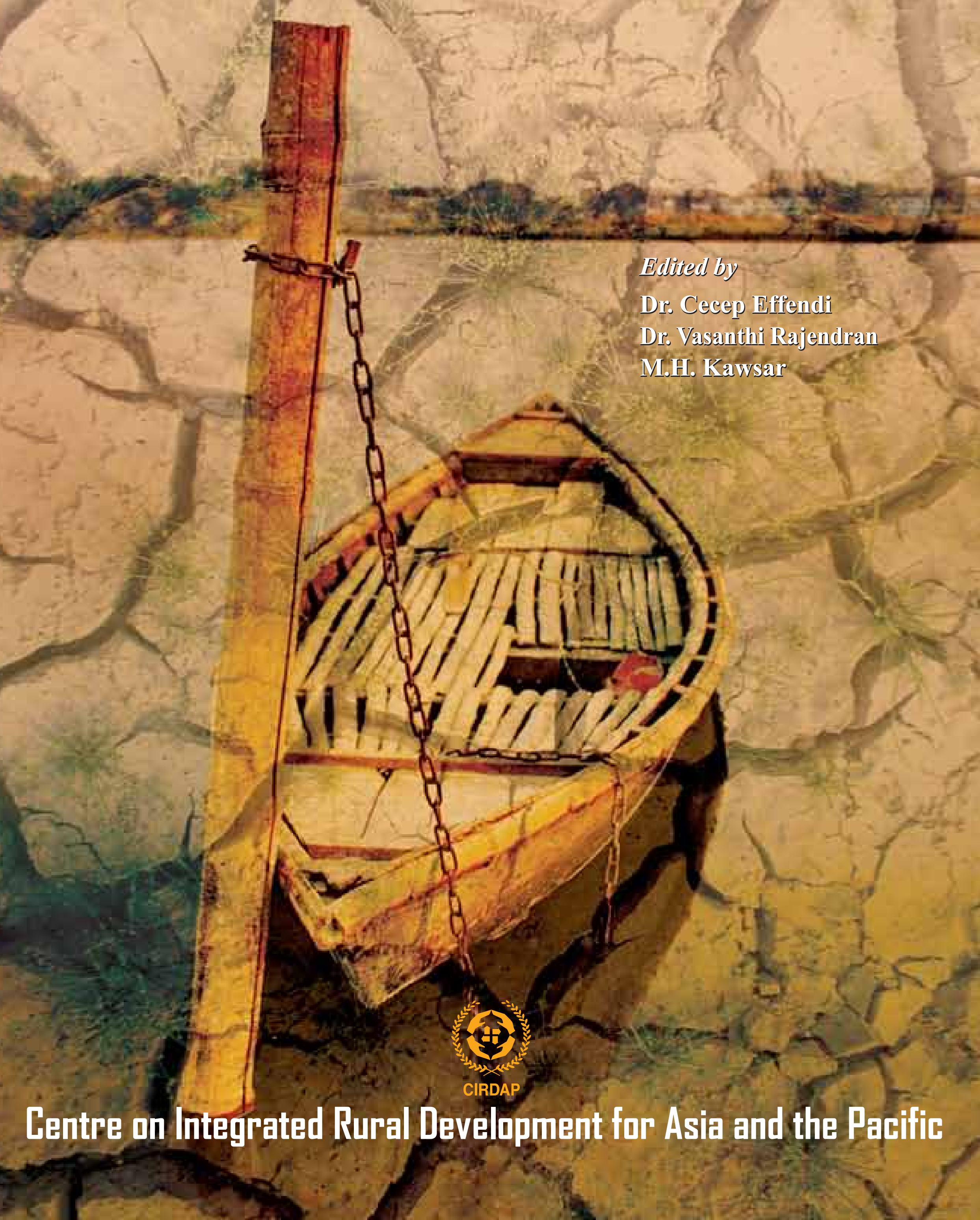
Climate Change Vulnerability

Cases from CIRDAP Member Countries



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CIRDAP

Centre on Integrated Rural Development for Asia and the Pacific

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Foreword

Climate change has emerged as an issue of great significance and influence in the twenty first century. It is considered as one of the greatest threat in the achievement of sustainable development and SDGs (Sustainable Development Goals). Scientific assessments of the Intergovernmental Panel on Climate Change (IPCC) show that climate is changing rapidly due to increase in Greenhouse Gases emitted in the atmosphere, and the impacts are more evident than ever before in the recent human history. With rising temperature, the year 2015 has been the warmest year and the decade 2005-2015 has been the warmest decade in recorded history.

With rising temperature, rising sea level, erratic rainfall in different areas, and frequent sometimes more severe and extreme weather events, including floods, cyclones, droughts, saline water intrusion in coastal areas, wild fires in the forests, the Asia Pacific region houses some of the most affected countries. The negative impact of climate change is already vivid in the fields of agriculture, water, fisheries, forestry and many other areas directly linked with the livelihood and poverty of rural population in the region.

Although some countries have made noteworthy progress in addressing the climate change, there is a critical demand for additional regional and global cooperation in terms of capacity building, funding, technology transfer, and knowledge dissemination to address the challenges.

Asia Pacific includes some of the most vulnerable countries experiencing the impacts of climate change induced extreme events in the world. Moreover, many of the poor communities in the poor countries are most vulnerable and exposed to the impacts of extreme climatic events.

The success of recently adopted Sustainable Development Goals (SDGs) largely depends on the way we tackle the challenges of climate change. Showcasing the success stories regarding climate change mitigation and adaptation, further actions need to be taken to motivate stakeholders in taking responsibility to protect the ecosystems and the human systems which are increasing becoming more vulnerable to climate change impacts.

Since its inception, the Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP) has been working to disseminate knowledge and best practices in different areas linked with rural development in the form of books and periodicals, reports, newsletters, e-bulletins, online database etc. I am happy to know that CIRDAP, as a part of its continuous effort for promotion of knowledge and research, is publishing a series of publications compiling some of the significant research articles, insights on success stories, lessons from failures related to cross-cutting issues of rural development.

This monograph focuses on the impact of climate change – one of the key concerns for sustainable rural development. Six insightful articles based on studies in different CIRDAP Member Countries including Bangladesh, Fiji, Iran, Nepal and Thailand. The studies examine the vulnerability of the Asia Pacific region, how climate change is affecting agriculture and livelihood of the people and different adaptation and mitigations initiatives taken to address the challenges posed by climate change. Although some of the articles were published earlier in journals or in other forms, the continued relevance of their underlying themes across all CMCs makes the articles worthy for further dissemination.

A key mandate for CIRDAP is to extend the frontier of knowledge on rural transformation and explore new avenues of sustainable rural development. I believe this effort will help scholars, development practitioners and policy makers of the Asia-Pacific region to rethink addressing the climate change.

Dr. A Atiq Rahman

Executive Director, Bangladesh Centre for Advanced Studies (BCAS), and Chairman, Climate Action Network South Asia (CANSA).

Contents

Overview

A Atiq Rahman*

Climate change is possibly the greatest threat that is faced by the human system and the ecosystems in the twenty first century. Countries of the Asia Pacific region are particularly vulnerable to the impacts of climate change as indicated by the global assessments by the IPCC (Intergovernmental Panel on Climate Change).

It is to be noted that 2015 was a unique year where three major global initiatives were taken. These are (a) The Sendai Framework for Disaster Management (b) The Paris Agreement on Climate Change; and (c) The global agreement on Sustainable Development Goals (SDGs) with 17 goals building on the outcomes of the Millennium Development Goals (MDGs) and having a 15 years framework (2015-2030).

The Sendai Framework has emphasised the need to integrate disaster risk reduction (DRR) with the climate change adaptation (CCA). While SDGs aim to eradicate poverty, decrease inequality, eliminate hunger, enhance for each country access to safe water and sanitation, food, energy and nutritional security, environmental protection, forestry cover increase and good governance in all the countries by 2030, a 15 years' time frame. In perusing the 17 SDGs, in particularly the poor countries and their communities it is of utmost importance that resilience is built against the impacts of climate change induced extreme climatic events. Particularly vulnerable are the sectors such as, agriculture, water, fisheries, forestry, livestock, the natural resource base on which much of rural development depends.

A few examples in some of the CIRDAP countries will make it quite clear.

Bangladesh has been identified as one of the most vulnerable countries and often referred as the ground zero of climate change because of the simultaneous impacts of sea level rise and associated saline intrusion, increasing cyclones, floods, droughts, landslides, river bank erosion, erratic rainfall and health impacts in different ecosystems of the country. India has suffered from simultaneous floods in the eastern states of Odissa and West Bengal while drought has affected the northern states of Rajasthan.

Several years ago southern coastal area of Myanmar has suffered from one of the most severe cyclone called Nargiswhich killed more than one hundred fifty thousand people in this single extreme climatic event. Nepal has been greatly affected by glacial melts and creation of hundreds of new lakes which are threatened by Glacial Lake Overflow Floods (GLOF) as a new emerging phenomenon induced by climate change.

The Philippines has faced repeated typhoons (cyclones) with unprecedented velocities and impacts on rural and urban areas, particularly affecting the poor. Sri Lanka has recently experienced floods and landslides induced by rapid, severe and erratic rainfall.

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Thailand on the other hand also experienced unprecedented floods recently which had severe impacts in and around Bangkok with major economic loss to the country. In Iran the repeated and extended droughts are affecting the northern nomadic populations and undermining their livelihoods.

The above examples show that the CIRDAP member countries are particularly exposed and vulnerable to the impacts of climate variability and change.

The future approaches to rural development will need to integrate climate change mitigation and particularly adaptation in the sustainable development process. This would be an integral requirement for achieving the SDGs of all the countries in the CIDRAP region. Though urbanisation is increasing more rapidly, rural development and livelihoods, poverty eradication and meeting the needs of the poor populations of food, water, energy, sanitation, health and nutrition for each country to meet their requirements of reaching their respective sustainable development goals.

A set of six papers are included in this monograph. These papers are:

These articles are:

1. Climate Change and Livelihood in Bangladesh: Experiences of People Living in the Coastal Regions.
2. Preliminary Study of Climate Change Impact on Rice Production and Export in Thailand.
3. Rethinking Concepts of Human Health, Food and Nutrition Security in the Pacific Region in the Era of Climate Change with Focus on the Fiji Islands.
4. Ecosystem Services and Livelihoods in a Changing Climate: Understanding Local Adaptations in the Upper Koshi, Nepal.
5. A Study to Investigate Sustainable Adaptation to Drought among Nomads in Iran.
6. Climate Change and Disaster Risk Management for Sustainable Development.

As evident, all the papers address a set of key issues with different level of emphasis. These issues include impacts of climate change, sustainable development concerns, risk assessment and reduction of risks and impacts on ecosystems and communities, adaptation measures, disaster management and social protection, climate variability and impacts, alternative livelihoods, use of different research methodologies and approaches, and enhancement of human welfare.

This short review summarises an overview of the six papers and tries to draw some common elements from rather disparate set of research and papers. Each of the paper had a different set of objectives and aimed for separate audiences, using relevant methodologies and approaches.

For the purpose of CIRDAP, there are opportunities of lessons to be learnt which can help in incorporating climate change issues and concerns in rural development of the Asia Pacific Region.

The first paper ***'Climate Change and Livelihood in Bangladesh: Experiences of People Living in the Coastal Regions'*** study has undertaken research on 220 statistically sampled households in 6 villages in two coastal districts of Patuakhali and Barguna in Bangladesh . Bangladesh is one of the most vulnerable countries to the impacts of climate change as it combines several climate change stressors which often reinforce the impacts on the vulnerable poor who are already exposed to various climatic extreme events. Coastal areas of Bangladesh are most vulnerable amongst the seven identified vulnerable ecosystems of the country.

Key objective of the study was to develop a better understanding of the impacts of climatic variability on the livelihoods by the coastal communities, who are mostly poor. Attempts have been made to include slow onset climatic processes also.

Methodologically the study has attempted to include a combination of qualitative and quantitative approaches. For quantitative method a semi structured survey questionnaire was used. While for qualitative approach, multiple techniques of 05 case studies, 05 key informant interviews, 10 focus group discussion and observation(participatory and non-participatory) were employed. Focus was on extracting information about the affected communities exposed to extreme climatic disasters and hazards.

Amongst study respondent nearly 70% were males and 30% females, and was dominated by younger age group. The average age of the respondents was 39.1 years with 41.2 years for males and 37.7 years for females. Economic status was mostly poor categorised into landless poor, vulnerable and destitute, marginal, medium and larger farmers. The respondents' occupation pattern reveals 22% self-employed (agriculture and animal husbandry), 16% daily agricultural labourers, 6% non-agricultural activities and others.

Several climatic stressors or challenges were identified as reported below and percentages of respondent who mentioned are within parenthesis. Vast majority (96.4%) respondents identified several major challenges faced by climate variability in last one decade. The challenges identified were cyclones (99%), floods (80%), water logging (65%), salinity intrusion (56%), tidal surge (32%), drought (10%), river erosion (10%) and tornado (9%). Others climatic and non-climatic stressors include nor'wester and low soil fertility. Generic analysis identified key socio-economic impacts of climate change on the population which include employment, income and occupation, loss of crops and status of chronic illness. The types of risks faced by coastal communities due to disasters were also identified. Most dominant were food security and lack of drinking water (100% each) while others were lack of health care services (96%) disruption on sanitation facilities, devastated kitchen garden (58%) water logging (45%). Other risks included intrusion of saline water, devastating culture fisheries, destroyed standing crops etc.

Social impacts of climate variability, in order of intensity, were identified as disruption of social network, undermining women's income and employment, disruption of communication and transportation, disruption of livelihoods, prevalence diarrheal and other related diseases, hindrance of movement of children, prevalence of skin diseases, gender based lack of security, forced migration etc.

Economic impacts of climate variability reported by the respondents included, in ranking from highest downward are, wage earners' loss of employment, loss of seasonal crops, difficulties is rearing animals, loss of soil fertility, destructions of homestead, and social forests, disruption of institutional linkages, loss of fruit/timber trees and horticulture etc. .

Further climate variability and climate induced extreme events cause forced internal migration, enhance occupational hazards and saline nutrition. Further exposure and impacts force families to incur loans at high interest from local loan shark.

General adaptation strategies undertaken by communities have been identified. These include: support from govt. safety net programmes, support and service from NGOs, use of salt tolerant rice varieties, assistance in health care support, alternative agriculture, horticulture, fish culture etc. A generic pathway of impacts on livelihood and alternative strategies has also been identified in the paper. The Bangladesh Climate Change Strategies and Action Plan (2009) and the Seventh Five Year Plan (2015-2020) offer some planning integration approaches. The paper suggested integrated approaches based on the specific learning for coastal communities to develop functional climate change adaptation strategies with special focus on local level adaptation planning.

The second paper ***'Preliminary Study of Climate Change Impact on Rice Production and Export in Thailand'*** attempts to report on the investigation on the effects of potential climate change impacts of rice production, consumption and export capacity of Thailand. The investigation uses two models: (a) EPIC, a biophysical process model and (b) Economic process model which includes World Rice Market model and Thai Price Market Model.

The models use the base year of 2007 and scenario for 2017 and 2027. It uses the special report on Emission Scenario (SRES) of IPCC and compares, A2 and B2 scenarios. The paper concluded that the "Main findings of the comparison showed that both the rice production and export in the base year (2007) are likely to expand until 2027 and there will be sufficient amounts of rice surplus for export". Further the paper suggests that Thailand will still have land available for rice production. Investment in irrigation and "comprehensive technical adaptation and mitigation" will be required for farmers benefit.

The paper also tries to analyse potential rice productivity in Thailand by key rice producing regions. Rice remains a large and essential part of Thai agriculture and economy. Choice of rice varieties has an important impact on the economy. The combination of the Biophysical and Economic models in a climate change world in rice production and export is an important innovation in this paper.

The third paper ***'Rethinking Concepts of Human Health, Food and Nutrition Security in the Pacific Region in the Era of Climate Change with Focus on the Fiji Islands'***aims to highlight the importance of how climate change is affecting health, food and nutrition security with Fiji and to propose a conceptual framework for better understanding on how climate change may affect health and food and nutrition security. A socio-ecological perspective is used to address these issues. Coordinated efforts from multiple sectors in society including agriculture, finance, social welfare and others are vital to food security and health attainment and are relevant to health-related adaptation initiatives to climate change.

The fourth paper ***'Ecosystem services and livelihoods in a Changing Climate: Understanding Local Adaptations in the Upper Koshi, Nepal'*** identifies increasing vulnerability of mountain ecosystems and associated human communities remoteness of mountain communities in Dolakha district of Nepal makes access as adaptation measures very difficult.

The paper uses participatory research methods to document and analyse local and regional impacts of climate change on ecosystem services and livelihood of remote communities. The observed impacts of climate change identified include reduced precipitation, erratic rainfall. These undermine both paddy and winter crops cultivation.

In Nepal participatory forest management has increased forest cover and forest ecosystem services, the availability of forest goods such as fuel wood, fodder and litter has decreased due to a combination of regulatory system and increasing climate change induced impacts.

The paper recognises that rural communities are mostly dependent on natural resources and their ecosystems services such as water, forest products, fodder livestock, fisheries for their livelihoods. Adaptation measures are location specific, though can be widely varied and are connected to impacts and the potential access to ecosystem services.

The Dolakha district studied vary in altitude between 723 to 7134 meters above sea level and hence have rapidly shifting ecosystems with altitude. Above 67% of the population have agriculture as their main livelihood supported by rain fed crops cultivation such as rice, wheat, millet, maize and potato. Changing in rainfall pattern is shifting the interface between agriculture and forest based livelihoods.

A number of participating research methodologies have been applied including Poverty Vulnerability Tool, Vulnerability Resilience Framework, Participatory Rural Appraisal, Vulnerability and Adaptive Capacity Assessment. Application of multiple methodologies enhanced the potential for more extended information for better policy development. There appear to be an agreement between peoples' perception of precipitation amounts and the scientific analysis. Reduction of water availability is the key impact on local livelihoods. The paper suggests the strong need for institutional capacity building for integrated planning and long term capacity development of stakeholders at local levels.

Farmers have been responding to climate change with both short and long term adaptation strategies. The paper suggests that adaptation must integrate in development discourse, planning and actions. For poor household incorporation of climate adaptation into local planning would be most helpful. These local adaptation plans developed with the communities need to be supported by adequate resources.

The fifth paper ***'A Study to Investigate Sustainable Adaptation to Drought among Nomads in Iran'*** focuses on the sustainability risks for nomadic communities who are located in the most vulnerable agriculture system in the arid, semi-arid regions of Iran, in the prince of Kerman.

In this highly vulnerable ecological system high rainfall variability and recurrent droughts and floods regularly disrupts food production contributing to increasing risks of poverty. The paper reports that climatic disasters in the arid and semi-arid regions have increased from

100 per decade in 1940 to nearly 2800 per decade in 1990. This enhances the risks of climate vulnerability undermining the poverty reduction efforts of the communities and ecosystems, in this region.

Attempts have been made to use a statistically valid sample size and design of nomadic households. Risk management and crisis management were perceived as two key factors in short and long term adaptation of the nomadic livelihoods which is dominated by repeated droughts. This paper attempts to explain adaptation with droughts by nomads with respect to sustainability dimensions.

The communities studied are very complex in Kerman province of Iran in terms of diversity of 31 tribes and 55 clans distributed over 56 Per cent of Kerman province. The attributes of adaptation with droughts faced by nomadic communities is further complicated by their very complex pastoral property system. This makes implementation of adaptive measures even more complex.

Despite methodological challenges attempts have been made to use Exploratory Factor Analysis (EFA) approaches to arrive at some quantitative results. The paper tries to identify adaptation strategies with droughts. The study highlights the need for integrating scientific methods and local knowledge of nomadic communities. For effective adaptation, building appropriate institutions are very important, while economic development measure can support adaptation capacities for the nomadic communities affected by repeated droughts.

The paper identified that diversity of approaches is important. Diversity of species, human opportunities and economic options encourages both adaptation and learning. The need for addressing appropriate development of interactive drought management and risk reduction policies for the nomadic communities has been recognised as one of the key approaches to support these very vulnerable and shifting communities.

The sixth paper ***'Climate Change and Disaster Risk Management for Sustainable Development'*** attempts to draw the relationship before climate change and disaster management. Moreover, it is in the context of sustainable development at large.

This paper tends to integrate climate change and risk management. It is in the framework of sustainable development which is best reflected by the SDGs which proposes to eradicate poverty for the first time as a global objective. The paper emphasised that those who are most exposed to severe climate related hazards most often have the least capacity to cope with or adapt to these stresses. It is to be noted that in rural systems the livelihoods of most are involved in agriculture, fisheries, forestry, livestock and water management. All these sectors are most vulnerable to extreme events related to climate change.

The paper briefly attempts to define some of the key concepts, such as, causes of climate change, weather and climate, linkages between risks, vulnerability and climate change; inputs and risk factors and risk management. Disaster and sustainable development is addressed through how disaster events undermine poverty eradication, increases inequality, linked globalisation and cascading risks. Special mentions have been made for cities and small development countries.

Attempt has been made to link reduced economic impacts to hazards and development baseline. It suggests climate sensitive economic policy is likely to reduce disaster risks and enhance resilience. The paper concludes that applying longer term perspective for social protection, inclusion of climate risk assessment, designating appropriate participatory adaptation measures and good monitoring and evaluation systems can enhance the potential for sustainable development and integration of climate change and disaster management practices.

The paper is more of a review of the existing literature and attempts to clarify some of the complexities and encourages better integration of components of sustainable development and climate risks.

If we summarise the findings of all the articles, it is evident that most of the Asia Pacific countries are vulnerable to Climate change which is affecting the agriculture, health, livelihood and all aspects of lives of the people in the region. Most vulnerable people are confined to the regions climatic extreme events in the regions in each country. Amongst them, most vulnerable are the poorest communities who have the lowest capacity to withstand the impacts. Impacts vary widely and adaptation measures are most often context specific.

In the context of CIRDAP member countries, rural development still dominates the welfare of the each country citizens. Though urbanisation is increasing rapidly, the context is the rural-urban continuum and rural development remains central to economic as well as sustainable development.

The rural poor depend on the natural resources of land, water, agricultural crops, vegetation, animal husbandry, fisheries and their ecosystem services. Climate change induced extreme events tend to impact and undermines both the ecosystems and human systems.

Climate change is the greatest threat that the Asia Pacific countries face in the twenty first century. Each country is developing their respective climatic change strategies and plans. As the world enters a new paradigm of Sustainable Development Goals (SDGs), each country must develop its own climate strategy, action plan and specific adaptation action plan. New policy dimension indicates the need for local level adaptation plan based on the population, ecosystem, climate change threats and impacts as well as enhancing adaptation capacities of vulnerable communities and incorporates these in local level governance systems. It is important to integrate climate change in the overall, regional and local planning of each country. Enhanced capacity building initiatives are essential. Better science and research for analysing the climate change parameters taking into consideration the global, national and local level scenarios of climate change in decade by decade transformation will be needed in each country and regionally.

CIRDAP has to develop its own learning with all the stakeholders of each member country and best scientific knowledge of climate change and sustainable development. This learning will form the basis of integration of climate change into sustainable development goals and each member country's development.

Integration of scientific knowledge, scenarios, modelling when combined with local community knowledge seems to offer best results in a dynamic situation posed by climate change and its variable impacts.

Climate Change and Livelihood in Bangladesh: Experiences of People Living in the Coastal Regions

Mahbuba Nasreen,* Khondoker Mokaddem Hossain,** and Md. Abul Kalam Azad***

Abstract

Bangladesh is particularly vulnerable to climate change because of its geographic location. Disasters caused by climate change such as floods, river bank erosion, cyclone, tornado, cold waves, arsenic contamination in ground water, water logging, salinity intrusion etc. are gradually intensifying the disasters and composing the risks to the coastal people in Bangladesh. The present study is concerned with climate change related risks and hazards which are affecting the inhabitants of coastal Bangladesh. The study findings demonstrated that the climate change has destroyed the livelihood of coastal people in many folds including scarcity of pure drinking water, malnutrition, extreme poverty, health problems, losses and damage in crop cultivation, fisheries, poultry, vegetables garden etc. It has also created a state of unemployment among the people of coastal communities. Thus, the affected people are losing their means of livelihoods and forced to take several alternative means of livelihoods to cope with the adverse impacts of climate change. The study findings also elicit the alternative adaptation strategies adopted by the affected coastal women and men in Bangladesh. The present paper, moreover, exhibits that the coastal community people are trying to build their resilience capacity through adopting and exploring alternative employments.

Keywords: Alternative livelihood, Climatic variability, Social implications, Economic implications.

Introduction

Climate change has become a global concern, especially the international forums (UNFCCC, COP 13, IPCC, and FAO) urge to take immediate collaborative actions to meet the challenges of climate change. Climate change contributes to increase frequency and severity of disasters with adverse impacts on humans, natural ecosystem and quality of human survival. Due to devastating impacts of disasters poor people suffer from malnutrition as they fail to procure food (crop loss/damage, high price of essentials etc.). Deforestation, over- fishing, over grazing, salt built up, water borne diseases from irrigation, endangered wild life from loss of

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habitat, loss of genetic diversity, water pollution, air pollution and climate change are closely interrelated to each other and having impacts on food production, lives and livelihoods on the people of Bangladesh.

Due to geo-political and territorial location, Bangladesh is widely considered to be one of the most climate vulnerable countries in the world. It has experienced frequent natural and human induced disasters including sea level rise, cyclones, storm surge, flooding, land erosion, water logging, and salinity intrusion in soil and water because of extreme variability of climate change which cause loss of life, damage the infrastructure and economic assets, and adversely affect the livelihoods of people especially the poor, vulnerable and destitute living in environmentally fragile areas. The combination of a high level of poverty, and a fragile ecological system increase the country's vulnerability to climate change (Khan et. al. 2010). Intergovernmental Panel for Climate Change (IPCC) also projected that South Asia will suffer most due to climate change as 22 per cent of word's population (about 1.4 billion) including 40 per cent of world's poor live of which more than half of the population is directly dependent on agriculture. It is also predicted that heart waves, heavy precipitation events will become more frequent and crop yields could decrease up to 30% in Central and South Asia by the mid-21st. All of these would contribute to increase the disaster events and Bangladesh would be the most vulnerable country to face climate induced disasters more frequently (Nasreen 2012).

The pioneer and longitudinal studies (Nasreen 1995; 2008) revel that although a disaster affects all segments of population, there are gender variations to vulnerability and resilience during disasters. Women and girls in the disaster prone areas face number of problems due to their gender identity. As a result, women and girls in poor and marginal households become more vulnerable and distressed (Nasreen 2012). Access to food, sanitation, pure drinking water, health care, education and social security are obviously inadequate in both urban and rural areas of Bangladesh. With this prevailing scenario there are gender variations in context of access to services and rights. Climate change has added a new dimension to the relational analysis from gender perspective (Nasreen 2008). Nasreen (1995; 2008) also argues that women are not only the mere victims of climate change but are also playing crucial roles for household's sustenance. Women's contribution to rural production activities include raising seedlings, gathering seeds, post-harvesting, cow fattening and milking, goat farming, backyard poultry rearing, pisciculture, agriculture, horticulture, food processing, cane and bamboo works, silk reeling, handloom weaving, garment making, fishnet making, coir production and handicrafts. It is evident that women's own adoptive techniques and initiatives become crucial for their family sustenance and ensuring food security (Nasreen 2008; 2012).

Objectives of the Study

The attempt of the study is to explore the impacts of climate change on the livelihoods of people living in coastal areas of Bangladesh. In the light of broad objective the study has been carried out based of the following specific objectives:

- To assess the climate induced risks and impacts on the poor people living in coastal areas.
- To identify the alternative livelihood options and adaptation strategies of affected people prone to climate change.

Research Questions

- What are the possible risks associated to climate induced disasters experienced by coastal communities?
- To what extent climate change affects the coastal people's livelihoods?
- What are the coping and or adaptation options in maintaining sustainable livelihood?

Rationale of the Study

It has been well established by the researchers that global climate change will have most adverse impact on the poorest and vulnerable segment of people of developing countries including Africa, Asia and Latin America. According to the assessment of IPCC (2007), because of human activities, such as the emission of greenhouse gases or changes in land use pattern, it is evident that the large-scale human-induced climate changes are visible. Therefore, the globally-averaged temperatures since the mid-20th century, has been increased, which is known as global warming, is very likely caused by human activity, principally because of burning fossil fuels and massive deforestation due to excessive cutting, felling, illegal smuggling and generation of revenue. However, there are international, regional and national efforts, initiatives and commitments towards adaptation with climate change (Nasreen et al. 2008).

Bangladesh is highly vulnerable to natural hazards and the extreme effect of climate change added a new dimension to community risk and vulnerability (MoDMR 2010-2015). According to World Bank (2006), Bangladesh is one the victims of extreme climate variability. Even, slight rise of sea level due to effect of global warming and greenhouse effect, a substantial part of coastal area will go under water, might cause displace of about 33 million people. Besides, different socio-political factors limit people's access to endowed resources and perpetuate risks and vulnerabilities of coastal inhabitants (Shamsuddoha and Chowdhury 2007). Different survey data also indicate that the living standard, average life expectancy, per capita farming land, access to education, health and other basic services, including social security etc. in the coastal areas are not at expected level in comparison to national average. Increasing trends of climate induced vulnerabilities and natural disasters gradually are also making coastal people's life more helpless (Shamsuddoha and Chowdhury 2007).

From the evidences it is presumed that the impact of climate change is now the most burning and highly concerned issue for Bangladesh. The socio-economic consequences of climate change, sea level rise, factors of salinity intrusion and its consequences, comparative analysis of salinity intrusion in different parts of the country are causing vulnerabilities. Thus, the present research is aimed to analyse more details about coastal people's vulnerable livelihoods due to climate induced challenges. The findings provided us a picture about the nature of relationship between climate change and livelihood of rural poor of coastal areas. To cope with the climate change, the coastal communities are taking different measures including alternative adaptation and mitigation options. From several studies (Nasreen 1995; 2012; Hossain 2012) it is revealed that the community based climate change risks reduction strategies and households and individual initiated mitigation strategies in the context of existing socio-economic and geographical setting of disaster affected people (including women) have always been overlooked. Besides, it is also noticeable, a very few studies have focused on health and food problems and the dynamics of the adaptation strategies to climate change of the coastal communities. The present study is a modest endeavor to explore the impact of climate change on the livelihood including health, housing, income, food etc., coping and adaptation strategies of people living in selected coastal communities. The present study has also assessed the impact of climate change and nature of vulnerability of coastal people's livelihood and especially to the vulnerability of low-income population. The growing literature on adaptation gives far more attention to agriculture and to rural livelihoods and climate change related risks of coastal communities.

The Possible Risk of Climate Change in Bangladesh: Impacts on Livelihood

The coastal zone of Bangladesh, an area covering 47,211 km^2 with a population of about 40 million facing the Bay of Bengal or having proximity to the Bay and the exclusive climatic vulnerable zone in the Bay is generally perceived to be a zone of multiple vulnerabilities. Records of last 200 years show that at least 70 major cyclones hit the coastal belt of Bangladesh and during last 35 years nearly 900,000 people died due to catastrophic cyclones (PDO-ICZMP 2004). Out of these extreme climate variability including cyclones a number of negative consequences have been developed in the coastal zones of Bangladesh. Among the challenges tidal surge, intrusion of salinity and devastation of the means of livelihood are the crucial factors. Even, the devastation of infrastructure, loss of standing crops and biodiversity has made the coastal people more vulnerable. The salinity conditions in the coastal area could further exacerbate due to reduced dry-season freshwater supply from upstream sources. The soil salinity has also increased and the productivity of agricultural products has decreased while the sea level rise has damaged Sundarbans biodiversity and crop lands. Studies (World Bank 2006; Shamsuddoha and Chowdhury 2007) note that the intrusion of salinity in coastal lands is expanding rapidly, i.e., 1.5 ha to 2.5 million ha of coastal lands already subject to saline contamination. And this process will be faster and will move upward and contaminate more fresh water. As a consequence, there will be a shortage of drinking water, and this will put extra burden to women and girl child children. Moreover, about 6 to 8 million coastal dwellers will be forced to displace by 2050 due to inundation and intrusion of saline water in the region. The recent loss and damage caused by Sidr and Aila was about 1.7 billion US$ and about 500,000 people displaced were displaced due to the Aila and there was a massive intrusion of saline water in the coastal belt due to both Sidr and Aila. About 100 km from Bay of Bengal is subject to salinity intrusion in coastal Bangladesh and the effect is very devastating. Literature on the impacts of climate change pointed out that most of the poorest people are experiencing with climate induced hazards. A comparative study conducted by Hossain and Nasreen (2012), indicate that in the four coastal villages of Bagerhat districts, i.e., in Burirdanga, Kalika Proshad, Adorshogram, Gobindopur village, almost 99% of the coastal people affected different disasters such as cyclone, tidal surge, salinity intrusion, water logging, coastal erosion etc. Evidence also shows that found that 81 per cent households of four coastal village of Satkhira district experienced high salinity compared only 2 per cent a decade ago due to gradual sea level rise (Rabbani et al. 2013).

Poor people living in the marginalised lands perusing nature dependant livelihoods are facing barriers and constraints earning wellbeing in the changing climate. The climate change is posing challenge to the livelihoods in different ways. Livelihoods are either disrupted by the extreme weather events like cyclone, heavy downpour, floods, erosion, storm surges, dense fogs, sea turbulence or by slow onset disasters like salinisation, dryness, ecosystem degradation etc. (OXFAM 2009). On the other hand, achieving food security and reducing poverty in the Bangladesh has been a major challenge for both governments and development agencies due to vulnerability of Bangladesh agriculture to Climate change. Currently, much more people in the rural Bangladesh are considered food insecure due to recurrent different climatic events like flood, storm, river bank erosion, salinity intrusion, and drought. The poor and marginal farmers are becoming more vulnerable as a result of crop loss due to climate change. Shortage of food and price hike goes beyond the purchasing capacity of the poor people (Nasreen et al. 2008).

People of coastal belt, char and haor areas in Bangladesh are continuously fighting with impact of climate change. Climate change is forcing people to take diversified occupation to maintain their livelihood. Researchers pointed out that agriculture in Bangladesh “is already under pressure from increasing demands for food and the parallel problems of depletion of agricultural land and water resources from overuse and contamination. Climate variability and projected global climate change makes the issue particularly urgent (Selvaraju 2006). It is also mentionable that extreme weather events not only limits livelihood persuasion during the event but also has the potential to erode household assets, like destruction of house, trees and even it may kill people or injure them. The extreme events also destroy local resource base and thus limits livelihoods and wellbeing. The household assets including human health and motivation, houses, trees, other physical assets, livelihood tools and equipment are destroyed in the extreme weather events and thus reducing capitals to pursue livelihoods and accordingly reducing resilience to extreme conditions (OXFAM 2009).

Climate Change and Gender Dimensions

Women are generally more vulnerable than men to climate-related impacts due to their social status, cultural norms, lack of access to and control over resources, and lack of participation in decision-making processes in the developing countries (Khan et al. 2010). It is evident from a number of studies (Nasreen 1995; 2008; 2012) that women especially the poor, destitute and vulnerable women in Bangladesh bear multiple responsibilities at home, including food preparation, provision of cooking fuel, health care, and caring for children and their education. It has also been found that women living in poverty bear a disproportionate burden of consequences of climate change because of their marginalised status and dependence on local natural resources. When a cyclone and floods hit Bangladesh in 1991, the death rate for women was almost five times higher than for men (Pender 2008). In recent studies, Nasreen (2012) shows that climate change induced disasters affect both women and men but the burden of coping with disasters falls heavily on women. Since, additional works are also performed by women to deal with the adverse situation. According to Nasreen (2012), during and aftermath of a disaster men in rural areas lose their places of work while women shoulder the responsibilities to maintain households' sustenance. Women suffer more than men from poverty, hunger, malnutrition, economic crises, environmental degradation, health related problems, insecurity and become victim of violence and political crises. The gendered division of labour becomes critical as gender roles are often re-enforced and even intensified – due to the additional work and changes in environment brought on by a disaster. It has been argued that violation of women's rights becomes more prominent due to crises created by climate change (Nasreen 2008). For example, people have to depend on relief to cope with disaster, however, relief do not reach to those people who mostly need it. It is evident that women's own adoptive techniques and initiatives become crucial for their family sustenance and ensuring food security (Nasreen et al. 2008).

Women are also engaged themselves in addition activities outside regular domestic works. In addition, it is also mentioned in a study (Khan et. al. 2010) that women often have to accompany their husbands for catching fish at night. In both waterlogged and flash flood prone hotspot, women also help their male counterparts in making handicrafts such as mats or fishing traps, which are later sold in the market. However, although poor rural women have very few options to them to overcome their problems, their roles in disasters are obviously not simple: they relate to complete range of socio-economic activities. Studies (Nasreen 2008; Alam 2008) also argue that women are the mere victims of climate change but are also playing crucial roles for household's sustenance. Women's contribution to rural production activities include raising seedlings, gathering seeds, post-harvesting, cow fattening and milking, goat farming, backyard poultry rearing, pisciculture, agriculture, horticulture, food processing, cane and bamboo works, silk reeling, handloom weaving, garment making, fishnet making, coir production and handicrafts. A significant number of rural women, particularly from extremely poor landless households, also engage in paid labour in construction, earthwork and field-based agricultural work, activities that traditionally have fallen within the male domain' (Alam et al. 2008). During floods women continue to be bearers, care givers and socialisers of children, collectors and providers of food, fuel, water, medical herbs, fodder, building materials and keepers of household belongings (Nasreen 2012).

Method of the Study

One of the main purposes of the present study was to understand the impacts of climatic variability on the livelihood including any slow on-set disasters that experienced by the people of coastal communities in Bangladesh. The data for the present study has been collected directly from the selected villages of coastal areas in Bangladesh. The present study has followed a triangulation method i.e., a combination of quantitative and qualitative research methods. For quantitative method, a semi-structured survey questionnaire was applied to collect the data while for qualitative data, case Study, Key Informants' Interview, Focus Group Discussions and Observation (participation and non-participation) methods were applied. By applying the qualitative approach, an attempt has been made to understand the experiences of the affected communities, especially who faced with harsh conditions at the time of extreme disasters and hazards.

Selection of Study Area

Bangladesh has seven administrative divisions three of which, i.e., Barisal, Khulna and Chittagong are located in the coastal region. Out of these divisions, Barisal division has been selected as the study area due to its exposure to the Bay of Bengal offshore, which is subject to frequent disasters and hazards due to extreme climatic variation.

Sample Size

- A total of 6 villages such as Chargarabdi, East Kyna, West Kyna, Kalarang, Arpangashia, Ghopkhali of four different Upazilas of Patukhali and Barguna Districts were selected as study locations based on the effect of climate variability in the affected areas. The study villages are under Dumki and Bauphal Upazila of Patukhali District and Taltali and Amtali Upazila of Barguna district respectively.
- In the survey, a total of 220 respondents from different households were selected from six villages. The list of landless poor was collected from local union parishad office. Putting the number in the sampling calculator with 95 per cent confidence level and confidence interval 4, it suggested a sample size of 220 respondents which were finally chosen purposely as the sample size of the survey. The unit of analysis was individual respondents of different households, selected on the basis of BBS selection criteria, especially from the list of Union parishad those have been living in the coastal regions.
- For qualitative data five (5) focus group discussions and 10 case studies at least 1 case study from each village had been conducted and 5 Key Informant Interviews (3 Key Informants Interviews among the local representatives and School teachers and 2 Key Informants Interview among NGO Officers) were also administrated to understand the critical situation of climate change.

Findings and Discussions

Socio-economic Profile of the Climate Change Affected People

The present section has furnished the information on the social, economic and demographic characteristics of sample households of the study. The study consists of 220 respondents of which 70.45 per cent are males and 29.54 per cent are females. The overall proportion of the younger age groups is substantially larger than that of older age groups for each sex. The average age of the respondents was 39.1 years whereas 41.2 years for males and 37.7 years for females. The present study shows a substantial variation in the educational attainment of the respondents. It is revealed from the study that a very insignificant number of the respondents (0.45%) have obtained master's degree and only 1 per cent respondents have graduation degree. On the other hand, about 36 per cent respondents have completed primary level education followed by 15 per cent up to class eight, 11 per cent S.S.C and 3 per cent H.S.C. Due to lack of available support from family they were unable to continue their higher study. Another significant finding is that more than 30 per cent of the respondents never attended any school/madrasa/formal educational institute. Income distribution of poor, non-poor, ultra and hard-core poor have been categorised into landless poor, vulnerable and destitute, marginal farmers, small farmers, medium farmers and larger farmers. It is evident from the findings that about 26 per cent households are landless poor, vulnerable and destitute and their monthly family income is below TK 2500 per month whereas about 28.6 per cent small farmers' monthly family income is between the range of TK 3500 to 5200. On the other hand 11 per cent medium farmers' income is within the range of TK 5200 to TK 7000 while more than 14 per cent of the household who are identified as larger farmers their family income is above TK 7000 per month.

To be familiar with the occupation pattern of the respondents like income an attempt is made to focus the frequency distribution and percentage of the respondents in all villages. It reveals from the findings that about 22 per cent respondents are engaged in self- employed profession, i.e., in agriculture/animal husbandry. On the other hand, about 16 per cent respondents are daily agricultural labours while more than 6 per cent respondents are involved in non-agricultural activities (daily basis). The study exhibits a significant variation in occupational pattern. Women are engaged in several income generating activities like men. Among the households more than 6 per cent respondent are supporting their families by engaging in handicraft making and many of them are women. Besides, these occupational groups, about 8 per cent are unemployed. On the other hand, about 3 per cent respondents are unable to work due to physical problem and chronic illness. The study also shows the ratio of unemployment between male to female which is 2:1. It was also observed that many respondents are engaged in small scale trading, fishing etc.

Table 1: Occupation of the Respondents by Sex						
Occupation	Sex				Total	
	Male		Female			
	Number	Per cent	Number	Per cent	Number	Per cent
Self- employed in agriculture/animal husbandry	42	27.1	8	12.3	50	22.7
Self- employed in: handicraft making	7	4.5	7	10.8	14	6.4
Petty business	9	5.8	5	7.7	14	6.4
Rickshaw puller	5	3.2	-	-	5	2.3
Other non-farm enterprise	10	6.4	2	3.1	12	5.5
Student	9	5.8	2	3.1	11	5
Daily agricultural labor	30	19.5	5	7.7	35	15.9
Daily non-agricultural labor	12	7.7	2	3.1	14	6.4
Salaried worker	8	5.2	4	6.1	12	5.5
Unemployed	12	7.7	6	9.2	18	8.2
Housework	-		22	33.8	22	10
Not able to work: chronically ill or disabled	4	2.6	2	3.1	6	2.7
Leisure	7	4.5	-	-	7	3.2
Total	**155**	**100**	**65**	**100**	**220**	**100**

Climatic Hazards, Risks and Its after Effects

Climatic Impact and Challenges for the Coastal People in the Last One Decade

Bangladesh is particularly vulnerable to climate change because of its geographic location at the north the Himalayan mountains and southern edge of the Bay of Bengal (Nasreen 2009). Disasters caused by climate change such as floods, river bank erosion, cyclone, tornado, cold waves, arsenic contamination in ground water, water logging, salinity intrusion etc. are observed in recent years. But the nature, season, severity, and extent of hazards are not same in all cases (Nasreen 2010). The frequent and different types of disaster management with the shift of paradigm from emergency response to proactive disaster risk reduction (Nasreen 2011). These disasters are gradually intensifying the disaster and composing the risks to the coastal people in Bangladesh. The study has tried to identify one of these major events so that the impacts of that particular hazard on the coastal community can be assessed. The most of the coastal people (96.4%) have experienced with several disasters. Climate change has created more challenges for the coastal people in the last one decade. Due to the change in climate the coastal communities are facing several challenges including climate change induced disasters as well as difficult livelihood. The study reveals that among such disasters cyclone (99.1%) is one of the key challenges. Like cyclone, flood (80.2%), water logging (65.1%) and salinity intrusion (55.7%) have become major problems in the coastal areas because these havocs damage agricultural production and create state of unemployment among coastal people. The study shows that tidal surge, tornado landslides, nor'wester, and drought and low fertility have become key challenges in the coastal zone of Bangladesh. The disaster affected local people are not well-known about emerging climate variability, but they are aware about several natural havocs. They expressed that in the last decade they faced many natural disasters such as cyclone, tidal surge, salinity intrusion, flood, river erosion, water logging or even earthquake etc. The cyclone SIDR which happened in the 15th November, 2007 was one of the pathetic events of all memorable events. Among these natural hazards, salinity intrusion is a silent disaster observed for a long period. Like cancer, the salinity intrusion has aggravated the risks such as health problem, physical problem, food scarcity, environmental imbalance etc.

Table 2: Percentage Distribution of the Respondents by Major Challenges Faced Due to Climate

Challenges created by climatic variability	Number	Per cent	Rank Mode
Yes	212	96.4	
No	8	3.6	
Total	220	100	
Kinds of challenges*	210	99.1	1
Cyclone	68	32.1	5
Tidal surge	118	55.7	4
Salinity intrusion	170	80.2	2
Flood	21	9.9	8
River erosion	138	65.1	3
Water logging	19	9	9
Tornado	3	1.4	11
Nor'wester	23	10.8	7
Drought	9	4.2	10
Low fertility			

n=212 *multiple responses

Therefore, it is clearly understandable that the effect of climate change has created new risks in the society for which the people are becoming more prone to risks and they are unable to cope with such disasters and hazards.

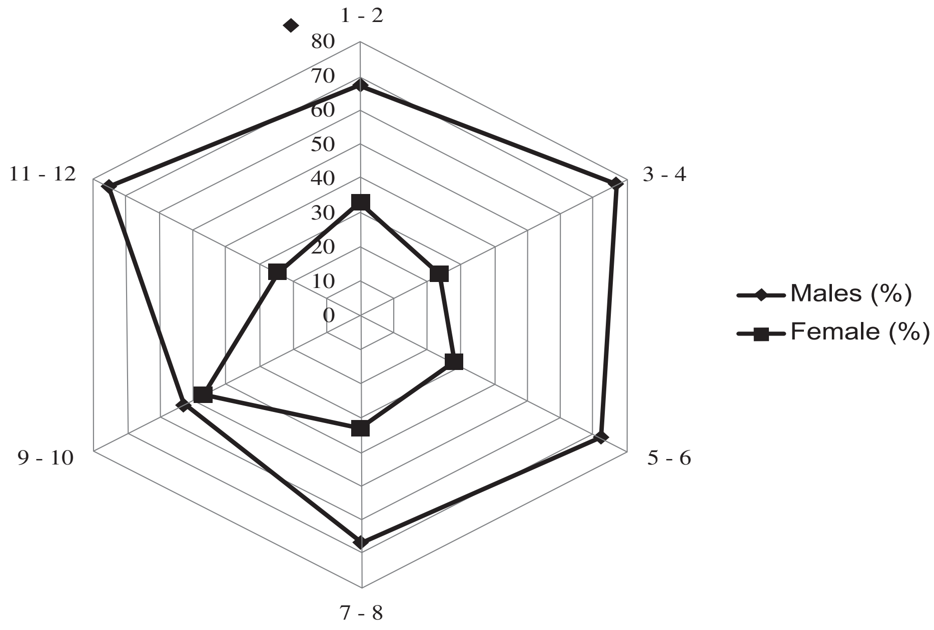
> *"Climate change has badly affected the availability of fresh water and it has aggravated intrusion of saline water. As a consequence we neither able to drink the contaminated water nor able to produce our valuable means of livelihood, i.e., the agro products which ultimately hamper our bumper harvest. Even we are not secured during the severe disaster as there is a little provision of safe place i.e., the cyclone shelter is within 2-3 kilometres. We cannot take much preparedness measures to face such natural disaster; actually we are facing more crises for not having enough cyclone shelters".*
>
> **- Voice of cyclone experienced woman, Fatema Begum, Taltoli, Barguna, Bangladesh.**
>
> *"I am living on the slope of the river bank. I am not sure when I would be able to back home and to settle in my homestead".*
>
> **- Concern expressed by a climate affected man from Barguna, Bangladesh.**

Impact of Climate Change on Employment, Income and Occupation

Income is the most important factor that determines the standard of living of the households. In the coastal areas, the majority of the villagers live on 'hand to mouth'. According to an assessment made by the International Labour Organisation and the Ministry of Labour and Employment of Bangladesh, some 567,000 people saw their livelihoods temporarily or permanently disrupted, mainly due to employment losses and damage to income-generating assets (ILO, 2008). Women are even less employed during these days of extreme weather. The market cannot be remained operative and thus limiting livelihoods of hundreds. It is observed that respondents of poor and destitute households are unable to afford to provide three meals a day for their families. Only middle and large farmer households have better income and better quality food whereas other occupational groups who are living below poverty line unable to afford any balanced meal. Sometime the income and occupation attainment is severely disrupted by frequent hazards and it incurs huge dame of standing crops and other standing resources. It is evident that the coastal people are subject to victims of natural calamities and on average they remain unemployed more than 4 months a year. Women remained unemployed about 4.6 months and males about 4.3 months a year. The sources of income and occupation of nearly 51 per cent respondents were mostly affected by disasters. Besides, the sources of income and occupation of nearly 48 per cent respondents were disrupted partially by climate induced hazards whereas only a few respondents (1.4%) inform that they were not affected by disasters. The study findings show that more than 29 per cent per cent of females remained unemployed. This piece of work further shows that out of 68 respondents nearly 76.5 per cent males were unemployed from about 3 months to 4 months followed by 23.5 per cent females. Besides, among out of 54, about 72 per cent male respondents mentioned that they remained unemployed for about 5-6 months and 75 per cent males out of 8 respondents remained unemployed for about 11-12 months followed by 47.1 per cent (out of 17) females. On the other hand, about 33 per cent (out of 61) respondents remained unemployed from about 1 month to 2 months and more than 33 per cent females have no job up to 8 months. It is evident that irrespective of gender variation, a significant number of males and females are unemployed in the coastal zone.

> *"As a day labour I have to work in agricultural fields. But my main occupation is hampered by disasters. Due to these natural calamities I don't get work and remain workless more than 8 months. In the last decade there are many disasters such as cyclone, flood, storm, sidr, drought occurred in my locality. These calamities have created more challenges for our livelihoods, domestic animals, crops, and other sectors. My family is now suffering from food insecurity and pure drinking water due to these calamities. Besides, we are unable to rear cattle and poultry because of lack of grass and lack of financial support".*
>
> **- Ruhul Amin Shikder, Arpangashia union, Amtoli, Barguna, Bangladesh.**

Figure 1: Duration of Unemployment of the Respondents Due to Climate Variability (in months)



Chronic Illness and Vulnerability in the Coastal Areas

The combination of extreme events along with higher temperatures that increases unfavourable conditions infectious diseases in Bangladesh (WB 2000). The perceived risk to human health is low relative to those in other sectors (such as water resources) mainly because of the higher uncertainty about many of the possible health outcomes. Increased risk to human health from increased flooding and cyclones seems most likely. Increase in surface temperature would practically help parasites such as mosquitoes. One may therefore infer that deadly diseases such as malaria, dengue etc. would put human health into higher risks under climate change (Agrawala et al. 2003). Changes in infectious disease are less certain, as the causes of outbreaks of infectious disease are quite complex and often do not have a simple relationship with increasing temperature or change in precipitation. This happens as thousands of people of Bangladesh live in climate vulnerable areas. The coastal people are frequently affected by several diseases including fever, cholera, skin diseases, asthma, etc. It is unveiled in the study that the impacts of climate change in terms of various contagious and viral diseases such as chronic fever, heart disease, blood pressure and arthritis etc. About 31 per cent respondents suffer from chronic dysentery or gastric/ulcer disease which are more than 44 per cent (18) for women and 25 per cent (10) for male respondents. It is also found that nearly 21 per cent respondents suffer from asthma or breathing trouble. The respondents who are also suffering from asthma or breathing trouble among them about 6 per cent are females while about 28 per cent are males. Besides, more than 17 per cent (10) of the total respondents reported that they suffer from blood pressure. It is also found that more than 10 per cent (6) respondents suffered from chronic fever and about 5.2 per cent from heart diseases. The findings also show that it is the female respondents who suffer more (27.8%) compared to male respondents (12.5%) from high blood pressure. Moreover, there are prevalence of some other diseases like arthritis/rheumatism (5.2%) and eczema (10.3%). It is clearly understandable that women bear more problems from several diseases. Therefore, there is a strong relationship between gender and types of chronic illness and diseases. From the qualitative finding it is also revealed that women and adolescent girls suffer more and they also suffer from various gynaecological problems and one of the reasons of such suffering is the after effect of using saline water during menstruation. Poor and vulnerable women and adolescent girls were explaining their helpless experiences about menstrual hygiene management, and said that the use of saline water during menstruation, especially findings no hygienic arrangement due to involvement of cost for buying sanitary napkins, that cause lot of irritating and infections in their genital organs during menstruation. As a consequence many of the respondents suffer from genital injury, including irregular and excessive bleeding, infection and other complications.

Table 3: Any Chronic Illness of the Respondents Having No Slash

Chronic Illness	Sex				Total	
	Male		Female			
	Number	Per cent	Number	Per cent	Number	Per cent
Chronic Fever	5	12.5	1	5.6	6	10.3
Heart disease	3	7.5	-	-	3	5.2
Asthma/Breathing Trouble	11	27.5	1	5.6	12	20.7
Chronic dysentery or gastric/ulcer diseases	10	25	8	44.4	18	31
Blood pressure	5	12.5	5	27.8	10	17.2
Arthritis/Rheumatism	2	5	1	5.6	3	5.2
Eczema	4	10	2	11.1	6	10.3
Total	**40**	**100**	**18**	**100**	**58**	**100**

Climate Change Related Risks Faced By the Coastal Families

Bangladesh is an innocent victim of climate change. Due to this change the common scenario is that the coastal people are striving with the natural calamities. The frequent natural disasters have posed them at multifarious risks. The Table 4 shows the risks created by climate change in all areas. The survey data exhibit that all respondents are facing food crises and scarcity of pure drinking water. Food is now seen as an acute problem in the climate change affected areas while the coastal people are unable to find due to scarcity of pure drinking water. On the other hand, saline water is available due to sea level rise where it causes water logging in the coastal Bangladesh. Salinity intrusion has devastated the cultured fisheries and the kitchen gardens and it has destroyed the crop production resulting food scarcity, malnutrition and poverty among the poor and ultra-poor people. The coastal people, in some cases, are planting trees and developing homestead forest to mitigate the adverse impacts of natural calamities. Disasters like cyclones and floods have destroyed and have washed away fish from the pond. Like floods and cyclone, tidal surge inundated and washed away shrimp ghers. Because of these losses, the coastal people are also unable to afford the health care services. So, it is clearly evident that the people who are encountered with climate change are more prone to climatic risks.

"Climate is changing for our activities and the world is getting fearful and dreadful. The local people do not get work. They are suffering from food scarcity and lack of medical services, medicine, sanitation problem etc. People cannot move due to severe disruption of communication and transportation system. Frequent disasters have devastated roads, culverts and embankments which paralysed our normal life. Village people are also unable to get pure drinking water due to salinity intrusion. Water table is gradually going down and has been interrupting us to get pure drinking water and for maintaining agricultural activities. Due to using saline water various water borne diseases have affected the local inhabitants and women, children and elderly are suffering more from such situation."

- Concern expressed by a key Informant, Barguna, Bangladesh.

Table 4: Types of Risks Faced by the Coastal Community Due to Disasters

Climatic variability	Number	Per cent	Rank Mode
Food insecurity	212	100	1
Lack of access to health care services	162	76.4	3
Disruption of sanitation facilities	146	68.9	4
Scarcity of pure drinking water	212	100	1
Destroyed the standing crops	51	24.1	8
Creating water logging	96	45.3	6
Saline water devastated the cultured fisheries	55	25.9	7
Shrimp gher have been inundated and washed away due to intrusion of tidal water	11	5.2	10
Devastated the kitchen gardens	124	58.5	5
Lack of crops due to salinity	16	7.5	
Washed away fish	11	5.2	10
Homestead forest	23	10.8	9

n=212 *multiple response

Social Implications of Climate Variability

The climate change induced disasters have broken down social order and social cohesion in the affected areas and even disrupted social network relationships. More than 98 per cent respondents report climate change induced disasters disrupt social network that climate change i. e. social bandage with kin relationship and neighbourhood is gradually become insignificant.

Nasreen (1995; 2012) pointed out that women are maintaining a strong relationship with kin. They exchanged goods, food and services. Women exchanged warm curry each other which these are seen at a very few scale. Similar have been reported by the respondents. The social implications including health related sufferings of climate variability are severe in Bangladesh. The affected people particularly poor and vulnerable people are suffering from diarrhoea and skin diseases since last decades. In the study areas, more than 72 per cent and nearly 68 per cent of the respondents reported high prevalence of diarrhoea and skin diseases. Besides, vector borne diseases such as dengue, malaria and water borne diseases like dysentery and jaundice have been observed in the study areas. On the other hand, due to disruption of livelihood the disasters affected people are suffering from malnutrition leading kwashiorkor and marasmus and hyponatremia due to dehydration. It is found that in previous year children did not face any acute physical problem. In recent years, some autistic children are seen in the study areas. The parents of the autistic children informed that new born babies are gradually growing as autistic or mentally handicapped. The study also represents that the affected women in the coastal areas are engaged in several income earning activities to support their families particularly for food. However, they are often unable to carry out their daily jobs due to lack of security. The women, further, face physical difficulties at time of work due to food scarcity and lack of health services. Thus, climate change impediments to women's income and employment opportunities. Indeed, the coastal people both male and female are simultaneously searching alternative livelihoods. If they are unable to get jobs or alternative livelihoods, they are moving out of the village to work in garments factories or in brick field and on other agricultural land.

Table 5: Nature of Social Implications of Climate Variability

Nature of Social Implications *	Number	Per cent	Rank Mode
Disruption of social net work	208	98.1	1
Hindrance to movement of children	149	70.3	6
Disruption of communication and transportation	176	83	3
Impediment to women's income and employment	192	90.6	2
Prevalence of diarrhoea	153	72.2	5
Spread of different vector borne diseases like dengue, malaria	63	29.7	11
Spread of water borne diseases like dysentery, jaundice,	80	37.7	10
Hyponatremia due to dehydration	33	15.6	13
Malnutrition leading kwashiorkor and marasmus	62	29.2	12
Prevalence of skin diseases	144	67.9	7
Forced migration	87	41	9
Disruption of the means of livelihood	173	81.6	4
Gender based vulnerability due to lack of security	128	60.4	8
Autism/handicap	10	4.7	14
Lack of cropping diversity	5	2.4	15

n=212 *multiple response

Climate change has exposed the coastal people to a wide range of vulnerabilities such as economic, physical, social, health and the people. Evidence shows that poverty is identified as one of the most important causes of vulnerability to climate threats (Khan et al. 2010). This piece of study has viewed that climatic variability has various physical and socio-economic impacts, both in the short and long run. Some hazards, like cyclones, are so intense that they destroy everything in few hours, while others, such as floods and water logging, take weeks to manifest their range of effects. While people have to live in hostile conditions during the disaster, the major hardships often arise in the post-disaster period when people are left with nothing. The survey data indicate that the wage earners of nearly 98 per cent household were unemployed while the female members of around 76 per cent household are unable to get jobs related to agro-based income earning activities. It is also found that climate change causes loss of the top soil fertility of agricultural land (88.7%) and in accordance with 44.3 per cent respondents they are unable to cultivate vegetables due to saline water in their land. Besides these, the coastal people are unable to cultivate seasonal crops (95.3%). Fruit and timber trees of more than 62 per cent of the households cannot be grown due to extreme climate. Climate change induced disasters destroyed homestead and community forest of nearly 86 per cent households. It is also observed that in the coastal areas due to availability of saline water the affected households (41%) are not able cultivate sweet water cultured fish while more than 49 per cent households are not able to rear animals due to lack of grazing fields and animal feeds and fodder. As, salinity intrusion resulting from sea level rise creates water logging, it is destroying the growth capacity of grass and variety of crops. It is seen that due to water logging people are unable to initiate poultry and layer firming due to lack of dry spaces. Even, climate change induced economic risks has disrupted the social and institutional linkages and networks such as contacting the local agriculture offices, banks, NGOs offices etc. of coastal communities. Thus, the economic challenges and family hardships are increasing among the respondent households of climate change affected areas.

"I think the impact of climate change makes the water layer very low and brings challenge of saline water which hampers our bumper agricultural production and harvest. There is no cyclone shelter or signal centre within 2-3 kilometres of our residence. We cannot be prepared to face this natural disaster except depending on my small savings. Actually more crises we face for not having adequate number of cyclone shelters".

- Fatema Begum, Taltoli, Barguna, Bangladesh.

"Most of the natural calamity occurs in our area in April to June and October to November months. In this time everybody of our area, suffer from frightening and panicky mentality as we do not know when the devastating natural calamity will attack us. I have lost my valuables including houses, trees and cattle, the economic value of which is more than 100000 taka".

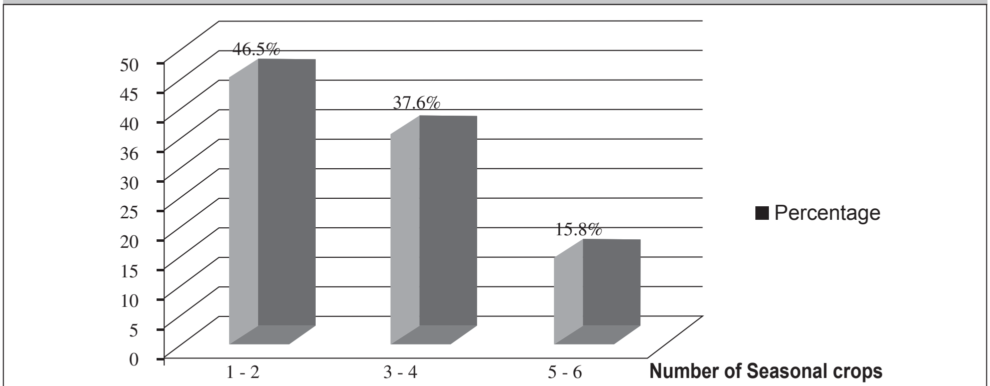
- Latif Talukdar, Patuakhali, Bangladesh.

Table 6: Economic Implications of Climate Variability*			
Economic implications of climate variability	**Number**	**Per cent**	**Rank Mode**
Wage earners of household remain unemployed	207	97.6	1
Female members are unable to get jobs related to agro-based income earning activities	160	75.5	6
Fertile agricultural land loss its top soil fertility due to climate change	188	88.7	4
Vegetables cannot be grown due to saline water	94	44.3	10
Seasonal crops cannot be cultivated due to extreme climate change	202	95.3	2
Sweet water cultured fish cannot be cultivated	87	41	11
Fruit and timber trees cannot be grown	132	62.3	8
Animals cannot be reared due to lack of grazing fields and animal feed	190	89.6	3
Poultry and layer cannot be commercially initiated due to lack of dry space	104	49.1	9
Homestead Forests/community forest have been destroyed	182		5
Disruption of Institutional linkages	135	85.8	7
n=212 Multiple response		63.7	

Loss of Seasonal Crops

Climate variability affects seasonal crop production. Due to prevalence of crop diseases and extreme weather crop cannot be grown smoothly. The Figure- 2 depicts that on an average around 3 seasonal crops cannot be cultivated due to extreme climate change it is reported by nearly 47 per cent (94) respondents that they loss 1 to 2 seasonal crops while about 38 per cent households cannot cultivate 3 to 4 types of seasonal crops. Besides, around 16 per cent household tried to plant seasonal crops. They are unable to cultivate 5 to 6 types of seasonal crops due to change taking place in climate. The qualitative study depicts that agricultural and livestock sectors are mostly destroyed by cyclone especially livestock, cattle, paddy, trees, and crops. Like cyclone flood water also swept away many crops. On the other hand, the farmers who are living on agriculture and fish production they suffer a lot during dry season as drought is observed which hampers agricultural and fisheries sector.

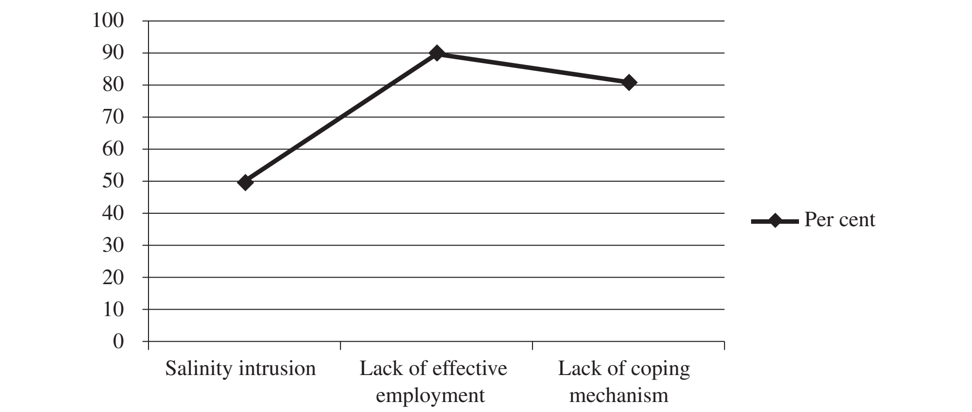
Figure 2: Percentage of Seasonal Crops that cannot be Cultivated Due to Extreme Climate Change



Climatic Variability and Forced Internal Migration

Population displacement or migration in the global world is directly related to extreme climatic variability that causes severe natural disasters and hazards. The International Organisation for Migration (IOM) mentioned that about 192 million people, or 3 per cent of the world's population are now living outside their place of birth 2050 (Brown 2008). In the context of migration and climate change the IPCC (2007) Assessment Reports predicts that the poorest people of developing countries have to go through hardship due to hostile environment and lack of capacities. These difficulties will generate new challenges which will be more unfavourable and will enforce them to move from one place to another for many reasons.

Figure 3: Out Migration of the Vulnerable Groups Forced to Migrate Elsewhere



It is found that frequent natural disasters have destroyed employment opportunities for people in the coastal areas. Affected people are losing their places of jobs due to decreasing in agricultural land and other income generating activities. The study depicts that due to sea level rise salinity intrusion has increased and people losing employment facilities. For example, according to 50 per cent of the respondents, the vulnerable people are migrating to the cities or going out of village because of salinity intrusion to look for alternatives. On the other hand, 90 per cent of the respondents mentioned about lack of suitable employment opportunities and the rest of 80.9 per cent respondents revealed that due to climatic variability they migrate to suitable places. It is also learnt that young people no longer interested in cultivating crops and are migrating to other places in search of work. A key informant Shahid Shikdar, Taltoli, Barguna expressed:

> *"I have observed that many people are unable to get adequate and balanced food, clothing, sanitation and other related facilities, even today. As a result the affected people, finding no other convenient options, forced to migrate either capital city Dhaka, or port city Chittagong or any other parts of the country to get alternative means and support for maintaining their livelihoods."*

Occupational Hazards, Risks and Challenges

Climate change has not only destroyed not only employment opportunities of rural people but also created new type of risks related to health, income and livelihoods. It is seen that though the human physical capital is available, demand for labour is not enough due to lack of employment opportunities in agricultural and fisheries sectors. For Example, the Table-18 shows that more than 49 per cent affected people reported about less demand for human labour. The employers take opportunity due to available of human labour and pay low wage or low salary to labours. Climate change has also negative impacts on women's labour and they are discriminated in terms of wage and work environment. The affected people, who are working in agricultural fields and shrimp gher contracted with several diseases such as diarrhoea, skin diseases, itching and so on. It is revealed from the study that more than 41 per cent respondents are now feeling physical irritation and health hazards due to saline water. Besides, the affected people (58.2%) also attracted by other types of health hazards due to saline water while fishing and doing agricultural works. It can be remarked that the coastal communities are now facing new types of occupational hazards and risks associated with climate change.

Table 7: Occupational Hazards, Risk and Challenges of the Respondents*

Occupational hazards, risks and challenges	Number	Per cent	Rank Mode
Workers suffer due to salinity and less demand for human labour	108	49.1	4
Feel physical irritation and hazards due to saline water in the paddy fields	91	41.4	5
Low wage and salary	165	75	1
Women are discriminated in terms of wage and work environment	141	64.1	2
Health hazards due to saline water while fishing and other agricultural work	128	58.2	3

n=200 *Multiple responses

Alternative Coping Mechanisms and Resilience of People Affected by Climate Change

Alternative Activities Taken by Climate Change Affected People

The concept of sustainable livelihood can be used to understand the alternative livelihood of the people in analysing the capacities. The climatic variability literatures view the concept of livelihood as means of living whereas sustainable livelihood links with other critical factors such as social, physical, natural and financial which enhance the capacity to people to resist any external shocks (Ellis 2000; Badjeck et al. 2009). Thus, an attempt has been employed to understand the alternative livelihood of people in the context of Sustainable Livelihood Framework (SLF). The study exhibits that the patterns of alternative livelihood and other activities vary according to nature of disasters induced by climate change. The affected people are adopting several strategies to cope with extreme climatic variability. It is found that the scarcity of food is an acute problem in the coastal zone. Like food problem, they also suffer from inadequate health care services, and resilient housing etc. When they are unable to solve their food crises and other challenges, they borrow money from others. Table-8 indicates that, to overcome their incidental and contingencies need including buying food and other household essentials and meeting daily needs, more than 72 per cent household borrow money from neighbours or relatives. On the other hand, more than 46 per cent of the household borrow money from mohajan (local money lenders) with high interest rate. During the lean/off seasons of agricultural production, most of the respondents borrow money but this is not the solution. Though, they got periodical relief from the government and NGOs, it further increases their dependencies and burden of borrowing as many of them are unable to maintain their livelihoods in normal times when there is least chances of getting income and employment opportunities. As a result, in disasters prone areas the coastal communities are trying to solve their problems by selling mat and other handicrafts in the local markets. Around 21 per cent families are now making mats and other handicrafts to maintain livelihoods. Livestock rearing is also an important source of income in all over the country. Though, the affected people cannot rear poultry and layer due to lack of dry space, but have taken livestock rearing as a main income earning source. For example, more than 68 per cent household are now rearing livestock to meet their basic needs. Besides, livestock rearing and sweet water fish cultivation are also found as important sources of income of 59.1 per cent households. During flood food crises is found as major problem. Women store food and fruits to solve the problem of food crises. Women face problems in cooking due to lack of water and fuel wood.

Agricultural lands are gradually losing its top soil fertility. Agricultural crops and vegetables cannot grow due to saline water and extreme temperature. The coastal people are now trying to cultivate extreme weather suitable and salinity tolerant crops. For example, 15 per cent of the coastal families have cultivated water lemon whereas more than 11 per cent households planted betel leafs to maintain livelihoods. As, frequent cyclones destroy houses of coastal people, they have to take shelter at the school compounds. At this time, schools are kept closed as they are used as cyclone shelters or temporary residence for the homeless people. However, they face difficulties at cyclone shelter as they are not sufficient. It is observed that in Boga Union of Patuakhali district, there is no cyclone shelter within 2 or 3 kilometres and two cyclone shelters are seen in whole Boga union.

Several NGOs are working in the coastal areas to support and to enhance the livelihood capacities of the affected people by providing jobs, training, providing poultry and animals, and giving credit with low interest etc. The affected people are also getting assistances from NGOs or other cooperative groups. These NGOs and cooperatives involved affected people in community based livelihood programmes and providing training in different livelihood activities. Many people are becoming members of social safety network programmes supported by youth club/citizens committee and also participating in innovative livelihood programmes initiated by government or other organisations. Besides these alternative strategies, the affected people are also trying to increase their knowledge on climate change, its' after effects and associated risks. They think that the knowledge on climate change and understanding of risks would help to learn more on crop cultivation patterns. Different clubs and citizen committees have been formed by GOs and NGOs to make people knowledgeable on the effects of climate change become more resilient.

Table 8: Types of Alternative Activities Taken by the Coastal People to Cope and Adopt with the Climatic Variability

Alternative livelihood strategies adopted by climate change affected people	Number	Per cent
Borrowed money from relatives/neighbours	159	72.3
Received relief	76	34.5
Moved to cyclone centre	69	31.4
Supported by NGOs	80	36.4
Borrowed money from Mohajon with high interest	102	46.4
Supported by cooperatives/Groups	48	21.8
Exploring alternative job opportunity	148	67.3
Exploring community based livelihood support	151	68.6
Be a member of social safety network supported by youth club/citizen's committee	9	4.1
Support from health care programme	45	20.5
Be part of innovative livelihood programme	56	25.5
Be part of training programme	29	13.2
Be part of resilient in terms of sweet water supply; PSF; rain water harvesting; ground water extraction, use of surface water	18	8.2
Be part of resilient in terms of: community based monitoring and need assessment, livelihood Support services through youth club/citizens' committee; knowledge on climate change and its after effect; understanding of risks	69	31.4
Mat and other handicrafts making	45	20.5
Culture fisheries	130	59.1
Livestock rearing	150	68.2
Timber sawing	17	7.7
Water melon cultivation	33	15
Plantation of betel leaf	25	11.4

n=220 Multiple answers

Resilience to water crisis is very difficult for the coastal people. To strengthen resilience capacity in terms of water scarcity different resilience measures taken by government and NGOs. Pond Sand Filters (PSF) is a new technology that is installed by government NGOs to make water free from salinity. The local people have also developed a system with the help of NGOs and GOs to harvest rain water as well as ground water. During monsoon period they store drinking water into water filters placing them on house roofs. Using surface water and extracting ground water for agricultural cultivation are also major adaptation strategies of the coastal people. These adaptive techniques are strengthening the resilience capacity to resist unnoticed impacts of climate change.

Alternative Means of Livelihoods for Women

The gender based adaptation to climate change impacts is significantly understood as a necessary technique to mitigation and reducing the risks of climate change and the pattern of strategies are taken to minimise the severity of climate change (Nasreen 2012; Klein et al. 2007). As of other parts of rural Bangladesh women in the coastal areas are playing key roles in supporting their families by adopting several means. The coastal women are maintaining their livelihoods and trying to fulfil basic needs of their families through involvement in earth filling, homestead platform raising and planting vegetables in the raised plinths. They also nurture poultry and involved in beef fattening or rearing milky cow to generate income and reduce family poverty. As shelter problem is another problem created by frequent cyclones and storm surge. The cyclones affected women protect their houses through planting saplings and trees. They also cultivate vegetables on the raised platforms around their homesteads and store fuel woods. The government is also allocating khash land to solve the residential problems of female headed household. Cottage industry is an important alternative strategy adopted by the women. They are taking credits from NGOs and GOs for producing cottage based products. Though women do not have sufficient training on how to produce cottage based products, they are getting training on skill development by different NGOs. The rural women are also getting training on rearing poultry and cattle. From the qualitative data, it is evident that women make and preserve the dry food like cake, chira, muri, khoi etc. during and pre disaster period. They also rear the livestock like cows, goats even buffaloes. They involve themselves in rising homestead plinths for planting vegetables and rearing poultry and animals, beef fattening, and rearing milky cow. The coastal affected women are also organised themselves in emergency responses and formed society/co-operatives etc. to reduce their livelihood risks.

Table 9: Coping and Resilience Strategies of Women Adopting for Climatic Variability *

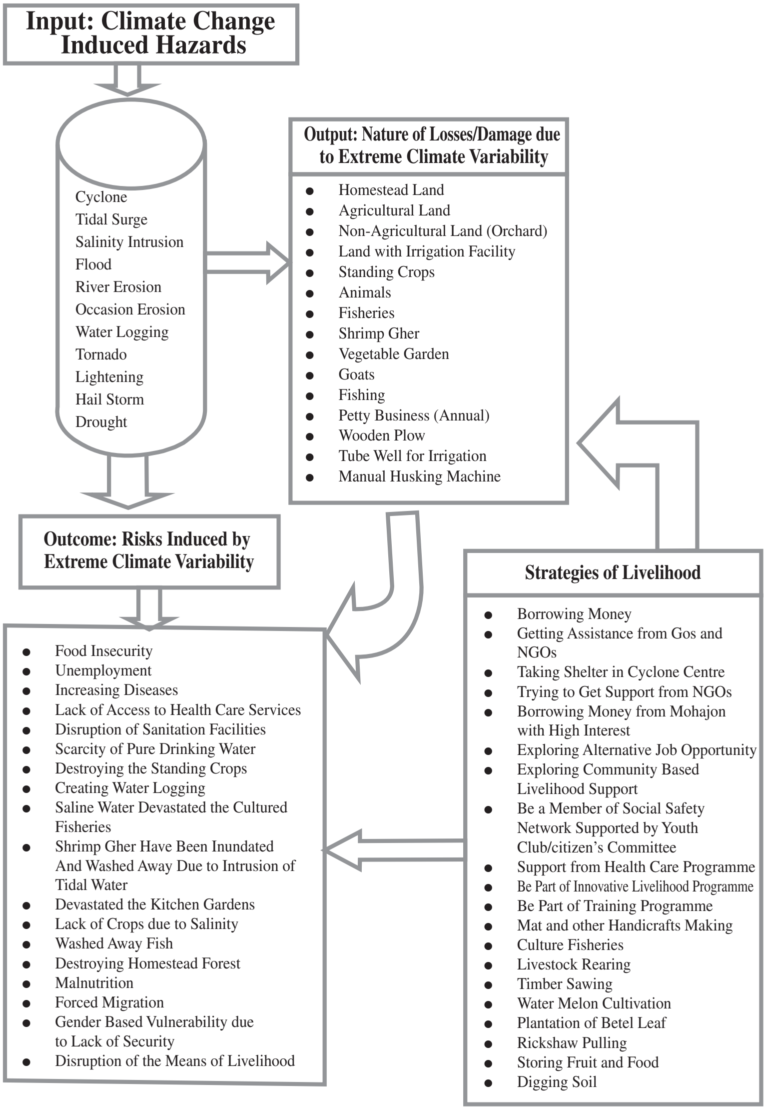
Alternative livelihood adopted by Women	Number	Per cent	Rank Mode
Allocation of *Khash* land	65	29.5	11
Formation of women's society/cooperative	149	67.7	6
Women's involvement in earth filling/homestead platform raising for planting vegetables and rearing poultry and animals/beef fattening/milking cow rearing	171	77.7	2
Store of fuel wood	165	75	3
Plantation of sapling/trees and cultivation of vegetables on the raised platform around homestead	210	95.5	1
Supply of credit and inputs for producing cottage based products	160	72.7	4
Formulation of training and skill programme	117	53.2	10
Involve women in collecting data to assess risk and mitigate risk	34	15.5	12
Organise women group to involve women in emergency response	164	74.5	5
Orient and involve trained and professional women in all aspects of response related to disasters	121	55	8
Tap women's talents as informal educators	118	53.6	9
Introduce co-ownership of women with their male counter-parts	131	59.5	7

n=220 *Multiple answers

Climate change has induced several risks for both men and women but the risks are different for those women who are particularly more vulnerable and living under below poverty line. Different NGOs and professional are collecting data and assessing the risks of women. It is evident that the risks burden is more for women than that of their male counterparts. NGOs are giving training to understand risks of women and formulating women groups to involve women in emergency responses.

It is well understood from the study that climate variability, livelihood and alternative strategy are closely interrelated. The following schematic diagram illustrates the generic links of climate change impacts along with alternative livelihood options of the people living in coastal zone of Bangladesh.

Figure 4: Pathways of Impacts of Climate Change on Livelihood and Alternative Strategies



Key Policy and Operational Implications

Several sectoral policies have been over the year to cope with recurrent climate risks, and to some extent the additional risks posed by climate change. The government of Bangladesh government is concern about the adverse impacts climate change as well as climate change sensitivity. There are several policy response options that exist that relate to climate change. The policy architecture of Seventh Five Year Plan SFYP has proposed with some targets following the Bangladesh Climate Change Strategy Action Plan (2009). The policy suggestions of this study has unlocked new door for the existing policies relating to climate changes and disaster risk reduction.

In the study areas there are numerous opportunities for cultivating soya bean and Napier grass as the locality is fit for cultivation of both the items. Therefore, the poor and marginal farmers can be provided with skilled training and resources. Such innovative project can be initiated and operated through local Youth Clubs so that they can operate the project on the basis of small cooperative system. The project, moreover, can be linked with the thana agriculture and livestock offices for getting technical assistance. Similarly, the project can be connected with marketing network so that the producers able to get the fair price of their produced goods and services. A dairy cooperative can be formed with the members of local Youth Club who can be granted a fund to buy the milking cows/calves so that the grown grasses can be utilised locally and it is the local poor and vulnerable people who can have their own sustainable resource generation and mobilisation mechanism and capacity.

Salinity tolerant crop variety needs to be introduced. At the same time, the poor and marginal farmer's needs to be facilitated with micro-credit (with soft and flexible loan) so that the under-privileged and disaster affected people can able to afford such type of innovative agro-based production. The farmers' groups are needed to be mobilised for providing adequate scientific knowledge through proper training so that they can able to replicate the initiatives to different parts of salinity affected areas. NGOs can be linked with local agricultural extension officer and agronomist so that they can provide technical knowledge and assistance. Moreover, they can able to extend their effective coordination and monitor the whole process of production relations and market network for better implementation of the initiated project.

It is observed that within the study area there are potential opportunities of small fish traders to be part of organised group for developing a network of fish market and marketing. For example, it is the individual small scale middlemen who are involved in fish trading at local level. These middlemen fish traders can be organised into an effective group (12 people can constitute a group) and be facilitated with resources including credit, skill knowledge and fish preserving facilities. Once, the group can be provided with adequate support services and facilities, able to be part of sustainable small scale fish processing, preservation and trading and development. This can also facilitate the local growers to get the fair prices of their fishes. Moreover, the groups can also be linked with the whole sellers and export groups through the market chain. The study, furthermore, also notes that gender sensitive analysis is important to ensure women's participation in long term climate change adaptation strategies, which might have been constrained due to their traditional social norms in Bangladesh.

Concluding Notes

The findings of the study provide a details overview of types of climate variability and climate induced disasters and their impacts on coastal people. It is evident that the impacts of climate change vary based on the socio-economic conditions amongst vulnerable groups, poor, ultra poor and rich categories. Climate change related hazards lead to multifarious risks and posed multiple threats on the communities. Climate change induced disasters devastate means of livelihood options and increase peoples' vulnerabilities. There are various elements of vulnerabilities associated to current climate variability. Due to extreme weather the climate change affected people are unable to perform their agro-based productions and face other occupational risks. Among the coastal people unemployment appears as a common phenomenon. Though the climate change affected people do not want to move from their residences, climate induced disasters force them to migrate outside of village in search of works. Like unemployment, food scarcity, health problem, water crises have been identified as major challenges in the coastal belt of Bangladesh.

It is evident from the study that in order to cope and/or adapt with the unexpected conditions contributed by climate change local communities are taking multiple alternative livelihood strategies based on their indigenous knowledge and coping mechanisms. They are trying to adopt with the adverse impacts of climate change by adopting alternative livelihood options such as rearing poultry, planting trees, cultivating vegetables in homestead land, using pond sand filter and harvesting rain water etc. to enhance their livelihood capacities. The government and other bodies are also providing supports to local people to develop a resilient society through their adaptation strategies. The government, often with support from development partners, INGOs, NGOs has introduced social safety net programmes and alternative employment opportunities for the disaster affected coastal people. Some of these include capacity building training in cottage industry, providing salinity tolerant seed and try to minimise their risks by strengthening capacity and building their assets.

This study has suggested some policy options for the climate affected people of coastal area. If those options can be introduced, it might help to bring a qualitative change in the lives and livelihoods of coastal people. Moreover the affected people might get ideas how to sustain their resources by introducing alternative means of livelihood and able to resilient their livelihood. Therefore by examining various impacts of climate change, the present study has given importance for developing inter-linkages amongst different governmental and non-governmental organisations and local communities. The study also draws an attention to the institutional and economic factors and opportunities that might facilitate people's well beings to cope with extreme climate variability and climate induced disasters in coastal Bangladesh.

References

Alam, K. et al. 2008. *Gender, Climate Change and Human Security in Bangladesh.* Dhaka: Action Aid Bangladesh.

Agrawala, S., T. Ota, A.U. Ahmed, J. Smith, and M.V. Aalst. 2003. *Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans.* France: OECD.

Badjeck, Marie-Caroline, E.H. Allison, A.S. Halls, and N.K. Dulvy. 2010. 'Impacts of Climate Variability and Change on Fishery-based Livelihoods.' *Marine Policy* 34 (3): 375-383.

Brown, O. 2008. *Migration and Climate Change*. IOM Migration Research Series No. 31. Geneva: International Organisation for Migration.

Ellis, F. 2000. *Rural Livelihoods and Diversity in Developing Countries*. Oxford: Oxford University Press.

ILO. 2008. *Cyclone Sidr: Preliminary Assessment of the Impact on Decent Employment and Proposed Recovery Strategy:* Geneva: International Labour Organisation.

IPCC. 2007. *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva: IPCC.

Khan, I.A., Z. Ali, M. Asaduzzaman, and M.H.R. Bhuyan. 2010. *The Social Dimensions of Adaptation to Climate Change in Bangladesh.* Dhaka: The World Bank.

Hossain, K. M. and Nasreen, M. 2012. *Alternative Livelihoods Options in Southwest Region Considering Salinity Intrusion.* Dhaka: VSO Bangladesh.

Nasreen, M. 1995. *Coping with Floods: The Experience of Rural Women in Bangladesh (*Unpublished PhD dissertation). New Zealand: Messey University.

Klein, R.J.T, S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, and F.L. Toth. 2007. 'Inter-relationships between Adaptation and Mitigation.' *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, 745-777. Cambridge: Cambridge University Press.

Nasreen, M. 2008. *Impact of Climate Change on Food Security in Bangladesh: Gender and Disaster Perspectives.* Paper presented at the International Symposium on Climate Change and Food Security in South Asia on 25-30 August, 2008 in Dhaka, Bangladesh.

Nasreen, M. et al. 2008. *Impact of Climate Change on Agriculture and Food Security.* Dhaka: Action Aid International and Action Aid Bangladesh

Nasreen, M. 2008. *Sustainable Development and Impacts of Climate Change: A Gender Perspective.* Dhaka: ITN, BUET.

Nasreen, M. 2008. 'Impact of Climate Induced Disasters and Adaptation Strategies: A Gender Perspective.' *Climate Change Impacts and Adaptation Strategies for Bangladesh.* Dhaka: ITN Centre and Dept. of Civil Engineering, BUET.

Nasreen, M. 2010. 'Rethinking Disaster Management: Violence against Women during Floods in Bangladesh.' In *Women's Encounter with Disaster,* edited by S. Dasgupta, I. Siriner and P. Sarathi De. London: Frontpage Publications Limited.

Nasreen, M. 2011. *Mapping Gender and Disaster Risk Reduction in Bangladesh*. Dhaka: SDC.

Nasreen, M. 2012. *Women and Girls Vulnerable or Resilient?* Dhaka: Institute of Disaster Management and Vulnerability Studies, University of Dhaka, Bangladesh.

Ministry of Food and Disaster Management (MoFDM). 2010. *National Plan for Disaster Management 2010-2015*. Dhaka: Government of the People's Republic of Bangladesh.

OXFAM. 2009. *Disaster Risk Reduction, Climate Change and Livelihood of the Poor and Marginalised People. A Framework for Oxfam GB Bangladesh.* Dhaka: OXFAM Bangladesh

Pender, J. S. 2008. *What Is Climate Change? And How It will Effect Bangladesh.* Dhaka: Church of Bangladesh Social Development Programme.

Rabbani, G. A. Rahman, and K. Mainuddin. 2013. 'Salinity-induced Loss and Damage to Farming Households in Coastal Bangladesh. *International Journal of Global Warming* 5 (4): 400-415.

Shamsuddoha, Md, and R.K. Chowdhury. 2007. *Climate Change Impact and Disaster Vulnerabilities in the Coastal Areas of Bangladesh.* Dhaka: COAST Trust.

Selvaraju, R., A.R. Subbiah, S. Baas, and I. Juergens. 2006. Livelihood Adaptation to Climate Variability and Change in Drought-Prone Areas of Bangladesh: Developing Institutions and Options. Rome: ADPC and FAO.

World Bank. 2000. *Bangladesh: Climate Change and Sustainable Development.* Report No. 21104-BD. Dhaka: Rural Development Unit, South Asia Region, the World Bank.

World Bank. 2006. *Bangladesh Country Environmental Analysis. Bangladesh* Development Series Paper No: 12. Dhaka: The World Bank.

Preliminary Study of Climate Change Impact on Rice Production and Export in Thailand*

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Abstract

Climate change affects crop production in two ways: changes in GDP and population, and changes in climate variables, especially temperature and precipitation. This study aims to investigate preliminary effects of climate change impacts on Thailand's rice production, consumption, and export capacity by integrated EPIC model and the World RIce Market model and Thai Rice Market models. Therefore, the Biophysical Process model (EPIC model) and Economic Processes model are employed as the research methodology of this study. Main findings of the comparison showed both rice production and export in the base year (2007) are likely to expand until 2027, and there will be a sufficient amount of rice surplus for export, which is nearly the same level as that of domestic consumption in A2 scenario. In 2017, the amount of rice production will be only slightly higher than the domestic demand, leaving a small rice surplus of up to 2 million tons for export, compared to 14 million tons in 2016. However, in B2 scenario, the rice production capacity will be much lower than the domestic demand, meeting only half of it in 2017. From 2017 to 2019, the rice production capacity will undergo a constant fall and no longer meet the market demand as a result; it is estimated that there will be a shortage of approximately 0.038 to 0.218 ton. It is therefore important to note that if B2 scenario became reality in 2017, the rice production capacity of Thailand would nearly fail to meet the minimum level of domestic demand. However, we assure that Thailand still have land which can be converted to rice production with multiple cropping through irrigation investment, while comprehensive technical adaptation and mitigation to enhance farmer benefits are required.

Keywords: Climate change, Economic impact, Rice production, Thailand

Introduction

Thailand is a major exporter of agricultural products with rice as one of its most important crops. Rice has not only played a part in contributing to food security of the world but also been an essential part of the Thai society and its culture for a very long time. Rice is the heart of the way of life of farmers in Thailand. However, there are many factors that have contributed to food insecurity these days. One of the factors is climate change, which has brought negative impacts to food production throughout the world. It has resulted not only in

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the increased temperature and decreased productivity but also in greater numbers of less predictable disasters such as drought. For decades scientists have agreed on the list of greenhouse gases – including carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4) – that lead to the change of global temperatures and amount of rainfall (IPCC 2007). Studies have been conducted on climate change's impacts on several aspects as well as the plausible ways of minimising such impacts in the future. There are several studies on impacts of climate change on rice production at national and international scales. According to the reports of the International Panel on Climate Change (IPCC) in 2007 and the Food and Agriculture Organisation of the United Nations (FAO) in 2008, humid tropical zones will suffer negative impacts of the climate change, which definitely affects the way of life and food production. Various studies have been conducted to measure the effects of climate change impacts on net farm revenue such as integration of the Environment Policy Integrated Climate (EPIC) model and International Food Policy and Agricultural Simulation (IFPSIM) model (Wu et al. 2007), ORYZA 2000 (Vaghefi et al. 2011), Global circulation model (GCM) (Tumbo et al. 2010), Ricardian model (Fleischer et al. 2007; Ajetomobi 2010; Thapa and Joshi 2010; Mendelsohn 2014), Statistical approaches were used to analyse the relationships between observed yield and climate (Chen et al. 2013; Huang et al. 2013; Wang et al. 2014). Mostly, their outcome found that rice production will decline with increase in temperature and decrease in precipitation, with decrease the net revenue per hectare, especially in dry land and non-irrigated areas. However, some results were inconsistent among studies due to differences of the empirical models, regional scale and the confronting effects of non-climate factors such as rice management practices, market mechanisms, policies and technology.

In Thailand, irrigation infrastructure covers only 21.82% of the entire agricultural area of the country, leaving 78.18% of the area to the hands of farmers themselves. Rice accounts for as much as 60% of the country's agricultural area, and most rice growing areas are in the northeastern region of Thailand (Isvilanonda and Bunyasiri 2009), most of which are dependent on rainfall. The impact caused by climate change will bring in domino effects into people's lives, possibly starting from bio-physical system to their economy, society, and way of life, thus making them more vulnerable. The degree of the impact depends on adaptability of each community. Despite the impact that climate change could potentially bring, few integrated studies have been conducted to reach a greater insight into the situation in Thailand. In this study, therefore, the EPIC model was used in predicting rice production under two climate conditions – A2 and B2 – in the next 10 years (2017). The year 2007 was set as the base year (BY), and the analysis was anticipated to show the potential loss in rice production in the future.

Climate change results in a set of long-term effects – involving demography, environment, economy, public health, politics, and technologies, as well as food and water security. To be specific, climate change is much likely to have a negative impact on the agricultural sector and their productivity, which will further affect the farmers' incomes as a result. There have been very few studies about the climate change's impact on the agricultural sector in Thailand, especially on rice. In this study, the data on the loss in rice production caused by climate change was analysed to find the preliminary impact on the economy using World Rice Market and Thai Rice Market models, and EPIC model to make suggestions on policy to address the changes to come.

Methodology

Biophysical Process Models: EPIC Model

In the early 1980s, EPIC, also known as the Environmental Policy Integrated Climate was created by teams of scientists of the U.S. Department of Agriculture, belonging to the following services: Agriculture Research Service (ARS), Soil Conservation Service (SCS), and Economic Research Service (ERS) (Sharpley and Williams 1990). EPIC was designed to simulate biophysical processes and the interaction of cropping systems over long periods of time, during which changes in the environment occur at a relatively slow rate. A wide range of soils, climates, and crops can be simulated, using predefined management practices, in an efficient and convenient manner (Smith 1997). EPIC is able to simulate processes such as weather, soil erosion, hydrological and nutrient cycling, tillage, crop management, crop growth potential and crop yield. Crop growth is calculated on a daily basis with the required weather inputs, precipitation, maximum and minimum temperature, solar radiation, wind speed and crop parameters such as morphology, phenology, physiology etc. (Gassman et al. 2003, 2005; Zhang et al. 2010; Rinaldi and De Luca 2012). It can calculate the potential daily photosynthetic production of biomass, which depends on radiation, water, nutrients, temperature, and soil aeration. Crop yield is simulated using the harvest index concept, which is affected by the heat unit factor and includes the amount of the crop removed from the field as well as the above-ground biomass. (Brown et al. 2000; Izaurralde et al. 2006; Rinaldi and De Luca 2012).

In this study, the EPIC0509 version was used and run using i-EPIC interface. The i-EPIC model is a programme that is linked to the EPIC model, an upgraded model that provides more accurate analysis (Willams et al. 2006). The input information and display of results are accomplished in Microsoft Access software. The i-EPIC model and its user manual can be downloaded from http://www.public.iastate.edu/~tdc/i_epic_main.html. The current EPIC community code can be downloaded from http://epicapex.brc.tamus.edu (Arunrat and Pumijumnong 2014; Arunrat et al. 2014).

Preparation and Data Collection

Based on the studies of Pumijumnong and Arunrat (2012; 2013; 2014) and Arunrat et al. (2014), the assumptions for the simulation are as follows; (1) the cropping calendar is fixed, (2) crop management is fixed (rice variety, fertiliser, pesticide and herbicide), (3) each simulation unit (SU) with similar environmental conditions (topology, soil property and weather data), (4) the climatic variables directly affect crop yields, (5) all parameters are fixed, and (6) current trade policy is not changed. For this study the essential data and information used for i-EPIC Model includes:

(1) Soil Data

From the survey of soil nutrient status in Thailand during 2004-2008, 6,422 soil nutrient test results (pH, organic matter content, available phosphorus, and available potassium contents) were collected in the laboratory of the Office of Science for Land Development, Land Development Department.

(2) Weather Data

Monthly weather data was obtained from the Thai Meteorological Department for the period 1988–2007 and weather data of A2 and B2 scenarios (IPCC SRES) for the next 10 years (2017) from Southeast Asia START Regional Center (SEA START) (www.Start.or.th). i-EPIC requires monthly weather variables such as precipitation, minimum/maximum air temperature, solar radiation, wind speed and relative humidity.

(3) Crop Management

In this study, relevant crop parameters and rotation operation (Table 1 and Table 2) were modified on the basis of the measured and published data. In the EPIC model, potential evaporation was calculated by the Penman-Monteith method. In addition, the period of plantation used in this research follows the Land Development Department planting calendar. The general chemical fertilisers were 16-20-0 and 46-0-0, which are considered appropriate for rice growth (Department of Agricultural Extension, 2010). Meanwhile, soil losses were computed using the Universal Soil Loss Equation (USLE).

Table 1: Important Crop Parameters for the EPIC Model Based on the Measured and Published Data

Input variable	Explanation	Value
WA	Biomass-Energy Ratio	25
HI	Harvest index	0.5
TOPC	Optimal temperature for plant growth	33
TBSC	Minimum temperature for plant growth	15
DMLA	Maximum potential leaf area index	6
DLAI	Fraction of growing season when leaf area declines	0.8
DLAP1	First point on optimal leaf area development curve	30.01
DLAP2	Second point on optimal leaf area development curve	70.95
RLAD	Leaf area index decline rate parameter	0.5
RBMD	Biomass-energy ratio decline rate parameter	0.5
ALT	Aluminum tolerance index	3
GSI	Maximum Stomatal Conductance	0.008
CAF	Critical aeration factor	1
SDW	Seeding rate	50
HMX	Maximum crop height in m	0.8
RDMX	Maximum root depth in m	0.9
WAC2	CO_2 Concentration /Resulting WA value (Split Variable)	660.31

Table 2: Rotation Operation of Rice in Thailand

Rotation operation	Major rice		Second rice	
	Date	Month	Date	Month
Tillage	1	June (06)	1	January (01)
Planting	15	June (06)	15	January (01)
Fertiliser	1	September (09)	1	February (02)
Harvest	31	December (12)	30	April (04)
Kill	31	December (12)	30	April (04)

(4) GIS Data

(i) land utilisation of 2007, (ii) digital elevation model (DEM), (iii) slope, (iv) sets of soil data in a form of GIS digital file, (v) location of 81 weather stations, and (vi) simulation units (a polygon type of data): In this study, a 0.1° x 0.1° SU is created and each grid covers an area of 11.11 x 11.12 km. Since rice production land is emphasised in this study, we separated the rice production area from land used for other utilisation purposes by overlapping the Land Utilisation data of 2007 provided by the Land Development Department with the developed simulation unit. The selected simulation unit of the study is an overlapping area that covers more than 50% of the rice production area, which consists of 1219 SU.

Model Validation and Statistical Analysis

The validation process focused on the rice yield using the observed values of yield that were collected from the Agricultural Statistics of Thailand for years 1996-2012, which were generated by the Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives (MOAC). A statistical measure was calculated to represent different aspects of model performance. Mean Absolute Percentage Error (MAPE) was computed for each of the regional models. MAPE is the most commonly used to evaluate cross-sectional forecasts, because of its simplicity to calculate and easiness to understand (Rayer, 2007; Wilson, 2007). Basically, it is a measure of forecast accuracy, which compares forecasts of a variable against actual values. ITSMF-NL (2006) noted that the forecasting model with MAPE below 40 % might be considered reasonably reliable (See in Table 3). The formula used in calculating MAPE is as follows:

$$\text{MAPE} = \frac{1}{n}\left[\sum_{t=1}^{n}\left|\frac{e_t}{A_t}\right| \times 100\right] = \frac{1}{n}\left[\sum_{t=1}^{n}\left|\frac{(A_t - P_t)}{A_t}\right| \times 100\right]$$

Where: A_t= actual value at time t; P_t = predicted value at time t; E_t = forecast error; n = total number of periods; t = time period

Table 3: Rule for MAPE Values	
Interpretation	**Range of MAPE values**
Highly accurate forecasting	< 10 %
Good forecasting	10 - 20 %
Reasonable forecasting	20 - 50 %
Inaccurate forecasting	> 50 %

Economic Processes Model

Based on the concept of supply and demand Equation (Alston et al. 1995; 1998), this study employed both World Rice Market and Thai Rice Market models to predict amounts of rice production, consumption and export capacity in two scenarios (A2 and B2) in the next 10 years from 2007 onwards. The A2 scenario assumes that each country holds its own culture and trade, labor movement, and that technology transfer is restricted. Temperature will be changedlikely range 2.0-5.4 ºC. The atmosphericCO_2concentrationreachesat432 and 549 ppmv in 2020 and 2050, respectively (IPCC 2007). Given these constraints, per capita GDP grows slowly and the annual average per capita income is 7,200 US$ in 2050, while the world population reaches 11 billion people (Garnaut et al. 2008). The B2 scenario assumes that trade is restricted and the cultural practices of each country are maintained such as those in the A2 scenario. However, low CO_2 emission energy technology is developed. The atmospheric CO_2 concentration reaches 432 in 2020 and 549 ppmv in 2050 for this scenario, with a projected temperature increase in the range of 1.4-3.8 ºC. The per capita income is 12,000 US$ in 2050 while the world population reaches 9.4 billion people (IPCC 2007).

World Rice Market Model

Amounts of rice in the world market are calculated using supply Equation (1).

$$SW = \alpha P^{\beta}_{-1} or ln SW = ln \alpha + \beta ln P_{-1} \quad (1)$$

Farmers usually base their decision about the amount of rice to be produced each year on the rice price of the previous year. α and β are coefficients in the supply Equation as explained in Table 4, and the data used for the world rice market model are presented in Appendix A; Table A1.

Table 4: Description Variables for World Rice Market Model	
Variable	**Description**
SW	World market supply
DW	World market demand
P	Rice pricein the world market
QW	Rice price equilibrium in world market
P-1	Rice price at previous year (current year-1)
PO	Crude oil price in the world market
PP	Potato price in theworld market
WP	World population

$$P = aDW^b WP^c PO^d PP^e$$
$$or \ln P = \ln a + b \ln DW + c \ln WP + d \ln PO + e \ln PP \quad (2)$$

In the demand Equation, the rice price depends on the market demand, the size of population, and crude oil and potato prices. In theory, market demand and price have an inverse relationship; the population size and production size have a positive relationship. The higher price of crude oil will lead to the higher market demand for agricultural products, thus increasing the rice price. As rice can be replaced by potato, rice price depends partly on the potato price as well.

Equation (3) determines the market equilibrium

$$QW=SW=DW \quad (3)$$

Thai Rice Market Model

The rice market in Thailand is structurally similar to the world rice market, as a result, the rice price is almost same. This is due to the fact the rice price is not determined at the national scale but at the global scale under the free trade policy. Supply Equation is shown in Equation (4) and rice price of the previous year is taken into account when the production size is determined.

$$ST = xP^y_{-1} or lnST = lnx + ylnP_{-1} \quad (4)$$

Equation (5) shows the relation between domestic market demand and related factors such as rice price, population size, prices of crude oil and substitute goods. Equation (6) shows the amount of rice exported by Thailand. Equation as explained in Table 5.

$$DT = fP^g TP^h PO^i PP^j$$
$$or \ln DT = \ln f + g \ln P + h \ln TP + i \ln PO + j \ln PP \quad (5)$$
$$E = ST - DT \quad (6)$$

Table 5: Description Variables for Thai Rice Market Model

Variable	Description
DT	Domestic market demand
ST	Domestic market supply
E	amount of domestic rice exported
TP	Thailand Population

Results

Impacts of Climate Change

According to the Special Report on Emissions Scenarios (SRES) by IPCC, the scenarios in 2017 will be as follows.

1. Temperature (ºC)

The highest average temperatures of 2007, A2 and B2 scenarios are 32.74, 33.13 and 33.20 ºC respectively. The lowest average temperatures of 2007, in A2 and B2 scenarios are 22.99, 24.18 and 22.52 ºC, respectively. It is found that in A2 and B2 scenarios the highest average temperature will become higher in 2017, and will become highest under B2 scenario, which is slightly higher than A2 scenario. Also, the lowest average temperature will become higher in 2017 in A2 scenario and it will decrease by 1-2 ºC in B2 scenario.

2. Rainfall (mm)

From the comparative analysis, it is found that the amount of rain in 2007, and under A2 and B2 scenarios are 141.24, 129.39, and 125.60 mm respectively as shown in Table 6. It shows that in 2017 the amount of rain will decrease in both A2 and B2 scenarios, and the amount of rain in A2 scenario will be lower than that in B2 scenario. Table 7 shows that in A2 scenario, the amount of rain in the central, northern, northeastern, and western regions of Thailand will decrease in the future whereas the amount of rain in the eastern and southern regions will increase. Also, the amount of rain in the central and northeastern regions in A2 scenario will be higher than those in B2 scenario while the amount of rain in the other regions – especially the eastern and southern regions – in A2 scenario are lower than those in B2 scenario.

3. Number of Raindays (day)

From Table 6 show the numbers of raindays in 2007, A2 and B2 scenarios – which are 10.93,18.73, and 18.49 respectively. It is found that in both scenarios there will be more raindays in 2017. The number of raindays in B2 scenario is slightly lower than that in A2 scenario. Table 7 shows that in A2 scenario, the number of raindays increases in every region, and when compared with B2 scenario, there will be more raindays in the A2 scenario.

4. Solar Radiation (MJ/m²)

Table 6 shows amount of solar radiation in 2007, A2 and B2 scenarios – which are 114.81, 198.78, and 200.17 MJ/m2. It is found that the amount of solar radiation will increase and become higher in 2017 in both scenarios, and the amount in B2 scenario will be higher than that in A2 scenario. Table 7 shows that in A2 scenario the amount of solar radiation increases in every region of Thailand, and that the amount of solar radiation in B2 scenario are higher than those in A2 scenario in every region.

Table 6: Summarised Climate Changesin Thailand

Parameter	2007	A2 scenario	B2 scenario
1) Temperature (ºC)			
Air Temperature Average Max	32.74	33.13	33.20
Air Temperature Average Min	22.99	24.18	22.52
2) Precipitation Average (mm)	141.24	129.39	125.60
3) Rain days Average (day)	10.93	18.73	18.49
4) Solar Radiation (MJ/m^2)	114.81	198.78	200.17

Table 7: Summarised Climate Changes Divided According to Regions of Thailand

Region	*Temperature (ºC)*						*Precipitation Average (mm)*			*Rain days Average (day)*			*Solar Radiation (MJ/m²)*		
	Temperature Average Max			*Temperature Average Min*											
	2007	*A2*	*B2*	*2007*	*A2*	*B2*	*2007*	*A2*	*B2*	*2007*	*A2*	*B2*	*2007*	*A2*	*B2*
C	32 90	33 96	34 07	22 76	24 60	22 69	122 46	114 36	113 32	10 40	17 47	17 07	114 81	108 17	108 19
E	32.73	33.16	33.46	22.97	25.89	24.30	138.87	144.11	155.37	10.82	20.47	20.41	114.81	112.86	112.84
N	32.52	32.99	32.94	22.64	21.81	21.01	117.86	116.66	117.28	10.14	18.25	17.76	114.81	199.02	100.74
NE	32.69	32.78	32.80	23.11	24.03	22.38	149.92	134.44	128.40	11.18	19.13	18.97	114.81	193.59	195.60
S	32.42	33.70	34.88	23.41	25.71	26.11	177.07	114.33	124.47	11.90	23.24	22.75	114.81	124.62	125.79
W	32.98	33.83	34.94	22.57	25.90	24.97	135.55	129.46	131.08	11.07	19.37	18.99	114.81	122.37	122.91

C = Central: E = Eastern: N = Northern: NE = Northeastern: S = Southern and W = Western

Climate Change Impacts on Rice Production

Comparison of Rice Production between Irrigated and Non-Irrigated Areas

This study investigated rice production in two kinds of area: irrigated and non-irrigated. EPIC model assumed that the area is ploughed and there is no weed or pest. The study period was set in accordance with the cropping calendar of the Rice Department. It is found that the average production capacity of second rice season in irrigated areas in 2007 is 3.65 ton/ha. It is estimated that in 2017 the production capacity of second rice season in irrigated areas in A2 and B2 scenarios will be 0.93 and 0.39 ton/ha, respectively. The production capacity of major rice season in irrigated areas in 2007 is 2.33 ton/ha. It is estimated that in 2017 the production capacity of major rice season in irrigated areas in A2 and B2 scenarios will be 1.76 and 0.79 ton/ha, respectively, as detailed in Table 8. In total, the amount of rice produced in A2 scenario will be higher than that in B2 scenario in 2017 over both irrigated and non-irrigated areas, yet such amount in both scenarios drop from those in 2007.

Table 8: Comparison between Irrigation and Non-Irrigation Conditions with the Change of Rice Production (Ton/Ha)

Water condition	*Major Rice Yield*			*Second Rice Yield*		
	2007	*A2 Scenario*	*B2 Scenario*	*2007*	*A2 Scenario*	*B2Scenario*
Irrigation	2.33	1.76	0.79	3.65	0.93	0.39
Non-irrigation	2.30	1.47	0.58	3.78	0.70	0.26

Total Domestic Rice Production

The entire rice growing areas of the country consist of 1219 simulation units, covering both major and second season rice growing areas. Of this units, 322 units are in the central region, 29 units in the eastern region, 48 units in the northern region, 793 units in the northeastern region, 12 units in the southern region, and 15 units in the western region. From analyses on the comparison between the amount of rice produced in 2007 and the estimated amount of rice to be produced in 2017 in A2 and B2 scenarios, the findings are as follows.

In the central region, the average amount of major rice season in 2007, A2 and B2 scenarios are 3.67, 2.54, and ton/ha respectively. The numbers for second rice production are 4.68, 1.06 and 0.39 ton/ha respectively. Details are provided in Table 9.

Table 9 : Comparison between Major and Second Rice Production (Ton/Ha)						
Region	***Major Rice Yield***			***Second Rice Yield***		
	2007	***A2 Scenario***	***B2 Scenario***	***2007***	***A2 Scenario***	***B2Scenario***
C	3.67	2.54	0.84	4.68	1.06	0.39
E	3.58	3.74	1.84	4.63	1.81	1.03
N	2.87	1.04	0.44	4.12	0.26	0.16
NE	1.67	0.84	0.42	3.41	0.45	0.19
S	5.58	14.02	6.02	5.18	12.20	3.57
W	3.16	6.24	2.19	2.50	2.13	0.89

In 2007, the rice production in the Central, Northern, and Northeastern parts of Thailand showed a decreasing rice production in both A2 and B2 scenarios (Table 9). In contrast, rice production in the Eastern, Southern, and Western regions showed an increasing level of rice production under the given conditions of both A2 and B2 scenarios. The major rice production also increased in the A2 scenario and decreased in the B2 scenario. When comparing the A2 and B2 scenarios, it was found that the A2 scenario had a higher level of major rice production in every region of Thailand. The second rice production under the A2 and B2 scenarios in 2007 decreased in the Central, Eastern, Northern, Northeastern, and Western parts of Thailand, with the exception of the Southern part of Thailand. According to the results, the second rice production of in Southern provincial areas increased under the A2 scenario, whereas under the B2 scenario, it decreased. The A2 scenario also resulted in a second rice production in every region of Thailand.

Climate Change Impacts on Rice Production, Consumption, and Export

Analysis Based on World Rice Market Model

From the world rice market model based on Equation 1-3 as shown in Table 4, Equation (1) was tested with regression analysis. Table 10 shows that R2 =0.614; t-statistic is high; the coefficient is significant, making the Equation nearly completely reliable. Therefore, Equation (7) would be used in the next step.

Table 10: Statistics of Equation (1)			
coefficient	*value*	*t-statistic*	*p*
lnα	17.592	60.910	0.000
β	0.481	7.879	0.000
	$R^2 = 0.614$		

$$lnSW=17.592+0.481\ lnP_{-1} \qquad (7)$$

Table 11 shows how Equation (2) was tested with regression analysis. Moreover, Table 11 shows that $R^2 = 0.672$; t-statistic is high, the significance level of 95% for the coefficient. The constant and coefficient of WP have significance levels of 91.5% and 94.9% respectively, standing above 90%.

Equation (5) shows that the price elasticity of rice demand is -0.317$\left(\frac{1}{-3.154}\right)$, implying that rice has the elasticity value of lower than 1.

Table 11: Statistics of Equation (2)

Coefficient	Value	*t*-statistic	P
ln a	9.610	1.694	0.085
b	-3.154	-4.430	0.022
c	3.574	1.970	0.051
d	0.193	3.236	0.003
e	0.513	2.810	0.008
$R^2 = 0.672$			

$$\ln P = 9.610 - 3.154 \ln DW + 3.574 \ln WP + 0.193 \ln PO + 0.513 \ln PP \quad (8)$$

$$or P = 14,913\ DW^{-3.154} WP^{3.574} PO^{0.193} PP^{0.513}$$

It is found that Equations (7) and (8) which are structural Equations used in predicting equilibrium quantity and rice price during 2007-2017 and next to 2027 are reliable only for the first four years. Equation (9) which is a reduced form is, as a result, used for estimation instead of Equation (8).

Table 12 shows how Equation (9) was tested with regression analysis. Table 12 shows that $R^2 = 0.873$; t-statistic is high, the significance level of 95% for the coefficient. The coefficient of PO has significance level of 93.5%, standing above 90%.

$$\ln P = \ln k + l \ln P_{-1} + m \ln WP + n \ln PO + o \ln PP \quad (9)$$

Table 12: Statistics of Equation (9)

Coefficient	Value	*t*-statistic	P
ln k	-18.510	-3.318	0.002
l	1.190	3.489	0.001
m	0.537	1.897	0.000
n	0.112	2.304	0.065
o	0.368	4.426	0.027
$R^2 = 0.873$			

$$\ln P = -18.510 + 1.190 \ln P_{-1} + 0.537 \ln WP + 0.112 \ln PO + 0.368 \ln PP \quad (10)$$

For estimations of 2007-2027, the population size was based on the data from FAO; the real crude oil price was set to increase by 3.24% each year – which was the average rate of 1996-2007; and the real potato price was fixed at 176 dollars per ton.

Equations (7) and (10) were used in estimating the equilibrium quantity and rice price from 2007 to 2027. We found that both equilibrium quantity and rice price are likely to make constant increase in the future (See Appendix B; Table B1).

Analysis Based on Thai Rice Market Model

Table 13 shows how Equation (4) was tested with regression analysis. Table 13 shows that $R^2 = 0.575$; t-statistic is high; the coefficient is nearly completely reliable. We also found that both equilibrium quantity and Thai rice price are increase in the future (See Appendix B; Table B2).

Table 13: Statistics of Equation (4)

Coefficient	Value	*t*-statistic	P
ln x	14.586	48.948	0.000
y	0.464	7.451	0.000
$R^2 = 0.575$			

$$lnST = 14.586 + 0.464\, lnP_{-1} \quad (11)$$

Table 14 shows how Equation (5) was tested with regression analysis. Table 14 shows that $R^2 = 0.706$; t-statistic is high; the coefficient is nearly completely reliable. Prices of rice, crude oil, and potato are excluded due to the fact that t-statistics are very low, and as a result, are assumed to be zero. It is then concluded that population size is the only factor that affects the domestic demand for rice, not prices of rice or any other products.

Table 14: Statistics of Equation (5)

Coefficient	Value	*t*-statistic	P
ln f	9.683	10.326	0.000
h	0.618	4.796	0.000
$R^2 = 0.706$			

$$\ln DT = 9.683 + 0.618 \ln P_{-1} \quad (12)$$

The estimated amount of rice production, consumption, and export by Thailand from 2007 to 2027, based on the data from FAO in 2007. It is found that the amount of rice production, consumption, and export are likely to increase in response to the increasing rice price and greater demand in the global market and the expanding population in Thailand (See Appendix B; Table B3).

Comparison of Situations in 2007, A2 and B2 Scenarios in 2027

Impact of climate change on rice production in different scenarios are shown in Table 9. Statistical data about rice production (by region) and productivity in 2007 from the Office of Agricultural Economics is presented in Table 9. This data, together with estimations in Appendix B; Table B3, allows us to estimate the amount of rice growing areas from 2007 to 2027 with an assumption that the amount are growing at a constant rate. After the amount of rice growing areas from 2007 to 2027 are successfully estimated, it is possible to compare climate change's impacts on rice production in different scenarios. In addition, the rice growing areas and rice productivity by region in different scenarios from 2007 to 2027 are shown in Appendix B; Table B4.

In terms of major rice season, it is found that the amount of rice growing areas will be increasing steadily from 2017 to 2027. We found that the northeastern region has the largest rice growing area before the northern, central, southern, eastern, and western regions, respectively (See Appendix B; Table B4 and B5). The amounts of rice production appear to conform to those of rice growing areas in each region. Also, the amount of rice production in A2 scenario are higher than those in B2 scenario in every region. In addition, it is found that in A2 scenario the yield rates are higher than those in the BY scenario in eastern, southern, and western regions, and that the southern region is the only region where yield rates in both A2 and B2 scenarios are higher than those in BY scenario. While, second rice season, it is found that the amount of rice growing areas will be increasing steadily from 2017 to 2027. The central region has the largest rice growing area before the northern, northeastern, eastern, western and southern regions, respectively (See Appendix B; Table B4 and B5). The amounts of rice production appear to conform to those of rice growing areas in each region. Also, the amounts of rice production in A2 scenario are higher than those in B2 scenario in every region. In addition, it is found that in A2 scenario the yield rates are higher than those in the BY scenario in eastern, southern, and western regions, and that the southern region is the only region where yield rates in A2 scenario are higher than those in BY scenario. As our results, we can mention the results of economic analyses are in accordance with estimations from the physical models.

Figure 1: Comparison of Economic Impact under Climate Condition in 2007 (BY)

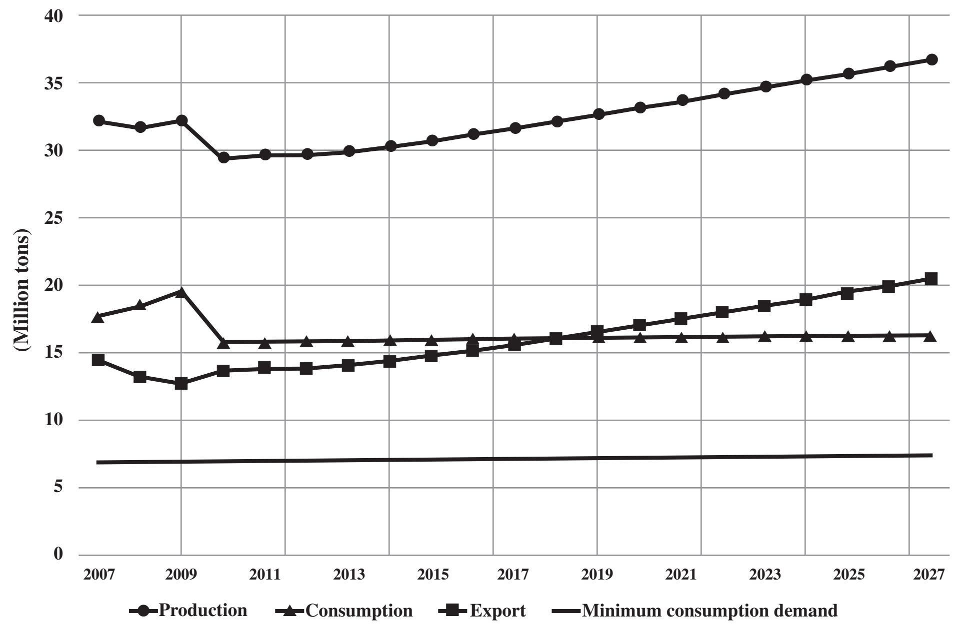


Figure 2: Comparison of Economic Impact under A2 Scenario during 2017-2027

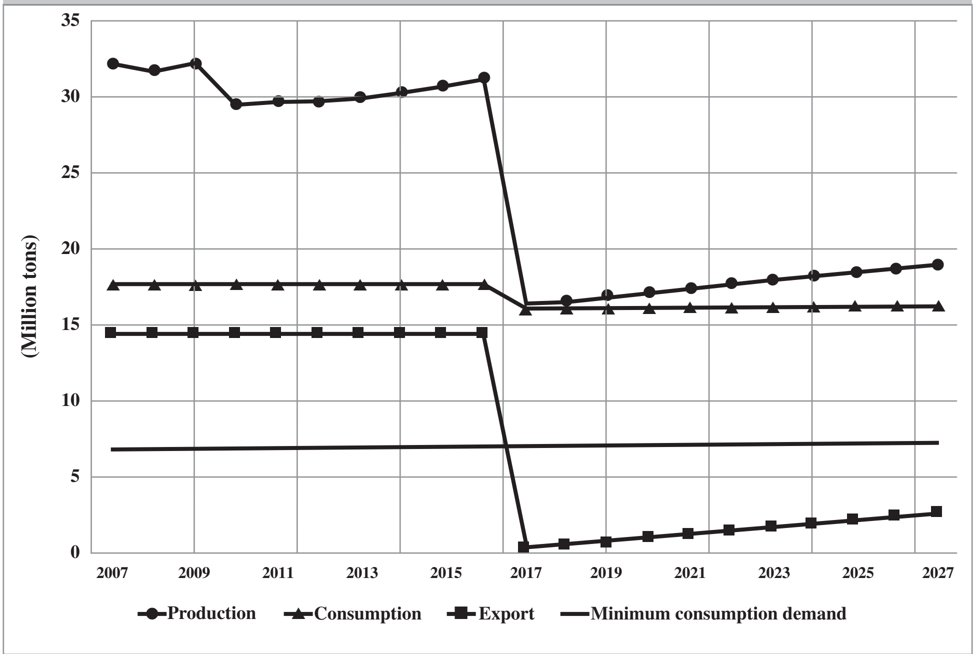


Figure 3: Comparison of Economic Impact under B2 Scenario during 2017-2027

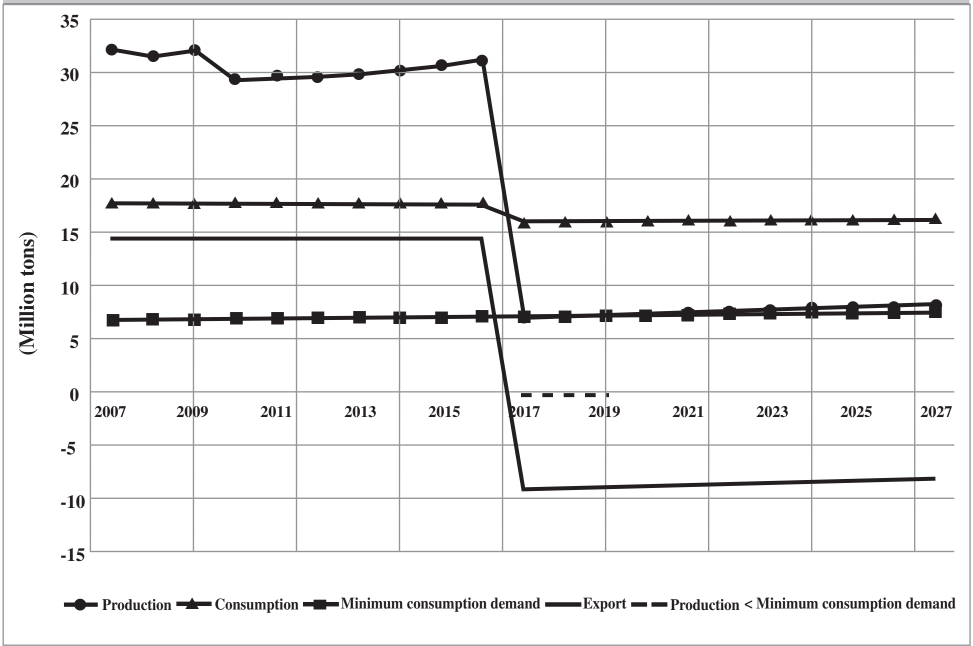


Figure 4: Comparison of the Amounts of Rice Production Under Climate Conditions in 2007, and A2 and B2 Scenarios during 2017-2027

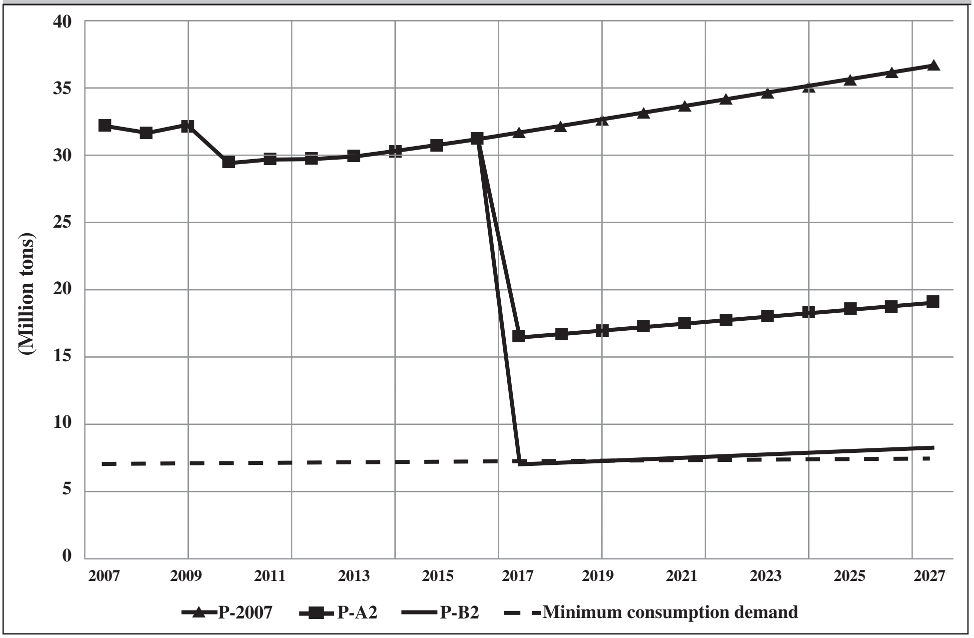


Figure 5: Comparison of the Level of Consumption Demand under Climate Conditions in 2007, and A2 and B2 Scenarios during 2017-2027

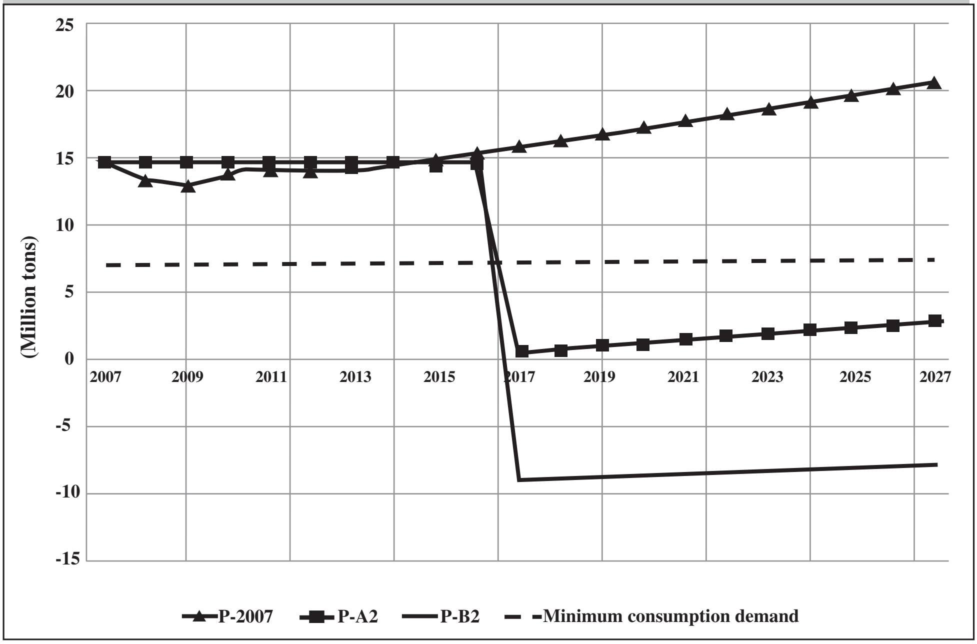
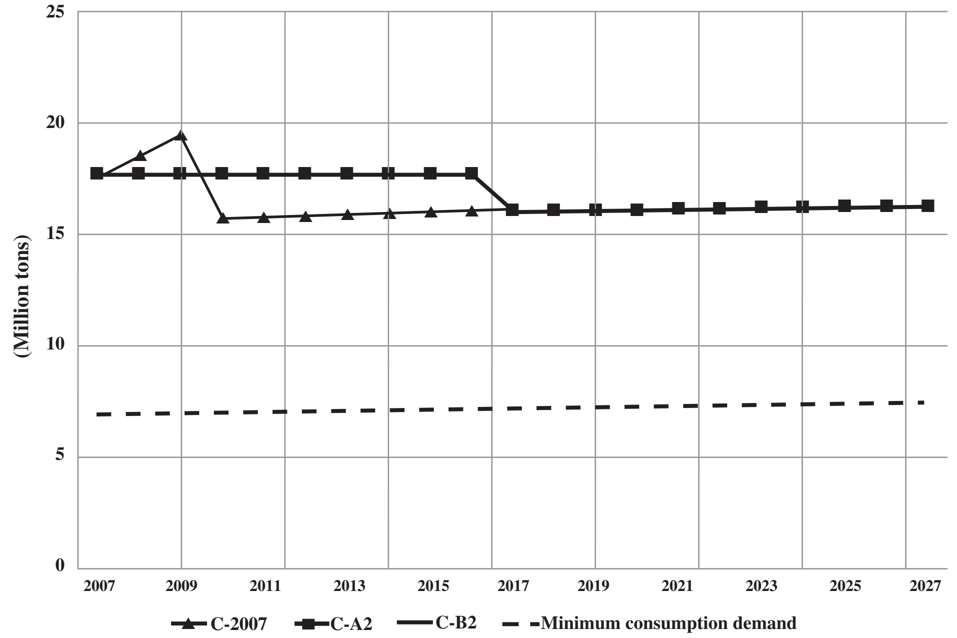


Figure 6: Comparison of the Volume of Exports under Climate Conditions in 2007, and A2 and B2 Scenarios during 2017-2027



Based on the estimation of rice production from 2007 to 2027, Figure 1 illustrates that the amount of rice production and export will constantly increase while the demand will not be changing significantly and will stay higher than the minimum demand level. Figure 2 illustrates that in A2 scenario the amount of rice production and export will fall sharply until 2017 when the amount will start increasing steadily again after farmers get used to the new weather. It is also found that after 2017 in A2 scenario the amount of rice export will be lower than the minimum level of consumption demand, and in B2 scenario (Figure 3), the amount of rice production will undergo a sharp fall after 2017, followed by a very small increase. The amount of rice production is likely to fail to meet the level of consumption in BY scenario as the production level will become equivalent to the minimum level of consumption demand, leaving no surplus rice for exports.

Figure 4 illustrates that in both A2 and B2 scenarios the amount of rice production will be lower than those in the predicted BY scenario. The amount of rice production in A2 scenario will be higher than that in B2 scenario while the levels of consumption are equal in both scenarios as shown in Figure 5. With regard to exports, the volumes of rice exports in both A2 and B2 scenarios will be lower than the volume of exports in the BY scenario, given that the volume of exports in A2 scenario is higher than that in B2 scenario, the scenario in which the volume of exports is nearly zero as shown in Figure 6.

Discussion

A comprehensive evaluation of the impact of climate change on the rice sector in Thailand is important, both for making policy decisions and considering adaptation processes. In some areas, they are autonomous reactions driven by self-regulatory mechanisms, but in some other areas they respond to specific and planned policy interventions. Changes in rice yields can be measured by field experiments and using the estimate results of the crop growth model to forecast future. However, evaluating the impact on economic mechanisms such as price effects, shifts in domestic and international supply and demand requires the economictheory. This study examines possible effects of climatic change focusing on weather data of A2 and B2 scenarios and its impacts on rice production, consumption, and export by using world and Thai rice market model. This is consistent with the study of Parry et al. (1999; 2004; 2005) that combined a supply and demand model of agricultural products such as basic linked system (BLS) and CERES-Wheat. Furthermore, Wu et al. (2007) also combined the EPIC model and IFPSIM model. Their results elucidate that climate change will generally reduce production potential and increase risk of hunger in poor countries. Also, many studies were able to find significant relationship between climate variables and rice yield using econometric models. Mendelsohn et al. (1994) mentioned that climate change's impacts can be measured by quantitative methods, the net production value, or changes in asset value such as land assets. Mendelsohn et al. (1994) employed Ricardian model to measure economic impacts on agricultural sector of the United States, and used multiple regression analysis to find the relationship between farmland value and climate factors such as temperature and amount of rain, as well as other physical factors such as soil type and slope. The analysis has led to a conclusion that climate factors such as temperature and amount of rain help raise the crop revenue in the United States. Similarly, Kabubo-Mariara and Karanja (2007) employed Ricardian model and multiple regression analysis to find the relationship among net income of farmers, climate and physical factors, and socio-economic data about farmers in Kenya. They found that climate change played a part in deducting net income of the farmers. Also, their model predicted that the climate change would cause a loss of approximately 97.01 to 236.63 US$ to the low-and-mid potential zones. In high potential zone, the loss would be approximately -0.11 to 63.34 US$. There was also a study conducted by Chang (2002) which investigated the economic impacts on the agricultural sector of Taiwan. Price-endogenous spatial equilibrium model was used to measure changes in and the distribution of welfare in the agricultural sector, with an assumption that the market has perfect competition in order to achieve the maximum total welfare – which is the sum of consumer surplus and producer surplus. In climate change scenarios, variables were temperature (from 0 to 2.5 ºC) and amount of rain (from -10% to 15%), and 1994 was set as base year. The findings indicated that despite changes in temperature and amount of rain that have impacts on the agricultural sector of a subtropical country like Taiwan, the total welfare has been constantly improving by 1.80 – 5.86% when compared with that of the base year. In terms of welfare distribution to producers and consumers, it is found that the producers receive more benefits than consumers. However, in scenarios where the amount of rain changes but temperature does not, it is found that the producer welfare will go down by 0.06 – 3.26% and will be good for consumers. Based on our scenarios, it is certainly possible that farmers' adaptation is still also important in the regional competitions. For instance, if their yields decline less than in other countries, and they can expand their rice farming, production and exports of the crop with reduced yields, they will gain in productivity and the profitability of growing higher due to the influence of international production, international markets and international trade might be changed. Similar arguments were also discussed in Juliá and Duchin (2007) and Nelson et al. (2009).

According to A2 and B2 scenarios of this study, it is found that both scenarios the temperature will be increased and precipitation will be decreased, it will be very harmful for rice yields and farmers would lose their net revenue. This is consistent with the studies of Sanghi et al. (1997; 1998) employed Ricardian model of India and Brazil found significant negative effects with a moderate long-run climate change scenario under increasing 2 ºC of mean temperature and 7 % in precipitation by the end of the 21st century leading to losses on the order of 10% of agricultural profits. Especially, dry land rice farms, non-irrigated areas and hilly regions in semi-arid regions may undermine any positive effects by reducing the net revenue whereas increase revenue for the irrigated rice farms (Ajetomobi et al. 2010; Thapa and Joshi 2010). For example the cereal production will be increased by 50% in irrigated areas and annual economic growth rate in Ethiopia might increase from1.9 to 2.1% by 2015 and this might increase the GDP by 3.6% per year (Diao and Pratt 2007). Moreover, Krishna (2011) mentioned that with climate change rice production in developing countries will be declined by 11.9%, which will reduce revenue to smallholder farmers. On the other hand, with Business-as-Usual rice production might have increased by 434.9% in 2050. However, farmers' profits from rice depend on input costs (i.e. labor, land, seeds, fertilisers, and other chemicals), yields, and market sales values for the crop. This entire factor can be affecting not only rice production but also food system in the future (Mngale 2009). Whenever, food security diminishes, then people's livelihoods get impaired. This leads to poverty and hunger, with negative impacts to smallholder farmers and poor countries (FAO 2008). Thus, adaptation and copping measures should be developed to combat the impact of climate change. Considering the climate change's impacts on agricultural productivity, the land use, and the agricultural policy, this study aims to examine farmers' behavioral adaptability, to encourage them to prepare for the upcoming impacts, and to suggest guidelines for their farm resising. Thornton et al. (2009) suggested that adaptation can be constrained by institutional, economic, political and social environment in which smallholder farmers operate. In addition, Kurukulasuriya and Mendelsohn (2008) recommended that lack of knowledge, financial constraints, knowledge and information on the choice of adaptation options, labor constraints, shortage of land, and poor potential for irrigation are barriers to adaptation facing most of the farmers. For Thailand, if problems of Thai farmers are carefully considerated, it can be seen that such problems have remained unsolved for a long time, including land-related issues, farming systems development, water management, production costs, and marketing. Most of the farmers have gone to only primary school and not above, and the education system is a factor that pushes local people to seek jobs elsewhere as it is not related to local jobs at all. The teaching method does not encourage students to become entrepreneurs, and when the students finish their high school they cannot find suitable local jobs. Also, they do not want to be farmer as the profession is not highly valued. Only a small number of farmers are eager to keep improving their knowledge and expertise, and when some of them are selected to serve as their community leadership, they are bound with so many rules and regulations that they cannot truly contribute to the rest of the farmers. It can be said that human resources in Thailand are of good quality. The farmers will do it well if the state agencies at local and national levels can provide proper supports for their farming and help them find the best way to reduce production costs, prepare the best seeds, manage water resources, make natural fertilisers, and stay hungry for new knowledge, technology, and information updates. Baldwin et al. (2013) showed that input cost of Thailand was 352 US$/ton (10912 baht/ton) higher than that of other exporters such as Vietnam and India, with at 225 US$/ton (6975 baht/ton) and 230 US$/ton (7,130 baht/ton), respectively. In term of rice consumption, Timmer et al. (2010) examined considerable evidence that rice consumption per person declines with increases. It means that rice consumption levels for food are inversely correlated with economic development, with the lowest income countries in the region (Cambodia, Burma, Laos, and Vietnam) consuming more rice per person than the wealthier countries (Malaysia and Thailand) as well as depend on rice demand and price. Thus, in the short run, farmers are suggested to find their optimal level of production. Major modifications of the farming system might not be finished shortly, but the crop choice can be improved immediately. For example, farmers may plant or harvest crops that grow well in warm weather earlier than before, allowing them to have more time to grow and yield more, and they may also have to come up with a new set of different crops after accepting the notion of optimal crop choice from Europe. According to Olesen and Bindi (2002), farmers may have to replace crops with high level of uncertainty in their yield rates such as barley with crops that have low yield rates but generate stable income such as pet grass, which also helps retain soil moisture.

Conclusion

Studies about the climate change's impacts on agriculture mostly focus on physical and biological impacts, and little has been done to investigate the socio-economic impacts of climate change. Only few studies have pointed out to the fact that an increase in temperature will result in lower agricultural productivity, and that farmers will have to make some adaptations to minimise the impacts – by optimising crop rotation and land use, and reuse their farmlands, for example. This study is among the first in Thailand to develop an integrated body of knowledge within this field, and further investigations are also required to make a complete body of knowledge. Generally, rice grown in irrigated areas has higher yield rate than that grown in non-irrigated areas where the yield rate depends largely on the amount of rain during the growing season in Thailand. Models and analyses based on the IPCC SRES – A2 and B2 scenarios in 2017 – have led to the following findings.

In the central region, the average amounts of major rice season production in 2007, A2 and B2 scenarios are 3.67, 2.54 and 0.84 ton/ha, respectively, whereas the average amounts of second rice season production are 4.68, 1.06 and 0.39 ton/ha. In both A2 and B2 scenarios, rice production is clearly affected by factors such as an increasing amount of carbon dioxide and rising temperatures. In the short run, weather change is the most influential factor, resulting in smaller amounts of rain in most of the regions in Thailand. The northeastern region is the most affected area by the weather change while such regions as the eastern and southern are least affected. In fact, these two regions turn out to enjoy larger amounts of rain due to the monsoon that carries heavy rain to the region.

From comparative analyses, it is found that both rice production and export in the B2 scenario are likely to expand until 2027, and there will be a sufficient amount of rice surplus for export, which is nearly the same level as that of domestic consumption in A2 scenario. In 2017, the amount of rice production will be only slightly higher than the domestic demand, leaving a small rice surplus of up to two million tons for export, compared to 14 million tons in 2016, will be created a loss in value approximately 5,280 dollar. However, in B2 scenario, the rice production capacity will be much lower than the domestic demand, meeting only half of it in 2017. From 2017 to 2019, the rice production capacity will undergo a constant fall and no longer meet the market demand as a result; it is estimated that there will be a shortage of approximately 0.038 to 0.218 ton of rice. It is therefore important to note that if B2 scenario became reality in 2017, the rice production capacity of Thailand would nearly fail to meet the minimum level of domestic demand. Ourresultspointoutthatboth A2 and B2 scenarios the amounts of rice production will be lower than those in the predicted BY scenario.The amounts of rice production in A2 scenario are higher than those in B2 scenario in every region. Rice exports in both A2 and B2 scenarios will be lower than the volume of exports in the B2 scenario while A2 scenario is higher than that in B2 scenario.

As rice is a large and essential part of the agricultural sector in Thailand, both positive and negative changes that might result from the selection of rice varieties all have great impact on the economy. Consequently, it is very important that the involved agencies thoroughly investigate the climate change’s impacts in different dimensions and develop a body of knowledge around this issue. However, economic analyses carried out in this study have several limitations. Some parameters used in the models are not up-to-date as the EPIC model has never been used in estimating rice production in Thailand before. These parameters need to be more specific in order to improve the accuracy of the models, particularly the shape of farmland and rice choices. For example, each study area is an 11x11 (km) grid and parameters are assumed to be the same throughout the grid despite the fact that there are some small differences across grids.

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References

Ajetomobi, J., A.O. Abiodun, and R. Hassan. 2010. *Economic Impact of Climate Change on Irrigated Rice Agriculture in Nigeria.* Ibadan, Nigeria: University of Ibadan Press.

Alston, J.M., G.W Norton,and P.G Pardey.1995. *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Ithaca, New York : Cornell University Press.

Alston, J.M., G.W. Norton, and P.G. Pardy. 1998. *Science under Scarcity Principle and Practice for Agricultural Research Evaluation and Priority Setting.* CAB International Publishing.

Arunrat, N. and N. Pumijumnong. 2014. 'Evaluation of Erosion Productivity Impact Calculator (EPIC) Model for Nitrogen Losses in Rice Paddy of Thailand.' *Asian Journal of Agricultural Research 8:* 70-83. http://dx.doi.org/10.3923/ajar. 2014

Arunrat, N., N. Pumijumnong, and A. Phinchongsakuldit. 2014. 'Estimating Soil Organic Carbon Sequestration in Rice Paddies as Influenced by Climate Change under Scenario A2 and B2 of an i-EPIC Model of Thailand.' *Environment Asia 7* (1): 65-80.

Baldwin, K., N. Chids, J. Dyck, and J. Hansen. 2013. *Southeast Asia's Rice Surplus*. A Report from the Economic Research Service. USDA.

Brown, R.A., N.J Rosenberg, C.J. Hays, W.E Easterling, and L.O. Mearns. 2000. 'Potential Production and Environmental Effects of Switchgrass and Traditional Crops under Current and Greenhouse - Altered Climate in the Central United States: A Simulation Study.' *Agriculture, Ecosystems and Environment 78* (1): 31-47.

Chang, C. 2002. 'The Potential Impact of Climate Change on Taiwan's Agriculture.' *Agricultural Economics 27:* 51-64. http://dx.doi.org/10.1016/S0169-5150 (01)00060-3

Chen, Y.F., Z.G. Wu, T.H. Zhu, L. Yang, G.Y. Ma, and H.P. Chien. 2013. 'Agricultural Policy, Climate Factors and Grain Output: Evidence from Household Survey Data in Rural China.' *Journal of Integrative Agriculture* 12: 169-183. http://dx.doi.org/10.1016/S2095 -3119(13)60217-8

Diao, A. and A.N. Pratt. 2007. 'Growth Options and Poverty Reduction in Ethiopia: An Economy Wide Analysis.' Food Policy 32 (2): 205-228. http://dx.doi.org/10.1016/ j.foodpol.2006.05.005

FAO. 2008. *Climate Change Adaptation and Mitigation in the Food and Agriculture Sector*. Rome, Italy: Food and Agriculture Organisation of the United Nations.

Fleischer, A., I. Lichtman, and R. Mendelsohn. 2007. 'Climate Change, Irrigation, and Israeli Agriculture: Will Warming be Harmful?' *Ecological Economics 65* (3): 508-515.

Garnaut, R., S. Howes, F. Jotzo,and P. Sheehan. 2008. 'Emissions in the Platinum Age: the Implications of Rapid Development for Climate-change Mitigation.' *Oxford Review of Economic Policy* 24 (2): 377-401.

Gassman, P.W., T. Campbell, C. Izaurralde, A.M. Thomson, and J.D. Atwood. 2003. *'Regional Estimation of Soil Carbon and Other Environmental Indicators Using EPIC and i_EPIC.'* Technical Report 03-TR 46 April 2003. *Ames*. USA: Center for Agricultural and Rural Development, Iowa State University.

Gassman, P.W., J.R. Williams, V.W. Benson, R.C Izaurralde, L.M. Hauck, C.A. Jones, J.D. Atwood, J.R. Kiniry, and J.D. Flowers. 2005. *Historical Development and Applications of the EPIC and APEX Models*. CARD Working Paper 05-WP. Ames, Iowa, USA: Center for Agricultural and Rural Development, Iowa State University.

Huang, M., W. Zhang, L. Jiang, and Y. Zou. 2013. 'Impact of Temperature Changes on Early-rice Productivity in Asubtropical Environment of China.' *Field Crop Research* 146:10-15.

IPCC. 2007. *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. NY, USA: Cambridge University Press, Cambridge.

Isvilanonda, S. and I. Bunyasiri. 2009. *Food Security in Thailand Status, Rural Poor Vulnerability, and Some Policy Options.* Paper presented on the international seminar on Agricultural and Food Policy Reforms: Food Security from the Perspective of Asian Small-scale Farmers held in Seoul on 24-28 August 2009.

ITSMF-NL. 2006. *Metrics for IT Service Management.* Zaltbommel, Netherlands: Van Haren Publishing.

Izaurralde, R.C., J.R. Williams, W.B. McGill, N.J. Rosenberg, and M.C.Q. Jakas. 2006. 'Simulating Soil C dynamics with EPIC: Model Description and Testing against Long-term Data.' *Ecological Modelling* 192: 362-384.

Juliá, R. and F. Duchin. 2007. 'World Trade as the Adjustment Mechanism of Agriculture to Climate Change.' *Climatic Change* 82: 393-409. http://dx.doi.org/10.1007/s 10584-006-9181-8

Kabubo-Mariara, J. and F.K. Karanja. 2007. 'The Economic Impact of Climate Change on Kenyan Crop Agriculture: A Ricardian Approach.' *Global and Planetary Change* 57: 319-330.

Krishna, P.P. 2011. 'Economics of Climate Change for Smallholder Farmers in Nepal.' *The Journal of Agriculture and Environment* 12: 1-14.

Kurukulasuriya, P. and A. Mendelsohn. 2008. 'A Ricardian Analysis of the Impact of Climate Change on African Cropland.' *African Journal of Agricultural and Resource Economics 2* (1): 1-23. http://dx.doi.org/10.1596/1813-9450-4305

Mendelsohn, R. 2014. 'The Impact of Climate Change on Agriculture in Asia.' *Journal of Integrative Agriculture* 13: 660-665. http://dx.doi.org/10.1016/S2095-3119(13)60701-7

Mendelsohn, R., W.D. Nordhaus, and D. Shaw. 1994. 'The Impact of Global Warming on Agriculture: A Ricardian Analysis.' *American Economic Review* 84: 753-771.

Mngale, A.S. 2009. *Climate Change Coping Strategies for Household Food Security in Singida District.* Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania.

Nelson, G., A. Palazzo, C. Ringler, T. Sulser,and M. Batka. 2009. *The Role of International Trade in Climate Change Adaptation.* ICTSD-IPC Platform on Climate Change, Agriculture and Trade. Issue Brief No. 4. Geneva: International Centre for Trade and Sustainable Development (ICTSD) and International Food & Agricultural Trade Policy Council (IPC).

Olesen, J.E. and M. Bindi. 2002. 'Consequences of Climate Change for European agricultural Productivity, Land Use and Policy.' *European Journal of Agronomy* 16: 239-262.

Parry, M.L., C. Fischer, M. Livermore, C. Rosenzweig, and A. Iglesias. 1999. 'Climate Change and World Food Security: A New Assessment.' *Global Environmental Change* 9: S51-S67.

Parry, M.L., C. Rosenzweig, and M. Livermore. 2005. 'Climate Change, Global Food Supply and Risk of Hunger.' *Philosophical Transactions of the Royal Society B, 360*: 2125-2138.

Parry, M.L., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer. 2004. 'Effects of Climate Change on Global Food Production under SRES Emissions and Socio-economic Scenarios. '*Global Environmental Change* 14: 53-67. http://dx.doi.org/10.1016/j.gloenvcha.2003.10.008

Pumijumnong, N. and N. Arunrat. 2012. 'Reliability and Evaluation of the Potential of the i_EPIC Model to Estimate Rice Yields in Thailand.' *Agricultural Science Research Journals* 2 (12): 614-622.

Pumijumnong, N. and N. Arunrat. 2013. 'Simulating the Rice Yield Change in Thailand under SRES A2 and B2 Scenarios with the EPIC Model.' *Journal of Agri-Food and Applied Sciences* 1 (4): 119-125.

Rayer, S. 2007. 'Population Forecast Accuracy: Does the Choice of Summary Measure of Error Matter?' *Population Research and Policy Review* 26: 163-184.

Rinaldi, M.,and D. de Luca. 2012. 'Application of EPIC Model to Assess Climate Change Impact on Sorghum in Southern Italy.' *Italian Journal of Agronomy 7*: 74-85.

Sanghi, A., D. Alves, R. Evenson, and R. Mendelsohn.1997. 'Global Warming Impacts on Brazilian Agriculture: Estimates of the Ricardian Model.' *Economia Aplicada* 1 (1): 7-33.

Sanghi, A., R. Mendelsohn, and A. Dinar. 1998. 'The Climate Sensitivity of Indian Agriculture. ' In *Measuring the Impact of Climate Change on Indian Agriculture,* edited by A. Dinar, R. Mendelsohn, R. Evenson, J. Parikh, A. Sanghi, K. Kumar, J. McKinsey, and S. Lonergon. Technical Paper No. 402. Washington, D.C: World Bank.

Sharpley, A.N. and J.R. Williams. 1990. *EPIC-Erosion/Productivity Impact Calculator*. Technical Bulletin No. 1768. Washington, D.C: Agricultural Research Service , USDA.

Smith, E.G. 1997. *Farm Management Practices and Environmental Effluents in the Western Lake Erie Basin of Ohio: An Economic Optimization of Far Systems* (Unpublished M.S. thesis at Ohio State University: Columbus, Ohio).

Thapa, S.,and G.R. Joshi. 2010. *A Ricardian Analysis of the Climate Change Impact on Nepalese Agriculture.* Paper No. 29785. Munich Personal RePEc Archive.

Thornton, P.K., A.N. Van De Steeg,and M. Herrero. 2009. 'The Impacts of Climate Change on Livestock and Livestock Systems in Developing Countries: A Review of What We Know and What We Need to Know.' *Agricultural Systems* 101: 113-127.

Timmer, C.P., S. Block, and D. Dawe. 2010. 'Long-run Dynamics of Rice Consumption, 1960-2050.' In *Rice in the Global Economy: Strategic Research and Policy Issues for Food Security,* edited by S. Pandey, D. Byerlee, D. Dawe, A. Dobermann, S. Mohanty, S. Rozelle. Amd and B. Hardy.International Rice Research Institute.

Tumbo, S.D., B.P. Mbilinyi, F.B. Rwehumbiza, and K.D. Mutabazi.2010. *Economics of Climate Change for Agriculture Sector in Tanzania: Adaptation Options and their Costs SWMRG*. SUA, Morogoro, Tanzania.

Vaghefi, N., M. Nasirshamsudin, A. Makmom, and M. Bagheri. 2011. The Economic Impacts of Climate Change on the Rice Production in Malaysia. *International Journal of Agricultural Research* 6: 67-74.

Wang, J., J. Huang,and J. Yang. 2014. 'Overview of Impacts of Climate Change and Adaptation in China's Agriculture.' *Journal of Integrative Agriculture* 13: 1-17.

Willams, J.R., E. Wang, A. Meinardus, W.L. Harman, S.M. Atwood, and D. Jay. 2006. *EPIC Users Guide v. 0509*. http://www.public.iastate.edu/~tdc/ i_epic_main.html

Wilson, T. 2007. 'The Forecast Accuracy of Australian Bureau of Statistics National Population Projections.' *Journal of Population Research* 24 (1): 91-117.

Wu, W., R. Shibasaki, P. Yang, G. Tan, K. Matsumura, and K. Sugimoto. 2007. 'Global-scale Modeling of Future Changes in Sown Areas of Major Crops.' *Ecological Modeling* 208: 378-390.

Zhang, X., R.C. Izaurralde, D. Manowitz, T.O. West, W.M. Post, A.M. Thomson, V.P Bandaru, J. Nichols, and J.R. Williams. 2010. 'An Integrative Modeling Framework to Evaluate the Productivity and Sustainability of Biofuel Crop Production Systems.' *Global Change Biol. – Bioenergy* 2: 258-277.

Appendix A

Table A1:The Data Used for the World Rice Market Model

Year	*QW*	*P*	*WP*	*PO*	*PP*	*I*
1966	245,122,007	55.25	3,392,364	11.89	297.03	0.1514
1967	250,408,972	58.00	3,463,446	11.56	264.80	0.1557
1968	257,808,654	58.50	3,537,051	11.09	302.90	0.1623
1969	264,171,283	48.50	3,612,027	10.53	288.94	0.1709
1970	285,877,621	31.40	3,687,496	9.94	269.02	0.1811
1971	292,303,528	40.00	3,763,291	11.85	221.64	0.1890
1972	294,913,104	65.55	3,839,485	12.72	341.44	0.1950
1973	301,464,991	96.75	3,915,749	15.89	521.88	0.2070
1974	307,767,233	105.20	3,991,767	50.41	384.89	0.2297
1975	319,705,231	97.45	4,067,338	45.98	393.82	0.2508
1976	324,459,501	92.45	4,142,238	48.25	298.34	0.2653
1977	341,233,664	115.10	4,216,604	49.24	276.83	0.2827
1978	346,986,961	109.20	4,291,046	46.13	245.21	0.3039
1979	355,031,912	130.25	4,366,459	93.41	224.11	0.3384
1980	365,585,801	154.10	4,443,492	95.89	375.94	0.3841
1981	374,508,765	130.11	4,522,203	84.80	282.02	0.4237
1982	397,856,522	118.39	4,602,460	73.30	218.12	0.4498
1983	411,536,427	123.35	4,684,373	63.65	276.35	0.4643
1984	420,004,259	120.27	4,768,042	59.43	259.01	0.4843
1985	428,293,137	98.79	4,853,449	54.95	172.32	0.5015
1986	432,072,647	86.77	4,940,684	28.25	217.09	0.5108
1987	444,777,057	106.97	5,029,533	34.82	182.33	0.5296
1988	455,444,129	160.12	5,119,111	27.06	240.70	0.5514
1989	468,264,692	157.03	5,208,291	31.53	280.63	0.5782
1990	471,420,842	149.73	5,296,249	38.94	219.95	0.6094
1991	462,387,874	160.00	5,382,632	31.51	171.73	0.6347
1992	472,026,320	151.00	5,478,014	29.54	186.54	0.6540
1993	488,543,901	127.00	5,561,745	25.20	201.96	0.6734
1994	496,944,096	153.00	5,644,416	22.90	178.05	0.6908
1995	517,240,958	166.00	5,726,236	23.95	209.68	0.7106
1996	521,447,815	205.00	5,807,205	28.26	147.66	0.7314
1997	529,998,080	212.00	5,887,258	25.52	165.78	0.7480
1998	547,666,622	139.00	5,966,463	16.74	161.86	0.7599
1999	556,918,124	128.00	6,044,931	23.14	163.53	0.7766
2000	557,234,517	109.00	6,122,769	35.50	139.51	0.8028
2001	566,574,210	109.00	6,200,004	29.61	186.58	0.8254
2002	571,615,527	118.00	6,276,717	29.84	175.31	0.8385
2003	572,689,030	134.00	6,353,190	33.62	151.60	0.8575
2004	581,092,058	166.00	6,429,754	43.46	141.95	0.8806
2005	587,932,491	172.00	6,506,645	59.89	170.27	0.9103
2006	598,188,640	181.00	6,583,961	69.32	171.33	0.9397
2007	608,803,782	327.00	6,661,634	74.90	171.75	0.9665
2008	NA	291.00	6,739,605	96.91	185.33	1.0036
2009	NA	291.00	6,817,737	61.67	176.00	1.0000

I = Level prices at the base year (2009)

Appendix B

Table B1: Estimating the Equilibrium Quantity and Rice Price in the World Market

Year	*QW*	*P*	*WP*	*PO*	*PP*
2008	707,303,805	312.375	6,739,605	96.91	185.33
2009	691,906,930	277.452	6,817,737	61.67	176.00
2010	653,555,086	282.249	6,895,888	63.67	176.00
2011	658,965,303	282.415	6,974,041	65.74	176.00
2012	659,152,315	287.299	7,052,133	67.87	176.00
2013	664,610,318	294.823	7,130,012	70.07	176.00
2014	672,926,215	303.897	7,207,456	72.35	176.00
2015	682,810,190	313.928	7,284,293	74.69	176.00
2016	693,559,467	324.586	7,360,429	77.12	176.00
2017	704,787,763	335.688	7,435,808	79.62	176.00
2018	716,281,336	347.126	7,510,344	82.20	176.00
2019	727,918,329	358.834	7,583,939	84.87	176.00
2020	739,626,130	370.771	7,656,527	87.62	176.00
2021	751,360,657	382.909	7,728,043	90.46	176.00
2022	763,093,374	395.229	7,798,445	93.40	176.00
2023	774,805,461	407.717	7,867,736	96.43	176.00
2024	786,485,926	420.364	7,935,915	99.56	176.00
2025	798,127,829	433.164	8,002,977	102.79	176.00
2026	809,726,210	446.109	8,068,917	106.12	176.00
2027	821,277,188	459.194	8,133,722	109.57	176.00

Table B2: Estimating the Equilibrium Quantity and Thai Rice Market Model

Year	*ST*	*DT*	*E*	*P*	*TP*	*FX*
1966	13,500,000	10,462,278	2,280,146	55.25	32,772	20.00
1967	11,198,000	9,702,173	2,253,403	58.00	33,774	20.00
1968	12,410,000	10,328,915	1,626,539	58.50	34,799	20.00
1969	13,410,000	10,642,301	1,555,578	48.50	35,847	20.00
1970	13,850,000	11,022,599	1,615,280	31.40	36,915	20.00
1971	13,744,000	11,343,685	2,400,315	40.00	38,004	20.00
1972	12,413,000	11,488,959	3,196,769	65.55	39,110	20.00
1973	14,899,000	12,091,357	1,292,492	96.75	40,219	20.00
1974	13,386,000	12,083,787	1,605,243	105.20	41,319	20.00
1975	15,300,000	12,618,047	1,469,853	97.45	42,399	20.00
1976	15,068,000	12,359,447	3,011,621	92.45	43,453	20.00
1977	13,921,000	12,164,190	4,484,165	115.10	44,484	20.00
1978	17,470,000	13,767,302	2,490,644	109.20	45,494	20.00
1979	15,758,000	12,676,953	4,293,240	130.25	46,492	20.00
1980	17,368,100	12,621,562	4,292,133	154.10	47,483	20.00
1981	17,774,320	12,662,844	4,657,084	130.11	48,460	21.82
1982	16,878,510	11,979,721	5,808,156	118.39	49,423	23.00
1983	19,548,940	13,153,827	5,334,739	123.35	50,380	23.00
1984	19,904,820	12,725,139	7,028,617	120.27	51,346	23.64
1985	20,263,870	12,232,877	6,213,442	98.79	52,329	27.16
1986	18,868,160	12,554,712	6,919,963	86.77	53,340	26.30

1987	18,428,270	12,514,158	6,807,573	106.97	54,369	25.74
1988	21,262,900	12,563,666	8,094,757	160.12	55,371	25.29
1989	20,601,010	11,978,575	9,675,468	157.03	56,285	25.70
1990	17,193,220	12,053,275	6,208,630	149.73	57,072	25.59
1991	20,400,000	12,786,360	6,721,129	160.00	57,712	25.52
1992	19,917,000	12,395,570	7,977,366	151.00	58,226	25.40
1993	19,530,000	12,113,378	7,721,810	127.00	58,671	25.32
1994	21,111,000	12,834,829	7,520,355	153.00	59,127	25.15
1995	22,015,500	12,817,632	9,501,730	166.00	59,650	24.92
1996	22,331,600	13,950,198	8,381,759	205.00	60,258	25.34
1997	23,580,000	14,136,383	8,535,147	212.00	60,934	31.37
1998	23,450,000	14,365,686	9,994,674	139.00	61,660	41.37
1999	24,172,000	14,323,182	10,459,736	128.00	62,409	37.84
2000	25,843,880	15,648,250	9,425,493	109.00	63,155	40.16
2001	28,033,750	15,522,895	11,749,120	109.00	63,899	44.48
2002	27,991,820	15,688,053	11,243,113	118.00	64,643	43.00
2003	29,473,520	16,177,096	12,843,984	134.00	65,370	41.53
2004	28,538,230	16,304,391	15,319,286	166.00	66,060	40.27
2005	30,291,870	17,324,426	11,465,131	172.00	66,698	40.27
2006	29,641,870	17,417,414	11,485,401	181.00	67,276	37.93
2007	32,099,400	17,663,557	14,016,227	327.00	67,796	34.56
2008	31,650,630	18,461,189	15,586,909	291.00	68,268	33.36
2009	32,116,060	19,437,698	13,202,909	291.00	68,706	34.34

FX = Exchange rate (Baht per US dollar)

Table B3: Estimating the Amounts of Rice Production, Consumption and Export

Year	*ST*	*DT*	*E*	*P*	*TP*
2008	31,650,630	18,461,189	15,586,909	312.375	68,268
2009	32,116,060	19,437,698	13,202,909	277.452	68,706
2010	29,394,006	15,709,007	13,684,999	282.249	69,122
2011	29,628,700	15,765,415	13,863,284	282.415	69,519
2012	29,636,811	15,817,138	13,819,673	287.299	69,892
2013	29,873,506	15,866,089	14,007,418	294.823	70,243
2014	30,234,007	15,912,240	14,321,766	303.897	70,571
2015	30,662,279	15,954,582	14,707,698	313.928	70,876
2016	31,127,798	15,994,070	15,133,727	324.586	71,158
2017	31,613,787	16,029,693	15,584,093	335.688	71,419
2018	32,110,976	16,063,410	16,047,566	347.126	71,661
2019	32,614,083	16,094,214	16,519,869	358.834	71,885
2020	33,119,963	16,123,084	16,996,879	370.771	72,091
2021	33,626,715	16,149,012	17,477,703	382.909	72,280
2022	34,133,108	16,172,982	17,960,126	395.229	72,454
2023	34,638,337	16,194,985	18,443,352	407.717	72,612
2024	35,141,933	16,215,015	18,926,918	420.364	72,755
2025	35,643,603	16,232,059	19,411,544	433.164	72,884
2026	36,143,141	16,248,117	19,895,024	446.109	73,000
2027	36,640,386	16,262,181	20,378,205	459.194	73,102

Table B4:Estimating the Amounts of Rice Production and Areas during 2007-2027 in Each Region of Thailand

Year		*Major rice (Million ha, Million tons)*						*Second rice (Million ha, Million tons)*						*Sum*
		C	*E*	*N*	*NE*	*S*	*W*	*C*	*E*	*N*	*NE*	*S*	*W*	
2007	Area	1.44	0.13	2.41	6.81	0.16	0.08	0.80	0.07	0.55	0.09	0.02	0.07	12.63
	Production	5.27	0.47	6.92	11.37	0.87	0.25	3.75	0.34	2.25	0.32	0.11	0.17	32.10
2008	Area	1.42	0.13	2.38	6.71	0.15	0.08	0.79	0.07	0.54	0.09	0.02	0.07	12.45
	Production	5.20	0.47	6.83	11.21	0.86	0.24	3.70	0.33	2.22	0.32	0.11	0.17	31.65
2009	Area	1.44	0.13	2.41	6.81	0.16	0.08	0.80	0.07	0.55	0.09	0.02	0.07	12.64
	Production	5.28	0.48	6.93	11.38	0.87	0.25	3.75	0.34	2.25	0.32	0.11	0.17	32.12
2010	Area	1.32	0.12	2.21	6.24	0.14	0.07	0.73	0.07	0.50	0.09	0.02	0.06	11.57
	Production	4.83	0.43	6.34	10.41	0.79	0.22	3.43	0.31	2.06	0.30	0.10	0.16	29.39
2011	Area	1.33	0.12	2.23	6.29	0.14	0.07	0.74	0.07	0.50	0.09	0.02	0.06	11.66
	Production	4.87	0.44	6.39	10.50	0.80	0.23	3.46	0.31	2.08	0.30	0.10	0.16	29.63
2012	Area	1.33	0.12	2.23	6.29	0.14	0.07	0.74	0.07	0.50	0.09	0.02	0.06	11.66
	Production	4.87	0.44	6.39	10.50	0.80	0.23	3.46	0.31	2.08	0.30	0.10	0.16	29.64
2013	Area	1.34	0.12	2.24	6.34	0.14	0.07	0.75	0.07	0.51	0.09	0.02	0.07	11.75
	Production	4.91	0.44	6.44	10.58	0.81	0.23	3.49	0.31	2.10	0.30	0.10	0.16	29.87
2014	Area	1.35	0.12	2.27	6.41	0.15	0.07	0.75	0.07	0.51	0.09	0.02	0.07	11.90
	Production	4.97	0.45	6.52	10.71	0.82	0.23	3.53	0.32	2.12	0.30	0.10	0.16	30.23
2015	Area	1.37	0.13	2.30	6.50	0.15	0.07	0.77	0.07	0.52	0.09	0.02	0.07	12.06
	Production	5.04	0.45	6.61	10.86	0.83	0.23	3.58	0.32	2.15	0.31	0.10	0.17	30.66
2016	Area	1.39	0.13	2.34	6.60	0.15	0.08	0.78	0.07	0.53	0.09	0.02	0.07	12.25
	Production	5.11	0.46	6.71	11.03	0.84	0.24	3.64	0.33	2.18	0.31	0.11	0.17	31.13
2017	Area	1.41	0.13	2.38	6.71	0.15	0.08	0.79	0.07	0.54	0.09	0.02	0.07	12.44
	Production	5.19	0.47	6.82	11.20	0.85	0.24	3.69	0.33	2.22	0.32	0.11	0.17	31.61
A2	Production	3.59	0.49	2.47	5.63	2.15	0.48	0.84	0.13	0.14	0.04	0.25	0.15	16.36
B2	Production	1.19	0.24	1.05	2.82	0.92	0.17	0.31	0.07	0.09	0.02	0.07	0.06	7.00
2018	Area	1.44	0.13	2.41	6.81	0.16	0.08	0.80	0.07	0.55	0.09	0.02	0.07	12.63
	Production	5.27	0.48	6.92	11.38	0.87	0.25	3.75	0.34	2.25	0.32	0.11	0.17	32.11
A2	Production	3.65	0.50	2.51	5.72	2.18	0.49	0.85	0.13	0.14	0.04	0.26	0.15	16.61
B2	Production	1.21	0.24	1.06	2.86	0.94	0.17	0.31	0.08	0.09	0.02	0.07	0.06	7.11
2019	Area	1.46	0.13	2.45	6.92	0.16	0.08	0.81	0.07	0.56	0.10	0.02	0.07	12.83
	Production	5.36	0.48	7.03	11.55	0.88	0.25	3.81	0.34	2.29	0.33	0.11	0.18	32.61
A2	Production	3.71	0.50	2.55	5.81	2.21	0.49	0.86	0.13	0.14	0.04	0.26	0.15	16.87
B2	Production	1.23	0.25	1.08	2.91	0.95	0.17	0.32	0.08	0.09	0.02	0.08	0.06	7.22
2020	Area	1.48	0.14	2.49	7.03	0.16	0.08	0.83	0.08	0.56	0.10	0.02	0.07	13.03
	Production	5.44	0.49	7.14	11.73	0.90	0.25	3.87	0.35	2.32	0.33	0.11	0.18	33.12
A2	Production	3.77	0.51	2.59	5.90	2.25	0.50	0.88	0.14	0.15	0.04	0.26	0.15	17.14
B2	Production	1.25	0.25	1.09	2.95	0.97	0.18	0.32	0.08	0.09	0.02	0.08	0.06	7.33
2021	Area	1.50	0.14	2.53	7.13	0.16	0.08	0.84	0.08	0.57	0.10	0.02	0.07	13.23
	Production	5.52	0.50	7.25	11.91	0.91	0.26	3.93	0.35	2.36	0.34	0.11	0.18	33.63
A2	Production	3.82	0.52	2.63	5.99	2.28	0.51	0.89	0.14	0.15	0.04	0.27	0.16	17.40
B2	Production	1.26	0.26	1.11	3.00	0.98	0.18	0.33	0.08	0.09	0.02	0.08	0.07	7.45
2022	Area	1.53	0.14	2.56	7.24	0.17	0.08	0.85	0.08	0.58	0.10	0.02	0.07	13.43
	Production	5.61	0.50	7.36	12.09	0.92	0.26	3.99	0.36	2.39	0.34	0.12	0.19	34.13
A2	Production	3.88	0.53	2.67	6.08	2.32	0.52	0.90	0.14	0.15	0.05	0.27	0.16	17.66
B2	Production	1.28	0.26	1.13	3.04	1.00	0.18	0.33	0.08	0.09	0.02	0.08	0.07	7.56
2023	Area	1.55	0.14	2.60	7.35	0.17	0.08	0.86	0.08	0.59	0.10	0.02	0.08	13.63
	Production	5.69	0.51	7.47	12.27	0.94	0.27	4.05	0.36	2.43	0.35	0.12	0.19	34.64
A2	Production	3.94	0.54	2.71	6.17	2.35	0.52	0.92	0.14	0.15	0.05	0.28	0.16	17.92
B2	Production	1.30	0.26	1.15	3.09	1.01	0.18	0.34	0.08	0.09	0.02	0.08	0.07	7.67
2024	Area	1.57	0.15	2.64	7.45	0.17	0.09	0.88	0.08	0.60	0.10	0.02	0.08	13.83
	Production	5.77	0.52	7.58	12.45	0.95	0.27	4.11	0.37	2.46	0.35	0.12	0.19	35.14
A2	Production	3.99	0.54	2.75	6.26	2.39	0.53	0.93	0.14	0.16	0.05	0.28	0.16	18.18
B2	Production	1.32	0.27	1.16	3.13	1.02	0.19	0.34	0.08	0.10	0.02	0.08	0.07	7.78
2025	Area	1.60	0.15	2.68	7.56	0.17	0.09	0.89	0.08	0.61	0.11	0.02	0.08	14.02
	Production	5.85	0.53	7.69	12.63	0.96	0.27	4.16	0.37	2.50	0.36	0.12	0.19	35.64
A2	Production	4.05	0.55	2.79	6.35	2.42	0.54	0.94	0.15	0.16	0.05	0.28	0.17	18.44
B2	Production	1.34	0.27	1.18	3.18	1.04	0.19	0.35	0.08	0.10	0.02	0.08	0.07	7.89
2026	Area	1.62	0.15	2.72	7.67	0.18	0.09	0.90	0.08	0.62	0.11	0.02	0.08	14.22
	Production	5.94	0.53	7.79	12.80	0.98	0.28	4.22	0.38	2.53	0.36	0.12	0.20	36.14
A2	Production	4.11	0.56	2.82	6.44	2.45	0.55	0.96	0.15	0.16	0.05	0.29	0.17	18.70
B2	Production	1.36	0.27	1.19	3.22	1.05	0.19	0.35	0.08	0.10	0.02	0.08	0.07	8.00

Table B5: Estimating the Economic Impact under Climate Conditions in 2007, A2 and B2 Scenarios

	2007(Million tons)				*A2(Million tons)*				*B2(Million tons)*				
Year	*P*	*C*	*Min.*	*E*	*P*	*C*	*Min.*	*E*	*P*	*C*	*Min.*	*E*	*P < Min.*
2007	32.10	17.66	6.85	14.44	32.10	17.66	6.85	14.44	32.10	17.66	6.85	14.44	
2008	31.65	18.46	6.90	13.19	31.65	17.66	6.90	14.44	31.65	17.66	6.90	14.44	
2009	32.12	19.44	6.94	12.68	32.12	17.66	6.94	14.44	32.12	17.66	6.94	14.44	
2010	29.39	15.71	6.98	13.68	29.39	17.66	6.98	14.44	29.39	17.66	6.98	14.44	
2011	29.63	15.77	7.02	13.86	29.63	17.66	7.02	14.44	29.63	17.66	7.02	14.44	
2012	29.64	15.82	7.06	13.82	29.64	17.66	7.06	14.44	29.64	17.66	7.06	14.44	
2013	29.87	15.87	7.09	14.01	29.87	17.66	7.09	14.44	29.87	17.66	7.09	14.44	
2014	30.23	15.91	7.13	14.32	30.23	17.66	7.13	14.44	30.23	17.66	7.13	14.44	
2015	30.66	15.95	7.16	14.71	30.66	17.66	7.16	14.44	30.66	17.66	7.16	14.44	
2016	31.13	15.99	7.19	15.13	31.13	17.66	7.19	14.44	31.13	17.66	7.19	14.44	
2017	31.61	16.03	7.21	15.58	16.36	16.03	7.21	0.33	7.00	16.03	7.21	-9.03	
2018	32.11	16.06	7.24	16.05	16.61	16.06	7.24	0.55	7.11	16.06	7.24	-8.95	-0.213
2019	32.61	16.09	7.26	16.52	16.87	16.09	7.26	0.78	7.22	16.09	7.26	-8.87	-0.127
2020	33.12	16.12	7.28	17.00	17.14	16.12	7.28	1.01	7.33	16.12	7.28	-8.79	-0.038
2021	33.63	16.15	7.30	17.48	17.40	16.15	7.30	1.25	7.45	16.15	7.30	-8.70	
2022	34.13	16.17	7.32	17.96	17.66	16.17	7.32	1.49	7.56	16.17	7.32	-8.61	
2023	34.64	16.19	7.33	18.44	17.92	16.19	7.33	1.73	7.67	16.19	7.33	-8.52	
2024	35.14	16.22	7.35	18.93	18.18	16.22	7.35	1.97	7.78	16.22	7.35	-8.43	
2025	35.64	16.23	7.36	19.41	18.44	16.23	7.36	2.21	7.89	16.23	7.36	-8.34	
2026	36.14	16.25	7.37	19.90	18.70	16.25	7.37	2.45	8.00	16.25	7.37	-8.24	
2027	36.64	16.26	7.38	20.38	18.96	16.26	7.38	2.70	8.11	16.26	7.38	-8.15	

P = Production: C = Consumption: Min. = Minimum level of consumption demand: E = Export

Rethinking Concepts of Human Health, Food and Nutrition Security in the Pacific Region in the Era of Climate Change with Focus on the Fiji Islands*

Erlidia L. Clark**

In the last decade, the connection between climate change and human health have been widely accepted. Evidence shows that climate change is happening in Fiji. The projection of increasing EWEs such as cyclones and floods present a risk to people as they transition from a subsistence to consumerist economy. This economic change including the global environmental and climate change impact health and nutrition outcomes. To be able to address the challenges of climate change including increasing EWEs and natural disaster occurrence in the context of Pacific Island countries such as Fiji in achieving health and food and nutrition security, a socio-ecological conceptual framework was deemed necessary.

Introduction

Global and Regional Climate Change

Worldwide, there is an increasing concern about the changing climate. Since its establishment in 1988, the Inter-governmental Panel on Climate Change (IPCC) has provided policy and programme decision-makers with scientific information about climate change. The IPCC attributed greenhouse gases from human activity as being responsible for continuing global climate change with global temperature increasing between 1.8 and 4°C by 2100 (IPCC 2007). Increasing frequency and destructiveness of extreme weather events (EWE) such as tropical cyclones were documented (Emanuel 2005). After five IPCC reports and numerous occurrence of EWE globally, it has become clear that climate change impacts will have more damage with increasing global temperature. Human-induced (anthropogenic) warming may lead to some abrupt and irreversible impacts which are dependent on the rate and magnitude of the climate change. Regional variations of these consequences are evident (Patz and Kovats 2002). Some countries may benefit in the short or medium term, but economic challenges to many developing nations including Pacific island countries and territories (PICTs) are anticipated. In these reports, it is certain that the most vulnerable and poorest developing countries will experience significant consequences if mitigation and adaptation strategies are not subscribed to. At this stage, though many developing countries have less contribution in the anthropogenic cause of climate change, their on-going transition to a consumption economy will also contribute in accelerating global environmental change. Therefore, both developing and developed nations have a common obligation to support each

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other in efforts to mitigate and adapt to climate change (IPCC 2012). Many countries and international agencies are mainstreaming climate change in their development agenda; however, more needs to be done in implementing policies. The future of human health and food nutrition security depends on everyone's efforts and action to strive for global environmentally-sustainable development.The IPCC 4th Assessment Report indicated that the climate of the PICTs has changed in the last several decades. Since 1910, ocean and land temperatures have increased 0.6-1°C (SPC Land Resources Division 2010). Parts of the region such as the Southwest Pacific have become drier while the Central Pacific have experienced increasing rainfall (Manton 2001). Change in the climatic trends including increasing sea-level rise are also projected to continue in the next decades. Annual and inter-decadal variability in climatic variables temperature and rainfall are felt due to the ENSO (El Nino/La Nina Southern Oscillation) which influences prevailing regional climate. All these are anticipated to impact on health, food and nutrition security.

Climate Change, Health, Food and Nutrition Security and Its Multi-Sectoral Links

In the last decade, the connections between climate change and human health have been widely accepted (Berry et al. 2010; Confalonieri et al. 2007; Costello et al. & UCL Institute for Global Health and Lancet Commission 2009; McMichael 2003). The climate-health pathway indicates that the consequences of climate change are not only confined to the direct environmental and economic impacts. Indirect pathways and inter-related mechanisms affect health and nutrition through the intermediate factors that involve agriculture, infrastructure and transport, sanitation and water, health services including disaster planning and management (Bowen et al. 2013). Unfortunately, many of the health effects will be unevenly distributed. People in developing countries and the marginalised sector in a developed society may experience severe outcomes (Friel and Baker, 2009; Frielet al. 2008; Wahlqvistet al. 2009). Many of the developing countries have fragile or transitioning economies with insufficient financial capability, poor governance, lack of infrastructure, and poor living conditions that add to the high level of disease risk burden which will be exacerbated by a changing climate (McMichael et al. 2004; 2006; Patz et al. 2005; Patz and Kovats 2002).

Objectives of the Paper

The objectives of this paper is to highlight the importance of how climate change is affecting health, food and nutrition security with Fiji and to propose a conceptual framework for better understanding on how climate change may affect health and food and nutrition security. A socio-ecological perspective is used to address these issues. Coordinated efforts from multiple sectors in society including agriculture, finance, social welfare and others are vital to food security and health attainment and are relevant to health-related adaptation initiatives to climate change. The following key questions are addressed: a) Is climate change happening in Fiji? b) Is climate change affecting health, food and nutrition security in Fiji? c) What are the impacts of climate change in Fiji relevant to health, food and nutrition security? and d) How should we use a socio-ecological perspective to address issues of health and food and nutrition security in the era of climate change?

Approach and Methods

Adapted Socio-ecological Model of Health

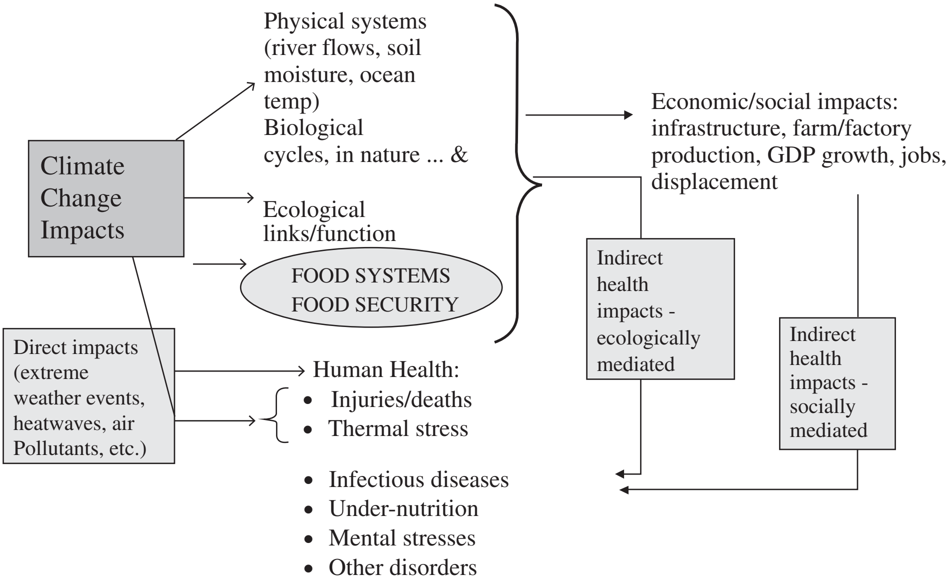
Here, the theoretical underpinnings in approaching the linkages to propose adaptation strategies for climate change, health and food and nutrition security is based on a socio-ecological theory (McLeroyet al. 1988; Stokols 1996), ecological systems theory/human ecology theory (Bronfenbrenner 1979) and social cognitive theory (Bandura 1986), among others. In climate change studies, socio-ecological models extending to health utilises an integrated systems approach. It has evolved to include conceptual frameworks from multiple disciplines to explain the complexity of how climate change will affect human health and food and nutrition security (Llamas-Clark 2011). This conceptual development is based on the underlying principle that multiple factors at different levels influence nutrition and therefore, health and well-being.

As a public health approach, the socio-ecological model has been widely used for health promotion strategies. It recognises the several levels in understanding the links between individual and the physical and social environment (McLeroyet al. 1988). Individuals are integral to this concept. However, interpersonal relationships, community and societal dynamics and institutional structures are equally important. Future interventions aimed at achieving satisfactory health and nutrition outcomes require a combination of individual, interpersonal (household), community, and public policy initiatives. (Fitzgerald 2009; Winch 2012). Climate Change and Health Pathway (Fig. 1) provides the conceptual framework to illustrate several direct and indirect pathways leading to the climate-health relationship including food and nutrition security outcomes (McMichael and Haines 1997).

Methods

A review and synthesis of available Pacific research studies and literature in the last 20 years on climate change, food security, health and malnutrition (undernutrition) focusing on Fiji was undertaken. Google scholar, Web of Science and Pubmed were searched using key words climate change, health, food security and nutrition security and Fiji. Additional search was done using references from available literature. Grey literature was sourced from the local libraries.

Figure 1: Climate Change and Health Pathways (McMichael 2010)



A public health perspective was used to understand the issues of health and food and nutrition security against the background of climate change. A guide to the direct and indirect health effects of climate change (Clark 2014) was used in selecting studies to be included. Based on the literature, findings of the first three key questions are discussed. Thereafter, the proposed Comprehensive Conceptual framework is explained. With climate change predicted to increase EWEs and disasters in future, this framework could be used to develop possible strategies to address health and food and nutrition security.

Results and Discussion

In the last two decades, studies on climate change and health has been slowly increasing due to research awareness and support. Many of these studies in recent years have been largely concentrated on climate adaptation strategies undertaken by the collaboration of technical, development and academic organisations. This study concurs with other research that there is still a need to fill gaps in knowledge, research and practice in Fiji and the rest of the PICTs in relation to climate change and its impact on health and food and nutrition security.

Is Climate Change Happening in Fiji?

Climate and Climate Change in Fiji: Fiji has a tropical climate with two distinct seasons, wet and dry, The warm wet season occurs between November and April, and the dry and cooler season from May to October. Seasonal temperature changes is minimal and dependent on the Pacific Ocean's temperature. The annual average temperature is between 20-27°C. The average night time temperature in the central parts and the coast is 15°C and 18°C respectively.

The maximum high temperature in the country is 32°C. Fiji's average rainfall is around 1,800 mm per year. It has a variable rainfall pattern that is dependent on the several factors such as the South Pacific Convergence Zone, mountain elevations, and east or south-east trade winds including the regional climate influence of ENSO (Bell et al. 2011; SPC and CSIRO 2011).

Under the low and high emissions scenarios for 2,035 and 2,100, air temperature and rainfall based on long-term averages are projected toincrease. Surrounding ocean waters sea surface temperature, sea level and acidification are also anticipated to rise (Bell et al. 2011).

Tropical cyclones (TC) and consequent floods: A tropical cyclone is a rotating windstorm developing over several days over waters warmer than 26.5°C that also has unpredictable paths (SOPAC 2006). Several factors such as sea surface temperature, wind speeds, humidity and atmospheric and trophospheric condition determine the formation and frequency of TC (Krishna 1984; Walsh &Pittock 1998). In Fiji, TCs occur when the Southern Oscillation Index has negative values and flooding happens in all TC during El Nino (Kostaschuk*et al.* 2001).

The 2013/14 TC seasonal forecast indicated that overall, there would be above average TC activity, with 1 to 2 TC affecting some parts of Fiji, with 1 expected to reach Category three (3) or above. Also, active cloud and rain bands associated with TCs nearby Fiji were predicted to bring heavy rain and stormy conditions with anticipated flooding and storm surge in low-lying coastal areas (Fiji Meteorological Services 2013).

Floods: Major floods are associated with TCs and cause negative public health effects (Malilay 1997). An approaching TC brings heavy rainfall with increasing intensity causing runoff from saturated catchment areas resulting in extensive floods. Low magnitude floods also occur due to seasonal weather events with high intensity rainfall. Annually, 1-2 TCs with high intensity rainfall affect Fiji. The scale of the flood depends on the distance, intensity, movement and speed of the TC system. Flash floods also occur infrequently including storm surges along coastal areas. When levees and seawalls are breached, flooding occurs. Documented TC-related floods have occurred in the Rewa River, one of the most important water systems in Fiji (Kostaschuk *et al.* 2001; Raj 2004). TCs and floods in the last decade have caused heavy losses to agriculture that have had economic, food security and health impacts. As an example, the 2003 Hurricane Ami which approached rapidly brought torrential rainfalls and record-breaking floods (Terry 2005).

What are the Impacts of Climate Change in Fiji Relevant to Health, Food and Nutrition Security?

Health Impacts of Climate Change in PICTs and Fiji: Like many countries in the Pacific, Fiji needs to address future health and food and nutrition security concerns. Climate change will be one of the ecological factors that will add to the future challenges of a country undergoing socio-economic and demographic transition. The yearly monsoon season between November and April brings public health risks of injury, death and diseases. Fiji is no exception to stories of disaster and devastation due to TCs. The cyclical occurrence of ENSO has significant effects on public health with impacts of natural disaster increasing during the El Nino years (Kovats *et al.* 2003). Likewise, vector-borne diseases such as dengue fever in the South Pacific were linked to ENSO (Hales et al. 1996). Diarrheal diseases have positive association with increasing average annual temperature in El Nino years in 18 PICTs. More specifically, in the years 1978–1998, it was demonstrated that there were positive associations between increasing infant diarrhea reports in Fiji and increasing temperature and extremes of rainfall (Singh et al. 2001). Climate-sensitive health risks in the PICTs are being targeted by the WHO. In Fiji, dengue fever, typhoid fever, leptospirosis, diarrhoeal diseases remain priorities. The recent dengue outbreak, which is due to the type 3 strain that has never been seen previously, claimed 11 confirmed deaths and more than 15,000 cases and was linked to climate change (Koroitanoa 2014).

Economic Impact of Tropical Cyclones to Fiji: Tropical cyclones and its consequent flooding bring immediate damage to agriculture, infrastructure and the economy, as well as bringing demographic, land use and socio-economic changes and environmental stress. For example, TC Bebe (1972) affected the Yasawa Islands, VitiLevu and Kadavu causing 19 deaths with a reported damage bill estimated to have been more than F$20 million. In 1993, TC Kina passed the main islands of VitiLevu and Vanua Levu, causing 23 deaths and an estimated F$170 million worth of damage, making it one of the deadliest and most expensive hurricanes in Fiji's recent history. TC Cyclone Ami left fourteen people dead and an estimated cost of damage of FJ$104.4 million. TC Evan in 2012 caused $75.29 million worth of damages (Kuleshov *et al.* 2013).

Is Climate Change Affecting Health, Food and Nutrition Security in Fiji?

Climate change impact on food and nutrition security in Fiji: Traditionally, PICTs rely on subsistence agriculture and fishing practices. People eat local staples such as roots and tubers, bananas and breadfruits and rely on fish and seafood as source of protein. Since the 1970's, imported foods complemented traditional food enhancing food security. However, with this dietary consumption change, the health and nutritional outcomes of Pacific populations is at risk. Based on the 2004 National Nutrition Survey, the growth pattern of children less than five years of age showed both over and under the reference standards. Overall, 14.5% and 12.5% of children less than 18 years were overweight and underweight respectively. The prevalence of anaemia was documented to be high (33.5% in rural and 31% in urban areas). Only 40% of infants were exclusively breastfed. Vitamins and minerals were deficient in the diet of most Fijians (National Food and Nutrition Centre (NFNC) 2004).

Fiji has supported initiatives to "ensure that all their people, at all times, have physical, social and economic access to sufficient, safe and nutritious food" in conjunction with the Pacific approach to fulfil the "Healthy Islands" objectives. It has also supported land acquisition for food security for a neighbouring country, Kiribati, that has been threatened by rising sea level rise attributed to climate change (Marau 2013). Fiji's national government agenda on agriculture in recent years has been targeting commercialisation while maintaining subsistence farming, fishing and livestock as the backbone of household's food security, particularly in the rural areas.

The main produce includes palm oil, coconut, sugarcane, cocoa and coffee plantations, and beef cattle. Modern methods of farming are still underdeveloped and many challenges due to availability and quality of seeds and crop planting material, post-harvest losses, poor animal health and high cost of purchased feed, pest control and management, shortage of human labour, expensive mechanised equipment and limited and underdeveloped domestic and export marketing.

Apart from food production and supply issues, food security is impacted by a several complex factors including and most importantly the changing climate and its weather events and consequent natural hazards and disasters. Some studies have shown that with climate change, TCs will become more intense with larger peak wind speeds and heavier rainfall (FAO 2010). These projections are likely to destabilise mostly rain-fed agriculture. Crops are more likely to be frequently damaged from the increasing winds and heavier rainfall. Coastal agricultural lands will also be increasingly impacted by fresh water salinisation due to storm surges thereby decreasing overall crop yields. The life cycle of insects and plant pests could potentially devastate food sources. This was documented by the occurrence of taro leaf blight in some PICTs including Fiji which threatened the availability of traditional staple food (Singh et al. 2012). Regional and national germplasm collection was developed as a climate change adaptation (McGregor *et al.* 2012)

In terms of ocean fisheries and aquaculture, water productivity is variable and depends on the nutrients of the ocean. Fisheries will likewise be potentially vulnerable due to fish stocks moving away from the Pacific exclusive economic zones (EEZ). Some types of fish such as big eye and skipjack tuna are expected to increase but overall, the changed ocean environment can bring less catch affecting locals dependent on seafood for their protein.

Climate change impact on health in Fiji: Environmental change and natural calamities can trigger economic shocks that can also impact household food security. Food production and supply is heavily dependent on the prevailing climatic variables and food prices can increase when there is lack of supply. Increases in fuel prices also determine food price volatility. These external factors can impinge on a household's capacity to access food of different varieties. Availability and accessibility of particular types of food determine the dietary patterns and nutritional consumption of people that keep them healthy and well.

The effect of climate and weather has the ability to change the state of nutrition and food security of the population, which has important implications for the well-being of individuals, households and societies. Several PICTs have a double burden ofhigh rates of under and overweight and obesity (Grieve *et al.* 2013). One of the direct consequences of food insecurity is hunger and malnutrition.

From the 1950's, several national nutrition surveys have been conducted in Fiji. Protein-energy malnutrition, anaemia, micronutrient deficiency and recently overweight and obesity have challenged the state of nutrition of Fiji. The state of nutrition is ultimately linked to the physical and social environment. Future health and nutritional interventions will need to take into account the impact of a changing climate.

Climate change has brought a rising incidence of climate-sensitive diseases and health risks such as air, water and vector-borne diseases such as malaria (Githeko 2009; Rivera 2009), dengue fever (Colón-González *et al.* 2013), and ciguatera poisoning (Llewellyn 2010). Many climate change support activities are provided in the PICTs from numerous organisations (SPC 2012). The economic and environmental sectors are given priority but health investments seem to be scarce in comparison and need to be strengthened. Climate change and its consequences is a major public health risk of this century (Costello *et al.* 2009).

How Should We Use a Socio-Ecological Perspective to Address Issues of Health and Food and Nutrition Security in the Era of Climate Change?

Figure 2 shows the schematic diagram that explains the interrelationships among the factors that are considered in this research: EWEs, food security and population health specifically in relation to the status of nutrition and health of children at the household level. It also indicates that EWEs lead to direct and indirect impacts on the socio-economic conditions of the community and individual households (Clark 2014). This framework has been used in the Philippines and is also applicable in Fiji.

More frequent and intense EWEs occurrence such as typhoons and floods are consequences of climate change. Some factors can influence the impacts of EWEs. The physical characteristics of a locality such as watershed, existing land use, vegetation and forest cover, and river and lake system's conditions influence the environment-related problems which magnify the magnitude of the impacts of EWEs.

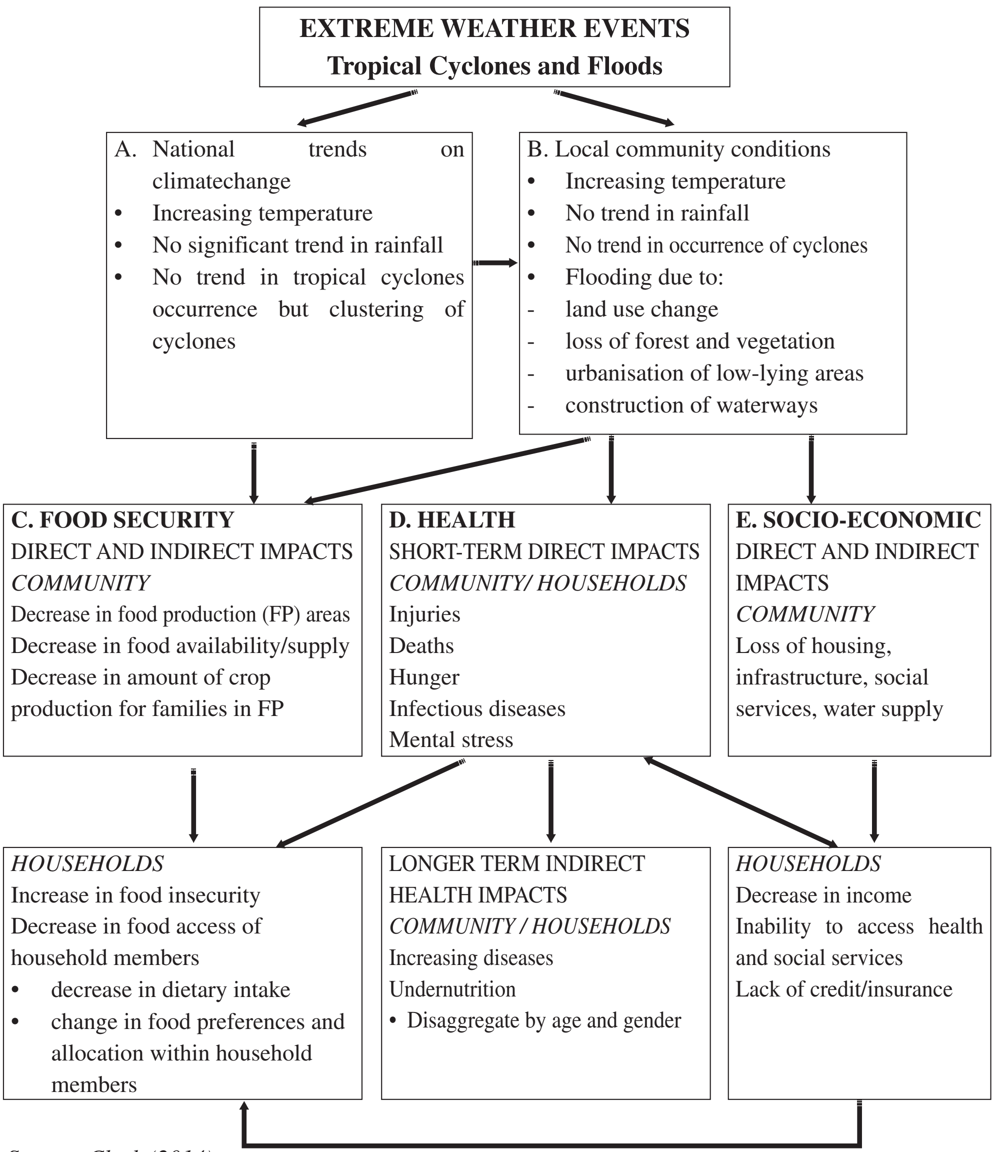
In Figure 2, Boxes A and B indicate that Fiji's climate and weather indicators showed some changes such as increasing temperature, while there appears to be no significant trends in rainfall and cyclone occurrence. The frequency of cyclones has not changed but there are suggestions of increased cyclone intensity was noted. EWEs can lead to increasing incidence of floods that impact local conditions.

Box C shows that EWEs have direct and indirect impacts on food security. EWEs can suddenly decrease food production (FP) areas which can threaten and abruptly decrease food availability/ supply. EWEs decrease the amount of crop production for families which can reduce the amount of food available for consumption. Apart from decrease in food supply, food access due to loss or lack of income leads to a decrease in dietary intake. Coping strategies in food preferences and allocation within household members are adopted.

In Box D, changes in national climate and local weather conditions can have both direct and indirect health effects at the community and households. The direct effects are injuries, deaths, initial hunger, and infectious diseases and mental stress. These short-term direct effects can compromise the health, socio-economic and food security of the household particularly if the head of household is affected. The indirect long-term health effects are changing incidence of illnesses and under nutrition. Again, these health effects are also influenced by both the socio-economic and nutritional status of the household.

In Box E, environment-related problems that cause flooding can magnify the impacts of the EWEs. It can also have socio-economic direct and indirect impacts to the community and households. In the community, EWEs can destroy infrastructure such as housing, hospitals, and communication facilities. It can also disrupt water supply and social services that are essential in maintaining health. Households during EWEs can experience a decrease in income and inability to access health and social services. EWEs also have an additional impact depending on household credit and insurance availability.

Figure 2: Extreme Weather Events, Food Security and Population Health Operational Framework



Source: Clark (2014).

Conclusion

This paper presented the evidence that climate change is happening in Fiji. The projection of increasing EWEs such as cyclones and floods present a risk to people as they transition from a subsistence to consumerist economy. This economic change including the global environmental and climate change impact health and nutrition outcomes. To be able to address the challenges of climate change including increasing EWEs and natural disaster occurrence in the context of Pacific Island countries such as Fiji in achieving health and food and nutrition security, a socio-ecological conceptual framework was deemed necessary. There are many possibilities in research, policies and programmes. Highlighting health and supporting the health sector is critical to the climate change initiatives. Reorienting all other sectors to collaboratively work and look at good health and nutrition as the end goal for all efforts to address climate change could provide a meaningful incentive to achieve a sustainable environment for healthy living. In future, this will be proof that the socio-ecological model has provided a holistic framework that can be utilised and adapted to achieve beneficial outcomes when addressing climate change.

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References

Bandura, A. 1986. *Social Foundations of Thought and Action: A Social Cognitive Theory.* Englewood Cliffs: Prentice-Hall.

Bell, J.D., J.E. Johnson, A.S. Ganachaud, P.C. Gehrke, A.J. Hobday, O. Hoegh- Guldberg et al. 2011. *Vulnerability of Tropical Fisheries and Aquaculture to Climate Change: Summary for Pacific Island Countries and Territories*. Noumea, New Caledonia: Secretariat of the Pacific Community.

Berry, H., K. Bowen, and T. Kjellstrom. 2010. 'Climate Change and Mental Health: A Causal Pathways Framework.' *International Journal of Public Health* 55 (2): 123-132.

Bowen, K.J., K. Ebi, S. Friel, and A.J. McMichael. 2013. 'A Multi-layered Governance Framework for Incorporating Social Science Insights into Adapting to the Health Impacts of Climate Change.' *Global Health Action* 6: 21820.

Bronfenbrenner, U. 1979. *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, MA: Harvard University Press.

Clark, E.L. 2014. *Extreme Weather Events, Household and Maternal Characteristics and Children's Nutrition in the Philippines: Policy and Programme Implications* (Unpublished Thesis). ACTON, Canberra: Australian National University National Centre for Epidemiology and Population Health College of Medicine, Biology and Environment.

Colón-González, F.J., C. Fezzi, I.R. Lake, and P.R. Hunter. 2013. *The Effects of Weather and Climate Change on Dengue*. PLoSNegl Trop Dis 7 (11): e2503.

Confalonieri, U., B. Menne, R. Akhtar, K.L Ebi, M. Hauengue, R.S. Kovats et al. 2007. 'Human Health.' In *Climate Change: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University.

Costello, A., M. Abbas and A. Allen et al. 2009. 'Managing Health Effect of Climate Change.' *The Lancet* 373: 937.

Emanuel, K. 2005. 'Increasing Destructiveness of Tropical Cyclones over the Past 30 years.*'* *Nature* 436: 686-688.

FAO. 2010. *Pacific Food Security Toolkit Building Resilience to Climate Change Root-crop and Fishery Production*. Rome: FAO.

Fiji Meteorological Services. 2013. *Fiji Meteorological Services Seasonal Outlook 2013/2014*. Suva, Fiji: Fiji Meteorological Services.

Fitzgerald, N. 2009. 'Barriers to a Healthy Lifestyle: From Individuals to Public Policy—An Ecological Perspective.' *Journal of Extension* 47 (1): 1-8.

Friedman, M.A., L.E. Fleming, M. Fernandez, P. Bienfang, K. Schrank, and R. Dickey et al. 2008. 'Ciguatera Fish Poisoning: Treatment, Prevention and Management.' *Mar Drugs* 6 (3): 456– 479.

Friel, S. and P.I.Baker. 2009. 'Equity, Food Security and Health Equity in the Asia Pacific Region.' *Asia Pacific Journal of Clinical Nutrition* 18 (4): 620-632.

Friel, S., M. Marmot, M., A.J. McMichael, T. Kjellstrom, and D. Vagero.2008. 'Global Health Equity and Climate Stabilisation: a Common Agenda.' *Lancet* 372: 1677-1683.

Githeko, A.K. 2009. *Malaria and Climate Change: Commonwealth Health Ministers' Update.* Centre for Global Health Research, Kenya Medical Research Institute.

Grieve, H., J. Busch-Hallen, and K. Mellor. 2013. *Under-nutrition in Pacific Island Countries: an Issue Requiring Further Attention.* ACT: Menzies School of Health Research.

Hales, S., P. Weinstein, and A, Woodward. 1996. 'Dengue Fever Epidemics in the South Pacific: Driven by El Nino Southern Oscillation?' *The Lancet* 348 (9042): 1664-1665.

IPCC. 2007. *Climate Change. Synthesis Report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report.

IPCC. 2012. *Summary for Policymakers: Managing the Risks of Extreme Weather Events and Disasters to Advance Climate Change Adaptation. Cambridge,* UK, and New York, NY, USA: IPCC.

Koroitanoa, S. 2014. *Climate Change Linked to Recent Dengue Outbreak*.
http://fijione.tv/climate-change-linked-to-recent-dengue-outbreak/

Kostaschuk, R., J. Terry, and R. Raj. 2001. 'The Impact of Tropical Cyclones on River Floods in Fiji.' *Hydrological Sciences Journal* 46: 435–450.

Kovats, R.S., M.J. Bouma, S. Hajat. E. Worrall, and A. Haines. 2003. 'El Niño and Health.' *The Lancet* 362 (9394): 1481-1489.

Krishna, R. 1984. *Tropical Cyclones*. Suva, Fiji: Fiji Bureau of Meteorology.

Kuleshov, Y., B. Prakash, T. Atalifo, A. Waqaicelua, S. Seuseu, and M.A. Titimaea. 2013. 'Impacts of Tropical Cyclones on Fiji and Samoa.' *Geophysical Research Abstracts* 15.

Llamas-Clark, E. 2011. 'Extreme Weather Events and Preserving Child Nutrition: Revising Concepts for Policy and Programmes.' *Philippine Journal of Nutrition* 58: 95-102.

Llewellyn, L.E. 2010. 'Revisiting the Association between Sea Surface Temperature and the Epidemiology of sh Poisoning in the South Pacific: Reassessing the Link between Ciguatera and Climate Change.' *Toxicon* 56 (5): 691–697.

Malilay, J. 1997. 'Floods.' In *The Public Health Consequences of Disasters,* edited by E. K. Noji, 287-301. Oxford, UK: University Press Oxford.

Manton, M.J., P.M. Della-Marta, M.R. Haylock, K.J. Hennessy, N. Nicholls, L.E. Chambers, D.A. Collins et al. 2001. 'Trends in Extreme Daily Rainfall and Temperature in Southeast Asia and the South Pacific: 1961-1998.' *International Journal of Climatology* 21 (3) :269-284.

Marau, M. 2013. Kiribati to Buy 6,000 Acres of Land in Fiji for Food Security. *Fiji Times* (Feb. 4, 2013).

McGregor, A., P. Kaoh, L. Tuioti Mariner, P.N. Lal, P. Narsey, and M. Taylor. 2012. *Assessing the Social and Economic Value of Germplasm and Crop Improvement as a Climate Change Adaptation Strategy: Samoa and Vanuatu Case Studies*. Suva, Fiji: Australian Department of Climate Change and Energy Efficiency (DCCEE), IUCN.

McLeroy, K.R., D. Bibeau, A. Steckler, and K. Glanz.1988. 'An Ecological Perspective on Health Promotion Programmes.' *Health Education & Behavior* 15 (4): 351-377.

McMichael, A.J. 2003. *Climate Change and Human Health: Risks and Responses*. Geneva: WHO.

McMichael, A.J. 2010. *Personal Communication Climate-Health Pathway Slide*. Canberra.

McMichael, A.J., D. Campbell-Lendrum, S. Kovats, S. Edwards, P. Wilkinson, and T. Wilson. 2004. Global *Climate Change*. Geneva: WHO.

McMichael, A.J. and A. Haines. 1997. *Global Climate Change: the Potential Effects on Health*.

McMichael, A.J., R.E. Woodruff, and S. Hales. 2006. 'Climate Change and human Health: Present and Future Risks.' *The Lancet* 367 (9513): 859-869.

National Food and Nutrition Centre (NFNC). 2004. *Fiji National Nutrition Survey 2004*. Suva, Fiji: NFNC.

Patz, J.A., D. Campbell-Lendrum, T. Holloway, and J.A. Foley. 2005. 'Impact of Regional Climate Change on Human Health.' *Nature* 438 (7066): 310-317.

Patz, J.A.and R.S. Kovats. 2002. 'Hotspots in Climate Change and Human Health.' *BMJ* 325: 1094-1098.

Raj, R. 2004. Integrated *Flood Management Study Fiji Islands: Flood Management Rewa River Basin*. World Meteorological Organization and Global Water Partnership.

Rivera, P.T., B.A. Crisostomo, R.U. Angluben, S. Kano (Ed.). 2009. *Climate Change and Malaria - A Baseline Study in Palawan, the Philippines*. Tokyo, Japan: Free Press Co.

Singh, D., G. Jackson, D. Hunter, R. Fullerton, V. Lebot, M. Taylor et al. 2012. 'Taro Leaf Blight—A Threat to Food Security.' *Agriculture* 2: 182-203.

Singh, R., S. Hales, N. de Wet, R. Raj, M. Hearnden, and P. Weinstein. 2001. 'The Influence of Climate Variation and Change on Diarrheal Disease in the Pacific Islands.' *Environmental Health Perspectives* 109 (2): 155-159.

SOPAC. 2006. *Tropical Cyclones Natural Hazards in the Pacific Fact Sheet 1*. Retrieved from www.sopac.org

SPC. 2012. 'SPC Climate Change Support Activities in the Pacific Island Countries and Territories.' In *Secretariat of the Pacific Community,* 14-17. Noumea, New Caledonia: SPC.

SPC and CSIRO. 2011. *Food Security in the Pacific and East Timor and its Vulnerability to Climate Change*. Noumea, New Caledonia: Secretariat of the Pacific Community.

SPC Land Resources Division. 2010. *Vulnerability of Pacific Island Countries*. Suva, Fiji: Secretariat of the Pacific Community Land Resources Division.

Stokols, D. 1996. 'Translating Social Ecological Theory into Guidelines for Community Health Promotion.' *American Journal of Health Promotion* 10 (4): 282-298.

Terry, J. 2005. 'Hazard Warning!Hydrological Responses in the Fiji Islands to Climate Variability and Severe Meteorological Events.' In *Regional Hydrological Impacts of Climatic Change: Hydroclimatic Variability,* edited by S. Franks, T. Wagener, E. Bøgh, H. V. Gupta, L. Bastidas, C. Nobre and C.O. d. Galvão, 33-41.

Wahlqvist, M.L., J.D.H. Keatinge, C.D. Butler, S. Friel, J. McKay, W. Easdownet al. 2009. 'A Food in Health Security (FIHS) Platform in the Asia-Pacific Region: the Way Forward.' *Asia Pacific Journal of Clinical Nutrition* 18 (4): 688-702.

Walsh, K. and A.B. Pittock. 1998. 'Potential Changes in Tropical Storms, Hurricanes, and Extreme Rainfall Events as a Result of Climate Change.' *Climatic Change* 39 (2-3): 199-213.

Winch, P. 2012. *Ecological Models and Multilevel Interventions, Health Behaviour Change at the Individual, Household and Community Levels Course* 224:689. Johns Hopkins Bloomberg School of Public Health.

Ecosystem Services and Livelihoods in a Changing Climate: Understanding Local Adaptations in the Upper Koshi, Nepal*

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Abstract

Mountain ecosystems are increasingly being affected by global environmental change, challenging the ubiquitous agro-ecosystem based livelihoods of the people. This paper uses participatory research methods to document and analyse 1) local and regional impacts of climate change on ecosystem services (ES), and livelihoods, and 2) the main current adaptation strategies of local people in the mountains of central Nepal. Major observed impacts include reduced precipitation and an irregular rainfall pattern, affecting paddy cultivation and winter crop production. Production is also affected by increased pest and pathogen prevalence. Other impacts include increased livestock disease and reduced forest regeneration. The results confirm earlier findings of a decrease in the district's forest cover in past; however; substantial efforts in forest conservation and management at the local level have gradually increased forest cover in recent years. Despite the increased potential for forest ecosystem services, the availability of forest goods, in particular fuel wood, fodder and litter, have decreased because of a strict regulation on forest goods extraction. Additionally, new invasive species are colonising these forests, preventing regeneration of preferred and local forest vegetation in some areas and, as a result, the densities of tree crops are changing. Most users cope with these changes by short term, reactive solutions. However, a number of local adaptation strategies, such as changing both agricultural practices and water harvesting and management are increasing efficiency in resource use. To increase the adaptive capacity of poor households, it is suggested to incorporate climate change adaptations within the local planning process.

Keywords: Climate change, Adaptation, Vulnerability assessment, Cropping pattern, Livelihoods, Local adaptive capacity.

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Introduction

Ecosystem services, the benefits that humans obtain from ecosystems, are vital for rural livelihoods. Mountain agro-ecosystems not only provide agricultural commodities such as food and fibre but also help protect biodiversity, water, carbon storage and landscape amenity. However, recent environmental change coupled with other stressorsis affecting the ability of mountain agro-ecosystems to continue to provide the quality and quantity of ecosystem services required for sustainable rural livelihoods (Gentle and Maraseni 2012; Shrestha et al. 2012; Baral 2013). For this reason, the effects of changing climate on provision of ecosystem services is becoming an increasingly important area of investigation (MEA 2005; Shrestha et al. 2012, Baral 2013; Baral et al. 2014a). Ecosystem services are defined and classified in a variety of ways as has been extensively elaborated elsewhere (MEA 2005; Boyd and Banzhaf 2007; Wallace 2007; Fisher et al. 2008, 2009; TEEB 2009). Baral et al. (2014b) outlined some influential definitions that are frequently cited in environmental literature and associated classification systems.

Global climate change scenarios suggest that there will be considerable impacts on ecosystems and their associated ecosystem services with serious consequences for the livelihoods of communities particularly in the most economically challenged parts of the world (IPCC 2001; Agrawal and Perrin, 2008; ICIMOD 2010; Isabel 2012). The Millennium Ecosystem Assessment (2005) recognises climate change as one of the major drivers of ecosystem change and argues that "*ecosystem degradation tends to harm rural populations more directly and has its more direct and severe impact on poor people*". Poor communities mostly rely on ecosystem services for their subsistence livelihoods and often have limited capacity to adapt to change, which makes them more vulnerable to climate change and other forms of changes (ICIMOD 2010). Limited access to resources, lack of diversification options for subsistence livelihoods, and lack of health and education, are some of the critical factors limiting the adaptive capacity of developing countries to climate change (Smit et al. 2000; Boon and Ahenkan 2012). The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007) projected a severe impact of climate change on mountain ecosystems, particularly because of their sensitivity to warming. The report also suggests that countries in Asia are likely to suffer from many extreme events, including glacier melts, flooding and droughts, and will have severe impacts on natural resources and the environment.

Nepal is very vulnerable to the impacts of climate change because it is spread across many altitudes from ≈70m asl to the tallest peak of the world and this then threatens its economy which is so highly dependent on land-based industries in particular agriculture. Between 1982 and 1996, the average annual mean temperature has increased by 1.5°C with an average increase of 0.06°C per annum (Shrestha et al. 2012) and, depending on which scenario is selected, recent projections indicate that this warming trend will accelerate, especially at higher elevations and during the summer (IPCC 2007a; Xu et al. 2007; Shrestha et al. 2012).

Although there is considerable spatial and seasonal variation in the Himalayas in climate and phenology, rainfall, growing season and ecosystems are changing in the Himalayas (Practical Action 2009; Shrestha et al. 2012). In general, precipitation is projected to decrease in the dry season and increase during the rest of the year for South Asia, while the reverse is true for Central Asia (IPCC 2007).

The impacts of these changes are well documented for the mountains of Nepal (Gentle and Maraseni 2012). For example, increasingly erratic rainfall, water scarcity and drought, flood and soil erosion, are affecting livelihoods of rural communities, primarily through their impact on the agriculture, forestry and pasture resources (Cannon and Muller 2010). Regmi (2007) reported a reduction in crop production in the year 2005 by 12.5% because of reduced early monsoon rainfall. While eastern Nepal received less rainfall in the same year, western Nepal suffered from a large flood which reduced crop production by 30% in the area (Regmi 2007).

The remoteness of mountain communities often means that they have limited communication and transportation and as a result, mountain communities are marginalised and more vulnerable to environmental impacts. Mountain communities alsohave limited access to other resources which means they have a relatively low capacity to adapt to these changes. While many studies discuss impacts of climate change on rural livelihoods (e.g., Ellis 2000; Boon and Ahenkan 2012), studies on the impacts on livelihoods in montane ecosystems are still very limited. In particular, in Nepal, the impacts of climate change on livelihoods need further understanding, both contextually and locally. This paper attempts to fill some of this gap and is based on research carried out in such remote communities in the mountains of the Dolakha district in Nepal. It documents and analyses – 1) major climate change impacts on agro-ecosystems and linked rural livelihoods, and 2) the main current adaptation strategies used by local communities to cope up with these changes.

Background

Climate Change Adaptation in Context of Development and Rural Livelihoods in Nepal

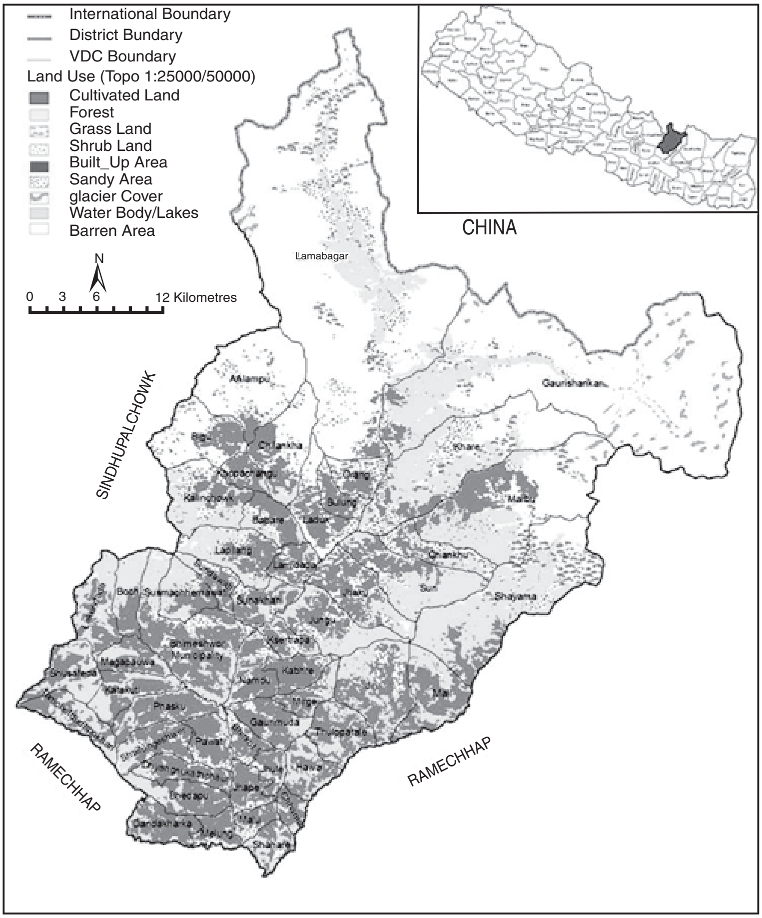
Adaptation to climate change in the context of development has been much discussed in recent years, with the discourse focussing primarily on whether adaptation is part and parcel of the development process in developing countries (IPCC 2001; Adger et al. 2003; Holmelin and Halfdan 2013). It has been argued that it is impossible to separate adaptation from development (Cannon and Muller 2010). Adaptation to climate change, as defined by the IPCC constitutes an "*adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*" (IPCC 2001, 2007). The term "adaptation" in the context of climate change impact is now mostly considered to be synonymous with the "capacity to cope with changes, reduce vulnerability and improve livelihoods" (Agrawal 2009; Orlove 2009). Adaptive capacity is contextual and varies among various segments of communities, countries, and societies, and individual, and changes over both time and scale.

Chamber and Conway (1992) describe livelihoods as a system comprising of assets, capabilities, and activities for a means of living. Different combinations of capacities and activities form different household level livelihoods strategies, which not only generate income but include many other elements, including social assets (Ellis 2000). The livelihood approach is further discussed by Hahn et al. (2009) who combine the IPCC vulnerability framework with livelihoods approach (Chamber and Conway 1992; Scoones 1998). Livelihoods are considered sustainable when they can cope with and recover from such stresses and shocks and maintain or enhance their capabilities and assets both now and in the future, while not undermining the natural resource base (Carney 1998). This definition strongly argues for and supports enhancement of the adaptive capacity of rural communities in order to ensure sustainability of their livelihoods.

Rural communities are mostly dependent on ecosystem services such as water, forest products, grass and fodder for livestock, fisheries, for their livelihoods although the priority ecosystem services may vary depending on different interest groups (Paudyal et al. 2015). Paudyal et al. (2015) found that in Dolakha district rural women'smain concern is forests as a source for firewood and while men are more concerned about timber production. Recent changes in local and regional climate, however, coupled with other drivers are affecting the continuous or sufficient supply of many ecosystem services. Availability and supply of such services is in large part weather dependent and may be seasonal. Evidence shows that communities that have been practicing adaptation to various changes in these resources for a long time have developed management decisions to cope with these changes (Dovers 2009; Alexander et al. 2010; Berrang-Ford et al. 2011; van Oort et al. 2014). However, these adaptation measures and practices vary widely and are contextualised. In particular, in developing countries and rural communities, these practices need to be understood and documented when aiming for a broader and more effective policy development (IPCC 2007a). The study presented here is part of the Himalayan Climate Change Adaptation Programme (HICAP, www.icimod.org/hicap) which links scenarios of climate change and hydrology to an assessment of vulnerability and adaptation, impacts on ecosystem services, food security, and gender issues in the Hindu-Kush Himalayas. The HICAP project has a particular focus on local level impacts and adaptation linked to sustaining livelihoods.

Ecosystem, Livelihoods and Climate Change in the Research Area

Dolakha district is a mountainous district of Nepal, varying in altitude from 723 to 7134 m above sea level (see Figure 1). The district has a human development index (HDI: 1 = best, 0=worst) of 0.450, life expectancy at birth is 63.5, human poverty index is 44.0, and adult literacy is 51.10, with an overall HDI ranking of 42 out of 75 districts in Nepal (UNDP 2004; CBS 2011). From 2001 to 2011, the population decreased by about 8.65% (CBS 2011).



Dolakha is considered to be one of the richest districts for natural resources in Nepal. Estimates of land cover vary from different sources but are roughly comparablewithon-going monitoring efforts aimed to improve the quality of these data (see e.g., www.franepal.org for current forest cover assessments). Forest and shrubs cover 47-55% of the area, followed by agriculture (≈ 26%) and pastureland (≈ 13%), unproductive land (barren/snow covered: ≈ 12-19%), and water bodies (≈0.19%) (Charmakar 2010; CBS 2011). Agriculture is the main source of income with about 67% of the population directly involved, followed by small scale enterprises and businesses. In recent years, remittances from outside the country have increased. Rain-fed agriculture is dominant with limited irrigation facilities for major crops, such as rice, wheat, millet, maize and potato. Besides agriculture, non-timber forest products (with possible added value through processing) are an important form of natural resource use (DFO 2009). Production of Nepali handmade paper, and aromatic and essential oils are major forest-based enterprises providing additional income to local communities.

In recent years, agriculture and forest interface based livelihoods have been changing along with a change in the rainfall pattern and increased drought periods (Charmakar 2010). Reduced precipitation and an irregular rainfall pattern have directly adversely affected the highly rain-dependent paddy cultivation. In addition, increased impacts from various insects pests were noticed in rice, potato and millet, reducing total production (Paudel 2013). For example, with prolonged drought, the incident of blight in potato is increasing. Similarly, with decrease in snowfall, caterpillar attack in Nepali alder (*Alnus nepalensis*) has increased. Chamrakar (2010) also reported on the direct impact of prolonged drought and less rainfall on the reduced production and quality of wintergrass (*Gaultheria fragrantissima*) used as a medicinal plant and an important source of cash income. There are a number of reasons behind the decrease in production, both in agriculture and forest crops. These include, 1) changes in rainfall patterns, 2) longer periods of drought, 3) decrease in soil moisture, 4) increased crop intensity with increased use of chemical fertiliser and pesticides and 5) consequential soil degradation. Importantly, forest cover in the region had decreased substantially between 1978 and 1994 but has increased since then due to the community forestry programme (Niraula et al. 2013; Paudyal et al. 2015). Theissuesdescribed above provide the background for the current paper and the pressing need to understand how climate may impact on local agro-ecosystems and natural resources, and how local communities are adapting to these changes.

Methods

Various toolshave been developed to assess the sustainability of land use and livelihoods, and to understand the role of stresses, risks and vulnerability of communities to climate change. These include the Poverty and Vulnerability tool (PVAT) and the Vulnerability to Resilience framework (Marshall et al. 2009; Pasteur 2010; Macchi 2011), and a number of participatory rural appraisal (PRA) techniques and tools (Chambers andConway 1992; Chambers 1994). The International Centre for Integrated Mountain Development (ICIMOD) developed a Vulnerability and Adaptive Capacity (VACA) Assessment tool, a refined version of the earlier PVAT. The ICIMOD developed VACA is based on theoretical framework on vulnerability as function of adaptive capacity, exposure and sensitivity. In each dimensions of vulnerability, a number of indicators are used to assess their significance.

In this study, PRA tools such as community resource mapping, developing seasonal calendars for agricultural and forest products and participatory rapid assessment of forest ecosystems and Focus Group Discussions (FGDs) to documentlocal knowledge and perceptions of change were used. Five FGDs, typically consisting of 12 invited persons, were organised in parallel including1) forest user groups, 2) water user groups, 3) women groups, 4) groups from the minority caste (mostly Tamang), and 5) groups from other castes (mostly Brahmin, chhetri). VACA surveys were carried out at household and community level throughout the Hindu Kush Himalayan region between 2011-2013, covering a total of 366 villages and 8,048 households in four countries, 120 villages and 2,311 households of these being in Nepal. For this paper, the VACA analysis was limited to 385 households in the

Dolakha district in Nepal, with a focus on local perceptions of the climate change impacts on community livelihoods, what local adaptation measures had been used to cope with these changes, and whether there were local social institutions to support such adaptation processes. In order to understand the significance of local contexts the VACA analysis was complemented by five semi-structured focus group discussions and five key informant surveys in one ward within the Lakuridanda Village Development Committee (VDC) of the Dolakha district. Additionally, an ethnographic analysis was conducted through a questionnaire to all households located within the ward. The VACA survey was based on a random sampling design across seven representative districts and several villages in the Koshi river basin. In the VACA, the head of household, which in most cases was male, was the informant for questionnaire. However, if the head of household was not available, the next most senior person was interviewed.

Finally, historical meteorological data comprising daily and annual maximum and minimum temperature and precipitation data from the local meteorological station at Jiri were compared with local perceptions of change. This comparison provides anindication of how recent climatic changes, if any,have been experienced, what impacts are attributed to these, and what adaptation measures (if any) had been implemented. This approach 'validates' qualitative experiences with quantitative measurements.

Here, the Millennium Ecosystem Assessment (MEA 2005) definition of ecosystem services 'the benefits people obtain from ecosystems' was considered. Community surveys indicate the ecosystem services that are recognised and prioritised at the local level as those that affect livelihoods. As such, provisioning services (products) from forests and agro-ecosystems, and water were particularly considered. Water, has become a key issue in the research area and has multiple impacts, particularly on the production of forest and agriculture products. Changes in these services were covered through questions regarding perceptions of change in the VACA survey and the complementary focus group and key informant discussions.

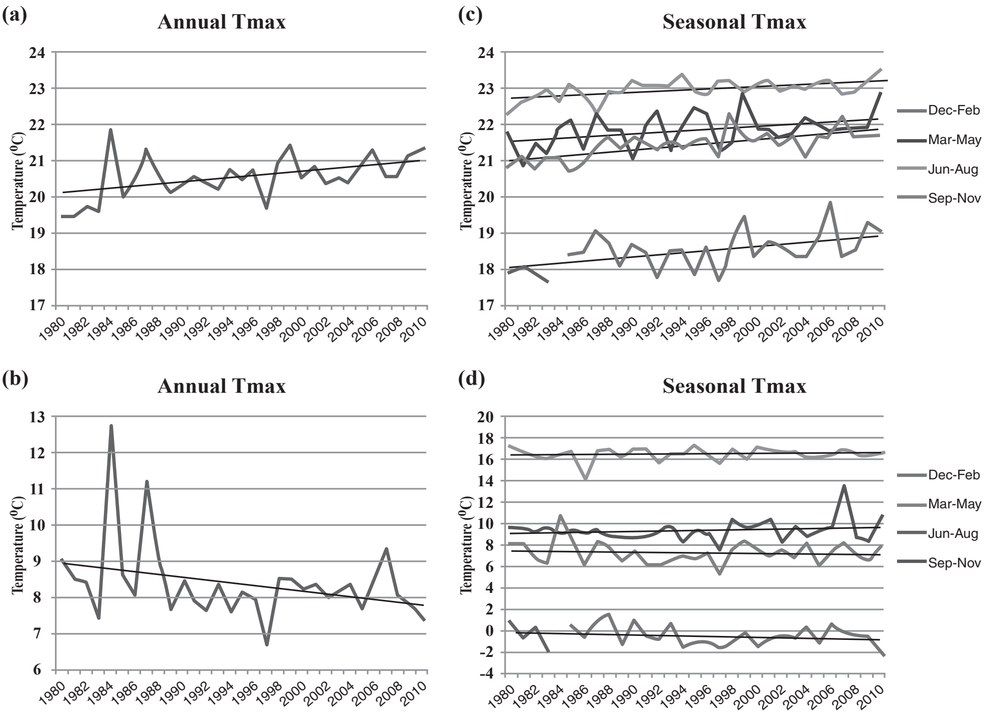
Result and Discussion

Changes in Climate and Natural Hazards

Changes in Temperature

Temperature data from the Jiri meteorological station over the period 1980-2010 show an increasing trend with an increase of approximately 1°C in the annual average max temperature. Since there is also a decreasing trend of the same order of the annual average minimum temperature, this indicates that the annual average temperature has remained the same, but that temperature variation has increased (Figure 2a, b). A more detailed examination of the data (Figure 2c, d) shows that the increasing trend of maximum temperatures is mainly due to increasing autumn and winter maximum temperatures of about 2°C. Spring and summer average maximum temperatures increased as well, but only by about 1°C. The annual decrease of minimum temperatures is mainly due to a decrease of winter minimum temperatures, of about 1°C.

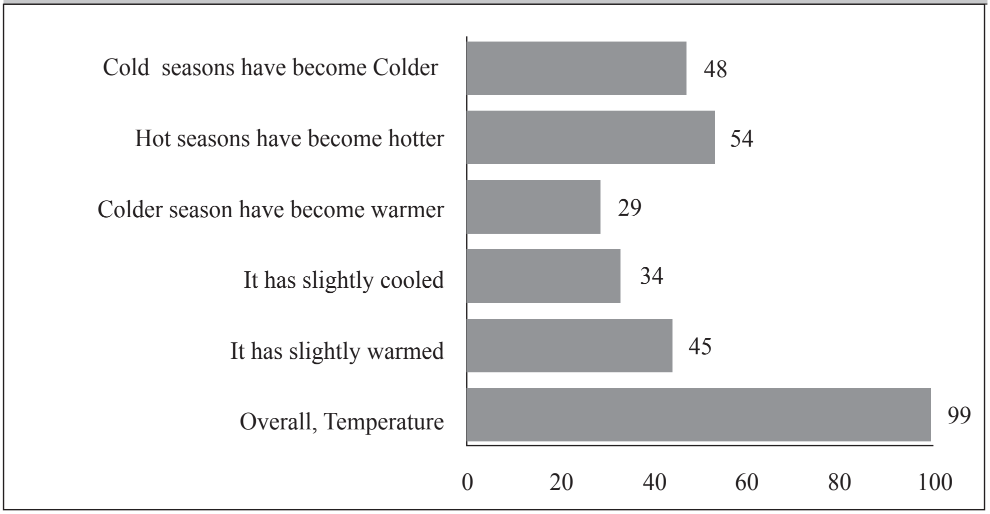
Figure 2: Variation in Mean Annual Maximum and Minimum Temperatures 1980-2010



The figure shows variation in a) annual average maximum temperatures; b) annual average minimum temperatures; c) seasonal average maximum temperatures, and d) seasonal average minimum temperatures. While winters and autumn have become warmer on average, the variation in temperatures has increased: average maximum temperatures increased by up to 2°C, but minimum temperatures decreased by ~ 1°C. (Source: Department of Hydrology and Meteorology, Government of Nepal).

Community perceptions and opinions, emanating from discussions on climate change directly and in the context of water availability and changes in phenology of some agriculture and forest crops, were in agreement with observed meteorological changes. Both indicate an increasing trend in maximum temperature. VACA data (Figure 3) indicate that 380 out of 385 household members answered positively on having noted a change in overall temperature, with most stating that the hot seasons have become hotter. Another perception was that colder seasons have become colder. Meteorological data shows that the average minimum temperatures in winter indeed have decreased by ≈1°C. However, the maximum temperatures in winter have increased by ≈2°C; so on average winters have in fact become warmer by ≈1°C, which conflicts with the general perception. This misconception that winters have become colder (instead of warmer) may be due to people referring to night-time or daily minimum temperatures which have indeed decreased over time, and not to the simultaneous increase of day-time or daily maximum temperatures. Finally, people experienced climate as more variable than before, which was also reflected by the increasing difference between observed annual mean minimum and maximum temperatures (Figure 2 a, b).

Figure 3: Top Five Perceived Changes in Temperature over 2003-2013 (In %)



Changes in Precipitation

Table 1: Changes in Average Rainfall Patterns (in mm) from 1980 to 2010

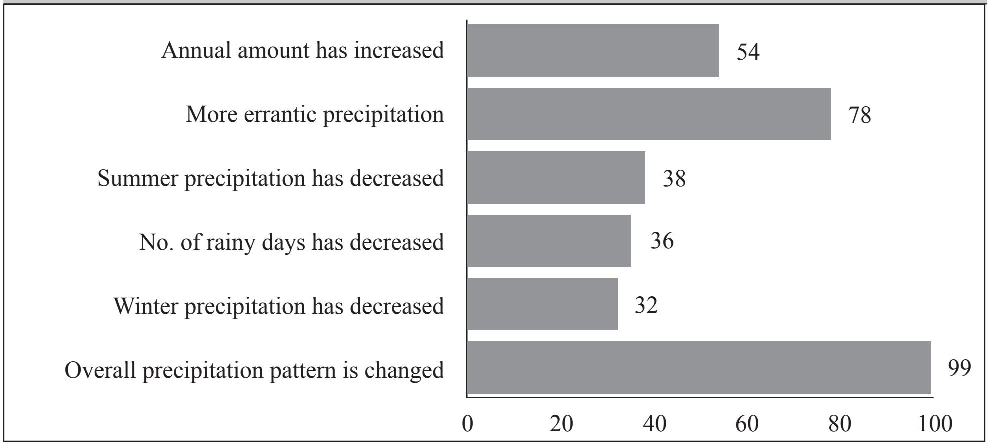
Range (in years)	Average Annual	Winter (Dec-Feb)	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep)	Post Monsoon (Oct-Nov)
1981-1990	5.843	0.561	3.113	14.271	1.004
1991-2000	6.597	0.527	3.512	16.035	1.453
2001-2010	6.640	0.619	3.498	16.127	1.409

Source: Department of Hydrology and Meteorology, Government of Nepal.

Table 1 shows the recorded change in precipitation for the last 30 years. The mean annual precipitation in Dolakha district from 1980 to 2010 is 2636 mm, which is greater than the national average (MoE 2010). The monsoon precipitation has seen a slight increase over time, especially from the '80s to the 90s'. The data also show that there has been an increase in the total annual precipitation in the first decade of the current century, and that this was due to increased precipitation in the winter and the monsoon, while the pre- and post-monsoon periods have been dryer than in the 90s.

Ninety nine percent of household members noted a change in precipitation over the last ten years, agreeing with the climate measurement observations (Figure 4). There was also a perceived increase in annual precipitation, but with rain being more intense and spread over fewer days. Also, rainfall was said to be less in both summer (monsoon) and winter (dry period), and more erratic.

Figure 4: Top Five Perceived Changes in Rainfall Pattern over 2003-2013 (In %)



Perceived Impacts on Livelihoods

Major Natural Hazards to Livelihood Resources

Communities identified eight major hazards affecting the availability and quality of their livelihood resources (Table 2), including (ranked by severity of impact); erratic rainfall, increased pests and pathogens in agricultural crops, livestock disease, and drought (particularly affecting paddy crops and vegetables). The changes in climate increase the hazard and risks. Increases in temperature and decreases in snowfall increase the risk of pests and pathogen. Similarly, erratic rainfall and hailstorm destroys the crops and increase flood risks. Single events may also have an impact on the response. For example, in 2012, frost damaged potato crops in some of the potato growing areas, such as the Lakuridanda VDC. The severity of impact was perceived from minimal to very high, with some communities experiencing (and being impacted by) frost more than others.

Table 2: Major Climatic Hazards to Livelihoods and their Perceived Severity in Percentages

Major Hazards	**Perceived severity of impact on livelihoods resources** Drought	**Percentage of respondents**
Drought	Medium to High	Medium to High
Erratic rainfall	High	High
Crop pests	High	High
Livestock disease	Medium to high	Medium to high
Hailstorm	Minimum to medium	Minimum to medium
Frost	Medium (very high in 2012)	Medium (very high in 2012)

Source: Household Survey, 2012 Dolakha District Nepal.

Forest Products Availability and Change Pattern

Focus group discussions, and also timeline analyses, indicated a changing trend in both rainfall intensity and snowfall. Local communities observed that snowfall regulates the pests in forests. With decrease in snowfall and increasing temperature trend, more pests and diseases in tree crops were witnessed. Additionally, heavy rainfall in short bursts increases surface run-off with little increase in soil moisture. Whether related to the above or not, local observations suggested that seedling survival in regenerating forest has become very reduced in recent years with resulting lower cash income for commercially valuable non-timber forest species, such as Lokta (Daphne species).

With changes in climate and especially precipitation, community perceptions suggest that the productivity of forest crops has reduced, although these links need further scientific investigation. Perceptions and observations resulting from the analysis of focus group discussion are presented in Table 3. One of the participants of focus group discussion at Lakuridanda mentioned changes in tree phenology and altitudinal shift as follows;

> *"I have noticed early flowering of some plants like Guras (Rhododendron species), Painyu (Prunus ceracoides). Similarly, plants like dudhilo (Ficus nemoralis), bhimsenpate (Buddleja asiatica) were previously only found on lower altitude but nowadays they are found at higher altitudes. It has been nearly 10 years since we have witnessed the change"*
>
> ***- Dawa Lama, Lakuridanda FGD.***

Although, forest cover in the area has been increasing at an average rate of 2.0% per year (Niraula et al. 2013), extraction of forest products from community forests is strictly regulated hence restricting local community access to these new resources. The increasing spread of invasive weed species such as *L. camara*, and *Eupatorium* reduce natural regeneration of local species, although the impacts of these invasives on forest regeneration needs further investigation.

Table 3: Major Forest Products for Community Livelihoods and their Changing Availability

Major forest products (Ecosystem goods)	Average use pattern per household	Change Trend on availability
Timber for house construction	As per requirement (once at the time of house construction). However, there is limited timber available in Community Forests (CF).	Stable
Timber of other use	As per requirement, need to pay royalty to Community Forest User Group committee (CFUG)	Stable
Fuel wood	CF opens twice a year, normally at the time of pruning, thinning for fuel wood collection.	Stable
Leaf litters (3)	CF opens 1-2 times per year for one month. Leaf litter is also supplied from private land.	Slightly declining
Pine needles, leaf litter for compost	As part of leaf litter	Slightly declining
Ningalo (Arundinaria species)	Limited *Ningalo* (Arundinaria species) available in CF, mostly in private land.	Heavily declining
Medicinal and aromatic plants	Many species of medicinal and aromatic plants available.	Some species such as *Nagbeli (Lycopodiumclavatum)* declining
Grass/fodder	Oak is primary fodder species supplying major fodder for livestock in the area. *Kutmiro (Litsea poliantha), Dudhilo (Ficusnemoralis*) are available in private land.	Declining
Lokta (Daphne species)	Two species available. Major source of income of poor households. Raw material for Nepali Handmade paper.	*Sikre (Daphne bhaula)* declining

Effects on Agriculture Practices and Production

Perceived impacts of a changing climate on agriculture practices and production are key topics of discussion in communities. Local observations of a decrease in water availability were attributed to increasing temperature and with reduced snowfall are considered to be major reasons for current changes in agricultural practices and cropping patterns. For example, communities in Lakuridanda VDC used to cultivate wheat and paddy in downstream sites when there was sufficient water available. However, they now no longer cultivate paddy as there is insufficient available water, reflecting the observed reduction in rainfall over the last 10 years. Similarly, some of Tamang community members mentioned that production of wheat in winter is reduced because of increasing winter drought. Some of the participants of the local focus group discussion mentioned a 50% reduction in production of winter vegetables. These potential impacts of climate change on cropping patterns and reduced production are reflected in an increased market demand, resulting in an increased focus on cultivation of vegetable crops instead of cereal crops in an area that in fact may not be suited for this.

Potato is one of the major cash crops for many poor families, but its cultivation also may be at risk due to water shortage and heavy rainfall events. One of the key informants during the interview stated;

> *"Before, due to the heavy snowfall and frost, the soil used to be moist throughout the year but nowadays soil has become drier causing difficulty even for potato cultivation. Moreover, in few years to come the possibility of water shortage has been sensed to increase such that the farmers are less hopeful for better cultivation (especially potatoes). Even during rainy season when the potato plants are big enough, they often get destroyed by heavy and erratic rainfall."*
>
> ***- Key Informant, Lakuridanda VDC***

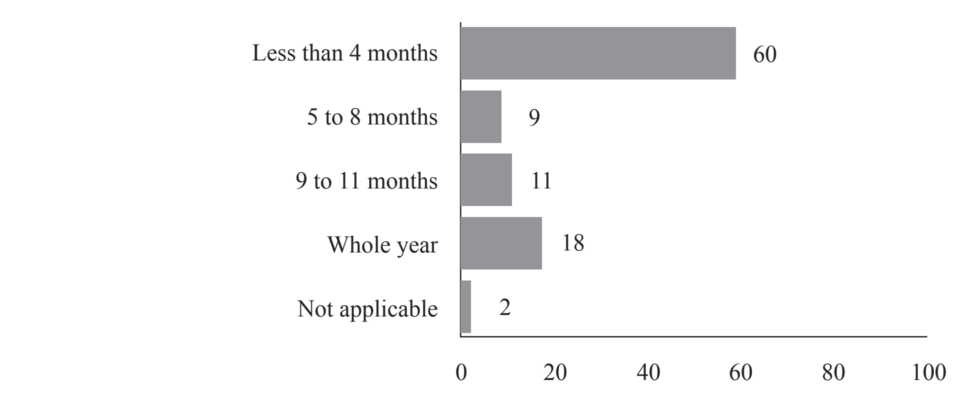
Livestock farming has been an important source of income for majority of population. There is a very famous saying in the village "Oon bechi sun lagau" which literally means "sell wool and wear gold" but now the situation has changed with the decline in sheep farming in the area. Rearing of sheep and Himalayan goat has drastically declined in recent years due to decreasing availability of grass/pasture for rearing. Farmers claim that the grass gets dry earlier or alternatively that there is a reduction in growth of grasses due to the drought.

The VACA analysis shows that there is a reported decrease in production of major cash and staple crops over the last 10 years. With a decrease in production of major crops, farmers have been introducing improved hybrid varieties of crops (see Figure 7). Data show that 7% of households considered use of hybrid seed as part of their adaptation strategy, as productivity from native varieties continued to decline.

Change in Water Availability

Reducing water availability appears to be the key issue impacting local livelihoods in the area. Members of the water management committees indicated in focus group discussions that many natural springs were drying up and that water availability has been reduced by ≈ 25%. Key informants indicated that one of the reasons for drying up of water springs was the increase in areas of monoculture pine plantation. According to them, pine plantations were introduced about 25 years ago when there were many natural water springs. Many of the water springs within pine forests are now dry. Local communities perceived that pine trees absorb a lot of water, reducing the underground water level. Additionally, they mention the effects of increased surface water runoff because of the understory of pine needles. Other studies on this topic in forests in Nepal suggest that planted pine forest has a greater evapotranspiration rate than natural forest or degraded land, and that this could be the reason for drying water resources in the middle hills in Nepal (Baral, 2011).VACA results suggested that availability of water for household use is still sufficient to meet demand, but not for agriculture. Of 385 respondents, 257 households have sufficient water for agriculture for less than six months in a year. Figure 5 provides details on perceived water availability for agriculture in a year.

Figure 5: Perceived Water Sufficiency for Agriculture Use during the last 12 Months (in %)



Local Institutions and Governance

Success of ecosystem management in developing countries is dependent on sound governance structures at various levels, in particular at the local level. Good Governance is discussed by many scholars as central to successful adaptation.Cannon and Muller-Mahn (2010) used the term adaptive governance which they considered part of institutional planning and argued for the need of critical assessment. Ribot (2011) considered good government is important and governing requires checks and balances. The checks and balances come from synergy and collaborative efforts while supporting government actions by various actors collectively rather than working in isolation (IPCC 2007b). Nepal's national adaptation plan of action identified six thematic areas of urgent focus to address issue of climate change while emphasising the need for an integrated approach between the various actors and economic sub-sectors. However, both vertical and horizontal coordination is often an issue while implementing at the local level (Bhatta et al. 2014; Gentle and Maraseni 2012; Ojha 2013). Focus group discussants also highlighted the need for synergy and collaboration among various institutions working in the areas for collective action in order to achieve concrete outcomesfor local livelihoods in adapting to climate change and other forms of changes.

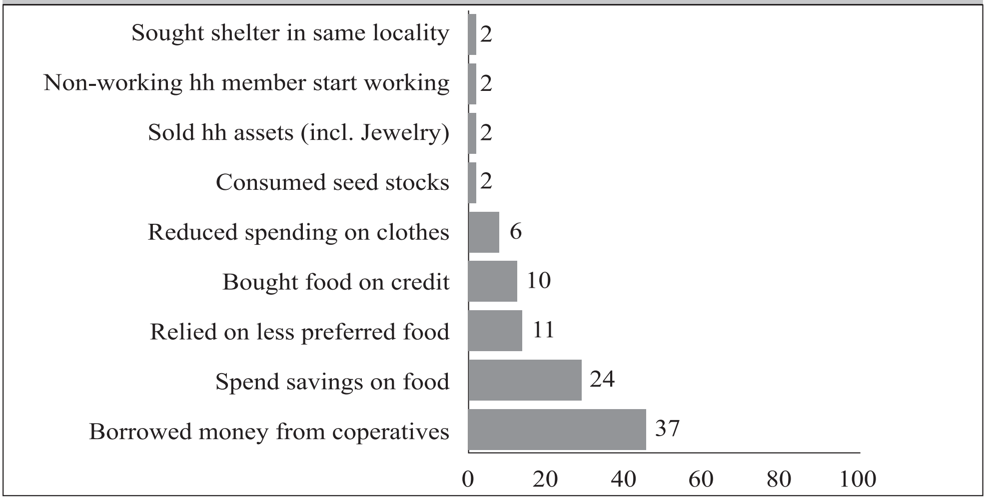
There are number of institutions providing services to the communities in the research area, for example, village development committees (VDCs), Community forest user groups (CFUGs), water management groups, saving and credit groups, and the agriculture service centre. CFUGs are considered to be very important institutions as they are mandated to manage local forest resources. VDCs are also important institutions in providing services in managing ecosystem services, and providing support for local adaptation strategies. However, participants of focus group discussions and also the key informant survey suggest that VDC plans are mostly focusing on infrastructure development. The district plans also fail in providing local adaptations in managing ecosystem services. Implementations of the activities from district line agencies, such as soil conservation, are in isolation from rather than being part of coherent and collective planning. There is a strong need for integrated planning and long-term capacity development of stakeholders at the local level to cope with recent environmental challenges.

Major Adaptation Practices

Global discussions on climate change are shifting from an emphasis on vulnerability (Orlove 2009) and active adaptation has now become central to the global climate change debate (Dovers 2009). Adaptation is now discussed as enabling communities to cope, and improve livelihoods in the light of climate stress and shocks (Agrwal 2009; Orlove 2009). Local communities have been practicing various adaptation measures based on their immediate needs. Sometimes thishas been referred to as unplanned or autonomous adaptation. However, greateradaptive planning is needed to increase the capacity of communities to cope with decreased water availability, crop failure and the resulting decrease in food production.

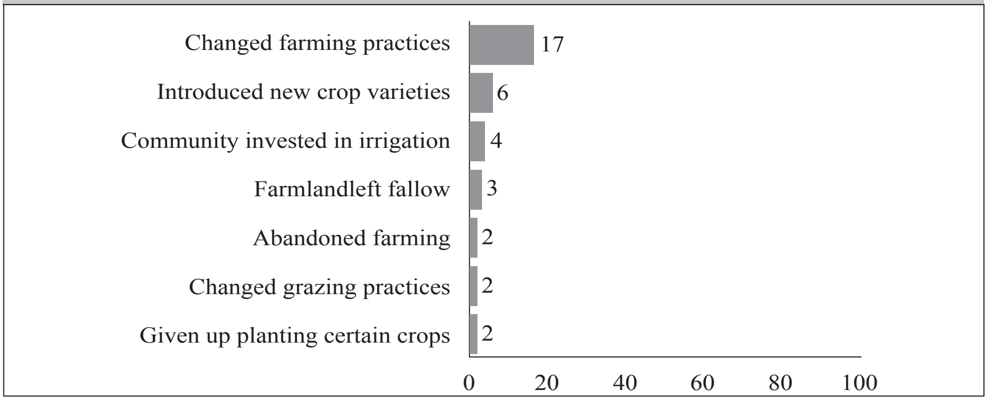
Focus group discussions suggested that communities are concerned with the immediate and short term as well as in developing long term coping strategies. Their ability to adopt these strategies is mostly based on their ability in terms of economy, and external support form society and other actors. Examples of short-term solutions during times of scarcity include selling of household property and livestock, reduced spending on clothes, consuming seed stocks, and looking for labouring jobs in other villages (Figure 6). Also rainwater harvesting has been introduced by some of the households. A majority of households borrowed money as a loan and considered this as a short-term and immediate strategy to deal with crop failure and scarcity.

Figure 6: Major Coping Mechanisms to Deal with Changes over 2003-2013 (in %)



Major long-term adaptation strategies (Figure 7) were found especially in the relatively wealthy households who owned land for agriculture, but some changes of practices appear to be independent of the state of the economy. Long-term solutions indicated by households included exploring improved varieties of seed, use of different agriculture practices requiring less water, and giving up growing some crops which require more water. Sustainable management of these ecosystem services must to be introduced to secure sustainable rural livelihoods and to avoid further unsustainable water- and land use and soil depletion. Additionally, some of those who can afford it have started to make investments in small-scale irrigation schemes.

Figure 7: Major Adaptive Strategies to Deal with Changes Observed over 2003-2013 (In %)



Conclusion

Community perceptions and experiences, supported by meteorological data, reveal that changing climate is negatively impactingon the provision of various ecosystem services and the livelihoods of local communities in the research area. Erratic rainfall, snowfall, and prolonged drought are the major climatic hazards which pose greatest risk on agricultural production, the major source of livelihoods. Additionally, forest products, in particular commercial non-timber forest products, and livestock rearing, particularly sheep and Himalayan goat, are also under threat. These threats and risks increase the vulnerability of low income farmers, in particular those who do not have the capacity for short- to long-term adaptation. Water, particularly for agricultural use, has become a scarce resource and often more so at some times of the year. With the observed drying up of natural springs, water availability has reduced substantially; forcing farmers to either change their agricultural practices or abandon agriculture.

Farmers have been practicing a range of both short-term and long-term strategies to deal with climate change impacts. The strategies cover both immediate and reactive solutions motivated by an imminent crisis (coping) as well as adaptation strategies which involved planning and are part of a more continuous process. The majority of farmers have borrowed money to cope. However, access to loans is limited and there is a need to diversify available financial services. Shifting agriculture practices from cereal crops to vegetables and introducing new varieties of agriculture crops are other major long-term adaptive strategies. It is suggested that investigations of more drought-tolerant varieties of crops might be a useful alternative adaptive strategy rather than the introduction of new exotic varieties of agricultural crops. The increasing impact of invasive weeds and insect pest species, in particular in reducing natural regeneration of forest crops, is a major threat to the supply of forest products. The degree of the impact of these species, however, needs further investigation.

Adapting to climate change is not just a technical issue and cannot be addressed in the same way as some dimensions of development and governance. It is suggested that climate adaptation needs to be considered in a wider context within the development dimension rather than in isolation. To increase the adaptive capacity of poor households, we suggest incorporating climate change adaptations within the local planning process. Additionally, local development infrastructures play a crucial role in increasing the adaptive capacities of communities and local governments can play crucial role in developing such infrastructures. The development dimension of climate change adaptation should focus on: (1)increased provision of agriculture services, including access to financial institution (2) crop and livestock insurance could be viable options to limit the impact of crop failures resulting from climate change, (3) securing land tenure and increased access to livelihood resources, including forest resources and finally, (4) strengthening the capacity of local governments such as VDC, DDC and associated local institutions to reduce the vulnerability and increase the adaptive capacity of local communities.

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References

Adger, W.N, S. Huq, K. Brown, D. Conway, and M. Hulme. 2003. 'Adaptation to Climate Change in the Developing World.' *Progress in Development Studies* 3 (3): 179-195.

Agrawal, A. 2009. 'Local Institutions and Adaptation to Climate Change.' In *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*, edited by R. Mearns, A. Norton, 173–198. Washington, DC: The World Bank.

Agrawal, A, N. Perrin. 2008. 'Climate Adaptation, Local Institutions and Rural Livelihoods.' *IFRI Working Paper Wo81-6*. International Forestry Resources and Institutions Programme, University of Michigan.

Alexander, K.S., J. Millar, N. Lipscombe. 2010. 'Sustainable Development in the Uplands of Lao PDR.' Sustainable Development 18 (1): 62–70.

Baral, H. 2013. *Ecosystem Goods and Services in Production Landscapes in South-eastern Australia* (Dissertation). Melbourne: Melbourne School of Land and Environment, The University of Melbourne.

Baral, H., R.J. Keenan, S.K. Sharma, N.E. Stork, and S. Kasel. 2014a. 'Economic Evaluation of Ecosystem Goods and Services under Different Landscape Management Scenarios.' *Land Use Policy* 39: 54-64.

Baral, H, R.J. Keenan, N.E Stork, S. Kasel. 2014b. 'Measuring and Managing Ecosystem Goods and Services in Changing Landscapes: a South-east Australian Perspective.' *Journal of Environmental Planning and Management* 57 (7): 961-983.

Baral, T.R. 2011. *Evapotranspiration from Natural and Planted Forest in the Middle Mountains of Nepal* (dissertation). Enschede, University of Twente, the Netherlands.

Berrang-Ford, L., J.D. Ford, and J. Paterson. 2011. 'Are We Adapting to Climate Change?' *Global Environmental Change* 21 (1): 25-33.

Bhatta, L.D., B.E.H. van Oort, I. Rucevska, and H. Baral. 'Payment for Ecosystem Services: Possible Instrument for Managing Ecosystem Services in Nepal.' *International Journal of Biodiversity Science, Ecosystem Services & Management* 10 (4).

Boyd, J., S. Banzhaf. 2007. 'What are Ecosystem Services? The Need for Standardised Environmental Accounting Units.' *Ecological Economics* 63 (2–3): 616–626

Boon, E., A. Ahenkan. 2012. 'Assessing Climate Change Impacts on Ecosystem Services and Livelihoods in Ghana: Case Study of Communities around Sui Forest Reserve.' *Journal of Ecosystem & Ecography* 2013.

Cannon, T.,D. Muüller-Mahn. 2010. 'Vulnerability, Resilience and Development Discourses in Context of Climate Change.' *Natural Hazards* 55 (3): 621-635

Carney, D. 1998. 'Implementing the Sustainable Rural Livelihoods Approach.' In *Sustainable Rural Livelihoods: What Contribution can We Make?*, edited by D. Carney. London: Department for International Development, UK.

CBS. 2011. *Environment Statistics of Nepal* 2011: 200. Kathmandu: CBS Nepal.

Chambers, R. 1994. 'The Origins and Practice of Participatory Rural Appraisal. '*World Development* 22 (7):953–969.

Chambers, R., G. Conway. 1992. 'Sustainable Rural Livelihoods: Practical Concepts for the 21st Century.*' IDS Discussion Paper* 296. Brighton, UK: Institute of Development Studies.

Charmakar, S. 2010. 'Exploring Existing Local Adaptation Practices and Potential Strategic Options to Address Climate Change Impact on Biodiversity and its Dependents of Nepal.*' Report submitted to National Adaptation Programme of Action/Ministry of Environment, Government of Nepal, Kathmandu.*

Dovers, S. 2009. 'Normalising Adaptation.' *Global Environmental Change* 19:4–6.

Ellis, F. 2000. *Rural Livelihoods and Diversity in Developing Countries.* Oxford, UK: Oxford University Press.

FAO. 1999. *Forest Resources of Nepal - Country Report*. Rome: FAO. Accessible at ftp://ftp.fao.org/docrep/fao/007/ae154e

Fisher, B., R.K. Turner. 2008. 'Ecosystem Services: Classification for Valuation.' *Biological Conservation* 141 (5): 1167-1169.

Fisher, B, R.K. Turner, P. Morling. 2009. 'Defining and Classifying Ecosystem Services for Decision Making.' *Ecological Economics* 68 (3): 643-653.

Gentle, P., T.N. Maraseni. 2012. 'Climate Change, Poverty and Livelihoods: Adaptation Practices by Rural Mountain Communities in Nepal.' *Environmental Science and Policy* 21:24–34.

Hahn, M.B, A.M. Riederer, S.O. Foster. 2009. 'The Livelihood Vulnerability Index: A Pragmatic Approach to Assessing Risks from Climate Variability and Change.' *Global Environmental Change* 19: 74-88.

Hannah, L., T.E. Lovejoy, S.H. Schneider. 2005. 'Biodiversity and Climate Change in Context.' In *Climate Change and Biodiversity*, edited by T.E. Lovejoy, L. Hannah. New Haven, CT USA and London, UK :Yale University Press.

Holmelin, N, T.A Halfdan. 2013. 'Flexibility of Scope, Type and Temporality in Mustang, Nepal. Opportunities for Adaptation in a Farming System Facing Climatic and Market Uncertainty.' *Sustainability* 5 (4):1387-1405.

ICIMOD. 2010. 'Climate Change Impact and Vulnerability in the Eastern Himalayas.' *Synthesis Report*. Kathmandu, Nepal: International Centre for Integrated Mountain Development.

IPCC. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Cambridge, UK: Cambridge University Press.

IPCC. 2007a. 'Summary for Policy Makers.' *In Climate Change: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

IPCC. 2007b. *Assessment of Adaptation Practices, Options, Constraints and Capacity*. Cambridge University Press, Cambridge

Macchi, M., A.M.Gurung, B. Hoermann, and D. Choudhury. 2011. *Climate Variability and Change in the Himalayas: Community Perceptions and Responses.* Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD).

Marshall, N., P. Marshall, J. Tamelander, D. Obura, D. Malleret-King, J. Cinner. 2009. *A Framework for Social Adaptationto Climate Change: Sustaining Tropical Coastal Communities and Industries*. Switzerland: IUCN.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

Niraula,R.J., H. Gilani, B.K. Pokharel, F.M. Qamer. 2013. 'Measuring Impacts of Community Forestry Programme through Repeat Photography and Satellite Remote Sensing in the Dolakha District of Nepal.' *Journal of Environmental Management*. 126: 20-29.

Ojha, H. 2013. 'Misplaced Adaptation.' *Kantipur Daily Vernacular*. http://www.ekantipur.com/2013/03/05/top-story/misplaced-adaptation/367979.html .

Orlove, B. 2009. 'The Past, the Present and some Possible Futures of Adaptation.' *In Adapting to Climate Change: Thresholds, Values, Governance,* edited by W.N Adger, I. Lorenzoni and K. O'Brien, 131-163. Cambridge:Cambridge University Press.

Pasteur, K. 2010. *From Vulnerability to Resilience: A Framework for Analysis and Action to Build Community Resilience*. UK: Practical Action.

Paudel, P. 2013. *Climate Change Vulnerability of Mountain Agriculture: A Case from Sushma Chhemawati VC, Dolakha District* (Dissertation). Kathmandu, Nepal: Tribhuvan University.

Paudyal, K., H. Baral, B. Burkhard, S.P. Bhandari, R.J. Keenan. 2015. 'Participatory Assessment and Mapping Ecosystem Services in Data Poor Region: Case Study of Community-managed Landscape in Central Nepal.' *Ecosystem Services* 13: 81-92.

Practical Action. 2009. *Temporal and Spatial Variability of Climate Change over Nepal* (1976-2005). Kathmandu, Nepal: Practical Action Nepal.

Regmi, H.R. 2007. 'Effect of Unusual Weather On Cereal Crops Production And Household Food Security.' *Journal of Agriculture and Environment* 8: 20-29

Ribo, J. 2011. 'Vulnerability before Adaptation: Towards Transformative Climate Action.' *Environmental Change* 21: 1160-1162

Scoones, I. 1998. *Sustainable Rural Livelihoods: A Framework for Analysis*. IDS Working Paper 72. Brighton, UK: Institute of Development Studies.

Shrestha, U.B., S. Gautam, K.S. Bawa. 2012. 'Widespread Climate Change in the Himalayas and Associated Changes in Local Ecosystems.' *PLoS One* 7 (5):1-10.

Smit, B., I. Burton, R.J.T. Kelin, J. Wandel. 2000. 'An Anatomy of Adaptation to Climate Change and Variability.' *Climate Change* 45 (1): 223–251.

TEEB. 2009. *TEEB for National and International Policy Makers. Summary: Responding to the Value of Nature.* Geneva: UNEP.

UNDP. 2004. *Reducing Disaster Risk: A Challenge for Development. Geneva*: UNDP. http://www. undp.org/cpr/whats_new/rdr_english.pdf

van de Sand, I. 2012. 'Payments for Ecosystem Services in the Context of Adaptation to Climate Change.' *Ecology and Society* 17 (1): 11.

van Oort, B., L.D. Bhatta, H. Baral, R.K. Rai, M. Dhakal, I. Rucevska, R. Adhikari. 2014. 'Mapping Community Values for Ecosystem Services in Koshi River Basin, Nepal.' *Ecosystem Service.* DOI: 10.1016/j.ecoser.2014.11.004

Wallace, K. 2007. 'Classification of Ecosystem Services: Problems and Solutions.' *Biological Conservation* 139 (3-4): 235-246.

Xu, J., A. Shrestha, R. Vaidya, M. Eriksson, K. Hewitt. 2007. *The Melting Himalayas: Regional Challenges and Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods.* Kathmandu, Nepal: ICIMOD.

A Study to Investigate Sustainable Adaptation to Drought among Nomads in Iran*

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Abstract

The purpose of this research was to explain adaptation to drought in the context of sustainability among Nomads in Iran. Validity of the research instrument was confirmed by the research group and α *Chronbach Coefficient was applied for the purpose of reliability through which* α*=0.89 was obtained. As sample for the study, 216 Nomads families were selected using stratified proportional sampling method. Findings of the study show that risk management and crisis management are two essential factors for short and long term adaptation to drought in Nomads. Moreover resilience is often associated with diversity of human opportunity, and economic options that support and encourages both adaptation and learning.*

Keywords: Drought, Adaptation, Sustainability, Nomads, Exploratory Factor Analysis (EFA).

Introduction

The most vulnerable agricultural systems occur in arid, semi-arid and dry sub-humid regions in the developing world, where high rainfall variability and recurrent droughts and floods regularly disrupt food production, and where poverty is pervasive (World Bank 2010, 3).

The frequency of recorded natural disasters rose sharply during the last century; rising from about 100 per decade till 1940 to nearly 2800 per decade during the 1990s. Economic crisis and natural disasters have been a recurrent phenomenon in the developing world. For the period 2000-2004, on an average annual basis one in 19 people living in the developing world was affected by climate disaster and the fourth assessment of the IPPC asserts that the world's area affected by drought has substantially increased in the past 37 years (UNDP 2007, 76; Fuentes and Seck 2007; ICSU 2005, 5).

Drought phenomena have occurred regularly in Iran over the past centuries and have negatively affected the people and society. According to United Nations Development Programme (2004, 67), the negative effects of severe drought that affected Islamic Republic

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of Iran from 1999 through 2002 were magnified by non-climate factors. In Iran, geographically distribution of drought showed that southern and south-eastern zones of Iran are more sensitive to drought both in intensity and frequency (Iran Meteorological Organisation 2008; Daneshvar et al. 2008, 69). Nomads in the Kerman province, located in south-east of Iran, have been particularly vulnerable to prolonged episodes of drought and the severity and persistence of the latest droughts has produced a wide range of impacts across the region. According to Adger et al. (2003), societal vulnerability to the risks associated with climate change may exacerbate on-going social and economic challenges, particularly for those parts of societies dependent on resources that are sensitive to changes in climate.

The purpose of this research was to explain adaptation to drought among Nomads in the . Among the all 30 provinces of Iran, Kerman is the first province in terms of diversity of tribe and clans including 31 tribes and 55 clans who are distributed in 56 per cent of the total province. Records from the Provincial Nomadic Office showed that there are more than three million livestock including cattle, sheep, goat and camel which are distributed in 65 per cent of the total rangelands.

According to Shokri (2008; 2010), Nomads Affair Office of Kerman Province (2008) and Nomads Office of Kahnouj Township (2009), Saboki nomads and Lard Meidan nomads who are located in southern of province were affected by the economic, social, and environmental costs and losses associated with drought including acute shortages of water and pasture, stock emaciation, loss from dairy and livestock production, productivity reduction, damage to animal species, high cost of purchasing forage or rent sward, poor economic feasibility of Nomadic husbandry, malnutrition, loss of employment, shift from productive jobs to working as labor, increase poverty, psychological stress on people,carrying water by women and girls from far away, school dropout, increasing insecurity, permanent and seasonal immigration to village and big cities and damage to the tribe and family social structure.

Nevertheless past attempts to manage drought and its impacts thorough a reactive, crisis management approach have been ineffective, poorly coordinated, and untimely in both developed and developing countries (Wilhite 2000, 13; Wilhite et al. 2005). The primary challenge, therefore, posed at both the scale of local natural resource management and at the scale of international agreements and actions, is to promote adaptive capacity in the context of competing sustainable development objectives. Additionally, active adaptive management is a useful tool for resilience building in social-ecological systems (Adger et al. 2003; Folke et al. 2002, 9). The goal of sustainable development is to create and maintain prosperous social, economic, and ecological systems (Folke et al. 2002, 7).

Now the basis of the question is what the attributes of adaptation with drought in Nomads from the view of sustainable dimensions are. Smith (2003) mentioned pastoral property is a complex adaptive system.

Adaptation and strengthening local adaptive capacity is one of the important areas of discussion. There are at least two areas where activities related to drought can be undertaken

(1): adaptation to the impacts of climate change; and (2): research and systematic observation (UN/ISDR 2003, 10; Eriksen and Lind 2009). Adaptation practices refer to actual adjustments, or changes in decision environments, which might ultimately enhance resilience or reduce vulnerability to expected changes in climate (Adger et al. 2007).

Methodology

This research is quantitative in its nature and applied in kind which was anticipated that would be exploratory, aiming to drive the factor structure of adaptation strategies with drought in the base on thesustainability in Nomads.Validity of the research instrument was confirmed by the research group and α Chronbach Coefficient was applied for the purpose of reliability through which α=0.89 was obtained.

The research population consisted of 6685 Nomad 's households according to summer quarters population, out of which 216 families were selected using a proportionalstratified sampling method(n=216). Time delimitation of the study was the late of 2007 until 2010.

Prior conducted Factor Analysis, missing values were substituted with the linear trend at point. The Kaiser-Mayer-Olkin measure of sampling adequacy index was 0.799 and Bartlett's test of sphericitywas obtained significantly with $p< 0.0001$. It demonstrates that the identity matrix instrument is reliable and confirms the usefulness of factor analysis.

Findings

Exploratory Factor Analysis (EFA) is a complex, multi-stage process. Factor analysis attempts to bring interrelated variables together under more general, underlying construct. In other word, EFA attempts to discover the nature of the constructs influencing a set of responses. More specifically, the goal of factor analysis is to reduce "the dimensionality of the original space and to give an interpretation to the new space, spanned by a reduced number of new dimensions which are supposed to underlie the old ones" (Costello and Osborne 2005; DeCoster 1998). It consisted of principal component analysis and orthogonal rotation named as Varimax rotation, performed with the 46 actual items. Factor rotation is a process of manipulating or adjusting the factor axes to achieve a simpler and pragmatically more meaningful factor solution (Hair et al. 2006 in Da Costa 2007). Field (2005) pointed out correlation coefficients fluctuate from sample to sample; therefore the reliability of factor analysis also depends on sample size.

In this study, a factor-loading criterion level of 0.5 was used (Mansourfar 2009; Kalantari 2006) in order to identify the structure of relationships among the variables. Findings of EFA in the first stage showed that ten extracted factors together explained about 66 per cent of the variation in the explicit variables; the sampling adequacy was 0.799, along with a significant p-value <.00001.

Table 1: Principal Component Analysis (PCA). Rotation Sums of Squared Loadings			
Factor	Eigenvalues	% of variance	Cumulative % of variance
1	5.443	11.833	11.833
2	5.212	11.329	23.163
3	4.496	9.774	32.937
4	3.332	7.243	40.180
5	3.132	6.810	46.990
6	2.562	5.570	52.560
7	2.363	5.136	57.696
8	1.776	3.861	61.557
9	1.773	3.854	65.411
10	1.568	3.409	68.820

KMO measure of sampling adequacy: 0.799; Batlett □s Test of Sphericity 6.514E3, df: 1035, Sig:0.0001

A ten-factor solution from the 46 items (questions) resulted in the loading of 31 items across six factors with at least three indicators.Extracted factors were: 1, 2, 3, 4, 6, 7. As shown in table 2, items 1, 3, 12, 22, 29, 30, 33, 37 were below the cutting-off point, and removed from the analysis.

Table 2: Factor Loading of Scale Items of the Questionnaire: Rotated Component Matrix[a]

	1	2	3	4	5	6	7	8	9	10	Communalities Extraction
Q 1	.467	.128	.255	.142	-.152	.068	.069	.315	.199	-.197	.530
Q2	-.238	.147	-.141	.029	-.131	.044	.619	.086	-.019	.222	.558
Q3	.128	-.035	.462	-.229	-.398	.160	-.131	-.316	.040	-.030	.587
Q4	.105	.208	.717	-.081	.175	-.019	.088	.199	-.024	-.018	.655
Q5	.093	-.196	.843	.003	-.094	.062	-.130	-.151	-.216	-.036	.858
Q6	.108	-.029	.818	-.058	-.160	.200	-.030	-.211	-.067	-.017	.801
Q7	.110	-.068	.819	.012	-.103	.193	-.008	-.104	.118	.064	.764
Q8	.339	.039	.674	.089	-.107	-.055	.187	.260	.132	-.003	.714
Q9	.373	.126	.729	-.045	.033	-.100	-.118	.044	.092	-.081	.730
Q10	.293	.274	.344	.143	.096	-.211	.545	.057	.024	-.183	.687
Q11	-.165	-.115	-.051	-.145	.217	.001	.711	.149	.244	-.042	.700
Q12	.355	.264	.207	.042	-.316	.055	.230	.311	-.044	-.303	.586
Q13	.174	.798	.079	.004	-.034	.226	.019	-.089	.056	-.064	.741
Q14	.168	.309	.005	.659	.003	.259	-.025	.006	.049	-.221	.677
Q15	.145	.187	-.009	.793	-.062	.156	-.036	.023	.089	-.113	.735
Q16	.019	-.035	-.056	.861	.159	-.091	.014	.086	-.164	.139	.834
Q17	.060	-.053	-.065	.790	.193	-.183	.062	.069	-.157	.241	.797
Q18	.115	.730	.179	.170	.095	-.088	.049	-.249	.005	.066	.693
Q19	.010	.671	-.131	.143	.116	.154	.139	.487	.064	-.049	.787
Q20	.001	.839	.016	.034	.053	.123	.094	-.012	-.097	-.031	.742
Q21	-.002	.738	-.055	.069	.266	.059	.180	.203	.039	.054	.705
Q22	-.223	.101	-.055	.187	.322	.461	.146	.367	-.122	.086	.593
Q23	.098	-.088	-.003	-.111	-.278	.094	-.005	-.061	.721	-.050	.642
Q24	-.014	.151	.001	-.098	.050	.299	.366	-.049	.627	-.085	.662

Q25	.035	.167	.140	.073	-.035	.721	.092	.168	.145	-.035	.634
Q26	.234	.162	.172	.003	-.201	.700	-.106	-.203	.200	-.109	.745
Q27	-.059	-.040	-.083	.397	.113	-.115	.219	.502	-.216	.242	.601
Q28	-.130	.195	.006	.154	.302	.394	.590	-.068	-.056	.014	.681
Q29	.410	.230	.142	.260	-.473	.036	-.036	-.241	.018	-.047	.596
Q30	.464	.345	.221	.178	-.420	.020	-.094	-.280	.172	.279	.787
Q31	.532	.391	.125	.033	-.447	.138	-.174	-.015	.057	.250	.767
Q32	.129	.586	-.122	.167	-.080	.132	-.143	.150	-.144	.492	.732
Q33	.240	.498	-.025	-.177	-.085	.439	.017	.022	.114	.386	.700
Q34	.103	.425	.139	-.232	-.094	.548	.047	-.235	.005	.251	.693
Q35	.573	-.052	.053	.048	-.166	.012	.275	-.177	-.435	-.152	.682
Q36	-.238	.185	.007	.143	.187	-.071	.330	.047	-.158	.539	.578
Q37	.463	.328	.140	.177	-.406	-.042	-.155	-.168	.166	.193	.656
Q38	.606	.039	.074	.042	-.046	-.036	-.098	.020	-.059	-.022	.393
Q39	.617	.056	.270	-.111	.274	-.110	.008	-.213	-.076	-.128	.624
Q40	.030	.348	-.074	.200	.794	-.053	.112	-.017	-.052	.045	.818
Q41	.111	.222	-.015	.198	.775	-.037	.049	-.017	-.092	.079	.721
Q42	.757	.075	.149	-.014	.003	.163	-.161	.003	.048	.066	.660
Q43	.593	.049	.123	.300	.053	-.148	.123	-.259	.304	-.178	.690
Q44	.372	.571	-.229	-.012	.162	.199	-.116	.187	.181	.297	.752
Q45	.772	.154	.112	.003	-.079	.101	-.191	.031	.043	.027	.689
Q46	.782	.000	.171	.130	.057	.107	.022	.078	.017	.014	.679
Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalisation; Rotation converged in 22 iterations.											

Finally six factors together explained about 51 per cent (50.886) of the variation in the data scores. In table 3, factors were named based on the nature of related items.

Table 3: Factors Named Based on the Nature of Loaded Questions- First Order Factor Analysis

No	Item	Factor
39	-The presence of extension worker and expert presence in Nomadic regions in order to assist Nomads during drought	(1) Risk Management
46	-Informing Nomads about the dangers of drought and preparing them psychologically and socially	
45	-Nomads education in the field of water use in pasture and water saving techniques	
31	-Construction of water reservoir in migration rout of Nomads and installation of livestock watering	
42	-Youth education for job creation (Training in various fields)	
43	-Health-health situation in migration route, and summer and winter quarters.	
35	-The presence of veterinarian in Nomad's regions during drought	
13	-Services provided by official office of Nomads, such as forage and water distribution	(2) Service-Support
32	-Rake up livestock wells in winter pastures	
44	-Construction, completion, and Restoration of Nomad's roads.	
18	-Your satisfaction of the services provided by official office of Nomads at the time of drought	
19	-The presence of Parliament representative in nomadic regions	
20	-Governor to investigate and track problems of nomads	
21	-Authorities to act promises given during the past four-five years	
4	-Income derived from the sale of handicrafts	
5	-Income derived from selling milk, cheese, yogurt, wool, etc.	
6	-Income derived from agriculture and farming along with livestock	

7	-Income derived from gardening (such as groves) along with livestock	(3) Production Economics
8	-Amount of revenue from beekeepers along with livestock	
9	-Amount of revenue from native and laying hens along with livestock	
14	-There are powerful leaders of tribe to pursue political, economic and livelihood necessity and demands of the Nomads	(4) Social Capital
15	-Clan elders meetings in order to problem solving during drought	
16	-Rain prayers and pray to end drought	
17	-Vow to kill, votive cooking food for seeking rain	
25	-Rationing of pasture forage during drought	(5) Nutrition
26	-Livestock feeding with farm s aftermath (wheat and barley)	
34	-Distribution of water storage tanks among nomads households	
2	Reduced the number of livestock through sales (to the lowest price)	(6) Crisis Management
10	Demand for bank loans and facilities in time of drought	
11	Utilisationrateofhouseholdsavingsintime ofdrought	
28	Usingof bottled gas for cooking and heating	

Second Order EFA

In the next stage an exploratory factor analysis applied for six factors extracted from the first stage. Finally three extracted factors together explained 70 per cent (70.191) of the variation in the six items extracted in the previous stage. The measure of sampling adequacy was 0.510 (moderate and acceptable), along with a significant P-value <.00001.

Table 4: Second Order Factor Analysis of Six Items Identified in Previous Stage

No	Item	1	2	3	Communalities Extraction
1	**Risk Management**	.776	-.094	.355	.736
2	**Service-Support**	.282	.630	.475	.701
3	**Economic**	.761	-.072	-.170	.613
4	**Social Capital**	-.061	.005	.904	.821
5	**Nutrition**	.617	.534	-.083	.673
6	**Crisis Management**	-.254	.774	-.059	.667

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.

Social capital removed due to loading on one factor (no 3). Thus refinement was performed again. Finally two extracted factors together explained about 61per cent (61.488) of the variation in the five extracted items (table 5).

Table 5: Second Order Factor Analysis of Five Items

No	Item	1	2	Communalities Extraction
1	**Risk Management**	.811	.145	.679
2	**Service-Support**	.190	.795	.668
3	**Production Economics**	.744	-.012	.553
4	**Nutrition**	.478	.600	.588
5	**Crisis Management**	-.407	.649	.587

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalisation.

In table 6, the factors were named based on the nature of related items identified in previous stage.

Table 6: Factors Named Based on The Nature of Loaded Previous Items- Second Order Factor Analysis

No	Items extracted from the first stage	Factor
1	Risk Management	Risk Management
2	Production Economics	
3	Service-Support	Crisis Management
4	Nutrition	
5	Crisis Management	

Third order EFA of items identified in the previous step

In this stage, the third order factor analysis was performed on two latent items extracted from the previous stage (table 7).

Table 7: Third Order Factor Analysis of Two Items

No	Item	1	Communalities Extraction
1	Risk Management	.774	.600
2	Crisis Management	.774	.600

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalisation.

As shown in table 7, one latent factor extracted from EFA and both itemshad equal loading on identified factor (0.774). Finally the extracted factor explained about 60per cent (59.975) of the variation in the two extracted items from the previous stage.This latent factor named adaptation with drought.

Results and Discussion

The aim of this study was to investigate factor structure of adaptation strategies with drought based on the sustainability in Nomads, which were clustered into six latent variables in the first stage. These factors respectively based on the nature of their constituent items, were named as risk management, service-support, economic, social capital,nutrition and crisis management. In other words the variance of observed variables could be explained by these factors. In this research 46 actual items, from different dimensions, had implications on the adaptation strategies in the Nomad society. In relation to service-support factor Eriksen and Lind (2009) pointed out that adaptation may need political solutions and there are political obstacles to developing effective adaptation policies. As well as results of a study done by Nelson et al. (2008) indicated that interactions between government and resource users in local communities need to be supported by regionally distributed scientific support capable of integrating local knowledge and informing the livelihood outcomes of critical importance to both rural communities and policy advisers. This finding emphasises development through education that encompasses political and institutional aspects. Results of research conducted by Marchildon et al. (2008) and Berkes et al. (2000) showed that institution-building may be of value in helping the residents adapt to predicted climate changes in the future as well as anticipate some of the barriers to effective institutional adaptation. Economic factor addresses strategies of livelihood and income diversification among pastoralists. The results from a study conducted by Jahromi (2008) about the production attributes of Nomads in Darzeh, Kahnooj township of Kerman province, showed that due to drought, the quality and quantity of agricultural production have been decreased and obviously it has a unfavorable consequence such as: unemployment, poverty, immigration and social difficulties on people specially youth. Therefore economic development can play an effective role in increasing the adaptation capacity in drought conditions (Little et al. 2001; Jahromi 2008). Moreover according Folke et al. (2002), resilience is often associated with diversity- of species, of human opportunity, and of economic options- that maintains and encourages both adaptation and learning. Finally, Smith (2003) pointed out that while it is possible to debate separately the biophysical elements that create drought, the social factors that structure producer's experiences and responses to it, and the policy environment that helps define those experiences and responses, ultimately the interactions between all these elements must drive the development of better drought policy in the future.

References

Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O' Brien, J. Pulhin, R. Pulwarty, B. Smith, and K. Takahashi. 2007. 'Assessment of Adaptation Practices, Options, Constraints and *Capacity.' In Climate Change: Impacts, Adaptation and Vulnerability,* 717-743. Contribution of working group II to the forth assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press.

Adger, W.N., S. Huq, K. Brown, D. Conway, and M. Hulme. 2003. 'Adaptation to Climate Change in the Developing World.' *Progress in Development Studies* 3 (3): 179-195.

Berkes, F.,J. Colding,and C. Folke. 2000. 'Rediscovery of Traditional Ecological Knowledge as Adaptive Management.' *Ecological Applications* 10 (5): 1251-1262.

Daneshvar, M. et al. 2008. *Final Report of Research Project on Reviewing Statistical Analysis Methods of Climate Drought in East and South East of Country*. Document number: 26932. Tehran, Iran: Institute of Soil Conservation and Watershed Management. Agricultural Education and Research Organisation. Ministry of Jahade Keshavarzi.

Eriksen, S. and J. Lind. 2009. 'Adaptation as a Political Process: Adjusting to Drought and Conflict in Kenya'sDry lands.' *Environmental Management* 43 (5): 817-835.

Folke, C.,S. Carpenter, T. Elmqvist, L. Gunderson, C.S. Holling, and B. Walker. 2002. 'Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations.' *Ambio* 31 (5): 437-440.

Fuentes, R. and P. Seck. 2007. *The Effects of Climate Related Disasters on Human Development*. Human Development Report Office, UNDP.

ICSU. 2005. *Natural and Human-induced Environmental Hazards*.Report from the ICSU Scoping Group. Sazhou, China.

Jahromi, A.B. 2008. 'The Analysis of Nomads' Production Economics and their Income (Case of Darzeh, Kahnooj, Kerman Province, Iran).' *American-Eurasian Journal of Agricultural and Environmental science* 2 (1): 42-45.

Little, P.D.,K. Smith, B.A. Cellarius, D.L. Coppock, and C.B. Barrett. 2001. 'Avoiding Disaster: Diversification and Risk Management among East African Herders.' *Development and Change* 32 (3): 401-433. DOI: 10.1111/1467-7660.00211.

Marchildon, G.P., S.Kulshreshtha, E. Wheaton, and D. Sauchyn. 2008. 'Drought and Institutional Adaptation in the Great Plains of Alberta and Saskatchewan, 1914-1939.' *Natural Hazards* 45 (3): 391-411.

Nelson, R.,M. Howden, and M.S. Smith. 2008. 'Using Adaptive Governance to Rethink the Way Science Supports Australian Drought Policy.' *Environmental* Science and Policy 11 (7): 588-601.

Nomads Office of Kahnouj Township. 2009. *Report No. 03495223527*. Report Studies office, Nomads Office of Kahnouj Township, Iran.

Shokri, Sh.A.2011. 'Drought Effects on Natural Ecosystems-Sky Avarice, is Broken the Safe from Nomads.' *Hamshahri Newspaper*, 9 April 2011. No. 5374:14.

Shokri, Sh.A. 2008. 'Kouch Dar Ilrahe Tafdide (Nomads Difficulties in Dealing with drought).' *Hamshahri Newspaper*. 16th years (4647).

Smith, M.S. 2003. 'Linking Environments, Decision-making and Policy in Handling Climate Variability.' *Beyond Drought in Australia: People, Policy and Perspective:,* 131- 151.

UNDP. 2007. 'Fighting Climate Change: Human Solidarity in a Divided World.' *Human Development Report 2007/2008*. UNDP.

UNDP. 2004. *Reducing Disaster Risk a Challenge for Development*. A Global Report from United Nations Development Programme. Bureau for Crisis Prevention and Recovery, UNDP.

UN/ISDR. 2003. *Information Note for the period 1 April - 31 October 2003*. http://www.unisdr.org/eng/un-isdr/secre-inf-notes/Info-notes-apr-oct03.pdf.

Wilhite, D.A., M.J. Hayes, C.L. Knutson. 2005. *Drought Preparedness Planning: Building Institutional Capacity.*

Wilhite, D.A. 2000. 'Drought as a Natural Hazard, Concepts and Definitions.' *In Drought: A Global Assessment,* edited by D.A. Wilhite, 3-18. London and New York: Routledge.

World Bank. 2010. *Economic Evaluation of Climate Change Adaptation Project. Approaches for the Agricultural Sector and Beyond.* Washington, D.C.: World Bank.

Climate Change and Disaster Risk Management for Sustainable Development*

Ime Edet Sam** and Hope Amba Neji***

Abstract

The main purpose of this paper is to find relationship between climate change and disaster management linking with sustainable development. Without doubt, the most important environmental issues we face today is climate change. Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes and greater reliance on climate sensitive sectors, particularly agriculture. People exposed to the most severe climate-related hazards are often those least able to cope with the associated impacts, due to their limited adaptive capacity. This in turns poses multiple threats to economic growth, poverty reduction and the achievement of the Sustainable Development Goals. Within this context, there is growing recognition of the potential role of social protection as a response to the multiple risks, and short/long term shocks associated with climate change.

Keywords: Climate change, Disaster management, Sustainability, Social protection.

Introduction

Climate change and disaster risk reduction are closely linked. More frequent extreme weather events in future are likely to increase the number and intensity of disasters, while at the same time, the existing methods and tools of disaster risk reduction provide powerful capacities for an adaptation to climate change. The expression "climate change" means the alteration of the world's climate that humans are causing, through fossil fuel burning, clearing forests and other practices that increase the concentration of greenhouse gases (GHG) in the atmosphere. This is in line with the official definition by the United Nations Framework Convention on Climate Change (UNFCCC) that climate change is the change that can be attributed "directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

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Meaning and Causes of Climate Change

Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as "global warming" (IPCC 2007).

Kasting (2002) stated that Scientists actively work to understand past and future climate by using observations and theoretical models. A climate record — extending deep into the Earth's past — has been assembled, and continues to be built up, based on geological evidence from borehole temperature profiles, cores removed from deep accumulations of ice, floral and faunal records, glacial and per glacial processes, stable- isotope and other analyses of sediment layers, and records of past sea levels. More recent data are provided by the instrumental record. General circulation models, based on the physical sciences, are often used in theoretical approaches to match past climate data, make future projections, and link causes and effects in climate change. On the broadest scale, the rate at which energy is received from the sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climates of different regions.

Factors that can shape climate are called climate forcing or "forcing mechanisms" (Kopp 2005). These include processes such as variations in solar radiation, variations in the Earth's orbit, mountain-building and continental drift and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps, respond slowly in reaction to climate forcing, while others respond more quickly.

Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes within the climate system itself (e.g., the thermohaline circulation). External forcing mechanisms can be either natural (e.g., changes in solar output) or anthropogenic (e.g., increased emissions of greenhouse gases).

Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination (e.g., sudden loss of albedo in the arctic ocean as sea ice melts, followed by more gradual thermal expansion of the water). Therefore, the climate system can respond abruptly, but the full response to forcing mechanisms might not be fully developed for centuries or even longer.

Weather and Climate

According to International Strategy for Disaster Reduction (ISDR 2008) opined that Weather is the set of meteorological conditions – wind, rain, snow, sunshine, temperature, etc. – at a particular time and place. By contrast, the term "climate" describes the overall long-term characteristics of the weather experienced at a place. For example, Singapore, in the tropics, has a hot wet climate, while continental Mongolia always has cold winters. The ecosystems, agriculture, livelihoods and settlements of a region are very dependent on its climate.

The climate therefore can be thought of as a long-term summary of weather conditions, taking account of the average conditions as well as the variability of these conditions. The fluctuations that occur from year to year, and the statistics of extreme conditions such as severe storms or unusually hot seasons, are part of the climatic variability. Some slowly changing climatic phenomena can last for whole seasons or even years; the best known of these is the El Niño phenomenon (Mills and Lecomte 2006).

Colarusso (1996) observed that since the atmosphere connects all weather systems and all climates, it is sometimes useful to describe the atmosphere, oceans and Earth surface as the "global climate system". Because the climate system is in a constant state of flux and has always exhibited natural fluctuations and extreme conditions, it is not possible to argue that any single extreme event is attributable to climate change. Only after a sufficient period and with hundreds of extreme events recorded can scientists determine if a specific event is within normal historical variation or is due to some other cause such as climate change.

Risk and Vulnerability in the Context of Climate Change

"Climate change will make it impossible for the world to achieve the Millennium Development Goals. Poverty is bound to increase. Food security is bound to get worse."

- Professor Richard Odingo, Vice-Chairman, IPCC.

Mark, Katy, and Tom (2008) stated that there is growing evidence that climate change is increasing the frequency and intensity of climate-related hazards, and hence the level and patterns of often inter-related risks, exacerbating levels of vulnerability for poor and excluded people. Poverty and social impacts, though generally not well-understood, are likely to be profound and will impact humans through a variety of direct (changes in climate variables) and indirect pathways (pests and diseases; degradation of natural resources; food price and employment risks; displacement; conflicts, negative spirals) (Heltberg et al. 2008).

For many poor rural people, reliance on subsistence agriculture means that the impact of climate shocks and stresses are likely to have negative implications for their food and livelihood security, human capital and welfare. Risks and uncertainties, often associated with seasonality, are typically embedded in agricultural practices and poor people often have considerable experience of coping and risk management strategies, which need to be built upon in developing more resilient livelihoods.

Climate change also has implications for the urban poor and for rural-urban change. Most informal urban settlements are built illegally and without formal planning. Limited availability of water, high child and infant mortality rates and a very high disease burden (malaria, tuberculosis, diarrhoea etc.) are common characteristics of such informal settlements (Satterthwaite et al. 2007). Planning for climate change in such situations will be extremely difficult when governments have limited authority and capacity to address the risks posed by existing hazards.

With climate change negatively impacting rural livelihoods, migration from rural to urban areas is increasingly likely to become the favoured adaptation strategy of the mobile, rural poor. This will further exacerbate the problem of people living in urban fringe hazardous environments with potential risks of social unrest. At the same time, the greater concentration of people creates opportunities for more effectively managing climate change risks vis-à-vis people living in remote rural locations. Furthermore, migration should not be viewed as a universally negative impact of climate change; it can serve a positive function. For both the poor and non-poor, migration can be an accumulative strategy (Scott 2008). For example, rural agricultural labourers may choose voluntary internal migration from rural to urban areas in the aftermath of a shock in order to move from the agricultural to non-agricultural sector. However, migration is not an option for all, especially the chronically poor or specific vulnerable or excluded people, who may face discrimination and severely limited mobility.

Poor people in Africa often face already high risks and use informal and often ineffective means to protect themselves against those risks, in the context of very low coverage of government and market-based instruments (Heltberg 2008). With climate change likely to result in an increased magnitude and frequency of shocks, innovative approaches to social protection and DRR will be needed to bolster local resilience, support livelihood diversification strategies, and reinforce people’s coping strategies.

Disaster Impacts

Globally, the impacts of disasters have risen rapidly over recent decades, affecting almost all sectors and rich countries and poor countries alike. Several hundred million people are affected annually and losses reached a record US$ 371 billion in 2012, (Annual Disaster Statistical Review 2012). This figure may underreport the true losses by 50% or more. It does not incorporate knock-on impacts across economies and it undervalues the relative economic impacts on individual and particularly poor households. In some regions numerous smaller-scale and unreported events are a major source of aggregate loss, especially in developing countries and poor communities (Bull-Kamanga et al. 2003). A particular concern is that disaster-damaged livelihoods and economies can set the preconditions for further rounds of excessive exposure, susceptibility and loss, blocked escapes from poverty and negative spirals of development failure. This may occur at any level, from household to state.

Underlying Risk Factors

The United Nation-proposed Hyogo Framework for Action 2005-2015 (Mark Pelling 2014) That seeks to build resilience of nations and communities to disasters, includes the integration of disaster risk considerations into sustainable development processes as a key strategy. One of its five priorities is the reduction of underlying risk factors, involving environmental, social and economic actions, but it is here that least progress has been achieved according to reporting by Governments. Explicit recognition of disaster risk reduction in the Sustainable Development Goals will provide critical weight to help drive the substantive work on underlying disaster risk in the parallel post-2015 framework planned to succeed the Hyogo Framework for Action.

The Disaster Risk Process and Risk Management

According to United Nation Integrated Research on Disaster Risk (UNIRDR 2009), Disasters can be considered an outcome of an on-going “risk process”, in which the prevailing circumstances of hazards, exposure and vulnerabilities combine to generate disaster risk. The risk may grow and accumulate over time, becoming evident as greater losses only when a hazard event strikes. This is a radical shift from earlier ideas of disasters as acts of God or as natural events. A geophysical hazard event may be natural but its impacts depend on the circumstances of people, households and societies, which in turn arise from diverse micro- to macro-level political, social, economic and environmental processes. Knowledge of the driving factors in disaster risk is the essential basis for pre-emptive policy and action to reduce the risks. Asia Pacific Disaster Report (2012) revealed that integrated approaches will improve outcomes and opportunities for both disaster risk reduction and sustainable development. A basic requirement in both cases is to systematically monitor disaster risk.

Linkages with Climate Change

It is well accepted that disaster risk reduction measures will play an important role in responding to the projected increases in weather- and climate-related hazards including sea-level rise. IPCC (2012) noted that good management of today’s existing risks is clearly the starting point for facing tomorrow’s changed risks, whether from climate change, globalisation or development. These three policy arenas share interests in monitoring changing risks, reducing exposure and vulnerability and advancing the transformation to resilience and sustainability.

Targets and Indicators

High-level meetings have identified the need to address resilience and disaster risk reduction in the Sustainable Development Goals. Targets and indicators work can draw on the experience gained in monitoring progress on the Hyogo Framework for Action. Various global and national databases are available for natural hazards, exposure and disaster losses, and research are advancing on measures of vulnerability and resilience. Resolution adopted by the General Assembly on 27 July 2012.

Disasters and Sustainable Development

Disaster Events Undermine Poverty Eradication

The livelihoods, productive economic activity and public capacities that keep poverty at bay are compromised when the underpinning assets and resources of households and countries are destroyed in disasters (Shepherd et al. 2013). This can generate new poor as well as deepening existing poverty. For example, a study of 2454 municipalities for a five-year period showed significant impacts from disasters, with a 0.8% decrease in the Human Development Index in affected areas, similar to a two-year setback, and a 3.6% increase in extreme food poverty (Rodriguez-Oreggia et al. 2013).

Disaster Linked To Unsustainable Growth

In 1998, Central America suffered massive losses associated with Hurricane Mitch, with thousands of deaths, millions of displaced people and estimated losses of about US$ 6 billion. Studies show that the impacts were particularly severe where the development model sought agricultural diversification and export-led growth but at the expense of floodplain exploitation, deforestation and soil degradation and reduced opportunities for small farmers (Ensor 2009). The social and economic processes involved rendered the environment, infrastructure and population exceptionally vulnerable to the hurricane. In this way, disaster risk was actively created through human action. Similar lessons have been learned in developed countries, for example as a result of major flood loss events in Europe and North America over recent decades.

Disasters and Inequality

On average, disasters disproportionately affect women, children, the aged and disabled (Enarson 2012). For example, a study of villages affected by the 2004 Indian Ocean tsunami as reported by Guha-Sapir et al. (2006) showed that the death rate was highest for young children and the elderly and was 40% higher for women than for men. These patterns are related to the prevailing social roles and expectations. Disadvantaged groups also are often excluded or not catered for in disaster response and recovery stages. While disasters can thus amplify social exclusion, economic inequality and poverty, they also provide an opportunity, through risk reduction action and post-disaster recovery, to address such issues as part of the promotion of resilience and sustainable development.

Magnified Impacts for Small Developing Countries

The greatest absolute losses occur in larger and richer countries, but the greatest relative losses occur in small countries and particularly small island countries. In some years, the disaster losses can exceed the annual GDP. One study showed that 26 countries have an average annual economic impact of more than 1% of GDP, with seven countries above 2% GDP (World Bank 2011). Most of these countries are small-island developing states or small coastal countries. Such high average impacts represent a serious drag on long-term development. The problem arises partly because hazard events such as a storm or earthquake may cover most of a small country leaving the remaining unaffected parts unable to internally fund the recovery (Annual Disaster Statistical Review 2012).

Disaster Impacts on Cities

Cities are engines of economic development. Large cities exposed to cyclones and earthquakes will more than double their population by 2050 (from 680 million in 2000 to 1.5 billion in 2050). The resulting growth in exposure will need to be matched by substantial reductions in urban vulnerability if disaster losses are to be restrained in these cities as they grow. Cities struck by major hazards can take years to recover. An economics study of the 1995 Kobe earthquake as reported by DuPont and Noy (2012) showed that in 2008, thirteen years after the event, the city's per capita GDP was lower by 12%. This impact is persistent, clearly observable, and attributable to the earthquake, and it occurred despite the relative wealth of the country and the considerable recovery support provided to the city. Another study has estimated a nine-fold increase in the global risk of floods in large port cities between now and 2050, as a result of rapid population increases, economic growth, land subsidence and climate change, with a similar increase in losses, rising to US$ 52 billion (Hallegate et al. 2013). The cost of required flood management for the 136 cities studied is estimated at around US$ 50 billion per year.

Globalisation and Cascading Risk

Globalised systems involving highly interactive and optimised productions give rise to large-scale vulnerabilities. In some countries, electricity failures arising from minor technical problems have cascaded to affect millions of people for several days. Imbalances in global grain supply and demand in 2008, precipitated by poor harvests in major grain production countries and market speculation led to a severe spike in food prices, with wheat prices rising to more than double the price of the previous five years. The impacts were mainly felt elsewhere, in poorer countries and communities, leading to food crises and urban food riots. The 2011 Tohoku earthquake and tsunami led to a cascade of power outages, radioactive pollution, closure of nuclear plants, reactivation of fossil fuel plants, and disruption of global industrial supply chains.

Disaster Impacts Extend Widely

Disasters bring a range of indirect and secondary impacts in addition to the direct losses (mortality, injury, physical damage and economic loss). Individuals may suffer long term disability, psychological harm, degraded living circumstances, and interrupted education, increased disease occurrence, loss of employment and relocation. Prolonged drought can lead to reduced nutrition and stunting. Expertise, skills and resources will be diverted from growth activities to recovery activities. Businesses and investment may fail and sectors may not reach their production targets and development targets. Government finances are often severely disrupted. A key lesson is that disaster risk is a systemic issue and must be managed on a system-wide basis.

Economic Impacts and Hazard and Development Status

A review of econometric literature has shown that:

I. Disasters have larger relative impacts on developing, than developed countries; II. The nature of impact varies between types of hazard;

III. Climatological hazards have negative long-term economic impacts, particularly in lower-income countries;

IV. Earthquakes may have positive long-term macroeconomic consequences for middle- and upper-income countries but negative consequences for lower-income states; and

V. Severe disaster events do not have positive economic impacts under any circumstances. Indirect losses and secondary effects can increase sharply if post disaster contraction and reallocation of government resources delay reconstruction and dampen the pace of capital accumulation. An alternative countercyclical response may be more cost-effective, by spurring recovery and reconstruction, and "building back better", with reduced risk and future losses (Benson 2012).

Development Opportunities Involve Risks

Taking on risks and proactively managing them is a natural element of development. This includes disaster risk, which is often associated with favourable economic assets such as fertile floodplains and volcanic soils and coastal zones. A key need is for shared action on risks which individuals or enterprises cannot handle alone. Governments have a critical role in managing systemic risks, providing an enabling environment, and channelling support to vulnerable groups. Measures to reduce damages from earthquakes, floods and tropical storms can have median benefit-cost ratios of 2 to 5, while the provision of earlier warnings of disasters in developing countries could yield estimated benefit-cost ratios of 4 to 36. By way of 4 example, a national system that provides flood warnings up to 10 days ahead to millions of Bangladesh villagers and supports community-level planning and household action to preserve assets and livelihoods generates 10-year savings of US$ 40 for each dollar invested, according to one study.

Private Sector Roles

The private sector is responsible for 70 to 85 per cent of all investment worldwide in new buildings, industry and small-to-medium-size enterprises. The pursuit of short-term gains can be a major factor in disaster risk generation, for example through inappropriate land use or building construction practices. Private sector enterprises are vulnerable to disasters not only through direct effects on plant, equipment and personnel but also through disruption of supporting infrastructure for inputs such as water and electricity and transportation to maintain supply chains and product distribution. When these lifelines are cut, costs rise, competitiveness and reputation suffer, and businesses may close or move elsewhere. The business sector is an important partner in systematic risk reduction action, alongside community and government sectors.

Broad Economic Policy Can Reduce Disaster Risks

One study by World Bank (2011) suggests that substantial reductions in risk could be achieved through relatively inexpensive interventions in broader policy settings, particularly in respect to information availability, the functioning of markets, the role of public infrastructure and the effectiveness of public institutions. Adequate funding of infrastructure, data gathering, basic services, and early warning and evacuation systems will have high payoffs.

Humanitarian Intervention and Resilience

Large sums of money are expended on international emergency assistance, approaching US$ 12.4 billion in 2010. This is in effect a risk transfer mechanism, as it helps in smoothing the economic impacts on the affected communities, albeit at a very basic level. Only about 4.2% of official humanitarian aid was invested in disaster risk reduction between 2006 and 2010. However, more timely interventions and sustained multi-year support to risk management and resilience building can pay handsomely. In one case studied, resilience building activities over 20 years costed US$ 21 billion less than the more common late humanitarian response. Good linkages between humanitarian relief, rehabilitation and reconstruction can lead to more sustainable, resilient and adaptive outcomes and avoid the common trap of re-creating the original risk profile.

Status of Disaster-Related Goals, Targets and Indicators

Existing Capabilities

The risk process described in the overview provides the basis for disaster related goals, targets and indicators. The key elements are: (i) the hazard profile; (ii) the exposure (of people and assets); (iii) the vulnerability of people and assets to hazards (including community and institutional capacities and the related concept of resilience); and (iv) the losses that occur, such as mortality, morbidity, livelihood and asset loss, social and macroeconomic impact, etc. The field relies on the physical, environmental and social sciences and relevant sector expertise.

Links to the UN Disaster Reduction Strategy

The Hyogo Framework for Action has stimulated the development of reporting and databases. A process of national self-reporting has been put in place to monitor progress against measures of national achievement on the priorities and tasks 6. Most of the measures address inputs and processes, rather than outcomes. The experience to date provides a valuable foundation for the consideration of disaster-related goals and targets in the Sustainable Development Goals process. A post-2015 successor arrangement to the Framework is being developed, in parallel with the Sustainable Development Goals process. Many United Nations member states have called for stronger targets and upgraded accountability in the new framework (UNISDR 2013).

Expert Workshop

A meeting of experts on disaster targets and indicators in July 2013 reviewed options for supporting the Sustainable Development Goals process. The meeting welcomed the target proposed by the High-Level Panel to "build resilience and reduce deaths from natural disasters by x%" and it's positioning within the goal to "end poverty." It also welcomed several other Panel-proposed targets that aim at increased resilience. The group reviewed a number of disaster related indicators, and concluded that a range of indicator types should be pursued, including outcome indicators where possible, but also process indicators and input indicators (Birkmann 2013).

Hazards, Exposure and Losses

Data gathering, historical databases and data modelling for hazards, exposure and losses are relatively well developed and can readily support indicator development, although the spatial scale rarely reaches down to community level. Hazard modelling is most developed and can be combined with population and asset data to form maps and indexes of exposure. However, disaster loss databases lack consistency in what they measure and in their geographic coverage. Consideration could be given to more informative indicators of disaster loss, such as working days lost, days of school closure, price of seasonal produce, etc.

Vulnerability and Resilience

Vulnerability and resilience are widely used concept, albeit with varied interpretations and with limited systematic collection of data (Birkmann 2013). However, with improved data systems at local and national levels there is good scope to generate data sets and indicators, and to measure long-term changes. Both can be represented by surrogates such as household income or community-level capacities. The establishment of vulnerability lines alongside poverty lines is a possibility. Observation and indexing of vulnerability (and associated capacity) is most developed at the community level, but there also exist a number of national and global tools, as well as some common frameworks. Indexes of relative vulnerability, expressed as the proportion of people or assets exposed to hazard types that suffer harm from events (e.g. mortality, homelessness, livelihood loss), or that benefit from protective capacities (e.g. early warnings, building codes, insurance), are simple to generate and communicate. Specific targets for vulnerability reduction and adaptation to extreme events also need to be defined to monitor progress.

Risk Measures are Least Developed

Risk requires the integration of hazard, exposure, vulnerability and capacity, and while this is difficult, models do exist. Risk management capability is also captured in some models but this relies on self-reporting by country officials. Comparative analysis and analyses of over time within a single unit are possible. Progress in the management and reduction of risk can only be demonstrated from data and longitudinal studies that span a decade or more.

Indicators of Disaster Risk Reduction Action

These include measures of public commitment, such as the availability and effective application of legislation, the level or proportion of annual government spending allocated to disaster risk reduction, and the integration of disaster risk assessment into private sector development projects. Though simple in concept, the implementation of action plan requires considerable effort and cooperation among countries and between different administrative levels.

Uncertainty of Loss Events

A particular challenge for the application and communication of disaster related indicators lies in the high variability of many hazards. In particular, the losses during a year may be substantial, despite major risk reduction efforts, or conversely may be minimal despite high risks and small efforts. This means that monitoring progress on disaster risk reduction cannot rely solely on direct disaster loss information, and that a variety of indicators are necessary to track exposure, vulnerability, risk and risk reduction actions to alternative interventions.

Conclusion and Recommendations

- Taking a longer term perspective for social protection initiatives that takes into account the changing nature of shocks and stresses;
- Developing Climate Risk Assessments for use in conjunction with sustainable programme design and implementation;
- Developing practical guidance on the design and implementation of appropriate adaptation methods, taking into account the views of affected groups particularly women, children and the elderly; and
- Designing monitoring and evaluation systems to capture further evidence and feedback on the effectiveness of an adaptive social protection approach.

References

Guha-Sapir, D., F. Vos, R. Below, and S. Penserre. 2012. *Annual Disaster Statistical Review 2011: The Numbers and Trends.* Brussels: the Centre for Research on the Epidemiology of Disasters (CRED), IRSS and UCL.

Velasquez, J., T. Bonapace, S.K. Srivastava, and S. Mohanty. 2013. *Reducing Vulnerability and Exposure to Disasters: the Asia-Pacific Disaster Report 2012.* Bangkok, Thailand: Economic and Social Commission for Asia and the Pacific & United Nations International Strategy for Disaster Reduction.

Benson, C. 2012. 'Indirect Economic Impacts from Disasters.' *Report produced for the Government Office of Science, Foresight Project Reducing Risks of Future Disasters: Priorities for Decision Makers.* United Kingdom: Government Office for Science, UK.

Birkmann, J. 2013. *Measuring Vulnerability to Natural Hazards – Towards Disaster Resilient Societies* (2nd ed.). Tokyo/New York/Paris: United Nations University Press.

UNDP. 2004. *Reducing Disaster Risk: A Challenge for Development – A Global Report.* New York, USA: UNDP.

Bull-Kamanga, L., K. Diagne, A. Lavell, E. Leon, F. Lerise, H. MacGregor, A. Maskrey et al. 2003. 'From Everyday Hazards to Disasters: the Accumulation of Risk in Urban Areas.' *Environment and Urbanization* 15 (1): 193-204.

Colarusso, N. 1996. *Key Elements of a Global Deal on Climate Change London.* London: London School of Economics and Political Science.

DuPont IV, W. and I. Noy. 2012. *'What Happened to Kobe? A Reassessment of the Impact of the 1995 Earthquake in Japan.'* Wellington: School of Economics and Finance, Victoria University of Wellington.

Enarson, E.P. 2012. *Women Confronting Natural Disaster: From Vulnerability to Resilience.* Lynne Rienner Publishers.

Ensor, M. J. (ed). 2009. *The Legacy of Mitch: Lessons from Post-Disaster Reconstruction in Honduras.* Tucson, Arizona: University of Arizona Press.

Hallegatte, S., C. Green, R.J. Nicholls, and J. Corfee-Morlot. 2013. 'Future Flood Losses in Major Coastal Cities.' *Nature Climate Change* 3 (9): 802-806.

IPCC. 2012. 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.' *Special Report of the Intergovernmental Panel on Climate Change,* 594. New York: Cambridge University Press.

Mills, E. and E. Lecomte. 2006. *From Risk to Opportunity: How Insurers Can Proactively and Profitably Manage Climate Change.*

Rodriguez-Oreggia, E., A. De La Fuente, R. De La Torre, and H.A. Moreno. 2013. 'Natural Disasters, Human Development and Poverty at the Municipal Level in Mexico.' *The Journal of Development Studies* 49 (3): 442-455.

Sattherwaite, D. 2007. 'Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low and Middle-income Nations.' *Human Settlements Discussion Paper Series: Climate Change and Cities 1*. London: International Institute of Environment and Development.

Scott, L. 2008. 'Climate Variability and Climate Change: Implications for Chronic Poverty.' *Working Paper 108.* Manchester: Chronic Poverty Research Centre (CPRC), University of Manchester.

UN-ISDR. 2004. 'Living with Risk: A Global Review of Disaster Reduction Initiatives.'*International Strategy for Disaster Reduction.* Geneva: United Nations International Strategy for Disaster Reduction, United Nations Inter-Agency Secretariat.

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