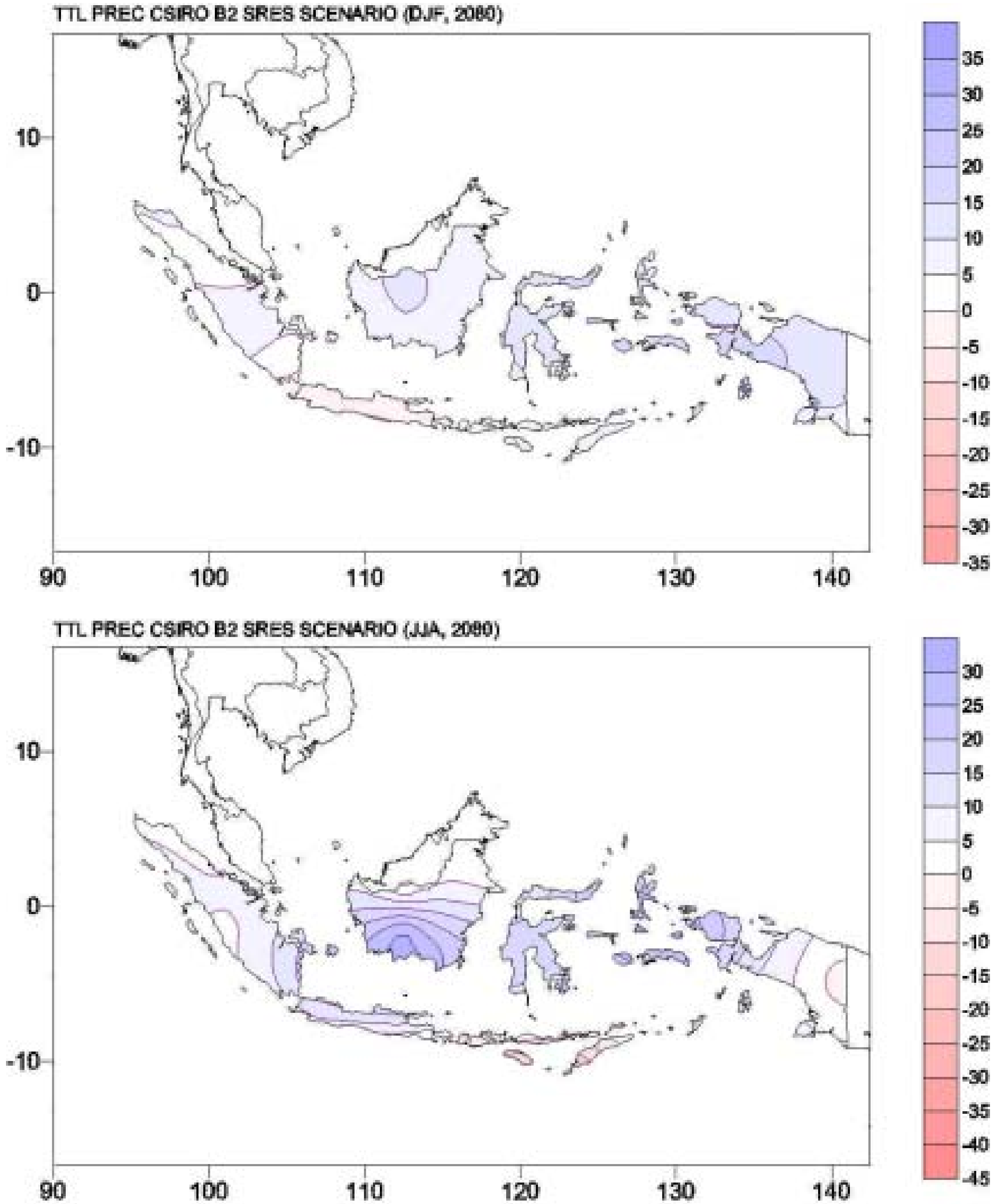


Figure 10. (c) Percent changes of seasonal rainfall of 2080 from the baseline rainfall under SRESB2 for CSIRO model

5. Discussion

Many studies stated that the behavior of El-Nino events were not always well-presented in climate models, so how these events behave under global warming would be difficult to be assessed (e.g. CRU, 1999; Trenberth, and Houghton, 1996). However, this study reveals that the variability of rainfall may change as the mean of the rainfall changes. In regions strongly affected by monsoon system, the variability of rainfall increase as the mean of rainfall increase, while those of strongly affected by equatorial and local systems, the variability of rainfall may decrease as mean of rainfall increased. As all GCM models suggests that the mean of Indonesian rainfall is very likely to change under changing climate, thus the variability of rainfall is also likely to change.

Relationship between mean of rainfall with variability of rainfall (using data from 62 stations in West Java ~ monsoon type) is very significant. The relationship could be presented in the form of power function, i.e. $Y=aX^b$ (Figure 11). By knowing the change in rainfall means, the likely change of rainfall variability can be roughly estimated using this equation. However, the use of this equation for regions strongly influenced by equatorial and local systems should be with caution as suggested by Figure 2. In these two regions, the increase in rainfall means was generally followed by the decreased in the standard deviation.

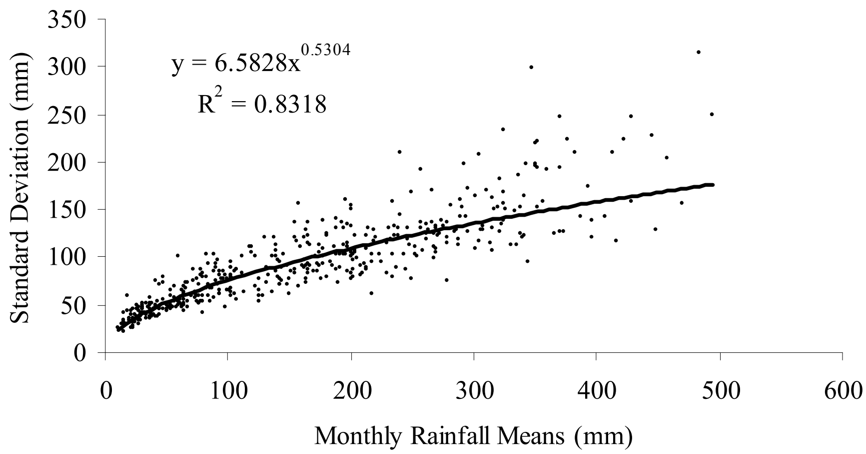


Figure 11. Relationship between rainfall means with their standard deviation

Many studies suggested that daily and monthly rainfall data normally followed gamma distribution (e.g. Ison *et al.*, 1971; Stern and Coe, 1984; Waggoner, 1989). Case studies in Indonesia, Indonesia also found that most of monthly rainfall data fit well with Gamma distribution (Boer and Las, 1998; Hasan, 1997; Boer *et al.*, 2000). The moment estimators for the parameters of the gamma distribution are defined as (Hann, 1977):

$$\hat{\lambda} = \overline{X} / S^2 \quad and \quad \hat{\eta} = \overline{X}^2 / S^2$$

where $\hat{\lambda}, \hat{\eta}, \overline{X}$ *and* S^2 are shape and scale parameters of the gamma distribution, mean and variance respectively. These equations implies that under global warming, there would be a possibility that change in the rainfall means would be followed by the change in variability.

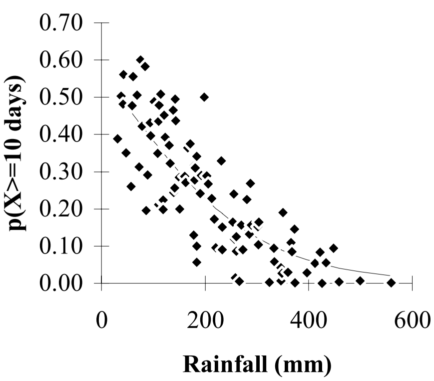
Other studies showed that the mean in monthly rainfall have significant relationship with the daily rainfall characteristics. Boer and Las (1998) found that the probability of having dry-spell of equal or more than 10 days ($p(x \geq 10)$) and equal or more than 15 days in a given month can be estimated from the monthly rainfall means (Figure 12). The forms of the equation are the following:

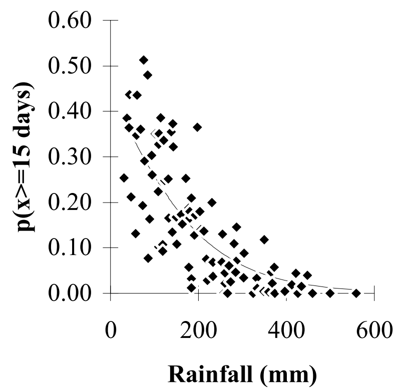
$$p(x \geq 10) = 1/[1+\exp(-0.2688+ 0.00745\ X)]$$

and

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

These equations have been validated 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. This suggests that the equation can be applied widely. Again this suggests that daily rainfall characteristics under changing climate may changes. Further study by Boer et al. (2000) showed that the probability of having rain on day *i* given that rain occurred on day *i-1* ($p_{11}(i)$) and not occurred on day *i-1* ($p_{01}(i)$) could also estimated from the monthly rainfall means using power function. The coefficient determination of the equations (R^2) was high, i.e. 75% and 88% respectively.





This study suggested that under changing climate, rainfall in Indonesia might increase or decrease depends on the region. In regions with decreasing rainfall might be exposed to high drought risk (long dry spell), while those with increasing rainfall might be exposed to high flood risk. The return period of such extreme events might increase.

Acknowledgement

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REFERENCES

ADPC. 2000. ENSO Impacts and potential forecast applications in Indonesia. Asian Disaster Preparedness Centre, Bangkok.

Boer, R. and Las, I. 1998. Metode untuk penentuan tingkat kerawanan kekeringan: Kasus untuk daerah pertanaman padi sawah tadah hujan di Jawa Barat (*Method for determining sensitivity of region to drought*). *Jurnal Agromet* **12**:1-9

Boer, R., Notodiputro, K.A. and Las, I. 2000. Prediction of daily rainfall characteristics from monthly climate indices. In Proceedings 'The Second International Conference on Science and Technology for the Assessment of Global Climate Change and Its Impacts on Indonesian Maritime Continent', 29 November-01 December 1999.

CRU. 1999. Climate change scenarios for Indonesia. Climatic Centre Research Unit, UEA, Norwich, UK. www.cru.uea.ac.uk

Hasan, D.I.. 1997. Analisis deret hari kering di wilayah persawahan Jawa Barat. Skripsi Jurusan geofisika dan Meteorologi FMIPA IPB. Bogor.

IPCC. 1996. Technical Summary' Op cit, Note 12. Intergrovernmental Panel on Climate Change

IPCC. 2000. Emission scenarios. A Special Rerport of Working Group III of the IPCC. Intergovernmental Panel on Climate Change. Cambridge University Press.

Irawan, B. 2002. Stabilization of upland agriculture under Al-Nino-induced climatic risk: Impact assessment and mitigation measures in Indonesia. Centre for Research and Development of Coarse Grain, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT Centre). Working Paper No. 62.

Ison, N.T., A.M. Feyerherm, and L.D. Bark. (1971). Wet period precipitation and the gamma distribution. J. Appl. Meteor. 10:658-665.

Jones, R., Mearns, L. Magezi, S., Boer, R. 2003. Assessing future climate risk. Technical Paper 5: Adaptation Policy Framework. UNDP, New York.

Kaimuddin, 2000. Dampak perubahan iklim dan tataguna lahan terhadap keseimbangan air wilayah Sulawesi Selatan: Studi kasus DAS Walanae Hulu dan DAS Saddang. Disertasi Program Pasca Sarjana, IPB, Bogor.

Kattenberg, A., Giorgi, F., Grassl, H., Meehl, G.A., Mitchell, J.F.B., Stouffer, R.J., Tokioka, T., Weaver, A.J., and Wigley, T.M.L. 1996. Climate models-projections of future climate. Pp:285-357 in Climate change 1994: radiative forcing of climate change and an evaluation of the IPCC IS92 emission scenarios [Haoughton, J.T., Meiro Filho, L.G., Callender, B.A., Kattenburg, A and Maskell, K. (eds)]. Cambridge University Press, UK, 572pp.

Kirono, D., Tapper, N. and McBride, J. 1998 Documenting Indonesian rainfall in the 1997-98 El Niño event. Unpublished paper prepared for submission to *The International Journal of Climatology*.

NCSP. 2000. Using a Climate Scenario Generator in Vulnerability and Adaptation Assessments: MAGICC and SCENGEN Version 2.4 Workbook. National Communications Support Programme, 62pp.

Pawitan, H. 2002. Long-term hidrological balance of Citarum Basin and Java island. Indonesian Journal Agricultural Meteorology 16:49-60.

Ratag, M.A., Asiati, S., Nuryanto, A, Siswanto, B and Suyadhi. 1998. Greenhouse gases, climate change and El-Nino. *In* Proceeding ALGAS-FINAL National

Workshop on '*Economic Assessment of Greenhouse Gas Abatement Options*'

Soerjadi, O. 1984 Study on weather and climate in Indonesia during 1982. In *TOGA Scientific Conference*, UNESCO, Paris, France.

Stern, R.D. and R. Coe. (1984). A model fitting analysis of daily rainfall data. J. Roy. Stat. Soc. A147:1-34.

Tjasyono, B. 1997. Mekanisme fisis para, selama, dan pasca El Niño. Paper disajikan pada Workshop Kelompok Peneliti Dinamika Atmosfer, 13-14 Maret 1997.

Trenberth, KE and Houghton, JT, 1996. *The Climate System*, and Maskell, K(eds) *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, pp 51-64.

Waggoner, P.E. (1989). Anticipating the frequency distribution of precipitation if climate change alters its mean. Agric. For. Meteor. 47:321-337.

Hydrology Balance of Citarum Watersheds under Current and Future Climate

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Abstract

Citarum is the biggest watershed in West Java. It plays important role in supplying water for many districts in West Java. It can supply about 7650 MCM (million cubic meters per year) where about 5750 MCM from Citarum dams (Saguling, Cirata and Jatiluhur) and about 1950 MCM 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. This watershed was found to be very vulnerable to climate change. In present, under no changing climate if level of water extraction from the stream flow were limited to 10% of the mean annual flow, it was found that all of sub-district already have water deficit problem, particularly in the lower area in a number of sub-districts of Kerawang, Bekasi and Purwakarta. Level of water deficit in these sub-districts would be more than 60 million cubic meters (MCM) per year. When rainfall increased by 10% or 20% from present condition, the water status of the Citarum still deficit if the level of water extraction were kept at 10%. More areas in these districts would have severe water deficit problems as the year move forward. In 2080, level of water deficit for most of sub-distric ts in this lower area would be more than 60 MCM. Increasing water extraction to 20% would not change the water status of these sub-districts even though the water demand scenario was changed to follow SRESB2 from IPCC (lower population growth rate). However, when rainfall was increased by 20% and level of water extraction was also increased to 20%, water balance status for most of sub-districts in the watershed will be surplus until year of 2020, but again sub-districts in the lower areas will remain deficit with lower intensity, i.e. between 0-30 MCM. It is expected that the level of water conflict in the future may increase.

Key words: Hydrology balance, Citarum Watershed, climate change.

1. Introduction

Citarum watershed is important watershed in West Java, Indonesia. Water supply from this watershed is used for many purposes, i.e. electricity generation, domestic consumption, irrigation water, flushing the canal etc. It can supply about 7650 MCM (million cubic meters per year) where about 5750 MCM from Citarum dams (Saguling, Cirata and Jatiluhur) and about 1950 MCM 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.

Water supplied for irrigation is not only for districts within the watershed area but also for districts outside the watershed. Jakarta, capital of Indonesia, receives clean water from Jatiluhur dam. Other districts outside Citarum such as Indramayu, and Sukamandi (main rice production centre of West Java) also get irrigation water from the Jatiluhur dam. Decreasing water supply due to current extreme climate events or climate change and forest degradation or land use change cover, will ha ve tremendous impact to the watershed. It was reported that during drought years associated ENSO, irrigation supply from most of watershed decreased significantly and it caused widespread of drought in irrigated rice paddy in particular in the end-tail irrigation area. In West Java, average area suffering from drought during normal years was about 7800 ha, while during ENSO years it increased sharply to 290 thousand ha (Directorate of Plant Protection, 2000).

It is very likely that due to increasing demand to water, conflicts between water users may increase and water scarcity problem is becoming more serious. It was predicted that after 2010, the Citarum watershed might not be able to meet the water demand (Hernowo, 2001). Moreover, based on observation to long historical data (1896-1991) it was found that annual rainfall over the Citarum catchments showed a negative trend at 10 mm reduction per year and the corresponding decreased in water discharge was approximately 3.1 mm per year. GCM output from ECHAM model also suggested that in the future, it is very likely that rainfall in this region would also decrease (see Technical Report-1). 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.

2. Methodology

2.1. Site

Citarum watershed situated at West Java Province. Catchments area is about 6867 km2 with length of about 269 km. The highest peak is about 1700 m a.s.l. and the lowest point is 0 m a.s.l. In the watershed there are three dams, i.e. Saguling in the upper part, Cirata in the middle and Jatiluhur or Juanda in the lower part, and nine hydrological observation stations (Figure 1). The main city is Bandung city which has a population of about 2.5 million people.

The annual rainfall is about 2580 mm divided into two seasons, rainy season (November to April) about 1840 mm and dry season (May-October) about 740 mm. Peak of rainy season is around January. The average stream flow of Citarum River is about 173 m3 per second. The main function of the Saguling and Cirata is only for electricity generation while the Jatiluhur is mainly for agriculture. Perum Jasatirta II (2002) predicted that the water demand for irrigation in year 2005 was approximately 5519 MCM (75%), drinking water 672 MCM (9%), industry 473 MCM (6%), fishery

315 MCM (4%), flushing Jakarta canals 315 MCM (4%), and electricity generation 100 MCM (1%).

Figure 1. Citarum watershed

The tree dams are connected each other. Outflow from Saguling Dam will go to Cirata Dam, and outflow from Cirata Dam will go to Jatiluhur Dam, and outflow from Jatiluhur will be used for many purposes as described above and then finally go to the sea (Figure 1). Inflow from other local rivers also contribute the three dams.

2.2. Method of Analysis

2.2.1. Stream Flow Analysis

ENSO events have been found to be one of dominant factors that cause extreme condition such as drought in Indonesia. Water inflow into water reservoirs such as Dams decreased significantly as a result of decreasing rainfall during the events. How the streamflow in the watershed behaved during the events was assessed using simple correlation analysis between SOI (Southern Oscillation Index) and streamflow data from one hydrology station that have long historical record. The change of streamflow distribution due to ENSO events was assessed using five SOI phases (Stone et al., 1996). The five SOI phases are consistently negative denoted as 1, consistently positive denoted as 2, rapidly falling denoted as 3, rapidly rising denoted as 4 and near zero denoted as 5. The value of SOI phase can be downloaded from http://www.dpi.qld.gov.au. When SOI fall rapidly and then remain negative, it indicates that the El-Nino may occur and this normally causes rainfall reduction in Indonesia, in particular part of South Sumatra, Java, and eastern part of Indonesia. Conversely, when SOI increase rapidly and then remain positive, it indicates that the La-Nina may occur and this normally causes rainfall increase. The analysis will use streamflow data from Cigulung-Maribaya station (1953-2002).

A graphical analysis to show the change in streamflow mean between normal, El-Nino, and La-Nina years was also carried out. The total inflow 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-Nino years (1987, 1991, 1994, 1997 and 2002), two La-Nina years (1989 and 1998) and ten normal years.

2.2.2. Hydrology Balance Analysis

This analysis is to assess the status of hydrology water balance at Citarum watershed under current and future climate. The analysis was done up to sub-district level.

Hydrology balance is expressed as the following:

Supply = Demand + Surplus

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

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 1874, 2477, and 2517 km2 respectively. The relationship between annual streamflow of local rivers and annual rainfall for each region was developed using the regression equation. As Cirata receives water outflow from Saguling and Jatiluhur receives water outflow from Cirata (see Figure 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 has unit of m3 s-1, unit conversion is required to get annual streamflow data with mm unit. 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 (m3 s-1) and A area of the corresponding sub-watersheds (m2). 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 reason, maximum annual streamflow (*VQ*) than can be used as water supply, should not be more than the minimum flow. Based on 15 years of data, it was found that the minimum inflow 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).

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 is (Table 1). Thus water demand projection will follow population projection.

Table 1. Consumption of Fresh Water per Capita in Indonesia
Water demand (l/cap/day) Population size

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)

For industrial sectors, water demand is estimated based on the size of industrial area. Two water demands 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 area proportion of the sub-district relative the total area of the watershed. The industrial area of the watershed was estimated to be about 49615 ha (0.3% of the total watershed).

For agriculture sector, the dominant water use is for irrigation (rice cultivation). The length of season for rice in the two watersheds is between 90 to 150 days. The amount of water required was between 140 mm and 150 mm per month or equivalent to about 4500 and 7000 m3 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.

2.2.3. Developing Scenarios

***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 (see Technical Report 1). 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, 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. 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 feature (Table 2).

Table 2. Precipitation anomalies of DJF and JJA in 2080 using SRESA2 and SRESB2

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)

Considering the impact of global warming on Indonesian rainfall is not consistent between 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%.

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 of at each sub-district for the other two scenarios followed those of the SRESA2 and SRESB2. Hereafter, these other two scenarios used were 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. Whereas, 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 3, 4, and 5

Table 3. Population growth rate at Citarum Watershed under baseline, SRESA2, and SRESB2 scenarios from 2005-2080

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 km2.

Table 4. Projection of rice planting area for 2000-2080

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 5. Projection of Industrial 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).

3. Results of Analysis

3.1. Impact of ENSO on Streamflow

Impact of ENSO on water inflows to the three dams was found to be significant in particular season. It was indicated that the impact was not significant for Feb-Apr streamflow. The impact of either El-Nino or La-Nina on this season streamflow was not consistent. The impact of El-Nino was clear on May-July, and Aug-Oct, Nov-Jan streamflows, while that of La-Nina was clear only on May-July inflow. The reduction of inflow to the three dams during EL-Nino years could be as much as 60% of the normal (Figure 2).

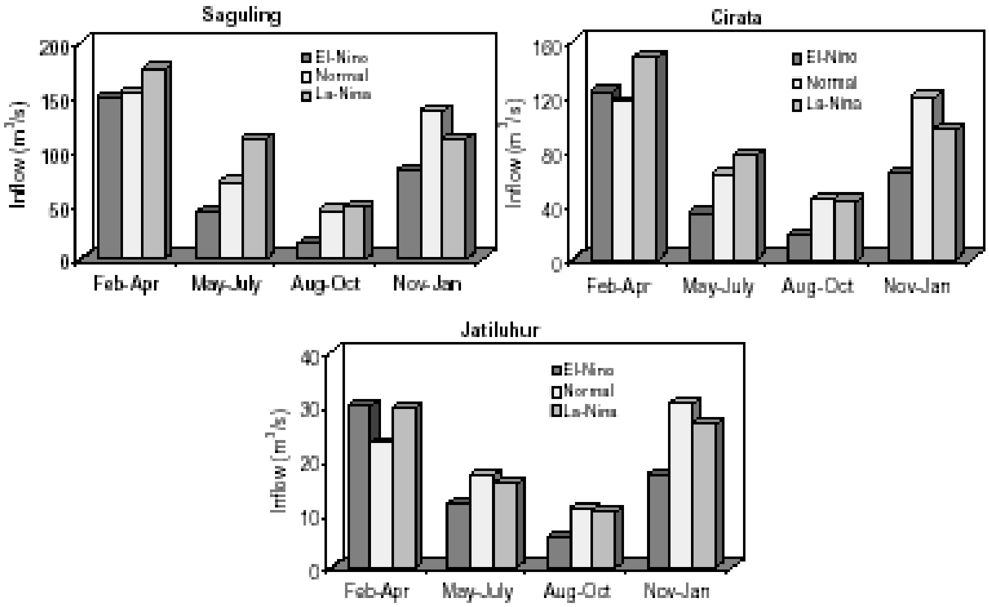

Figure 2. Mean of inflow to the three dams during El-Nino, normal and La-Nina years

Further analysis to long-term historical streamflow data of Citarum-Nanjung also showed similar result. The impact of El-Nino was significant only on May-July and Aug-Sept streamflows. From regression analysis between the seasonal rainfall and SOI, it was found that May-July streamflow would increase by about 0.37 m^3 s^{-1} for every 10 unit increase in SOI, while Aug-Oct streamflow would increase by about 0.24 m^3 s^{-1} for every 10 unit increase in SOI (Figure 3). The Nov-Jan and Feb-Apr streamflows were found not significantly related with the SOI.

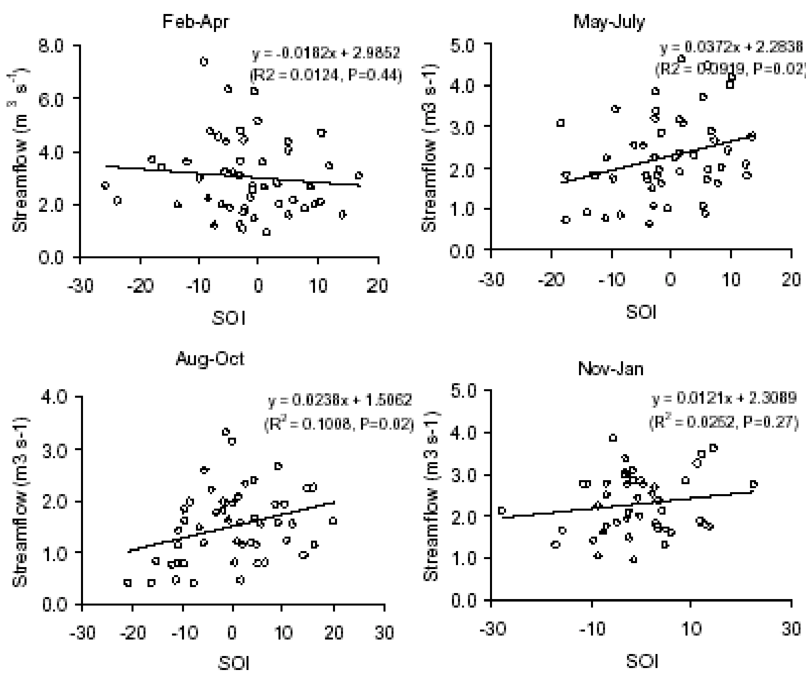

Figure 3. Relationship between SOI and Streamflow of Citarum Nanjung

Seasonal streamflows distribution developed from SOI phases one month before the season start is shown in Figure 4. It was suggested that the Aug-Oct streamflow distribution might change when the July SOI fall rapidly or consistently negative, or when the July SOI increase rapidly or consistently positive. Similarly, for Nov-Jan streamflow. The result of this analysis suggests that when SOI phase of July fall rapidly or consistently negative, the chance to have high streamflow in the Aug-Oct will be low. Whereas, if SOI phase of July increase rapidly or consistently positive, the chance to have high streamflow in Aug-Oct will increase. Similarly for Nov-Jan streamflow, the chance to have high stream flow in this season will be low if the October SOI fall rapidly or consistently negative. For example, the change to have Nov-Jan streamflow at least 2 m3 s-1 when the October SOI fall rapidly or consistently negative (Phase 1+3) is only 0.35, while when the October SOI increase rapidly or consistently positive (Phase 2+4), the chance will increase to more than 0.60 (Figure 4).

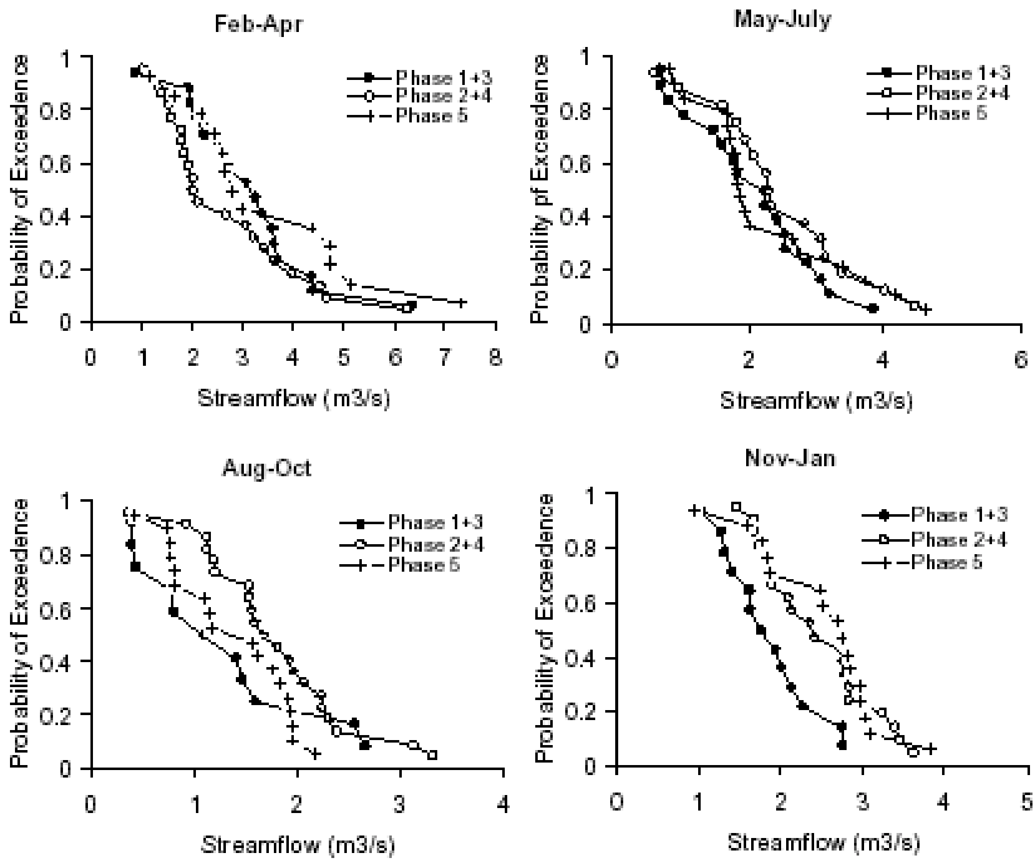

Figure 4. Seasonal streamflow probability distribution for Citarum Nanjung, associated with SOI phase of the previous month

3.2. Water Supply

The increase and decrease in streamflow is highly associated with the increase and decrease in rainfall. Ar Citarum watershed it was found that the relationship between annual rainfall and total annual streamflow could be presented in the form of simple linear regression equations (Figure 5). For upstream area, every 1000 mm of rainfall would be yield 547 mm of streamflow, for middle area it would be about 736 mm while for lower area it was only 92 mm.

For the middle and the lower area, they will receive water not only from the local rivers but also from the dams (see the equations in Figure 1). The middle area will receive outflow from Saguling Dam (Is), and the lower area from Cirata Dam (Ic). While outflow from Jatiluhur will be 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 m3 s-1) for normal years and about 434 mm (34 m3 s-1) for dry years. From Cirata, the outflow is about 1532 mm (122 m3 s-1) for normal years and 888 mm (71 m3 s-1) for dry years, and for Jatiluhur it is about 2505 mm (200 m3 s-1) for normal years and 1447 mm (116 m3 s-1) for dry years.

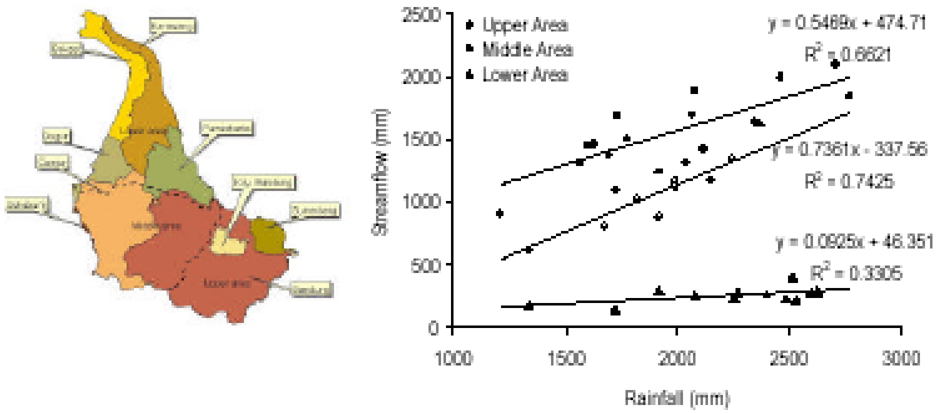

Figure 5. Relationship between annual streamflow and annual rainfall in the upper (upstream), middle, and lower (downstream) areas of Citarum watershed

3.3. Water Balance

Water balance analysis consists of 30 scenarios, i.e. rainfall 5 scenarios, water supply 2 scenarios, and water demand 3 scenarios thus total 5*2*3=30. The diagram tree of the scenarios is given in Figure 6.

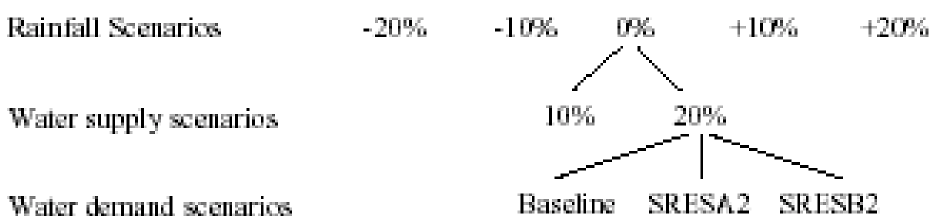

Figure 6. Water balance scenarios

3.3.1. No Change in Rainfall

Under present climate (no change in rainfall), if level of water extraction from the stream flow were limited to 10%, it was found that all of sub-district already have water deficit problem, particularly in the lower area in a number of sub-districts of Kerawang, Bekasi and Purwakarta (Figure 7). Level of water deficit in these sub-districts would be more than 60 million cubic meters (MCM) per year. In 2020, more areas in these districts would have severe water deficit problems. In 2080, the status of water balance for most of sub-districts in this lower area would be deficit. Increasing water extraction to 20% would not change the water status of these sub-districts (Figure 8). Therefore, these sub-districts could be considered as vulnerable areas.

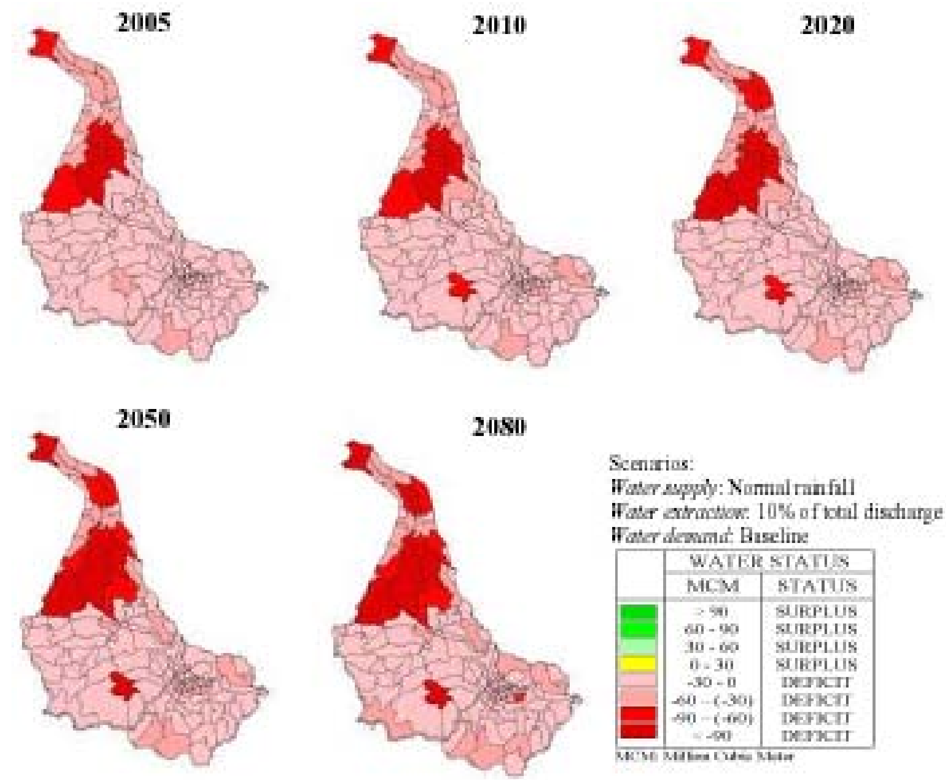

Figure 7. Projection of water status by sub-district at Citarum watersheds with no change in rainfall and water extraction of 10% using baseline demand scenario

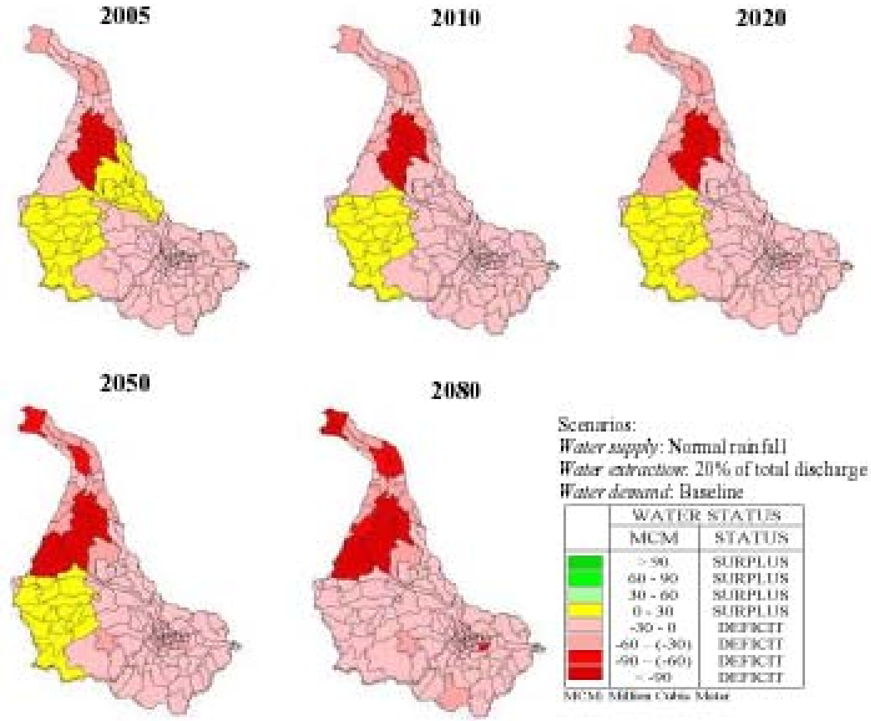

Figure 8. Projection of water status by sub-district at Citarum watersheds with no change in rainfall and water extraction of 20% using baseline demand scenario

Figure 8 shows that by increasing level of water extraction from 10% to 20%, the status of water balance in a number of sub-district of Sukabumi and Purwakarta would be surplus (Figure 8). By changing water demand scenarios to either to SRESA2 or SRESB2, the water status of Citarum watershed remains the same as those at the baseline.

3.3.2. Change in Rainfall

As indicated by some of GCM models, rainfall in West Java might change in the magnitude of between 5% and 50%. ECHAM model suggested that the rainfall in this region would decrease. The magnitude decrease will increase as the time move forward from 2020 to 2080 (Table 6). On the other hand, rainfall decrease in dry season would be more pronounced in dry season than in rainy season (see Technical paper-1). This feature is similar to what already happened in the past (Pawitan, 2002).

Table 6. Percent changes in rainfall under SRESA2 and SRESB2 suggested by ECHAM in West Java, Indonesia

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

By decreasing rainfall by 10% or 20%, and the level of water extraction was kept at 20%, the water status at sub-districts of Sukabumi will remain surplus up to 2010 irrespective of water demand scenarios. If, the water extraction were reduced to 10%, all sub-districts would be deficit similar to that shown in Figure 7. However, if water demand scenarios followed SRESA2 and SRESB2, number of sub-districts with deficit more than 60 MCM would be less. Further analysis showed that if level of water extraction were 10%, increase in rainfall by 10% or 20% would not change the status of water deficit in the Citarum watershed significantly, irrespective of water demand scenarios. The condition would be similar to those with no change in rainfall (see Figure 7). However, if the level of water extraction were increased to 20%, most of sub-districts at Citarum watershed would be surplus (Figure 9). Sub-districts at Sukabumi might be surplus up to 2080. CSIRO model suggests that the rainfall in West Java might increase up to 20% under global warming (see Technical Report-1).

4. Discussion

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

Based on observed inflow data to the three 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-Nino years. As this study suggests that if water extraction 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 change to have serious deficit problem is between once 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; see Technical Report-1) and historical trend data (Pawitan, 2002; Kaimuddin, 2002). From analysis to annual rainfall data of Citarum watershed which covering 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 1900's the mean annual rainfall was about 2800 mm per year and in the 1990s it decreased to about 2350 mm (Pawitan, 2002).

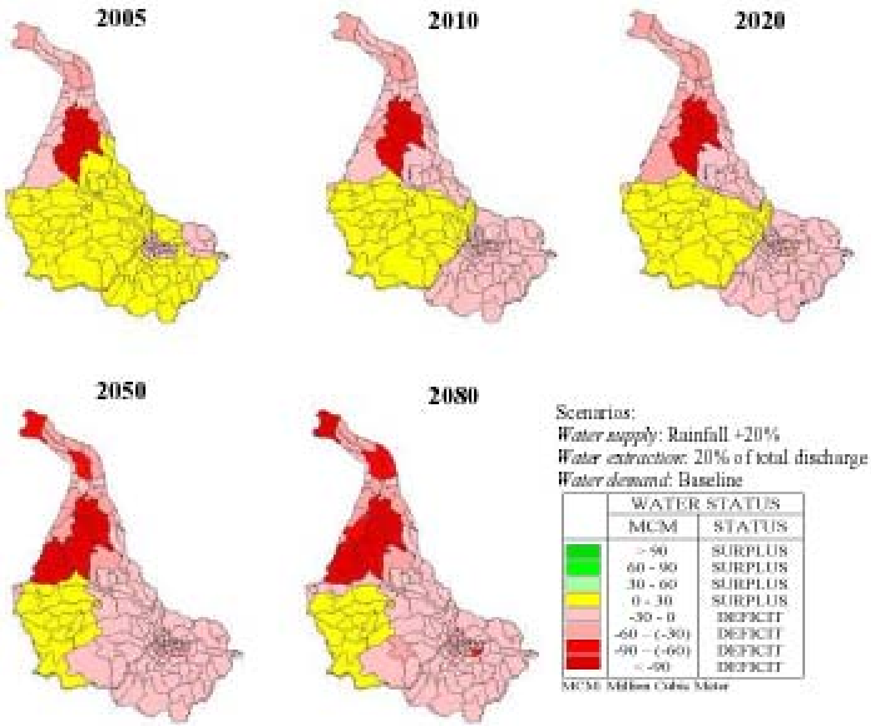

Figure 9. Projection of water status by sub-district at Citarum watersheds with 20% rainfall increase and water extraction of 20% using baseline demand scenario. Water status for SRESA2 and SRESB2 were the same as the baseline.

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 supply of water from Citarum would not change. Under this condition, conflict of water might increase. On the other hand, if program for reforesting critical land could not be achieved as planned, percent of forest cover might decrease and this would further increase flood and drought risk in the future. It was indicated that reducing percent forest cover by 10% would increase the variability of daily flow by about 9 m3/s (see Technical Report-3), implying that the difference between maximum flow and minimum would get higher.

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References

Bapenas (1991). Perkiraan kebutuhan air industri sampai tahun 2020. *In* Pengkajian Kebijaksanaan Strategi Pengembangan Sumberdaya Air Jangka Panjang di Indonesia, Badan Perencanaan Nasional, Jakarta.

Bina Program Cipta Karya. 1991. Perkiraan perkembangan penggunaan air di Indonesia menjelang tahun 2020. *In* Pengkajian Kebijaksanaan Strategi Pengembangan Sumberdaya Air Jangka Panjang di Indonesia, Badan Perencanaan Nasional, Jakarta.

CRU. 1999. Climate change scenarios for Indonesia. Climatic Centre Research Unit, UEA, Norwich, UK. www.cru.uea.ac.uk

Dinas Pertanian Jawa Barat, 2002. Jawa Barat dalam Angka. Biro Pusat Statistik Propinsi Jawa Barat, Bandung.

Directorate of Plant Protection, 2000. Impact of extreme climate events on crop management in Indonesia. Directorate General of Food Crops and Horticulture, Ministry of Agriculture Indonesia in collaboration with NOAA/OFDA, USA and Asian Disaster Preparedness Center, Bangkok.

Hernowo, 2001. Pengelolaan waduk Ir. H. Juanda di Jatiluhur. *In* Prisiding Lokakarya 'Selamatkan Air Citarum, pp:75:80.

IPCC. 2000. Emission scenarios. A Special Rerport of Working Group III of the IPCC. Intergovernmental Panel on Climate Change. Cambridge University Press.

Kaimuddin, 2000. Dampak perubahan iklim dan tataguna lahan terhadap keseimbangan air wilayah Sulawesi Selatan: Studi kasus DAS Walanae Hulu dan DAS Saddang. Disertasi Program Pasca Sarjana, IPB, Bogor.

Pawitan, H. 1996. Keseimbangan Hidrology menurut Kabupaten di Indonesia. Laporan Penelitian ARMP, Bogor (Unpublished Report).

Pawitan, H. 2002. Long-term hidrological balance of Citarum Basin and Java island. Indonesian Journal Agricultural Meteorology 16:49-60.

Perum Jasa Tirta II, 2003. Data utama bendungan Jatiluhur. Perusahaan Umum Jasa Tirta II, Jatiluhur.

Stone, R., Hammer, G.L., and Marcussen, T. 1996. Prediction of global rainfall probabilities using phases of the Southern Oscillation Index. Nature 384:252-255

Annex E

Assessing the Impact of Land Use Change and Climate Change on River Flow at Citarum Upper Catchments

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1. Introduction

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 stakeholders 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).

Studies to assess impact of forest cover change on river flow will be required in the process of setting up land use planning. Many attempts have been done, however, the works are largely independently of climate change (Arnell et al. *in* IPCC 2001). Considering climate change in assessing impact of land use and forest cover changes on river flow is very important for developing long-term water management planning. This will assist policy makers in assessing impact of changing land use policy on water sector under different plausible climate changes. This technical paper describes (i) land use hanges in upper catchments area of Citarum watershed, (ii) simple approach to downscale GCM output, (iii) generation of daily climatic data from monthly GCM outputs, (iv) evaluation of hydrology model, VIC Basin, and (v) assessment of impact of changing land use in the upper catchments area of Citarum watershed on river flow under different climate change scenarios.

2. Methodology

2.1. Site

Upper catchments area of Citarum watershed situated at 06o48’-07o07’ S and 107o31’53”-107o49’ E (Figure 1). Total area is about 1,873 km2. Topography is quite complex with slopes ranging from 0% to 45%. This catchments area has 13 subwatersheds with size varying from 29.7 km2 to 281 km2 (Ridwan, 1993). Organic pollution in the Citarum upper catchments is quite high due to rapid growth of industries development and population. In 1994, there were about 484 industries and number of population was about 4.4 million and. In 2000, number of industries increased by about 50% and size of population became 5.0 million people (Bukit, 2001). Without proper management, degradation of the upper catchments will continue and will have serious impact not only for this area but also for downstream areas.

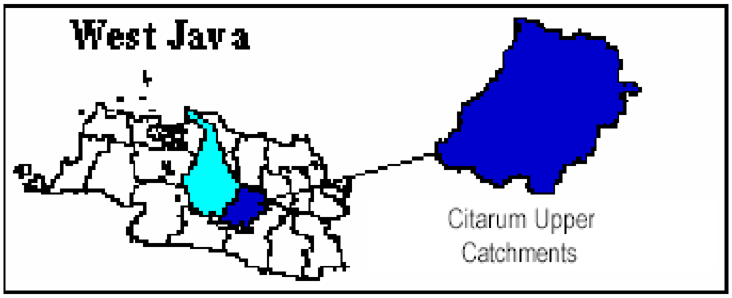

Figure 1. Citarum Upper Catchments

2.2. Data and Softwares

Data used for the analysis were satellite image data of 1989, 1993, 1999, and 2001 obtained from TRFIC, monthly rainfall data from 26 stations at Bandung District (Table 1) and daily climatic data from three stations (Sindangkerta, Patuahwattee, and Sukawana), soil and land use maps from Research Centre on Soil and Agroclimate, GCM outputs from ECHAM model downloaded from Data Distribution Centre. Population data, and long-term land use plan was obtain from BAPEDA (Development Planning Agency), land and forest rehabilitation program from Balai Pengelolaan DAS Citarum- Ciliwung. Software used in the analysis is VIC-BASIN (hydrological model), CLIMGEN (climatic data generator model), and image processing software including GIS.

Table 1. Rainfall stations at Bandung District used in the Analysis

No	Station Name	Lat	Long	Alt (m)	No. of years	Period
1	Arjasari(perk)	-7.05	107.65	920	12	1971-1983
2	Bandung (meteo)	-6.90	107.60	730	33	1962-1997
3	Batu jajar	-6.91	107.50	660	8	1971-1978
4	Cibeureum	-7.04	107.49	560	28	1972-1974, 1976-1986, 1989, 1991-2002
5	Cibitu	-7.22	107.36	1800	20	1971-1978, 1980-1983, 1991-1998
6	Cibuni	-7.19	107.33	1260	29	1964, 1967-1984, 1989-2000
7	Cimangsud(perk)	-6.80	107.39	1150	11	1971-1981
8	Ciparay	-7.04	107.71	673	15	1989-2002
9	Cisondari/pasirjambu	-7.09	107.47	1050	34	1963-1967, 1970-1980, 1989-2000
10	H. Sastranegara	-6.91	107.57	746	19	1961-1962, 1967-1973, 1977-1978, 1983-1990
11	Lembang(meteo)	-6.82	107.62	1300	12	1964, 1972-1983
12	Leuweungenit	-7.15	107.43	1750	19	1961, 1963-1980
13	Malabar	-7.18	107.60	1550	24	1962, 1964, 1967, 1969-1972, 1978-1979, 1984-1986, 1989-2000, 2002
14	Margahayu	-6.80	107.65	1250	26	1961-1964, 1967-1975, 1980-1983, 1985-1989, 1993, 1997-2000
15	Montaya	-7.03	107.33	990	20	1971-1981, 1989-1996, 1998
16	Padalarang	-6.85	107.48	685	9	1963-1964, 1971-1972, 1975-1979
17	Panglejar	-6.72	107.45	600	15	1971, 1978-1979, 1989-2000
18	Paseh-Cipaku	-7.05	107.78	910	27	1967-1989, 1991-1995, 1997-2000
19	Pasir malang	-7.22	107.54	252	21	1971-1974, 1978-1981, 1983-1984, 1990-2000
20	Paluahwattee	-7.21	107.40	1772	27	1975-2002
21	Purbasari	-7.24	107.62	1600	21	1961, 1964, 1966-1969, 1979-1981, 1983-1984, 1993-2002
22	Raja mandala	-6.84	107.35	330	11	1983, 1989-1998
23	Rongga	-6.98	107.25	1093	11	1983, 1989-1998
24	Sinumbra	-7.15	107.30	1496	13	1981-1984, 1992-2002
25	Sukawana	-6.78	107.59	1543	24	1971-1981, 1988-2001
26	Talun	-7.27	107.67	1650	20	1977-1982, 1984, 1986, 1989-2000

2.3. Method of Analysis

2.3.1. Development of Land Use Change Scenarios

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):

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

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

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

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 m2) to a center of a given land use (X1), population density (X2) and distance a given land use to rivers (X3). 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 ends 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 us e 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 andung District, and the last scenarios developed based on land/forest rehabilitation plan set up by Balai Pengelolaan DAS Citarum-Ciliwung (2003).

2.3.2. Development of Downscaling Model for GCM

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 and 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. Many dowscaling techniques have been developed. The methods used include multiple linear regression (e.g. Huth and Kysely, 2000; Mpelaska et al., 2001; Uvo et al., 2001; Lanza et al., 2001), 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). Application of these techniques in Indonesia is very limited. This study applies a simple technique for downscaling using regression analysis. This is an initial effort.

The downscaling process followed a number of steps. First is to select climatic riables at local scale (called predictor). Second is defining domain of GCM used in the analysis, third is selecting GCM variables as predictors, four reducing number of predictors using Principal Component Analysis and fifth is developing the downscaling model using Principal Components (PC) as predictors. There are a number of predictors from GCM that can be used in developing the models, such as precipitation, maximum temperature, minimum temperature, 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 (Wilby and Dawson, 2001). As an initial effort, this study only used one GCM predictor, i.e. rainfall.

Domain of GCM used in the analysis was in the region of 104.063-115.313 E and 1.395N-9.767S, which has resolution of 2,8125 °Lon. x 2,8125 °Lat. This region covers 25 grid points. Length of monthly data series was 54 years (Januari 1950-Agustus 2003).

2.3.3. Development of Climatic Data Generator Model

As hydrology impact model requires daily climatic data inputs, while the available data of GCM model are mostly monthly basis, the model to generate daily data from monthly means is required. This study was evaluated CLIMGEN v1.0 developed by Boer *et al.* (2000). The model was developed based on works of Stern, and Coe (1984), Epstein (1991) and McCaskill (1990).

The analysis consists of a number of steps. First, to estimate the probability of having rain on day *i* given that rain occurred on day *i-1* (*p11(i)*) and rain not occurred on day *i-1* (*p01(i)*). The *pj1(i)* were estimated from the proportion of years for which rain occurred on day *i*, considering only those years for which rain occurred (*j=1*) or not occurred (*j=0*) on day (*i-1)*. Second is to pool *pj1*(i) estimates from daily basis to monthly basis. Third is to develop equations for estimating pooled *pj1(i)* from monthly rainfall using Epstein approach (1991). Fourth is to develop equations to fit seasonal pattern of the *pj1(i)* using Fourier regression (Stern, and Coe, 1994). Fifth is to determine statistical distribution for depth of daily rainfall. Sixth is to develop regression equations for estimating parameters of the distribution from rainfall amounts. Seven is to develop equations for generating other climatic variables other than rainfall using McCaskill approach (1990). Eight is to develop model error using Auto Regression (AR). This step is required since error of the non-rainfall generator models may not be independence.

2.3.4. Impact Assessment

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 component 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 (LAI) which affect infiltration capacity and evapotranspiration, respectively.

The models required the following inputs, daily data for rainfall, maximum and minimum temperature, and wind speed, land use/land cover, soil property (percent sand, silt and clay for every soils series), river network, contour map (scale of 1:50000), rainfall and water stations position, daily discharge data in a give outlet which is required for validation of the model. As land use data only available for 1989, 1993, 1999 and 2001, the validation of the VIC model was carried out using daily discharge data of these corresponding years.

Impact of changing land use and climate change on river flows was assessed using the VIC-BASIN model by varying land-use cover following the four land use scenarios as described in section 2.3.1, and daily rainfall data inputs for the three stations. Downscaled monthly GCM rainfall data under two scenarios SRESA2 and SRESB2 were used to generate daily rainfall data under changing climate.

3. Result of Analysis

3.1. Land Use Change Scenarios

Historical Land Use. 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 in2001 (Table 2; and Figure 2). While agriculture area 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 have stated that lakes that have been converted to other uses would be restored again to its original condition.

Table 2. Land use change in the period of 1989, 1993, 1999, and 2001

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	11420	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.

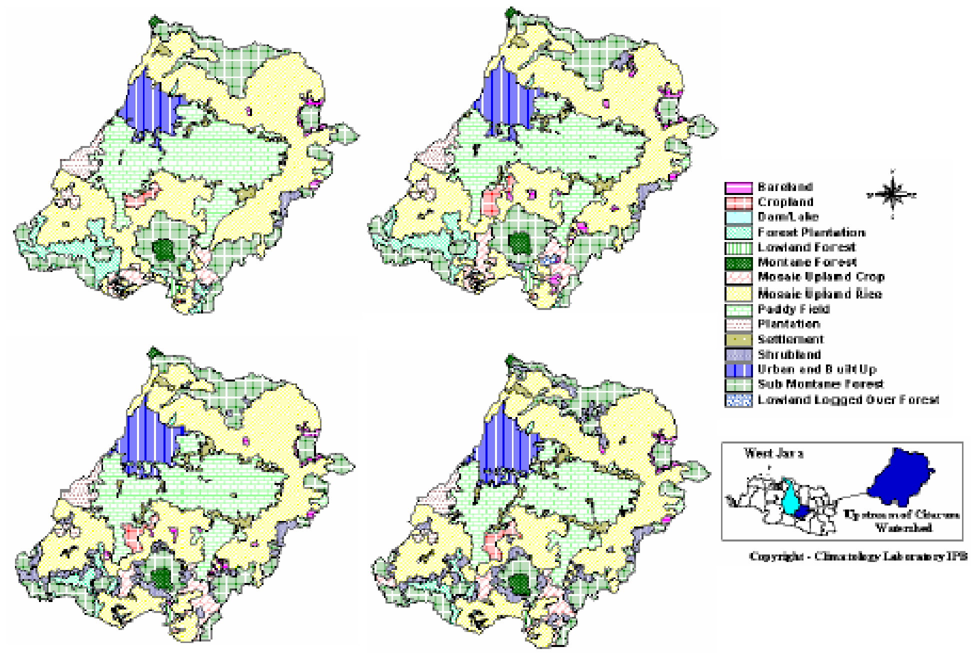

Figure 2. Land use and forest cover at Citarum Upper Catchments in 1989, 1993, 1999 and 2001

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 intercept, 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 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 whereland use changes are very dynamic.

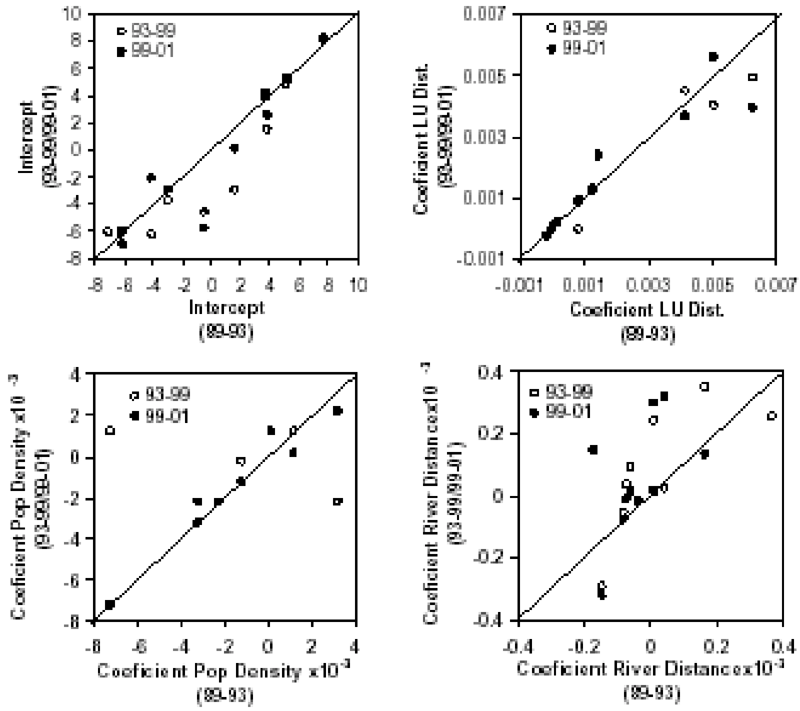

Figure 3. Relationship between regression coefficients of logistic equations developed using image data of 1989-1993 and image data of 1993-1999/1999-2001

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. Since, the change was not significant, the baseline scenario was not discussed further in the following section.

According to government plan (Balai Pengelolaan DAS Citarum-Ciliwung, 2003), area of critical land/degraded forest in the Citarum watershed going to be refo rested during 2003-2007 is about 138 thousand ha or equivalent to about 27,760 ha per year (Table 3). While total area of critical lands inside and outside forest area are very large, i.e. about 390 thousand ha (Table 4). Citarum upper catchments which is located mostly in Bandung area has critical land of about 140 thousand ha. Considering this condition, total area allocated for the two mitigation scenarios, mitigation scenario-1 and 2, were 22.5 thousand ha and 45 thousand ha respectively.

Table 3. Government plan for rehabilitation of critical land located inside and outside forest area in the period 2003-2007

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 4. Critical land at Citarum watershed in 2001

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)

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 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 5).

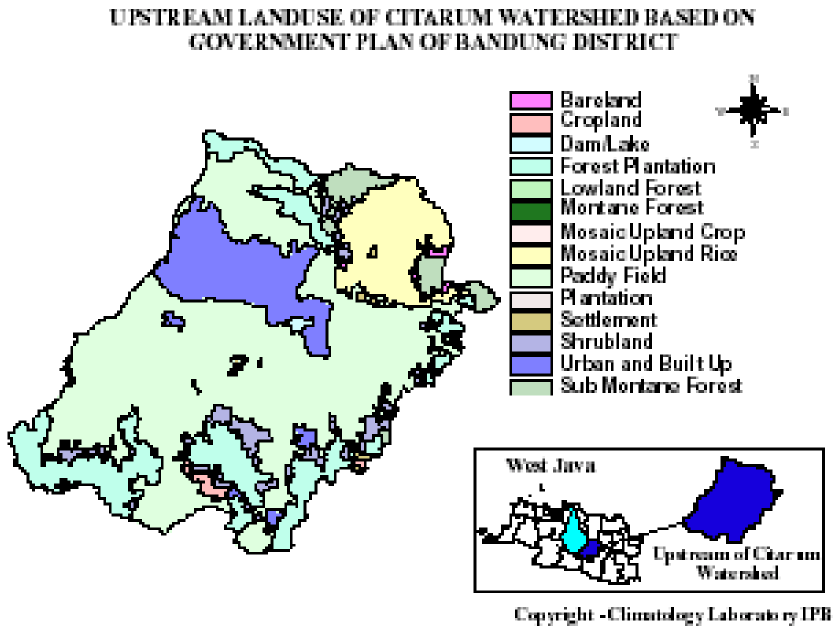

Figure 4. Government Land Use Plan for 2010 at Citarum Upper Catchments (Bapeda, 2002)

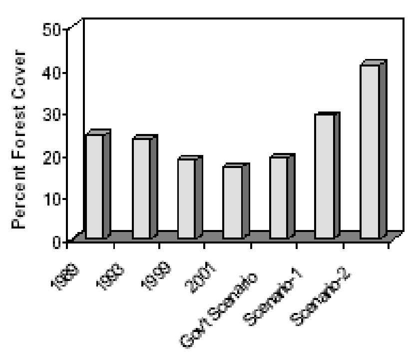

Figure 5. Historical and future scenarios of percent forest cover at Citarum upper catchments area

3.2. GCM Downscaling Model

The result of analysis showed that simple linear regression could not downscaled GCM rainfall data into local rainfall very well. The models are able to follow the pattern of monthly rainfall data, however, they could not produce good downscaled data for months with very high rainfall (Figure 6). Therefore, in general monthly rainfall data from the downscaled models were lower than those of observations as shown in Figure 7). In addition, when the downscaled models were used to downscale monthly rainfall from the 26 stations under changing climate (2020, 2050 and 2080), the spatial rainfall pattern resulted from the models was not in conformity with the global pattern. Global pattern suggests that rainfall in West Java under changing climate may decrease, while the downscaled analysis suggest it will increased. Therefore, analysis for developing GCM downscaling model in the study area using more sophisticated statistical models with more number of predictors is required. As the downscaled model was not able to provide good result, the climate change scenarios in this analysis will use synthetic scenarios.

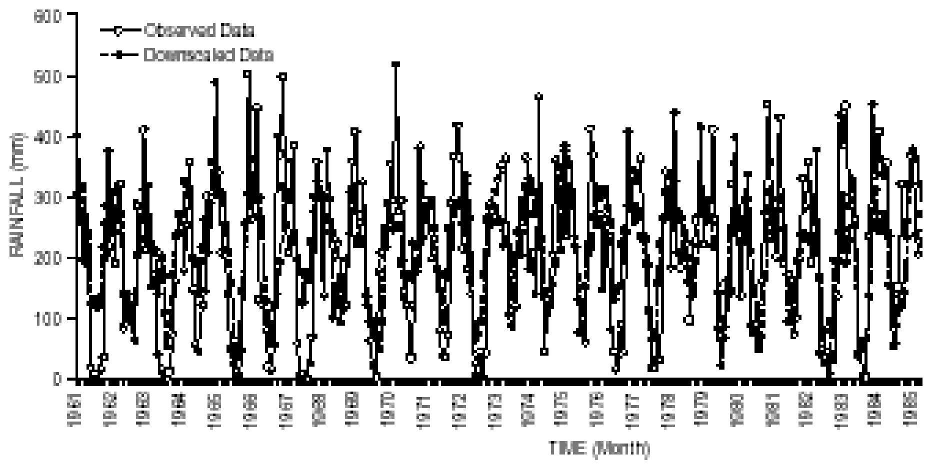

Figure 6. Comparison of regional rainfall at Bandung district between observed and downscaled data

3.3. Climatic Data Generator Model

The climate data generator model developed by Boer *et al.* (2000) has been improved and could produced generated data that have similar statistical characteristic with observed data. Validation of the model was performed in a number of stations in Citarum watershed. Documentation of the model is being prepared. The following section discussed the used of generated climatic data in the impact model for assessing impact of land use change and climate change on river flow.

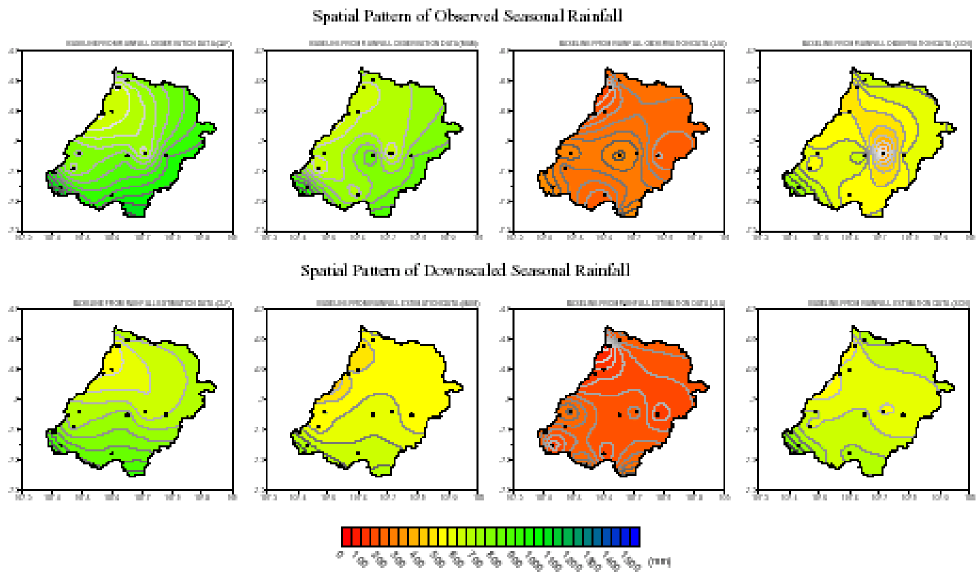

Figure 7. Spatial patterns of observed and downscaled seasonal rainfall at Citarum Upper Catchments

3.4. Impact of Land Use and Climate Change on River Flow

Historical Land Use Change and Its Impact on River Flow. 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. Therefore, 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 8). The data suggested that variability of daily river flow would decrease by about 2 m3 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.

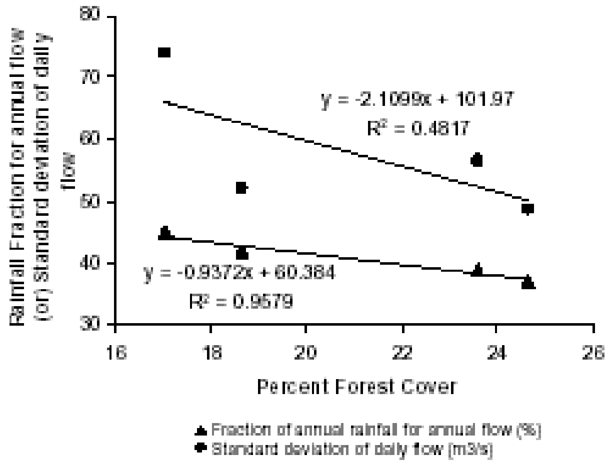

Figure 8. Relationship between percent forest cover and rainfall fraction being run off as well as variability of daily river flow

Sensitivity Analysis of VIC-BASIN Model. For hydrological impact assessment study, hydrology model used should be sensitive to the change in forest cover as the forest will determine fraction of rainfall being direct run-off (surface flow), infiltrate to soils and release to rivers via sub surface flow. However, from the sensitivity analysis, it was found that the VIC-BASIN model did not sensitive to the change in land use patterns (forest/vegetation cover), if base flow parameter was not changed. Therefore, in order to capture the impact of land use change on river flow, the base flow parameter should be adjusted accordingly. The result of study shows that the base flow parameter was significantly correlated with changes of percent forest cover irrespective of land use pattern (Figure 9). The base flow parameter increases exponentially with percent forest cover.

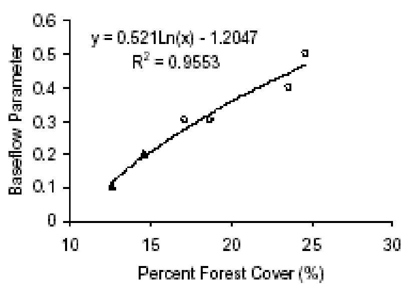

Figure 7. Relationship between percent forest cover and base flow parameter of VIC Model. Note: The circles in the figures are base flow parameters of Citarum and black triangles from Sumberjaya.

Validation. 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 8). Statistical test using simulated monthly aggregate data suggested that there were no significance different between simulated and observed data. All P-values were higher than 5% (Figure 9). However, in general the simulated data were lower than observed ones. Further improvement of the VIC-BASIN model may be required.

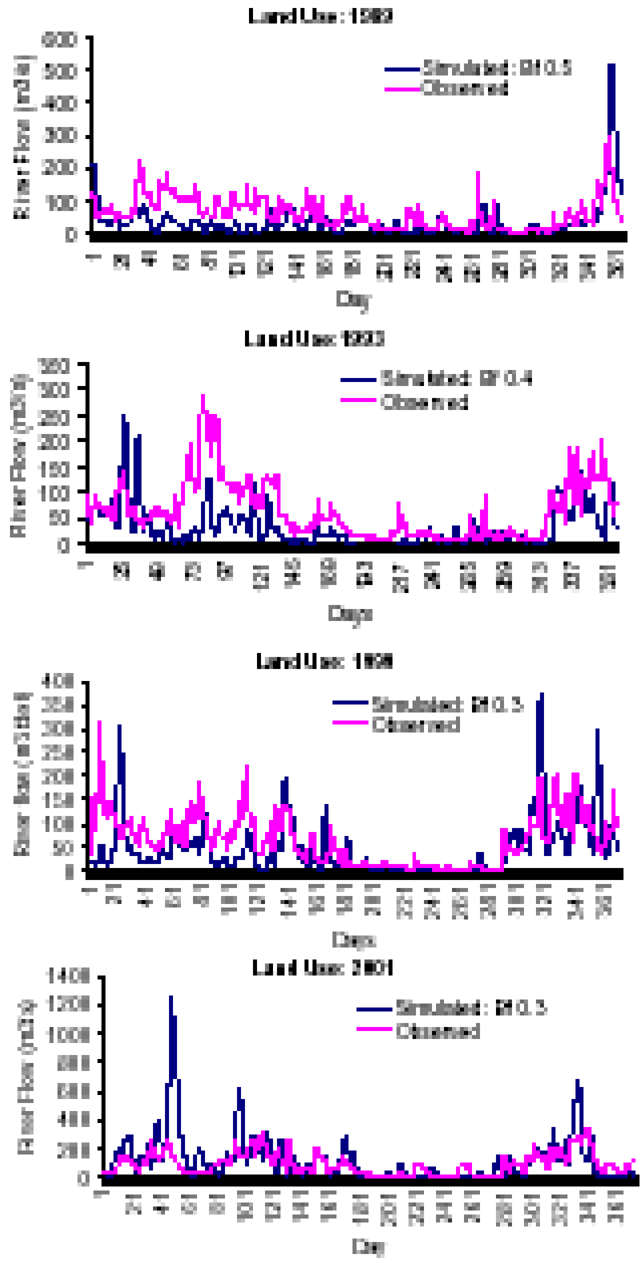

Figure 8. Comparison between observed and simulated river flow from VIC-BASIN

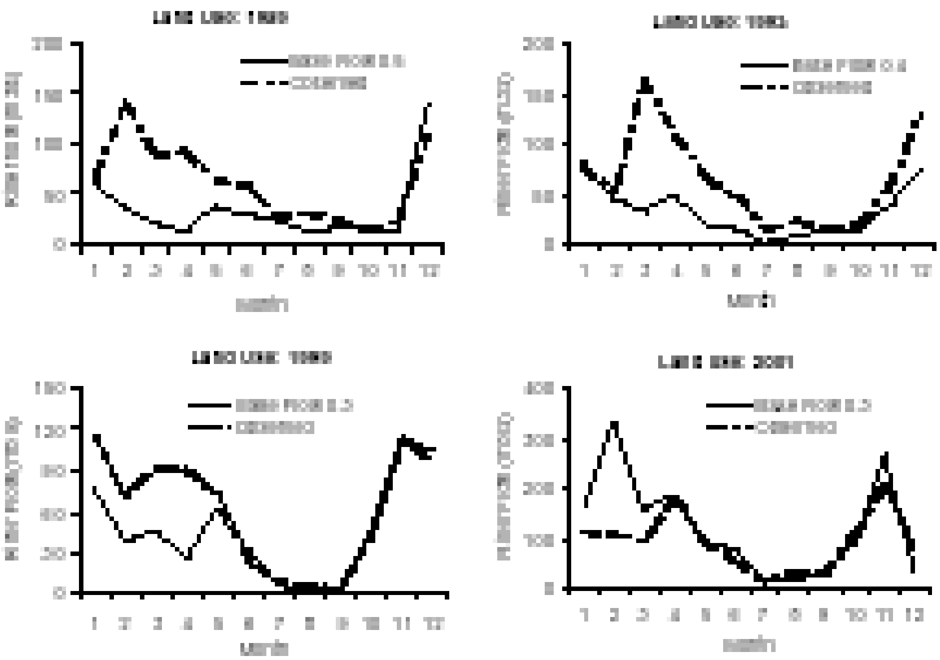

Figure 9. Comparison between observed and simulated data. P-values of t-test for land use 1989, 1993, 1999, and 2000 were higher than 5% (11, 7, 37, and 39% respectively).

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 10). However, in general the model is not able to produce good river flow predictions when the observed river flows are high or extreme (Figure 8). Nevertheless, as the model is able to produce simulated data that have similar pattern with observed ones, its use for impact assessment is still applicable with a caution.

Impact of Land Use Change and Climate Change on River Flow. Using the government land use scenarios and two mitigation scenarios, the VIC-BASIN model was run using present climate data. Data analysis is still progressing and the report will be made available early 2004.

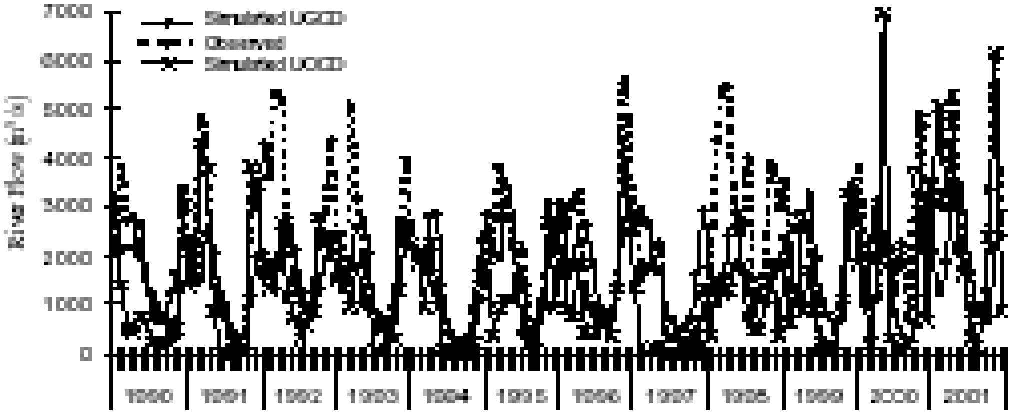

Figure 10. Validation of VIC-BASIN model using observed (UOCD) and generated climatic data (UGCD). Note: For 1990 up to 1991, VIC model used the land use data of 1989, for 1992-1996, it used the land use data of 1993, for 1997 to 1999, it used land use data of 1999 and for 2001, it used land use data of 2001.