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Vulnerability and Resilience of Social-Ecological Systems

社会・生態システムの脆弱性とレジリアンス

FY2010 FR4 Project Report

平成 22 年度 FR4 研究プロジェクト報告

Project E-04 (FR4)
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Project Leader: Chieko Umetsu
プロジェクトリーダー　梅津　千恵子

January 2011
2011 年 1 月

Inter-University Research Institute Corporation, National Institutes for the Humanities
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Preface

The project on "Vulnerability and Resilience of Social-Ecological Systems", a member project of the RIHN's Ecosophy program, is now in its fourth of the five-year Full Research (FR4) status. RIHN's research projects have been organized by its dominant configurations into one of the five programs, i.e. Circulation, Diversity, Ecohistory, Ecosophy and Resources. This fiscal year coincides with the first transitioning year into the RIHN's 2nd phase, the commencement of the RIHN's Futurability Initiatives. The resilience project is expected to contribute to a transition to the new initiatives.

During the FY2010, we completed surveys for the 3rd cropping season. The rainfall continued to be above normal level for the last three consecutive cropping seasons. According to the Zambian government's forecast, the 4th cropping season of 2010/2011, which just started, is also expected to have above normal rainfall. Our field studies reveal that farmers diversify their plots by geographic locations to hedge against risks associated with rainfall variations. Clearer pictures are emerging from our intensive survey data as to how households vary their consumption patterns in response to the unexpected shock of heavy rainfall and flood in December 2007.

In this year, we focused more on disseminating our project outcomes both domestically and internationally. In October, four project members presented their research findings at the first GLP Open Meeting 2010 held at the Arizona State University. In November, two members attended AIWEST-DR 2010 held in Indonesia's Aceh, a province suffering the hardest hit from the 2004 Indian Ocean's tsunami. The main theme of the conference was how to build community resilience. Also, we plan to attend the Resilience2011 Meeting at Arizona State University as well as EnvironmentAsia Conference in March 2011 to build academic network for potential international collaborations. In Japan, we organized a session at the JASID Meeting on resilience and attracted a large group of audiences.

With the fourth year of the project coming to its completion, I wish to express my appreciations to our project members for their efforts and contributions to the steady progress of our project. We also wish to thank all the member of Project Evaluation Committee (PEC), the Director, program directors, administrative staff and all the colleagues at RIHN for their kind support and for facilitating this integrated research program.

January 2011

Chieko Umetsu
E-04(FR4) Project Leader
Research Institute for Humanity and Nature, Kyoto, Japan

E-04 (FR4)

Vulnerability and Resilience of Social-Ecological Systems

Project Leader : Chieko UMETSU Short name : Resilience Project
Home page : http://www.chikyu.ac.jp/resilience/
Program : Ecosophy program
Keywords : resilience, poverty, social-ecological system, resource management, environmental variability, vulnerability, human security, semi-arid tropics, adaptive capacity

SUMMARY OF RESEARCH OBJECTIVES AND CONTENTS

1. Research Objectives

The objective of this research is 1) to consider impacts of environmental variability on vulnerability and resilience of human activities in the semi-arid tropics; 2) to study factors affecting social-ecological systems and their recovery from shocks; 3) to analyze factors determining ability of households and communities to recover from environmental shocks and the roles of institutions in improving household resilience; and 4) to identify the factors affecting resilience of social-ecological systems and ways in which the resilience of subsistence farmers in the semi-arid tropics to environmental variability can be strengthened.

2. Background

A vicious cycle of poverty and environmental degradation, such as forest degradation and desertification, is a major cause of global environmental problems. This is especially the case in the semi-arid tropics (SAT) including Sub-Saharan Africa and South Asia, where a majority of the world's poor are concentrated. Within the SAT, communities' livelihoods depend critically on fragile and poorly endowed natural resources, and poverty and environmental degradation are widespread. People in these regions depend largely on rain-fed agriculture, and their livelihoods are vulnerable to environmental variability. Environmental resources such as vegetation and soil are also vulnerable to human activities. To surmount these environmental challenges, human society and ecosystems must be resilient to (recover quickly from) environmental shocks. Thus in this project we consider society and ecology as one social-ecological system and empirically analyze its resilience.

3. Research Methods

a. Research Contents and Methodology

The research is organized into four themes focusing on different dimensions of resilience. Theme I investigates the influences of ecological resilience on human activities by comparing soil properties in different landscapes (e.g. valleys, hill slopes and plains), the types and histories of land use, and agro-ecological succession. Theme II evaluates household resilience in risky environments in terms of income-smoothing, consumption-smoothing, and nutrition status. Theme III focuses on the institutional aspects of social resilience in the SAT. It examines how social, political, economic and ecological changes shape social resilience. Theme IV clarifies the relationship between ecological vulnerability, resilience and human activities, through investigations of historical and spatial changes in land use and multi-level social-ecological systems.

b. Research Areas

The primary study sites are in the drought-prone Eastern and Southern provinces of Zambia, Southern Africa (Figure 1).

4. Project Organization

Research Organization

The four themes interlink and thus provide a comprehensive assessment of resilience of social-ecological systems

Theme I: Ecological resilience and human activities under variable environment

Theme II: Household and community responses to variable environment

Theme III: Political-ecology of vulnerability and resilience: historical and institutional perspective

Theme IV: Integrated analysis of social-ecological systems

5. Research goals in FY2010

During the FY2010, we continue household surveys and weather monitoring for the third cropping season 2009/2010.

- We refined and sharpened working hypotheses for our resilience empirical studies and proceed with qualitative and quantitative analyses.
- Factors controlling maize yields will be clarified from the field experiments in Eastern and Southern Province. Those factors will be spatially evaluated in the study area of Southern Province.
- The household survey, anthropometric measurements, and rainfall recording that were initiated in November 2007 (the onset of the rainy season of 2007/08) in the project site in Southern Province of Zambia will continue until November 2010. The analyses of the impact of rainfall variability on household consumption and nutritional conditions will be extended covering two cropping seasons, namely 2007/08 and 2008/09.
- Multi-temporal and spatial change analysis caused by environmental change in 2008-09 and its effects on household's livelihood and food aid activities by the Zambian Government and NGO in Sinazongwe will be investigated.
- Based on the analysis from two-decades of field survey in a village of Central Zambia, we examine the reasons and process of increased vulnerability among farmers and households.

6. Progress up to Now

In FY2006 (PR) we focussed on establishing research collaborations with various institutions in Zambia. In FY2007 (FR1) we prepared experimental field sites and installed monitoring equipment such as weather stations, on-farm rain gauges and soil moisture measurement devices. Comprehensive household surveys and monitoring of rainfall and crop growth commenced in November 2007. Intensive field data collections for the 2007/2008 and 2008/2009 agricultural seasons and data compilations were completed in subsequent fiscal years of FY2008 (FR2) and FY 2009 (FR3). For the current fiscal year of FY 2010 (FR4), filed surveys, other field monitors and data compilations for the 2009/20010 seasons have just been completed.

- We approach resilience of farming households to climatic variability by focusing on mechanisms and speed of consumption, food production and livelihood recovery after experiencing shocks such as drought and floods (see conceptual diagram in Figure 2). Theme 1 measures the level of decline of agricultural production through maize yields. Theme 2 observes the speed of recovery in food consumption and health and nutritional status such as body weight, growth and skinfold thickness. Theme 3 qualitatively considers conditions under which livelihoods decline or do not decline; how they recover; and how differential coping strategies and the household access to resources in response to shocks. Theme 4 visualizes the spatial pattern of agricultural households' resource use and cross-scale interactions.

- Analysis of household food consumption after climatic shocks using data from high frequency household surveys is in progress.
- In the field experiment in Eastern Province, impacts of tree burning on soil nutrient status and maize yield varied according to the amount of tree biomass burnt. The field experiment in Southern Province suggested that maize yield was strongly influenced by topography and temperature.
- Dataset covering two cropping seasons of 2007/08 and 2008/09 was established for the analyses. Using the dataset, resilience at household level was quantitatively measured and factors affecting the resilience were identified. The decline of food consumption through calorie intake before harvest (February) was observed during both 2007/08 and 2008/09 cropping seasons. After March 2008, food consumption gradually recovered, however the speed of recovery was slow. The effect of heavy rainfall in December 2007 appeared after one year as the hike of maize price. It took more than one year for most households to recover food consumption (calorie intake) to the level before December 2007 heavy rainfall.
- After floods, farmers responded by replanting maize, shifting from maize to potato and beans. In addition, some new activities for getting cash income, such as livestock sales, fishery and wage labor, emerged to offset a shortfall of income, which indicated varieties of coping mechanisms exist for affected households.
- We could explain that the increased process of vulnerability differs by each actors, such as farmers, households and rural societies. And also we revealed that vulnerability increased by various reasons, and it could be transmittable among economic, socio-political and even cultural sphere.
- Cellular phones are playing an important role in helping farmers to cope with shocks. Farmers under financial and non-financial stresses started utilizing cellular phones to garner support from their social network.
- We disseminated our project outcomes at the international conferences. We presented at ISPRS 20101 (Kyoto), GLP Open Meeting 2010 (USA), AIWEST-DR2010 (Indonesia), and plan to participate at Resilinece2011 (USA), EnvironmentAsia (Thailand). We organized a session at the JASID 2010 (Japan Society for International Development). We also organized Resilience Workshops (12^{th}, 13^{th}) and Resilience Seminars (30^{th}, 31^{st}, 32^{nd}).
- Project annual reports (FS,PR,FR1,FR2,FR3,FR4), working papers (#001-#012) and a Japanese

translation of a resilience workbook by Resilience Alliance, are all available at the project web site. http://www.chikyu.ac.jp/resilience/publication-W_e.html

・ Three project members are now participating IHDP committee and sub-committee of the Science Council of Japan and actively contributing to international community.

7. Research Plan until the next PEC Meeting in FY2010

For the next two years of research (FR4, FR5), we plan to conduct the following:

1. While refining the theoretical aspects of resilience, we need to consider the practical applicability of the resilience approach based on the field research.
2. Integration of the research and data should be accelerated for the common goal for analyzing resilience of the farm households qualitatively and quantitatively.
3. For FY2010 and early FY2011 weather monitoring, plot experiments, household surveys, and the accumulation, compilation and analysis of data sets will be continued.
4. The first monitored 2007/2008 cropping season was an abnormal flood year, against which the 2008/2009 and 2009/2010 cropping season should be compared.
5. Coping strategies of farm households to environmental changes will be analyzed and assessed qualitatively and quantitatively.
6. To give feedback to the local community we provided rainfall information for the first cropping season 2007/2008 to local farmers. We will continue to do so.
7. We prepare for the RIHN International Symposium and RIHN Forum for FY2011. We also prepare for working workshop for book publication.
8. Collaboration with other international research organizations should be enhanced.
9. The concept of resilience can be applied to other RIHN project as well. We continue promoting inter-project initiatives within RIHN projects and other research groups.

8. Research Activities from FY2006 to FY2011

Time Schedule

	2005 FS	2006 PR	2007 FR1	2008 FR2	2009 FR3	2010 FR4	2011 FR5
Research Methodology	xxx	xx	xx	x			
Zambia							
I. Ecological Resilience	x	xx	xxx	xxx	xxx	xx	x
II.Household/Community	x	xxx	xxx	xxx	xxx	xx	x
III. History/Institution	xx	xx	xxx	xxx	xxx	xxx	x
IV. Integrated Analysis	x	xx	xxx	xxx	xxx	xxx	xxx
India		x	x	x	x		
Burkinafaso			x	x	x	x	
International Workshop			x		x		x
Project Report	FS Report	PR Report	Annual Report	Interim Report	Annual Report	Annual Report	Final Report

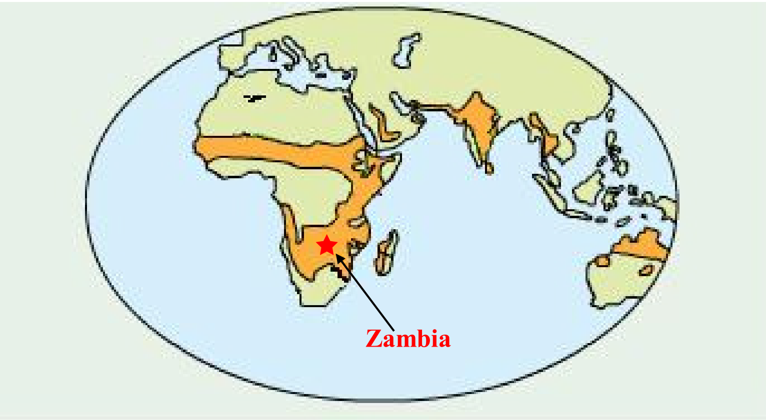

Figure 1. Regions of Semi-Arid Tropics and Study Areas

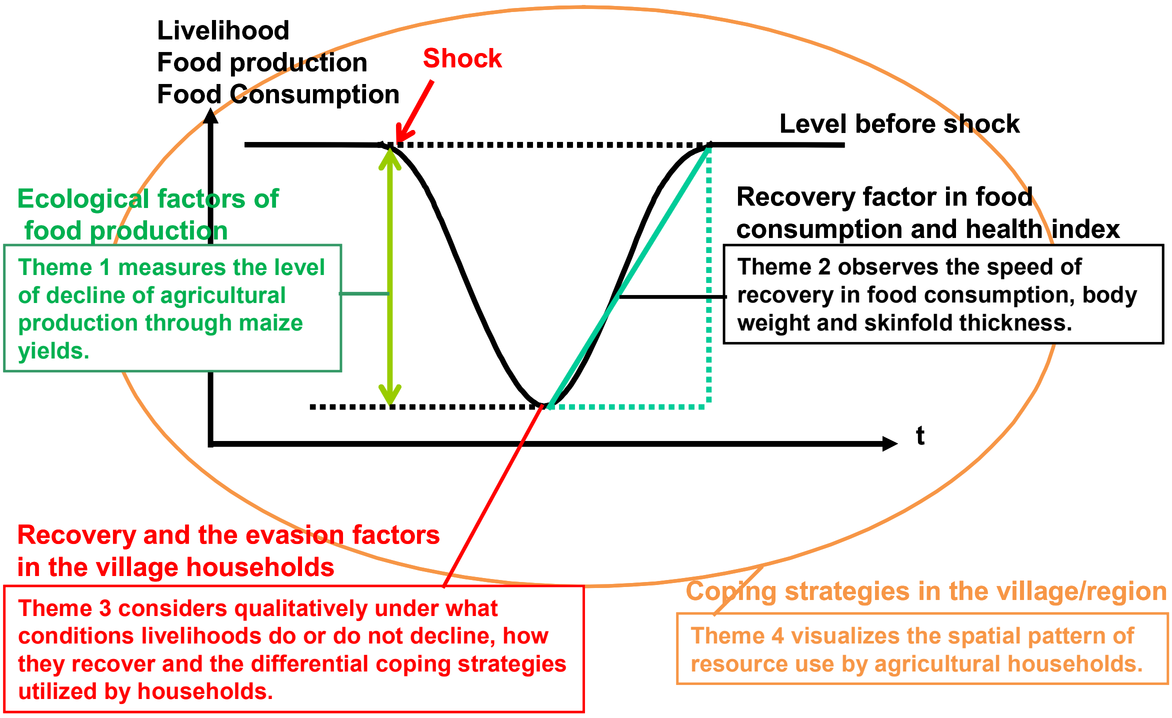

Figure 2. Approaches to Resilience

E-04 (FR4) Project Member List (FY2010)

revised Dec, 2010

	Name	Affiliation	Department	Title	Field	Role
Leader	Chieko UMETSU	RIHN	Research Department	Associate Professor	resource & environmental economics	Regional analysis, farm survey
A	Shigeo YACHI	Center for Ecological Research, Kyoto University		Associate Professor	mathematical ecology	Advisor
	Theme I					
○	Hitoshi SHINJO	Graduate School of Agriculture, Kyoto Univ.	Division of Environmental Science and Technology	Assistant Professor	soil science	organic materials and soil fertility
	Kaoru ANDO	Graduate School of Agriculture, Kyoto Univ.	Division of Environmental Science and Technology	Graduate Student (Ph.D)	soil science	organic materials and soil fertility
	Hajime KURAMITSU	Graduate School of Agriculture, Kyoto Univ.	Division of Environmental Science and Technology	Graduate Student (MS)	botany	grass/herb components and its succession
	Reiichi MIURA	Graduate School of Agriculture, Kyoto Univ.	Division of Agronomy and Horticulture Science	Lecturer	botany	grass/herb components and its succession
○	Hidetoshi MIYAZAKI	RIHN	Research Department	Project Researcher	soil science	measurement of land plot, crop components
○	Moses MWALE	Mt. Makulu Central Research Station, Zambia Agricultural Research Station	Ministry of Agriculture and Cooperatives	Vice Director	soil science	soil analysis
	Shozo SHIBATA	Field Science Education and Research Center, Kyoto Univ.	Kamigamo Experimental Station	Professor	forest ecology	tree/shrub components and its succession
○	Ueru TANAKA	Graduate School of Global Environmental Studies, Kyoto Univ.	Terrestrial Ecosystems Management	Associate Professor	agronomy	Landuse and risk management
	Theme II					
○	Takeshi SAKURAI	Hitotsubashi University	Institute of Economic Research	Professor	development economics	household survey and analysis
	Hiromitsu KANNO	National Agricultural Research Center for Tohoku Region	Laboratory of Agricultural Meteorology	Team Leader	agricultural meteorology	measurement of rainfall data
	Akinori KITSUKI	Hitotsubashi University	Graduate School of Economics	Graduate Student (MS)	development economics	household survey and analysis
	Sayuri KON	Graduate School of Health Sciences, Hokkaido University	Devision of Health Sciences	Graduate Student (MS)	human ecology	human growth, nutrition and health
	Harutaka KUBO	Graduate School of Health Sciences, Hokkaido University	Devision of Health Sciences	Graduate Student (MS)	human ecology	human growth, nutrition and health
	Ken MIURA	Hitotsubashi University	Graduate School of Economics	Graduate Student (MS)	development economics	household survey and analysis
	Hiroyuki SHIMONO	Faculty of Agriculture, Iwate University	Crop Science Laboratory	Associate Professor	crop science	Crop Science Modelling
	Taro YAMAUCHI	Graduate School of Health Sciences, Hokkaido University	Devision of Health Sciences	Associate Professor	human ecology	human growth, nutrition and health
	Theme III					
○	Shuhei SHIMADA	Graduate School of Asian and African Area Studies, Kyoto University	Division of African Area Studies	Professor	environmental geography	village society and institution
	Kazuo HANZAWA	College of Bioresource Sciences, Nihon University	Department of International Development Studies	Professor	agricultural economics	farm household survey
○	Yudai ISHIMOTO	RIHN	Research Department	Project Researcher	ecological Anthropology	emergency food of farm household
	Chihiro ITO	Graduate School of Asian and African Area Studies, Kyoto University	Division of African Area Studies	Graduate student	human geography	labor migration in rural area
	Gear M. Kajoba	University of Zambia	Department of Geography	Senior Lecturer	geography	land tenure system and food security
	Shiro KODAMAYA	Graduate School of Social Sciences, Hitotsubashi University	Division of African Area Studies	Professor	African sociology	agricultural development and social change
	Akie KYO	Graduate School of Asian and African Area Studies, Kyoto University	Division of African Area Studies	Graduate student	palliative medicine	co-existence with sickness and care
	Chileshe MULENGA	University of Zambia	Institute of Economic and Social Research	Senior Lecturer	economic geography	analysis of social behaviors
	Noriko NARISAWA	Graduate School of Asian and African Area Studies, Kyoto University	Division of African Area Studies	Graduate student	gender anthropology	economic activities of female farmers
	Theme IV					
○	Mitsunori YOSHIMURA	Psco Corporation	Research and Development Center	Senior Researcher	remote sensing	ecological change monitoring
○	Thamana LEKPRICHAKUL	RIHN	Research Department	Senior Project Researcher	environmental & health economics	household survey and analysis
	Keiichiro MATSUMURA	Rikkyo University	Department of Sociology	Assistant Professor	cultural anthropology	land tenure system and rural livelihood
	Tazu SAEKI	National Institute for Environmental Studies	Center for Global Environmental Research	NIES Assistant Fellow	atmospheric physics	climate monitoring
	Chieko UMETSU	RIHN	Research Department	Associate Professor	resource & environmental economics	regional analysis
○	Megumi YAMASHITA	Survey College of Kinki		Lecturer	geographic information	vegetation monitoring
	India					
○	K. Palanisami	International Water Management Institute	IWMI-TaTAs Program	Program Coordinator	agricultural economics	household survey and analysis
	V. Geethalakshmi	Tamilnadu Agricultural University	Department of Agricultural Meteorology	Professor	agriculatural meteorology	monsoon rainfall analysis
○	Takashi KUME	RIHN	Center for Coordination, Promotion and Communication	Associate Professor	soil hydrology	tsunami impact study
	C.R. Ranganathan	Tamilnadu Agricultural University	Department of Mathematics	Professor	mathematics	economic modelling
	Akiyo YATAGAI	RIHN	Research Department	Assistant Professor	climatology meteorology	monsoon rainfall analysis
	Burkina Faso					
○	Tom Evans	Indiana University	Department of Geography	Associate Professor	geography	agent-based modelling

○＝Core Member; A = Advisor; MAFF=Ministry of Agriculture, Forestry and Fisheries

Resilience of Rural Households in Semi-Arid Tropics:
A Linkage of Social-Ecological Systems

Chieko Umetsu
Research Institute for Humanity and Nature, Kyoto Japan

Introduction

Resilience is defined as "the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity (Walker et al. 2004)". Although resilience has been defined and analyzed as ecological as well as social-ecological terms, their integration is still under development. Recently, the concept of resilience has been directly applied to regional development and food security issues where people heavily rely their livelihoods on natural resource base (Perrings, 2006; Mäler 2008; UNDP, UNEP, WB, WRI, 2008; ICRISAT, 2010). Also, academic communities consider that resilience is an important component for achieving sustainability (ICSU, 2010).

Within the Semi-Arid Tropical Sub-Saharan Africa, communities' livelihoods depend critically on fragile and poorly endowed natural resources, and poverty and environmental degradation are widespread. People in these regions depend largely on rain-fed agriculture, and their livelihoods are vulnerable to environmental variability. Environmental resources such as vegetation and soil are also vulnerable to human activities. To surmount these environmental challenges, human society and ecosystems must be resilient to (recover quickly from) environmental shocks. Although the concept of the resilience has been discussed for the last decade, there are few empirical studies that address empirical investigation of resilience for rural livelihood in developing countries.

"Vulnerability and Resilience of Social-Ecological Systems" (Resilience Project) has proposed qualitative and quantitative approaches to empirically analyze resilience of rural households in Zambia (Umetsu, Shinjo, Sakurai, Shimada, Yoshimura, 2010). We argued that in order to operationalize resilience, it is important for us to consider *resilience* in the context of the human security of rural households in SAT region. In the Resilience Project, we consider resilience *to* environmental variability, such as drought, flooding and social changes. We consider resilience *of* food supply and consumption, health status, agricultural production and livelihoods. Lastly we consider resilience *for* protecting human security, i.e., survival, livelihoods and dignity (Commission on Human Security, 2003).

The purpose of this chapter is to address approaches to study resilience we employ in our Resilience Project and summarize research outcomes in reference to a linkage of social-ecological systems.

Approaches to Resilience

The resilience of social-ecological system for subsistence agricultural households in SAT we consider is resilience *to* environmental variability, *of* food supply and consumption, health status, agricultural production and livelihoods since, in case of emergency such as drought and flood, the most important mission is to secure food supply for survival. Environmental variability that we concern is mainly drought, food and disasters that regions and communities are affected equally (covariate shock).

In Resilience Project, four themes work together while employing various approaches to resilience. For an empirical approach to resilience, we focus on the mechanism and the speed of recovery in food consumption and livelihoods of agricultural households after shocks such as drought and flooding (Figure 1). Theme 1 measures the level of decline of agricultural production through maize yields. Theme 2 observes the speed of recovery in food consumption, body weight and skinfold thickness. Theme 3 considers qualitatively under what conditions livelihoods do or do not decline, how they recover and the differential coping strategies utilized by households. Theme 4 visualizes the spatial pattern of resource use such as land use by agricultural households and land cover changes. This theme also includes spatial heterogeneity and dynamics of resilience and historical investigation (Evans et al. 2010). For a major disaster, the social-ecological system (SES) has possibly shifted to alternative state in transitional stage in case of 2004 Indian Ocean tsunami.

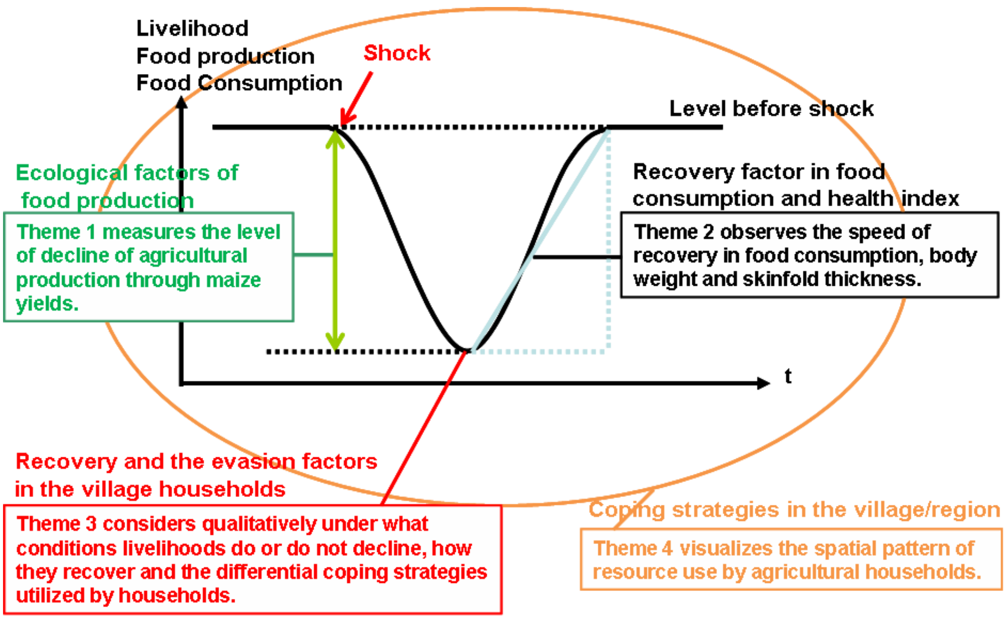

Figure 1. Approaches to Resilience

A Linkage of Social-Ecological Systems and Resilience

Figure 2 indicates our research components, indicators and factors affecting resilience. This figure illustrates the linkage between rainfall, food supply, food consumption, health, and ecosystem services in drought prone area. Environmental variability such as rainfall and social changes (resilience *to* what) is shown in blue. Indicators are food supply, food consumption, food production and health status (resilience *of* what) shown in orange. The connecting arrows show the working hypothesis of the project. Our purpose is to find out the strength and weakness of the connection between these components, test indicators of resilience, and verify factors and conditions for resilience.

Our three field sites are located in Sinazongwe and Choma Districts, Southern Province of Zambia. People in our sample villages are called Valley Tonga. After the construction of Kariba Dam in 1959, Valley Tonga people suffered from huge social and political shocks, i.e., forced relocation from the valley bottom (Colson, 1960; Scudder, 1962, 2010). Site A is close to Kariba Lake and has an old village before dam construction and a new village relocated after the dam construction. The land is flat. On the other hand Site B is in mid-escarpment with hilly farm lands. Site B residents relocated during the 1990s. Site C is located at the highest altitude at the edge of plateau. Site C

How rainfall variability and other factors are affecting crop production?

Environmental variability (e.g. rainfall variability) affects crop yield from farmer's field, thus directly affecting food availability and consumption i.e., survival of household. The historical rainfall data indicate that in Southern Province in Zambia, the major drought occurred in 1991/1992, 1994/1995, 2001/2002, 2004/2005 cropping seasons. In addition, less rainfall was associated with El Nino years and more rainfall with La Nina years (Yatagai in this issue). The productions of maize, major staple food in Zambia, as well as the rural livelihoods have been directly affected by the level of precipitation. The share of poverty in Southern Province increased from 79 per cent in 1991 up to 86 per cent in 1993 immediately after severe 1991/1992 drought. Although poverty headcounts decreased

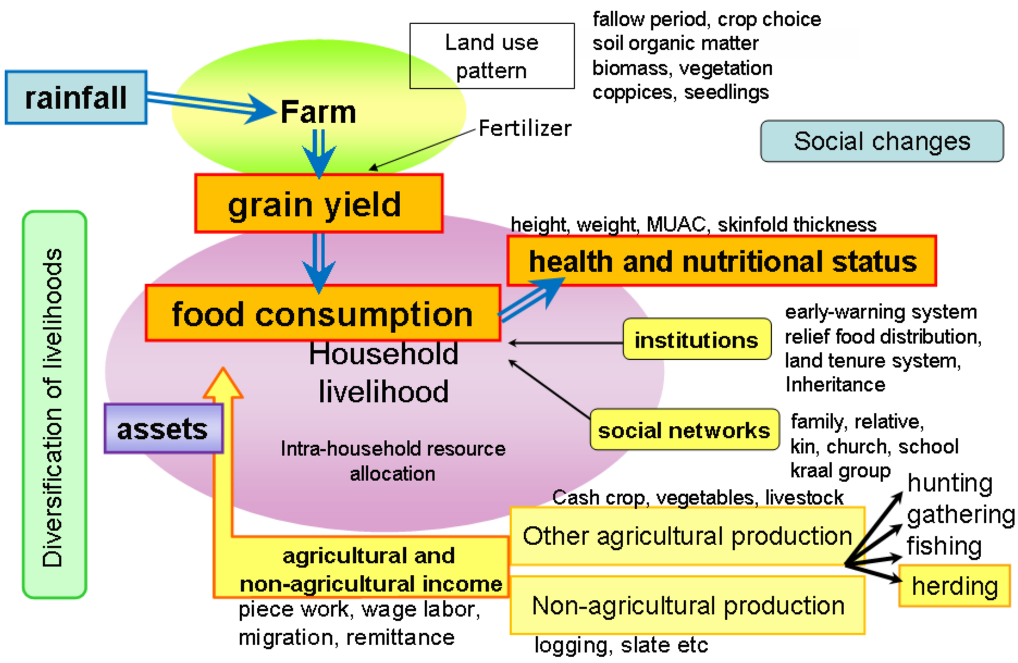

Figure 2. Factors affecting resilience for food consumption levels among households in Zambia (Hypothesis)

until 2002, there is an increasing trend in recent years (Thamana in this issue). Although drought has been a major climatic shock in our study site, the last three cropping seasons 2007/2008, 2008/2009 and 2009/2010 received larger rainfall than the annual average in our study site. The seasonal pattern of rainfall varied among three rainy seasons (Kanno et al., in this issue). Reduced yield by delayed planting indicated that the timing of planting is critical for maize yield (Shimono et al., in this issue). Maize yield is also affected by topography and temperature in Southern Province (Miyazaki et al., 2010); and tree biomass after burning trees in the fields in Eastern Province (Shinjo et al., Miura et al., Sokotela et al., in this issue).

Heavy rain as environmental shock to households production and food consumption

On the 29th of December 2007, heavy rainfall affected the Sinazongwe District, Southern Province. The rain gauges we installed in Site A (among Site A, B and C) received 473 mm this week on average where the annual average rainfall in Sinazongwe District is 694.9mm (Saeki et al., 2008). This heavy rainfall damaged the maize field in the region. In Site A the damage was the most severe among three study sites. After the heavy rain, about 30% of the damaged field was abandoned and 54% of the damaged fields were replanted with maize. In Site C, switching from maize to sweet potato was a common practice. Topographical location of agricultural fields has been shown to mitigate climate variability (Miyazaki; Yamashita; in this issue). This heavy rainfall resulted in decline of maize production in 2008 and affected food consumption, health and nutritional status of household members. Based on the food consumption survey in three study sites, about 80 per cent of energy intake of household members depends on cereals mainly maize (Kon et al., in this issue). Although stunting was prevalent, the nutritional status of sample children was generally good compared to U.S. reference data (Yamauchi et al., in this issue). The long-term weekly interview survey data identified rapid decline and gradual recovery of food consumption after the heavy rainfall. Also body weight declined after food consumption declined. This recovery path became the base for quantitative analysis of resilience. It was revealed that it took almost one year for most households to recover food consumption from the after the rainfall shock and the poor are more sensitive to the rainfall shock in food consumption. The decline of maize yield in 2008 brought food price hike before the next harvest season in February 2009 and affected poor farmers directly (Sakurai et al., in this issue).

Various coping strategies after the heavy rainfall shock to recover food consumption and livelihood

When food supply from their own fields declines, household heads try all measures to secure food supply for the household from other means. In this event, cash in hand played very important role for smoothing consumption levels particularly staple food (Kitsuki and Sakurai in this issue). After the heavy rain, some households started new cash income activities such as vegetable, livestock and poultry sales. From the analysis of cattle holding as an asset, the poor farmers tend to protect cattle and the wealthier farmers tend to protect consumption by selling cattle (Miura et al. in this issue). Nasuda et al., (in this issue) found that households in Site A and B suffering significant crop loss from heavy rain responded not only by cutting consumption by also by increasing working hours among both adults and children. Increasing working hours among children during school semester may have serious implications on children's school attendances and school performances. If agricultural production is not enough to support food supply, then household members pursue non-agricultural activities such as piecework to supply food to the household and maintain livelihoods. For household survival and maintenance of livelihoods, food distribution system of aid agencies and local institutions and organizations that secure access to resources are important (Matsumura in this issue). Also social networks such as relatives and friends play an important role. Recently the use of mobile phone is becoming very popular for requesting monetary support (Ishimoto in this issue).

Even though food production declines in flood years, households employ various coping strategies and alternative economic activities to try to recover from these shocks (Yoshimura et al., in this issue). In addition, regional scale dynamics of resources and livelihoods are the source of resilience to maintain survival and livelihood. Ecosystem services provide a variety of resources to rural communities in the region. For example, agro-ecological systems provide food supply, lake ecosystems provide fish, forest ecosystems provide emergency food, firewood as energy, water for cooking, and material for construction.

As an ex-ante and ex-post risk coping strategies, the capacity of diversified access to resources is one important condition for resilience (Shimada, 2009; Thamana, 2007). Ishimoto, in this issue, consider resilience with three components, i.e., external shock, assets and capacity. Capacity can be separated into ex-ante adaptive capacity and ex-post coping capacity. The access to resources is facilitated through a transfer and/or substitution of livelihood from agriculture to livestock, agriculture to non-agriculture, market, social organization and institution, as well as social network. Rural household and communities in Africa are facing not only risks from natural disasters but also risks from social and economic changes, such as international price hike of cash crops, political transition, changes in land tenure systems and agricultural policies. During the course of transition from old systems to new systems, some access channels to resources decreased while other access channels expanded. It is important to consider decline and rise of vulnerability as a bundle in historical context in order to understand resilience (Shimada in this issue).

Indian Ocean Tsunami as covariate shock to the communities

Disaster such as Indian Ocean Tsunami is a covariate shock where communities and region receive a common shock. The Indian Ocean Tsunami that occurred on 26th December 2004 caused severe damage to coastal areas in Indian Ocean. How did Social-Ecological Systems (SES) changed in response to great shock like tsunami? Coastal regions of Nagapattinam District in Tamil Nadu State received the largest damages in India by 2004 Tsunami. After tsunami hit the coastal regions, it took one and a half years for paddy fields to recover from salinity since heavy Monsoon rainfall in 2005 washed salts away from the fields. Human activities to intervene agricultural systems were also important for the recovery (Kume et al., 2009; Kume in this issue). Although the recovery of the farm was rather quick, it took almost three years for social system to recover from the income shock according to our long-term household survey. For the household income to recover to pre-tsunami level, the availability of labor market played a crucial role（Umetsu et al., in this issue）.

Understanding resilience in a comprehensive manner

This paper provides an overview of our results from empirical approaches to resilience. We consider resilience in the context of agricultural livelihood of SAT region. Our target is agricultural households in drought-prone Southern Zambia and their survival and livelihood. We especially consider the recovery of food consumption and food supply as well as livelihood after environmental shock such as drought and flood. What is important is that we need to understand resilience of social-ecological systems in a comprehensive manner in people’s daily livelihoods. Resilience is a set of recovery (speed), recovery path (how to recover), recovery mechanism (what drives recovery), and ability including learning process, self-organization and institution that facilitate households and communities to exercise their ability.

Resilience is a concept that has a potential for opening doors to a different approach to natural resource management (Resilience Alliance 2007). The sustainability of rural societies requires an appreciation of the resilience of households and communities. Resilience is the basic capacity that the societies need to acquire to build sustainability at all levels.

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Effects of Clearing and Burning on Soil Nutrients and Maize Growth in a Miombo Woodland in Eastern Zambia

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Abstract

This paper reports interim results from a 5-year experiment on the effects of clearing and burning on a miombo woodland in Eastern Province, Zambia. The amount of tree biomass burnt determined the soil nutrient status after burning, as a result of the amount of ash added to the soil. The intensity and duration of the burning event also affected the soil. Carbon mineralization, NH_4-N, and available phosphorus increased after burning because of degradation of soil organic matter and addition of microbial detritus. However, net nitrogen mineralization was not active because N was immobilized by microbes. Maize grain yield increased after burning because of the increase in plant-available nutrients and suppression of weed growth. Although the burnt area was only 13% of the total area, the grain yield from burnt spots accounted for 30% of the total yield; therefore, burning markedly increased grain yield. A high yield of maize was maintained for at least 2 years after burning because of the high available P and available N. However, the labile organic matter was similar in non-burnt and burnt areas. Although the amounts of plant-available nutrients in the spots burnt with large trees were higher than their respective amounts in spots burnt with small trees, these higher levels of nutrients contributed only to stover biomass. Therefore, an increase in grain yield can be achieved by burning only small trees. The burnt area was extended by burning large and small trees separately, increasing the grain yield from the entire field. Soil conditions were affected more strongly by burning of large trees, compared with burning of small trees. In the non-burnt spots, the amounts of plant-available nutrients in the soil changed during the cultivation period, alongside changes in soil organic matter. In the first year, immobilization exceeded mineralization because of the high C:N ratio of soil organic matter after clearing. However, the soil organic matter gradually decomposed during the wet season, increasing the labile fraction in the second year. This resulted in increased net N mineralization and available P in the second year. Although the amounts of plant-available nutrients increased in the second year, maize stover biomass and grain yield were the same in the first and second year. The amount of nutrients available for maize growth may have decreased in the second year as a result of vigorous weed growth.

A Field Guide to Common Plants of the Petauke District
(Partial Presentation)

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Abstract

To facilitate plant identification in the field experiment station in Petauke District, Eastern Zambia, a field guide to 80 most common plants in the area was compiled in Japanese for temporary use. Presented here is its partial English translation. The entire translation is in preparation to be made accessible via the internet.

1. Introduction

As described elsewhere in this volume, Dr. H. Shinjo et al. are conducting a field experiment in Mwelwa village, Petauke District, Eastern Zambia, to evaluate the effects of the slash-and-burn system and continuous cropping of maize on soil fertility and structure. This research involves monitoring of vegetation using the quadrat method from before the start of the experiment through various cropping and fallow sequences. In this research, plant identification has been frequently problematic, because trees, herbs, and seedlings often lack flowers and fruits in agricultural situations. To facilitate the vegetation survey, plants in the district were photographed and a field guide to 80 common plants in the area was compiled in Japanese for temporary use by non-botanists. Here, an English translation is presented for the most common species in the study plot. The entire field guide will be added to the project after some amendments and translation. This will make it accessible to all those involved in ecological/agricultural research in Zambia.

2. The field guide

(1)

Brachystegia manga De Wild.
Vernacular name: *mputi*
Family: FABACEAE
Habitat: Miombo
Notes: High tree. Leaflet bluish green, rhombic, in 3–4 pairs. Leaflets arranged in same plane as middle axis, so the whole leaf is flat (Cf. *B. allenii*). Pod purplish green, surface smooth.

(2)

Brachystegia allenii Hutch. & Burtt Davy
Vernacular name: *mganza*
Family: FABACEAE
Habitat: Miombo
Notes: High tree. Leaflets bluish green, broadly elliptic, apex truncate to emarginate (having a central notch), base markedly asymmetrical, in 4 or more pairs along the mid-axis. Leaflets overlap each other, with their surfaces not in a single plane, giving a thick appearance to the leaf bunches. Pod brown, surface rough.

3)

Brachystegia stipulata De Wild
Vernacular name: *mfundanzinzi*
Family: FABACEAE
Habitat: Transition zone between miombo and dambo, common also in degraded miombo.
Notes: High to medium-height tree. Leaflet elliptic, deep green on upper side, pale green on lower side. Stipules ear-like, large, and persistent (note that stipule of *B. allenii* is also somewhat persistent).

4)

Julbernardia globiflora (Benth.) Troupin
Vernacular name: *kamponi*
Family: FABACEAE
Habitat: Degraded miombo, also in and around villages
Notes: Tree. Leaflets narrowly rhomboid-elliptic, blight green on both surfaces. Starts flowering and producing fruits at a much younger stage than *Brachystegia* spp. Pods have a brown suede-like surface.

5)

Dalbergiella nyasae Baker f.
Vernacular name: *kafundakweo*
Family: FABACEAE
Habitat: Degraded miombo
Notes: Tree with a narrow silhouette due to sparse branching and the narrow angle between branches and trunk. Pinnate leaves gathered near the top of each branch like umbrella ribs. Terminal leaflet may or may not be present (i.e., there may be an odd or even number of leaflets). Leaflets in 8 or more pairs, dull green on upper side, pale green on lower side, covered with indumentum (a layer of soft fine hairs).

6)

Pterocarpus angolensis DC.
Vernacular name: *mlombe*
Family: FABACEAE
Habitat: Miombo
Notes: Tree of medium height with a flat canopy. Leaf pinnate with a terminal leaflet. Unlike most other leguminous trees, leaflet has a rather long petiole and an acuminate apex. Each leaflet has thin but prominent veins running in a herring-bone pattern. When cut, the trunk produces copious amounts of blood-red resinous sap.

7)

Burkea africana Hook.
Vernacular name: *msase*
Family: FABACEAE
Habitat: Degraded miombo
Notes: Tree with bipinnate leaves. Leaf similar to that of *Albizzia antunesiana*. Shoot tips covered with rust-colored short hairs.

8)

Albizia antunesiana Harms
Vernacular name: *msase-pouvu*
Family: FABACEAE
Habitat: Degraded miombo
Notes: Tree with bipinnate leaves. Leaf similar to that of *Burkea africana* but distinguishable by powdery white lower surface and asymmetrical base of each leaflet (much wider towards the rachis tip). Leaf upper surface often tinged purple.

9)

Dichrostachys cinerea (L.) Wight & Arn.
Vernacular name: *kalumpangala*
Family: FABACEAE
Habitat: Degraded miombo
Notes: Low tree with a rough shape due to coarse irregular branching. Trunk cross-section is irregular, not circular. Branches are thorny to varying degrees, and are sometimes thornless.

10)

Diplorhynchus condylocarpon (Müll.Arg.) Pichon
Vernacular name: *mtowa*
Family: APOCYNACEAE
Habitat: Degraded miombo
Notes: Low to medium-height tree with long slender flexible branches. All parts excrete copious amounts of white latex when cut. Fire-tolerant because of the bulky bark, which has both longitudinal and transverse fissures resembling the pattern on an alligator's back. Easily regenerates from stumps in slash-and-burn fields, forming low dense thickets.

11)

Bridelia cathartica G. Bertol.
Vernacular name: *shimpombo*
Family: PHYLLANTHACEAE
Habitat: Degraded miombo, also around villages.
Notes: Leaves elliptic to obovate, rough on both surfaces, distinctly smaller on fruiting branches and becoming even smaller towards the branch end. Ripe fruits are dark purple.

12)

Pseudolachnostylis maprouneifolia Pax
Vernacular name: *msolo*
Family: PHYLLANTHACEAE
Habitat: Degraded miombo
Notes: Medium-height tree. Leaf nearly circular, quite smooth, concave above, convex below. Fruits fleshy but hard, dull green to yellow-green even when ripe.

13)

Lannea discolor Engl.
Vernacular name: *shaomboa*
Family: ANACARDIACEAE
Habitat: Degraded miombo
Notes: Medium-height tree. Lower surface of leaves distinctly whitish. Produces copious amounts of clear resin when cut. At the beginning of the dry season leaves turn yellow and fall earlier than most other trees.
Notes: Shrub to low tree producing edible fleshy fruits. Leaf hairiness and branch thorn size highly variable, sometimes thornless.

14)

Flacourtia indica (Burm.f.) Merr.
Vernacular name: *nkondonkondo*
Family: SALICACEAE
Habitat: From degraded miombo to surroundings of villages

15)

Melinis repens (Willd.) Zizka
Vernacular name:
Family: POACEAE
Habitat: Cultivated field
Notes: One of the most dominant weeds in maize field. Lower part trails on the ground and produce roots from each node.

16)

Heteropogon contortus Beauv. ex Roem. & Schult.
Vernacular name: Sajje
Family: POACEAE
Habitat: Disturbed grassland and roadsides
Notes: Sometimes forms pure stand on gravelly soil on the roadside. Mature spikelets are pungent when detached from the plant, very notorious, piercing the clothing and even skin.

17)

Rottboellia exaltata L. f.
Vernacular name:
Family: POACEAE
Habitat: Cultivated field
Notes: Tall grass sometimes outgrows and suppresses maize. A notorious weed that can injure skin by its coarse hairs on its culm.

18)

Hyparrhenia filipendula Stapf
Vernacular name:
Family: POACEAE
Habitat: Forest margin
Notes: Branch shoots from the upper leaf axils stay green long after the main culm senesced.

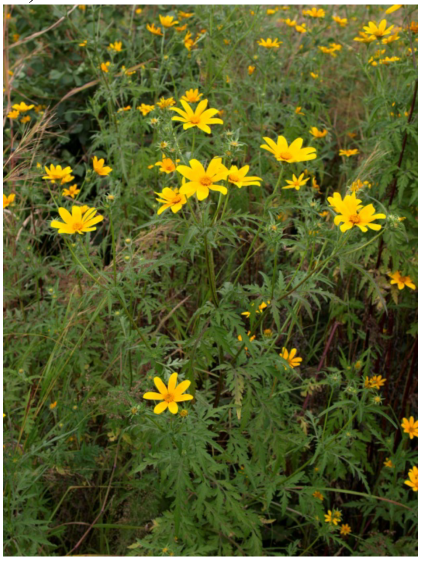
19)

Hyparrhenia variabilis Stapf
Vernacular name:
Family: POACEAE
Habitat: Half shade in the woodland
Notes: Produce stiff supportive aerial roots from lower nodes.

20)

Hyparrhenia dichroa Stapf
Vernacular name:
Family: POACEAE
Habitat: Roadside and disturbed grassland
Notes: The tallest of all *Hyparrhenia* species found in the area.

21)



Bidens schimperi Sch.Bip. ex Walp.
Vernacular name:
Family: ASTERACEAE
Habitat: Cultivated field but apparently native to woodlands.
Notes: One of the most troublesome weed of maize especially when the field is fertilized.

22)

Vernonia petersii Oliv. & Hiern ex Oliv.
Vernacular name:
Family:
Habitat:
Notes: One of the most common weeds in newly established slash-and-burn field.

23)

Vernonia poskeana Vatke & Hildeb.
Vernacular name:
Family: ASTERACEAE
Habitat: Cultivated field
Notes: Common weed both in new and old fields.

24)

Trichodesma zeylanicum R.Br.
Vernacular name:
Family: BORAGINACEAE
Habitat: Cultivated field
Notes: Common weed in continuously cultivated field. The whole plant is covered by white hairs, which look soft but are actually dangerous: they sting on skin badly.

25)

Amaranthus hybridus L.
Vernacular name:
Family: AMARANTHACEAE
Habitat: Cultivated field, sometimes on termite hill
Notes: Being a member of weedy *Amaranthus*, likely to require high concentration of nitrogen. Rare in newly opened field.

Preliminary Report: Evaluation of Agro-Forestry Plants for Soil Fertility Restoration and Enhancement of Sustainable Agriculture in the Petauke District, Eastern Zambia (10th May 2010)

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Abstract

A field trial for demonstration and evaluation of agro-forestry plants to restore soil fertility is being conducted at the plots adjacent to the RIHN plots in Eastern Province, Zambia. Good growth of agro-forestry plants were observed. Three rainy seasons after planting, *Glilicidia sepium* and pigeon pea plants grew well to reach their heights to about 3 m. We will cut them down to plant maize so that we can estimate the effects of them as agroforestry plants on the improvement of the maize productivity.

1. Introduction

This progress report presents an update of the activities on 'Evaluation of Agro-Forestry Plants for Soil Fertility Restoration and Enhancement of Sustainable Agriculture', being carried out in eastern Zambia at Mwelwa Village, Chief Sandwe, Petauke District. It covers the 2009/2010 crop-growing season (November 2009 to April 2010).

The study serves as a demonstration to evaluate the effectiveness of agro-forestry technologies in enhancing soil ecological resilience as measured by the efficacy of some selected agro-forestry and green manure plant species for soil fertility restoration and enhancement of sustainable agricultural practices. Three specific objectives are:

1) To demonstrate the effect of the named plant species in soil fertility improvement for improved short fallow agricultural technology practices,
2) To measure soil property dynamics and characteristics that occur as a result of defined land use practices and imposed field practices and
3) To assess any socioeconomic impact of (long-term) benefits achieved following adoption of the technologies by various households and communities, thereby reinforcing ecological and social resilience concepts and principles.

Below is a sketch drawing of the ZARI trial and demonstration layout.

F 13	D 14	A 15	C 16	B 17	E 18
A 12	C 11	D 10	E 9	B 8	F 7
B 1	E 2	C 3	F 4	D 5	A 6

↑ N

Note: A = Treatment; 1 = Sub-plot No. 1

Treatments

A *Grilicidia sepium* fallow (GSF)

B Maize continuous fertilizer (MCF)

C Native Forest fallow (NFF)

D Maize, no Fertilizer (MoF)

E Green Manure fallow (GMF *Mucuna*)

F *Cajanus cajan* fallow (CCF)

2. Methodology

Measurement of initial soil conditions

a) At the beginning of the experiment (October 2007) the soil in each subplot (measuring 20 × 20 m) was sampled at two depths, the topsoil at 0–20 cm and the subsoil at 40–60 cm for subsequent laboratory analyses for pH, bases, CEC, organic carbon, total nitrogen, available phosphate and particle size distribution (PSD).

b) Grilicidia was initially raised in nursery beds, and later planted into the field from potted seedlings at a spacing of 1 m × 1 m. The spacing for pigeon pea (Cajanus cajan) in the field was the same as for Grilicidia, but the crop was direct planted from seed.

c) A hybrid maize variety MM 604 was used as the test crop and planted at a spacing of 90 cm between rows and 25 cm between plants within the rows. The fertilizer application rate followed the LIMA recommendation of 4 × 50 kg/ha of compound D (10N, $20P_2O_5$, $10K_2O$, 4–6 S), and the same rate for urea (46% N) as top-dressing in the continuous maize with fertilizer treatment. (MCF).

d) The native forest fallow treatment had no land clearing or preparation with the bush left in the virgin or natural state it was in before beginning the study.

e) The green manure plot was planted with Velvet bean (Mucuna).

f) On all the cultivated plots initial land preparation consisted of felling and stumping all trees, followed by digging with hand hoes well before the onset of the rainy season in October.

g) After planting, crop performance monitoring was instituted. It included replanting (filling in gaps where necessary), weeding and scoring for disease, pests, etc. Grain yield and stover were harvested in the maize plots and measured by weight to determine the yield performance. Pigeon pea seed is harvested from dry pods later in the dry season (August–September) when the fields are being protected from fire by clearing the fire breaks around the trial plots.

The current cropping season (2009/2010) marks the third year of crop growth in all the plots.

Field Day

No field day was held at the site in the 2009/2010 cropping season because, having held one the previous year, researchers believed that little difference would be apparent from what was shown the previous season (2008/2009). However, in the coming season after three-years of imposed treatments, more interesting results are expected.

Biomass Estimation

Aboveground plant biomass in the agro-forestry and native fallow plots was estimated by measuring plant height and stem girth (diameter) at ground level. Results for the different agro-forestry and native fallow plots are shown in the tables below.

3. Performance of the various treatments

Field measurements were made in 5 × 5 m units within the 20m × 20m plots.

Native Forest - Plot 3

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	2.43	35.54
2	2.78	50.30
3	3.46	69.02
4	2.92	57.00
5	3.26	50.36
Av.	2.97	52.44

Average native forest trees were about 3 meters tall, with a girth of about 52.4 mm at ground collar level.

Cajanus cajan - Plot 4

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	2.64	50.76
2	3.73	51.58
3	3.04	45.02
4	3.48	40.28
5	3.61	54.68
Av.	3.3	48.46

Grilicidia sepium - Plot 6

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	2.05	49.96
2	2.26	44.9
3	2.48	50.08
4	2.06	46.78
5	2.2	35.2
Av.	2.21	45.38

This plant shows resilience for survival.

Cajanus cajan - Plot 7

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	3.28	36.76
2	3.11	38.82
3	3.25	36.48
4	3.2	33.94
5	2.9	33.14
Av.	3.15	35.83

Native Forest - Plot 11

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	3.59	56.08
2	4.21	75.62
3	4.4	83.4
4	3.93	66.02
5	2.57	56.04
Av.	3.73	67.43

There is high termite activity in this plot.

Grilicidia sepium - Plot 12

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	2.84	46.93
2	2.53	50.98
3	2.65	62.14
4	4.88	82.32
5	3.35	53.5
Av.	3.25	59.17

The plants in this plot showed resilience. Also the *Grilicidia* plants grew faster in subplot # 04 where there was a termite mound, in contrast to other parts of the plot.

Cajanus cajan - Plot 13

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	3.74	35.48
2	3.54	40.54
3	3.74	38.2
4	3.94	55.9
5	3.52	37.48
Av.	3.70	41.52

Grilicidia sepium - Plot 15

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	2.34	43.68
2	2.52	48.8
3	1.7	33.88
4	1.93	39.98
5	1.89	42.94
Av.	2.08	41.86

Plants were stunted.

Native Forest - Plot 16

Serial No. (Subplot)	Average Height (m) /Subplot	Average Girth (mm)
1	4.26	63.02
2	4.43	76.88
3	3.56	57.02
4	4.54	64.9
5	5.17	69.96
Av.	4.39	66.36

Trees in this plot were sparsely populated and there was little branching.

Mean values of performance

Plant Species	***Height (m)***	**Girth (mm)**
Native forest	3.70	62.08
Cajanus cajan	3.38	41.94
Grilicidia sepium	2.51	48.80

Maize Harvesting

Within the maize plots, five (5m × 5m) subplots were measured and maize cobs harvested from each subplot were counted. After sun-drying the cobs for about three days, grain was shelled from the cobs. The weight of the maize grain was then measured and the moisture content determined. The results are presented in the tables below.

Remarks

Plot 1: The stover sample for moisture determination from this plot was 1.9kg. The diseased cobs were due to cob rot (*Fuserium*). The dominant weed species were shrubs (Chikoswa, Nyazongo and Kabalukila), followed by grasses (Kankululu).

Plot 14:The dominant weed was the yellow head shrub weed followed by Miombo trees (regrowth) and red head grass. The stover weight for moisture determination was 1.6kg.

Plot 10:The stover weight for moisture determination was 1.2kg. One maize cob from subplot #3 was eaten by rats.

Plot 17: The stover weight for moisture determination was 2.5kg. The dominant weed is the yellow head weed. There are few grasses and more herbaceous type of weeds.

Plot 8: The dominant weed in this plot is the purple head shrub with sparse yellow head weeds. There was hardly any grass in this plot. The stover weight for moisture determination was 1.7kg.

Plot 5: The stover weight for moisture determination was 1.1kg.

Plot	Treatment	Subplot #	Cob No.	Wt. of Cobs (kg)	Stover Wt. (kg)	Diseased Cobs	Grain Wt. (kg)	Corn Moisture	Dry Grain Wt/25m^2	Grain yield (Mg/ha)
5	M0F	1	71	5.6	5.2	19	3	12.2	2.6	
		2	66	8.4	6.7	11	7	13.2	6.1	
		3	66	5.8	5.8	14	3.5	12.7	3.1	
		4	74	6.1	5	11	5	12.5	4.4	
		5	58	6.5	5.3	4	6	12.8	5.2	
		Average	**67**	**6.48**	**5.6**	**11.8**	**4.9**	**12.68**	**4.3**	**1.71**
10	M0F	1	69	7.2	7.6	11	4	13.2	3.5	
		2	81	8.2	8.8	5	5.1	13.2	4.4	
		3	72	5.2	4.7	7	4.5	12.7	3.9	
		4	57	4.9	5.5	7	4	12.4	3.5	
		5	59	4.2	4	6	3.5	12.9	3.0	
		Average	**67.6**	**5.94**	**6.12**	**7.2**	**4.22**	**12.88**	**3.7**	**1.47**
14	M0F	1	56	5.8	5.8	8	4	13.2	3.5	
		2	59	3.8	3.9	3	3.5	12.5	3.1	
		3	61	7.2	6.4	10	3	13.5	2.6	
		4	61	6.3	6	6	5	13.3	4.3	
		5	55	3.2	3.7	5	3	12.1	2.6	
		Average	**58.4**	**5.26**	**5.16**	**6.4**	**3.7**	**12.92**	**3.2**	**1.29**
1	MCF	1	105	23.3	24.9	3	14	16.1	11.7	
		2	85	18.2	24.4	2	10.5	16.3	8.8	
		3	90	19.4	21.8	3	12	17.4	9.9	
		4	103	19.4	16.2	3	12.5	14.6	10.7	
		5	110	25.4	28.2	2	16.5	17.5	13.6	
		Average	**98.6**	**21.14**	**23.1**	**2.6**	**13.1**	**16.38**	**10.9**	**4.38**
8	MCF	1	98	18.2	18	6	13	14.4	11.1	
		2	122	17.5	15.7	4	5.5	14.9	4.7	
		3	205	24.3	23.7	3	16	19.1	12.9	
		4	120	19.4	20.7	4	13.5	15.5	11.4	
		5	109	22.2	18.8	1	13.5	15.9	11.4	
		Average	**130.8**	**20.32**	**19.38**	**3.6**	**12.3**	**15.96**	**10.3**	**4.12**
17	MCF	1	239	23	31	7	11.5	15.9	9.7	
		2	190	23.1	24.2	13	14.5	16.7	12.1	
		3	180	20.8	25.6	4	12.5	16.9	10.4	
		4	83	11.6	15.8	14	9	15.2	7.6	
		5	103	17	24.3	5	10	17	8.3	
		Average	**159**	**19.1**	**24.18**	**8.6**	**11.5**	**16.34**	**9.6**	**3.85**

4. Other Results

Maize Yield

Yield measurement data for the maize crop is still to be obtained.

Soil Analysis

Using the NEWS method, soils were sampled from depths of 0-20cm (topsoil) and 40-60 (subsoil) from all plots.

Soil Laboratory Analytical Results

Soil samples are being prepared for laboratory analyses. Exchangeable bases (Ca, Mg, K, Na), soil pH ($CaCl_2$), organic carbon (C), nitrogen (N), phosphate and cation exchange capacity (CEC) are the soil properties to be used to assess soil fertility status.

Plant Survival Rate

To obtain the plant survival rate, dead plants in each plot were counted. Results are presented in the table below.

PLOT #	***ROW*** **Spp.**	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	∑	***Mean***	**%**
4	Pigeon pea	2	5	3	4	4	4	4	5	5	4	2	**42**	**3.82**	**0.382**
6	*G. sepium*	0	2	2	1	1	0	2	1	1	3	2	**15**	**1.36**	**0.136**
7	Pigeon pea	4	3	3	4	3	1	2	3	3	2	3	**31**	**2.82**	**0.282**
12	*G. sepium*	2	2	3	2	1	1	2	0	0	1	2	**16**	**1.45**	**0.145**
13	Pigeon pea	3	2	5	3	3	4	3	6	4	5	4	**42**	**3.82**	**0.382**
15	*G. sepium*	3	1	0	0	1	2	0	1	2	4	1	**15**	**1.36**	**0.136**

Climatic Data

Climate conditions are monitored by an automatic weather station at the research site. Rainfall was 'normal' and well distributed for crop growth. The total rainfall for this season was 950mm.

Vulnerability and Resilience of Household Consumption and Their Determinants
-The Case of the Southern Province of Zambia-

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Abstract

Risk coping and consumption smoothing in rural areas of developing countries, where people's livelihood is often subject to various risks, have been well documented. However, the literature has not properly considered the time required for households and/or individuals to recover their level of consumption. To address the lack in the literature, we have incorporated the time dimension in the process of recovery from a shock in this paper. For this purpose, we have adapted the concept of resilience from ecology and define it in the context of consumption smoothing. Moreover, unlike most previous studies on consumption smoothing, we utilize weekly data collected before and after a covariate shock so as to provide empirical evidence of resilience.

In this paper, we provide an empirically workable definition of "resilience" at the household level. Resilience is based on the measurement of household food consumption per capita and is defined by the speed of the recovery of food consumption from a shock. Then, following the definition, we empirically estimate resilience using data collected in a rural area of Zambia, where its rain-fed agriculture is highly affected by rainfall variation. In this particular dataset, a heavy rain took place in December 2007. Resilience is measured as the speed of consumption recovery after the heavy rain shock.

Our panel data analyses reveal that the heavy rain caused a shock, i.e., reduction of food consumption, among the sample households, and it took almost one year for them to recover from the shock. Our analyses also show that household assets, such as land and livestock, have a positive effect on enhancing resilience. Then, dividing the sample into rich and poor groups based on the value of cattle holdings, we conducted similar analyses for each group separately and found that households in the rich group were more resilient than those in the poor group. The results indicate that some poor households that lack sufficient assets may not be able to recover consumption. Moreover, it is found that households in the poor group were more sensitive to the rainfall shock: they reduced consumption more quickly after the shock than did those in the rich group. We do not indicate in this paper how the sample households recover their consumption from the shock such as labor supply and livestock sales. Incorporating those coping behaviors is our next research topic as we have enough data to do it.

1. Introduction

Risks exist everywhere, and they are a part of rural life in developing countries. It is well known that rural households practice a variety of measures to manage *ex-ante* risk, such as crop and income diversification (Dercon, 2005). However, because such risk-management measures are costly and imperfect, risk events like drought often cause shocks to households, e.g., a decline of consumption. That is, shocks are almost inevitable in a risky environment. This does not necessarily imply that the impact of such shocks is significantly serious because households can mitigate the impact by undertaking various coping behaviors, such as liquidating assets, increasing labor supply, and receiving gifts (Dercon, 2002). Hence, so far as households have the capacity to cope with shocks, they can mitigate their impact, and thus their consumption is smoothed. The literature examines coping behaviors and consumption smoothing in rural areas of developing countries, generally demonstrating that rural households are usually able to smooth consumption in the case of idiosyncratic shocks, and even in the case of covariate shocks they can smooth consumption to some extent, depending on their capacity (Hoddinott and Harrower, 2005; and Dercon, Hoddinott, and Woldehanna, 2005).

However, the existing literature on consumption smoothing does not adequately consider the time required for households to recover their level of consumption. To test consumption smoothing, a panel dataset containing at least two observations at different time points is required. But because the interval between two observations is usually one or even several years, some shocks cannot be observed if consumption level recovers within the interval. This is particularly pertinent because household surveys typically ask about consumption over a recent short period, such as one month before the interview. One obvious shortcoming of such analyses is that the welfare impact of a shock can be underestimated if data collection on the risk event is conducted after the recovery or even while the recovery is in process. Another problem is that such analyses cannot exactly estimate the magnitude of the shock (i.e., reduction of consumption) and the speed of recovery (i.e., time required for recovery), if recovery has already started when *ex-post* data collection is being carried out.

To address apparent lacks in the literature on consumption smoothing, the present paper incorporates the time dimension in the process of recovery from a shock. For this purpose, we have adapted the concept of resilience from ecology and defined it in the context of consumption smoothing. Moreover, in contrast to most previous studies on consumption smoothing, the present study utilizes weekly data collected before and after a covariate shock so as to provide empirical evidence of resilience.

2. Definitions

The definitions of vulnerability and resilience are provided by Sakurai et al. (2010), based on the concept of Gunderson et al.'s engineering resilience. Gunderson et al. (2002) distinguish two ways of defining resilience in the ecological literature: one is engineering resilience, the other an ecological definition. Engineering resilience is "the speed of return to the steady state following a perturbation," conceiving ecological systems as existing close to a stable steady state. Conversely, ecological resilience assumes multiple stability domains and is measured by "the magnitude of disturbance that can be absorbed before instabilities shift or flip a system into another regime of behavior." The concept of engineering resilience fits into economics, which assumes a single stable equilibrium, while that of ecological resilience corresponds to multiple equilibria in economics.

In this paper, we adapt previous definitions and propose a new set. The definitions are schematically presented in Figure 1. The vertical axis measures the level of consumption, and the horizontal axis represents time. Figure 1 shows that the consumption level at the steady state is c_n. From time 0 to the time when a shock occurs, the consumption level remains at the steady-state level. In a short run, we can assume the consumption level to be constant. Then, owing to the shock, household consumption plunges from c_n. In this regard, two types of household are displayed in the figure. In Household A, after the shock the consumption declines to c_{sa}, a level above the threshold c_t, then it starts recovering at time t_1 and reaches the original level at time t_2. The recovery may not take place immediately after the shock; rather, the lowest level of welfare may continue for a while. But the point is that the consumption of Household A recovers within a short period of time ($t_2 - t_1$). The other type is Household B. The consumption goes down to c_{sb}, a level below the threshold c_t, after the shock. In this case, the household's consumption remains at c_{sb} for a long period—enough to allow us to consider it "permanent." The contrast in the two types of consumption dynamics is very similar to that between transitory and chronic poverty, but the threshold is not the same as a poverty line.

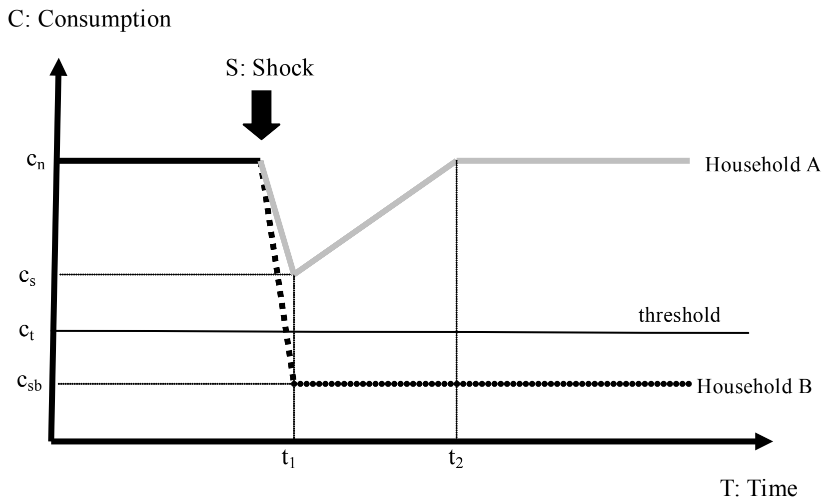

Figure 1 Schematic Definitions of Vulnerability and Resilience

Based on Figure 1, sensitivity, vulnerability, engineering resilience, and ecological resilience can be defined as follows. Sensitivity refers to the reduction of consumption against one unit of an exogenous shock: Household B is more sensitive to the shock than Household A because the former reduces consumption more than the latter, assuming the size of the shock to be the same. A household with lower sensitivity is not necessarily a better household: for example, a very poor household already below the threshold will make a very small reduction in consumption even if a shock occurs. Vulnerability is a very similar concept to sensitivity; but unlike with sensitivity, vulnerable households should be judged worse than non-vulnerable households. Thus, vulnerability can be defined as the probability that a household's consumption level will fall below the threshold level given a shock of fixed magnitude. A household whose consumption level is currently below the threshold should be excluded from the application of this definition or be considered 100% vulnerable. If we compare Household A and Household B, although the consumption level of the former is always above the threshold and that of the latter falls below the threshold, the probabilities are not 0% and 100%, respectively. We can say qualitatively that Household A is less vulnerable than Household B, but in order to obtain the probabilities we need to empirically estimate their sensitivity against a shock and the threshold.

Conversely, resilience concerns the recovery rather than the shock itself. If we assume a system with a single equilibrium, the concept of engineering resilience can be applied, and resilience can be defined as the speed of recovery of consumption from a shock. In Figure 1, the recovery speed is the slope between t_1 and t_2: it is $(c_a - c_{sa}) / (t_2 - t_1)$ in the case of Household A and 0 in the case of Household B. Thus, we can say that the resilience level of Household A is higher than that of Household B. This definition is simple, and the speed is easily calculated if the data are available, but in practice we need to control for the magnitude of shock. Otherwise, a household with less shock could be considered less resilient because there is no recovery. Finally, considering a system with multiple equilibriums, Household B is regarded as having changed its regime, e.g., from a high-consumption to a low-consumption regime, owing to the shock, and therefore we can qualitatively define Household A as resilient and Household B as not resilient. Quantitatively, ecological resilience is defined by the maximum magnitude of a shock from which a household can recover its consumption to the original level. Thus, it will be obtained by estimating the magnitude of a shock required to reduce the consumption level of a household to the threshold level. By this definition, the greater the shock, the more resilient is the household.

3. Data

This paper uses data collected as part of the Resilience Project of the Research Institute of Humanity and Nature. The project's study area is the Southern Province of Zambia, the most drought-prone zone in the country, with annual precipitation of less than 800 mm. Within the study area, three agro-ecologically distinctive sites, namely Site A, Site B, and Site C, were selected for detailed household survey, based on our own preliminary extensive survey in the study area (Sakurai, 2008). The three sites are spread over the slope adjoining Lake Kariba: Site A is located on the lower terrace of the slope on the lakeshore; Site C is on the upper terrace of the slope on the southern edge of the Zambian plateau; and Site B is located on mid-escarpment between the other two sites. Based on a village census conducted before the rainy season in 2007, 16 households in each site, thus 48 households in total, were selected for the survey.

The household survey consists of three components: (i) interview of sample households; (ii) anthropometric measurement; and (iii) rainfall measurement at the plot level. The interview was conducted every week by an enumerator, using structured questionnaires to obtain information about household agricultural production, income, consumption, and time use. For the anthropometrics, the same enumerator measured household members' body weight, height, skin-fold thickness, and upper-middle arm circumference using special instruments at the time of interview. Plot-level rainfall was recorded every 30 minutes by a rain gauge installed on a plot of each sample household. The data collection started in November 2007 at the beginning of the 2007/08 rainy season and is planned to continue until November 2011, at the end of the 2010/11 cropping season.

In December 2007, just after the beginning of the household survey, a heavy rainfall occurred at the study site. This was a very rare event in the drought-prone zone of Zambia and caused serious damage to agricultural production. Hence, this paper focuses on this heavy rain shock using data collected at site A because this site was the one most severely affected. We analyze the data covering the first two cropping years (i.e., from November 2007 to December 2009) so as to observe the heavy rain shock and the process of recovery from it. Household data were collected every week during the two-year period, but they are aggregated at the monthly level for this paper. As a result, the structure of the dataset is a panel of 16 households for 26 months. It is an unbalanced panel because some data are missing.

4. Rainfall

Following the definition of resilience given in the previous section and in Figure 1, a shock must be specified in terms of timing and magnitude. First, we confirmed the heavy rain from the rainfall pattern recorded by the rain gauges. As shown in Figure 2, there was a sharp rise in weekly rainfall in December 2007, which was not observed in December 2008 and 2009. The average rainfall of 16 rain gauge spots amounted to 473 mm in the week of December 24th, 2007. It was almost 30% of the total rainfall of the rainy season of 2007/08 (November 2007 to April 2008), and more than twice as high as the highest weekly rainfall in the rainy season of 2008/09, which was 239 mm, recorded during the week of March 12th, 2009.

Not only the rainfall during the week of December 24th, 2007, but also the total rainfall of the rainy season was much higher in 2007/08 than in 2008/09: the former was 1,596 mm and the latter 1,312 mm on average. But the difference is smaller than that of the week of December 24th (473 mm vs. 102 mm). This is because in February and March rainfall was greater in 2008/09 than in 2007/08. We cannot confirm, however, how unusual the heavy rainfall in 2007/08 was because no long-term rainfall records are available for our study sites. Nevertheless, villagers judged the heavy rain in 2007/08 to be a rare event that may happen once in several decades, and we could observe that many farmers lost maize plants, which were in the growing stage at the time of the rain, and some important infrastructure, such as roads and bridges, was lost because of floods caused by the rain. Therefore, we consider that there was a common shock in December 2007 among the sample households at site A.

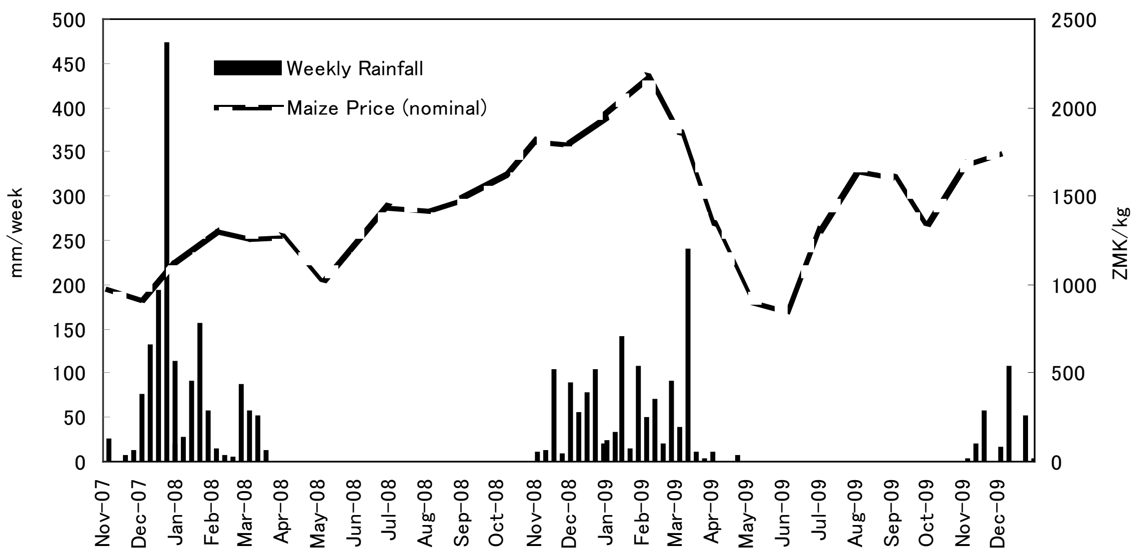

Figure 2 Average Weekly Rainfall and Maize Price

Although this report does not show any impact of the heavy rainfall on agricultural production, the aggregate impact is obvious: the price of maize, the most important staple food at the study site, increased in the local market after the rainy season of 2007/08, as shown in Figure 2, probably owing to the poor harvest that season. The nominal price continued to escalate until the harvesting of the 2008/09 crop in March 2009.

The 16 rain gauges of the sample households are distributed within just a 5-km radius. But rainfall levels among them are not uniform. As summarized in Table 1, the amount of annual rainfall was higher in 2007/08 than in 2008/09, averaged for the 16 rain gauges, but their standard deviation was lower in 2007/08 than in 2008/09. As a result, the coefficient of variation was much lower in 2007/08 than in 2008/09. We suppose that the case of 2008/09 is closer to the ordinary condition at the study site, but, as noted above, we do not have any reference with which to compare our data.

Figure 3 shows the amount of annual rainfall recorded at each sample household's plot. The household IDs on the horizontal axis are in the order of annual rainfall for 2007/08. The lowest rainfall observed at the plot of household 103 was 1,558 mm per year, while the highest rainfall was 1,698 mm per year at the plot of household 116. The annual rainfall for 2008/09 was lower than that for 2007/08 at every household, as shown in Figure 3. But the order is not the same over the two years: the lowest was 1,151 mm, recorded at household 113; the highest was 1,404 mm, recorded at household 109. The amount of rainfall in 2007/08 and 2008/09 is positively correlated, with a coefficient of 0.417, but it is not statistically significant at the 10 percent level. By comparing the two patterns of rainfall distribution among the sample households, the heavy rain in 2007/08 seemed to have been a common shock for them, though the amount of rainfall varies temporally as well as spatially. Thus, rainfall can be considered an idiosyncratic shock.

Table 1 Annual Precipitation of 2007/08 and 2008/09 Cropping Year

Cropping Year	Number of Rain Gauges	Mean (mm)	Standard Dev. (mm)	Coefficient of Variation	Maximum (mm)	Minimum (mm)
2007/08	16	1,596	40	0.025	1,698	1,558
2008/09	16	1,312	78	0.059	1,404	1,151

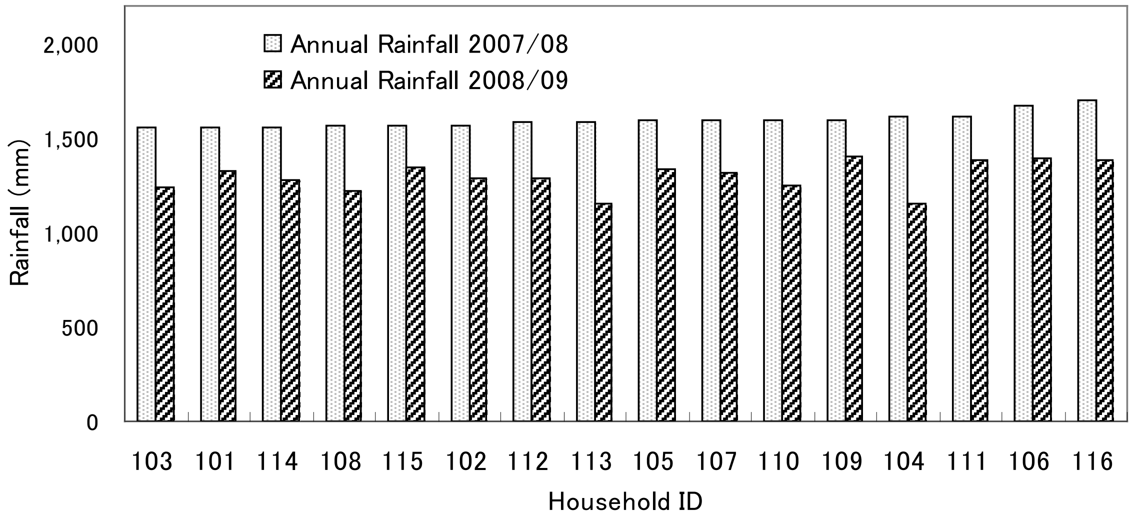

Figure 3 Distribution of Annual Rainfall among Sample Households

5. Food Consumption

Average food consumption per week per adult equivalent (hereafter, simply adult) among the sample households is calculated for every month from November 2007 to December 2009. The food includes not only self-produced food, but also food purchased, received either as public food aid or a gift, and collected/caught in the field. Except for purchased food, the values are estimated based on respondents' subjective judgment and the market price. The total value of the food consumed per week is averaged for the monthly level and then deflated by the monthly price index, based on observed prices at the local market and consumption baskets at the study sites estimated from our own data. It should be noted that because maize amounts to about half the total value of consumption, the curve of the monthly price index is quite similar to that of the nominal maize price shown in Figure 2. In addition to the real value, this paper presents the amount of food consumption in terms of its total calories. The calorific values are estimates based on the weight of food items consumed by sample households using standard coefficients given in Zambia Food Composition Tables (National Food and Nutrition Commission, 2009). They are calculated only for selected high-calorie foods, such as cereals, beans/peas, and roots/tubers. The results are given in Figure 4.

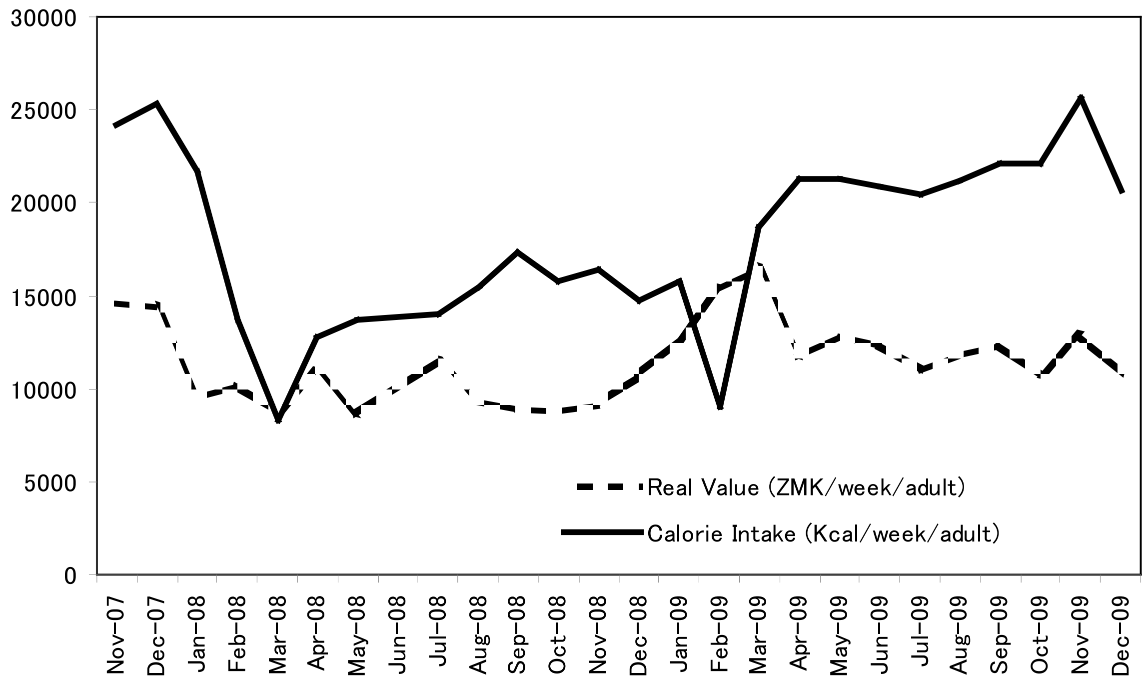

Figure 4 Average Food Consumption per Week per Adult

As shown in the figure, food consumption in terms of both real value and energy plunged in January 2008 just after the heavy rain and started recovering after March 2008. However, while we can observe a modest recovery in calorie intake after March, the recovery of food value is very slow. Considering that the maize price began to increase after the harvest season of 2007/08, the widening gap between value and calorie intake implies that villagers consumed relatively cheap, high-energy food. In fact, wheat flour and beans were distributed as food aid during that period (Kitsuki and Sakurai, 2011), and wheat flour was a cheaper energy source than maize flour in April and May 2008 (0.41 ZMK/kcal vs. 0.65 ZMK/kcal). Then, towards the end of the dry season of 2008, the maize price increased, and as a result the real value of consumption also increased, while the calorie intake decreased. This has to be another impact of the heavy rain in December 2007 through the higher market price of maize. Only after the harvest of the 2008/09 rainy season in March 2009 did calorie intake recover to a level close to that before the heavy rain, and the real value of food consumption stabilized. Applying this observed pattern to Figure 2, we could say that a shock occurred in December 2007 and recovery from the shock started in April 2008, taking one year to complete.

We can confirm that the change in calorie intake had some impact on the villagers' well-being by examining their body weight. Figure 5 is produced from the data of weekly body-weight measurement of household members and shows the ratio of deviation from the sample mean for each month. From the figure, although body weight was quite variable, we can see a small drop during the cropping season of 2007/08 and a big drop during the cropping season of 2008/09, both of which correspond to the plunge in calorie intake. Therefore, we may consider that the change in calorie intake after the heavy rain in December 2007 had a real impact on the villagers. The impact is somewhat greater with female adults than with male adults, but the pattern of the two curves is almost identical. Body-weight change is affected not only by the amount of food intake, but also by the intensity of physical activities. Based on the same weekly survey, Nasuda et al. (2011) show that males and females equally increased their working time after the heavy rain in December 2007, although females always work longer than males, including domestic chores. This observation concerning working time seems to be consistent with the body-weight change shown in Figure 5.

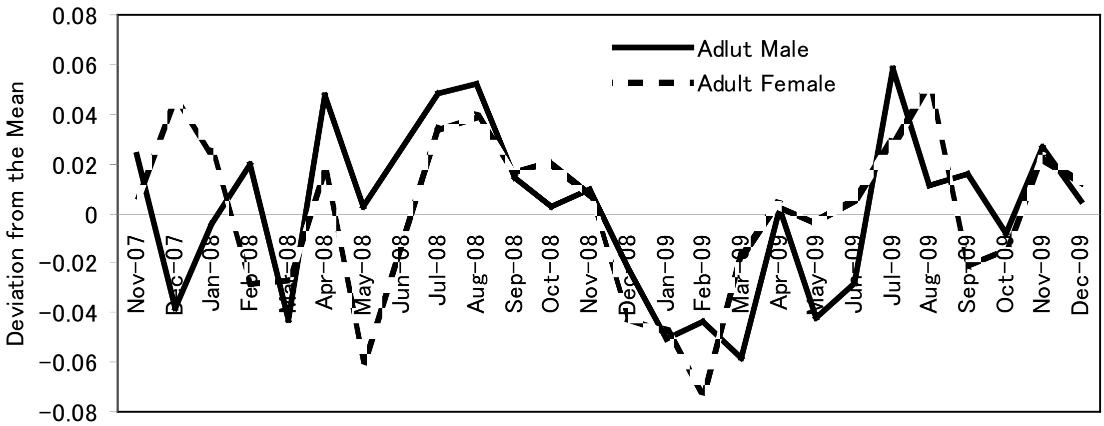

Figure 5 Monthly Body-Weight Change

6. Measuring Resilience

Following the definition of resilience discussed in section 2, engineering resilience is measured by the speed of consumption growth during the recovery period after a shock, namely from March 2008 to April 2009 according to Figure 4.

The speed of consumption growth can be written as

$$R^{c}_{it} = \log (C_{it}) - \log (C_{it-1}) \quad (1) \text{ or}$$
$$R^{k}_{it} = \log (K_{it}) - \log (K_{it-1}) \quad (2)$$

where R^{c}_{it} stands for resilience measured by real value of food consumption and R^{k}_{it} stands for resilience measured by calories for household i at time t. The former is obtained by the difference of natural logarithms of real value of food consumption per week per adult in time $t1$, C_{it} and that in time t-1, C_{it-1}. The latter, on the other hand, is obtained similarly from the difference of natural logarithms of calorie intake per week per adult, K_{it-1} and K_{it}. In our case, the unit of time is one month.

We use either consumption growth measures as the dependent variable and regress it on the explanatory variables given in Table 2.

Table 2 Explanatory Variables for Regression Analyses

Variable	Description
$RAIN_{it}$	Amount of rainfall recorded on household *i*'s plot in time *t*
$VRAIN_t$	Average amount of rainfall of sample households in time *t*
RECOV	A dummy variable for the period of recovery, i.e. from April 2008 to April 2009
$LAND_{iy}$	Total acreage of household *i*'s cropped land in agricultural year *y*
$CATL_{iy}$	Real value of cattle per adult that household *i* owns at the beginning of ag. year *y*
$SMLV_{iy}$	Real value of livestock other than cattle (small livestock such as goats and pigs) per adult that household *i* owns at the beginning of agricultural year *y*
$ASSET_{iy}$	Real value of assets other than land or livestock per adult that household *i* owns at the beginning of agricultural year *y*
AGE_{iy}	Age of the head of household *i* at the beginning of agricultural year *y*
AE_{iy}	Adult equivalent size of household *i* at the beginning of agricultural year *y*. The weight for children at and under the age of 12 is one third of adult.
D_n	Dummies for each period excluding November and December 2007 (they are assumed to be base month) and the recovery period (from April 2008 to April 2009). The subscription *n* indicates a serial number of month during the survey period: for example, *n*=3 for January 2008, *n*=4 for February 2008, *n*=25 for November 2009, *n*=26 for December 2009, and so on.

As explained above, the data-collection period was 26 months, from November 2007 to December 2009. Hence, time period t is from 1 to 26. However, the agricultural year starts in November, the onset of the rainy season, and ends in October of the following year. Therefore, the dataset covers two agricultural years fully, i.e., 2007/08 and 2008/09, plus two months in 2009/10, i.e., November and December 2009.

Among the explanatory variables listed in Table 2, *RECOV* signifies directly measuring "resilience" because the estimated coefficient for *RECOV* is the speed of recovery averaged among the sample households during the period April 2008 to April 2009. $RAIN_{it}$, household-specific rainfall, is to capture household *i* specific shocks from rainfall. As discussed earlier, rainfall is spatially variable, and we would expect its variation to be sufficient to capture a household-specific shock. Therefore, it is hypothesized that a household with a higher rainfall suffers a severer shock and hence reduces consumption more. Such an effect can be observed soon after the shock, when villagers start expecting lower income, but because the heaviest rainfall took place at the end of December 2007, we conjecture that its impact is likely to appear the following month in our monthly dataset. Therefore, lagged variables, namely $RAIN_{it-1}$ and $RAIN_{it-2}$, are used as the explanatory variables. Moreover, because the immediate effect of the heavy rain should last for a few months, interaction terms between the household-specific rainfall and dummy variables for the months after the heavy rain period (January to March 2008) are added to the explanatory variables. $VRAIN_t$ is, on the other hand, common to all the households, although it varies every month. For the same reason as with $RAIN_{it}$, $VRAIN_t$ also takes lags.

Table 3 Regression Results for Measuring Resilience

Model	RE	FE	RE	FE
Dependent Variable / Explanatory Variables	R^c_{it} (real value)	R^c_{it} (real value)	R^k_{it} (calorie)	R^k_{it} (calorie)
RECOV (n=6 – 18)	-0.17 (0.11)	-0.11 (0.19)	0.65 (0.32)*	0.62 (0.38)
$RAIN_{it-1}$ (10^{-2})	0.07 (0.16)	0.09 (0.17)	1.02 (0.42)**	1.22 (0.41)***
$RAIN_{it-2}$ (10^{-2})	-0.14 (0.18)	-0.12 (0.20)	-0.40 (0.40)	-0.24 (0.41)
$VRAIN_{t-1}$ (10^{-2})	-0.06 (0.15)	-0.10 (0.15)	-0.08 (0.04)**	-0.98 (0.40)**
$VRAIN_{t-2}$ (10^{-2})	0.13 (0.18)	0.09 (0.21)	0.26 (0.43)	0.11 (0.47)
D_3 (January 2008)	-0.13 (3.52)	-0.46 (3.37)	13.2 (5.70)**	9.84 (6.12)
D_4 (February 2008)	-8.55 (5.93)	-8.78 (6.24)	-11.2 (9.70)	-14.3 (9.79)
D_5 (March 2008)	11.4 (7.05)	12.4 (7.30)	37.0 (20.0)*	38.5 (21.3)*
$RAIN_{it-1} \times D_3$(10^{-2})	-0.13 (0.43)	-0.06 (0.42)	-1.58 (0.62)**	-1.25 (6.22)*
$RAIN_{it-2} \times D_3$(10^{-2})	1.64 (1.41)	1.54 (1.47)	-0.38 (2.35)	-0.89 (2.29)
$RAIN_{it-1} \times D_4$(10^{-2})	0.26 (1.00)	0.32 (1.07)	2.43 (1.84)	2.80 (1.98)
$RAIN_{it-2} \times D_4$(10^{-2})	8.21 (0.62)	0.85 (0.67)	0.20 (0.91)	0.32 (1.04)
$RAIN_{it-1} \times D_5$(10^{-2})	-5.04 (4.28)	-6.02 (4.70)	-12.3 (9.22)	-15.7 (10.3)
$RAIN_{it-2} \times D_5$(10^{-2})	-1.45 (1.07)	-1.46 (1.07)	-5.65 (3.19)*	-5.22 (3.26)
$LAND_{iy}$	-0.01 (0.10)	0.01 (0.17)	0.31 (0.24)	0.13 (0.34)
$CATL_{iy}$(10^{-7})	1.34 (0.99)	-0.08 (1.77)	1.89 (3.71)	0.22 (3.73)
$SMLV_{iy}$(10^{-7})	1.43 (1.24)	0.54 (1.61)	3.15 (2.51)	3.42 (4.03)
$ASSET_{iy}$(10^{-6})	-5.15 (4.06)	-3.89 (4.07)	-2.16 (1.44)	-2.53 (1.89)
AGE_{iy}(10^{-2})	-0.34 (0.15)**	-0.66 (2.22)	-0.04 (0.04)	-18.5 (47.5)
AE_{iy}(10^{-1})	-0.23 (0.22)	0.60 (0.33)*	0.29 (0.56)	-1.14 (0.63)*
D_n (n=19 – 26)	+ , - , -*	+ or -	+*** , +* or +	+* or +
Constant	0.38 (0.19)**	-4.23 (9.42)	-0.87 (0.48)*	8.23 (21.5)
Number of observations	257	257	256	256
Number of households	15	15	15	15
R^2(overall/within)	0.13	0.14	0.16	0.18

Note: Robust standard errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level respectively. The number of sample households in site A is 16 as described, but one household has been dropped from the regression because of missing data.

Because the data are panel data, we tried to estimate both fixed-effect and random-effect models, although the Hausman test generally supports the use of the random-effect model. The regression results are given in Table 3. Because the real value and calorie intake move differently, as shown in Figure 4, regression results differ between the two dependent variables. Generally, the results for calorie intake are better in terms of significance and fitness.

First of all, for the calorie intake, the sample households generally show significant "resilience" for the period April 2008 to April 2009 because the coefficient for *RECOV* is positive and significantly different from zero (random-effect model only). As for real value of food consumption, however, it is not significant. From Figure 4, it is apparent that contrasting results are plausible.

With regard to rainfall variables, the results are not so straightforward. First, household-specific rainfall has a significantly positive effect on consumption growth. If we consider that this variable is to capture the heavy rain effect, the sign is unexpected. But because we have interaction terms, rainfall without interaction should capture an ordinary relationship between rainfall and consumption via agricultural production: the better the rainfall, the better the harvest, resulting in more consumption. Second, village average rainfall has a significantly negative effect. Does it capture the heavy rainfall shock? No, it expresses a simple seasonal relationship between rainfall and consumption: during the rainy season, rainfall is high and consumption is low even without rainfall shock. Third, out of the three dummy variables for the months after the heavy rain (D_3, D_4, and D_5), two have a significantly positive sign, which is unexpected considering that consumption was declining during this period. However, the interaction terms between $RAIN_{it-1}$ and D_3 and D_5 have a significantly negative sign and cancel the positive effect of the month dummies. As a result, we can confirm that the postulated hypothesis, whereby a household with a higher rainfall suffers a severer shock and hence reduces consumption more, is supported by the data.

7. Factors Affecting Resilience

Now, our questions are who is more resilient and whether there are any households that do not recover from the shock. To identify factors affecting resilience, i.e., the speed of recovery, new interaction terms are added to the previous regression models. They are the product of *RECOV* (dummy for recovery period) and household asset variables ($LAND_{iy}$, $CATL_{iy}$, $SMLV_{iy}$, and $ASSET_{iy}$) because we expect that asset holding is the key for households to recover from a shock. Assets should include human capital and social capital, but this paper focuses only on physical assets. To see the effect of asset holdings clearly, the 16 sample households are divided into two groups based on the asset-holding level: one is rich, whose total value of cattle holdings as of October 2007 was above the median, and the other is poor, who are not in the rich group. Then, random-effect regressions are conducted for the full sample as well as each group separately.

Regarding sensitivity to rainfall shock, the regression results in Table 4 exhibit some interesting contrasts. First, the rich do not seem to be so sensitive to rainfall, while the poor are more sensitive because the coefficients for *RAIN* and *VRAIN* are significant only for the poor. In addition, the negative impact of heavy rain began appearing in January 2008 in the case of poor households, but in the case of rich households the impact was observed only after February 2008. Thus, there is one-month delay for the rich households to reduce consumption after the heavy rain.

This also implies that the poor are more sensitive to rainfall shock than the rich. As discussed in section 2, sensitivity is not the same as vulnerability, but because the poor are more sensitive to the rainfall shock than the rich, some of the poor households could easily fall below the threshold, i.e., they are vulnerable.

Table 4 Regression Results for Identifying Factors Affecting Resilience

Model	RE	RE	RE
Stratum	Full Sample	Rich	Poor
Dependent Variable	R^k_{it}	R^k_{it}	R^k_{it}
Explanatory Variables	(calorie)	(calorie)	(calorie)
RECOV (n=6 – 18)	0.62 (0.34)*	0.87 (0.53)*	0.33 (0.57)
$RAIN_{it-1}$ (10^{-2})	1.05 (0.20)**	1.03 (1.04)	1.30 (0.41)***
$RAIN_{it-2}$ (10^{-2})	-0.39 (0.19)	-0.32 (0.91)	-0.39 (0.65)
$VRAIN_{t-1}$ (10^{-2})	-0.87 (0.42)**	-0.73 (1.00)	-1.21 (0.32)***
$VRAIN_{t-2}$ (10^{-2})	0.22 (0.46)	0.06 (0.91)	0.32 (0.72)
D_3 (January 2008)	15.2 (6.01)**	8.03 (11.5)	16.0 (8.80)*
D_4 (February 2008)	-9.33 (9.98)	-17.9 (4.79)***	14.3 (10.4)
D_5 (March 2008)	38.3 (20.5)*	74.8 (20.1)***	8.33 (15.2)
$RAIN_{it-1} \times D_3$(10^{-2})	-1.80 (0.68)***	-1.06 (1.44)	-1.87 (1.10)*
$RAIN_{it-2} \times D_3$(10^{-2})	-0.31 (1.97)	-0.99 (9.17)	0.03 (1.94)
$RAIN_{it-1} \times D_4$(10^{-2})	2.41 (1.91)	4.28 (2.90)	-2.52 (0.94)***
$RAIN_{it-2} \times D_4$(10^{-2})	0.01 (1.01)	0.12 (1.47)	-0.36 (0.73)
$RAIN_{it-1} \times D_5$(10^{-2})	-12.7 (9.50)	-27.0 (10.8)**	-3.67 (10.5)
$RAIN_{it-2} \times D_5$(10^{-2})	-5.87 (3.17)*	-11.0 (2.44)***	-1.08 (3.42)
$LAND_{iy}$	-0.17 (0.19)	0.49 (0.15)***	0.13 (0.08)*
$CATL_{iy}$(10^{-7})	-1.50 (2.28)	-0.17 (4.51)	-6.34 (22.1)
$SMLV_{iy}$(10^{-7})	-0.38 (2.64)	4.76 (4.18)	-9.41 (26.9)
$ASSET_{iy}$(10^{-6})	-0.76 (0.50)	-0.70 (1.00)	-2.62 (25.8)
AGE_{iy}(10^{-2})	-0.22 (0.33)	-0.18 (0.41)	-0.08 (0.36)
AE_{iy}(10^{-1})	0.16 (0.43)	0.56 (0.69)	0.13 (0.26)
$RECOV \times LAND_{iy}$	0.29 (0.55)	0.30 (0.43)	0.67 (0.37)*
$RECOV \times CATL_{iy}$(10^{-7})	8.12 (4.99)*	-7.37 (7.50)	4.71 (33.2)
$RECOV \times SMLV_{iy}$(10^{-7})	6.75 (2.81)**	-3.96 (7.94)	-30.0 (85.4)
$RECOV \times ASSET_{iy}$(10^{-6})	-3.85 (2.88)	3.96 (2.77)	-5.93 (5.96)
D_n (*n*=19 – 26)	$+^{***}$, $+^{**}$ or +	$+^{***}$, $+^{**}$ or +	$+^{*}$ or +
Constant	-0.66 (0.36)*	-1.42 (0.68)**	-0.43 (0.69)
Number of observations	256	125	131
Number of households	15	8	7
R^2(overall)	0.18	0.34	0.21

Note: Robust standard errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level respectively. The number of sample households in site A is 16 as described, but one household has been dropped.

8. Conclusions

In this paper, we first present a new, empirically workable definition of resilience in the context of consumption smoothing. Then, following the definition, we empirically estimate resilience using the data collected in a rural area of Zambia, where its rain-fed agriculture is highly affected by rainfall variation. In this particular dataset, a heavy rain took place in December 2007. Resilience is measured as the speed of consumption recovery after the heavy rain shock.

Our panel data analyses reveal that the heavy rain caused a shock, i.e., reduction of food consumption, among the sample households, and it took almost one year for them to recover from the shock. Resilience is defined as the speed of recovery, and our analyses show that household assets, such as land and livestock, have a positive effect on enhancing resilience. If we divide the sample into rich and poor groups based on the value of cattle holdings, households in the rich group are more resilient than those in the poor group on average because the coefficient of *RECOV* is significantly positive for the rich group but it is not significantly different from zero for the poor group on average. The insignificant sign for the poor implies that some of them who lack sufficient assets may not be able to recover consumption. Moreover, it is found that households in the poor group are more sensitive to the rainfall shock: they reduce consumption more quickly after the shock than those in the rich group. Following our definition, sensitivity is not the same as vulnerability, but because the poor are more sensitive to the rainfall shock than the rich, some of the poor could easily fall below the threshold, i.e., they are vulnerable.

We do not indicate how the sample households recover their consumption from the shock in this paper, although we have evidence that households increase labor supply not only in agriculture but also in non-agriculture after the shock, and households increase the sales of livestock, particularly small animals like goats and pigs, after the shock. Moreover, we find that households reduce consumption of non-food goods and services after the shock, although they maintain the level of food consumption. Incorporating those coping behaviors into analyses of factors affecting resilience is a very important research topic that we intend to tackle very soon.

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Effect of Heavy Rainfall Shock on Asset Dynamics in Rural Zambia
- an examination of fluctuations in cattle numbers -

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Abstract

In rural Africa, the liquidation and accumulation of productive assets, such as large livestock, lie at the heart of livelihood strategies to smooth consumption against fluctuating income (the buffer stock hypothesis). Previous studies have tested this hypothesis but have reported inconsistent results. A possible explanation for such results, and one noted in the growing literature on asset dynamics, is that poorer households may choose to maintain and smooth productive assets rather than to smooth consumption. However, very little empirical evidence exists on the matter.

This study re-examines the buffer stock hypothesis regarding cattle by taking wealth-differentiated smoothing tendencies into account. First, this paper introduces measurable definitions of sensitivity and resilience in terms of asset fluctuations. The former is defined as the level of impact a shock has on household assets, while the latter is the recovery level after the shock.

Second, this paper employs a high-frequency panel data set of agricultural households from Southern Province, Zambia, one of the most drought-prone areas in the country. The data were collected between 2007 and 2009, a period that includes the occurrence of a rare heavy rainfall year within the study site. This study uses panel estimation techniques to investigate whether a threshold exists in asset holding level that distinguishes between asset smoothing and consumption smoothing, and to estimate the determinants of asset sensitivity to a heavy rainfall shock for each regime.

Results reveal that household sensitivity depends on the number of cattle held before the shock, suggesting the existence of multiple dynamic asset equilibria. However, those who preserve their cattle holdings during a flood-year may be affected by a lagged rainfall shock in the following year, with implications for the long-term relationship between asset dynamics and economic mobility. This paper also suggests that the determinants of sensitivity may be distinct in each wealth quartile.

1. Introduction

Many of the poor living in rural Africa face significant risks and are highly vulnerable to unexpected negative income shocks such as family illness and natural disasters (Dercon, 2005). Their responses to these shocks are twofold: *ex-ante* risk-management strategies and *ex-post* risk-coping strategies (Morduch, 1995). Traditionally, with regard to the latter, it has been hypothesized that households liquidate productive assets, such as large livestock, to maintain their consumption standards. This strategy is very costly in terms of forgone future income and has a direct relationship with poverty dynamics. There have been a great number of studies to test this hypothesis.

Such studies, however, have reported inconsistent results and have provided very little evidence of consumption smoothing (Rosenzweig and Wolpin, 1993; Kurosaki, 1995; Fafchamps et al., 1998). For example, Fafchamps et al. (1998) found that livestock sales in Burkina Faso offset 15–30%, at most, of the crop income shortfalls during severe drought years in the 1980s, and the majority of the surveyed households still held livestock by the end of the drought. One possible explanation for these results is that poorer households may choose to maintain and smooth productive assets rather than to smooth consumption, implying the existence of a threshold level of asset holding between the two types behavior (Zimmerman and Carter, 2003). To our knowledge, only Lybbert and Carter (2010) have provided empirical evidence of this threshold. Using the same data as Fafchamps et al. (1998), they directly estimated a dynamic asset threshold that divided asset smoothers and consumption smoothers by using sample splitting techniques.

This study also examines the buffer stock hypothesis with regard to cattle and provides evidence of a threshold in asset holdings. However, unlike Lybbert and Carter (2010) who used yearly livestock transaction data, this paper uses a high-frequency panel data set of agricultural households from Southern Province, Zambia, which allows us to examine asset dynamics after a shock in detail and distinguish clearly between a coping period and a recovery period. The data were collected between 2007 and 2009, a period that includes a year of extremely heavy rain, a rare event in one of the most drought-prone zones in the country. This heavy rainfall produced a deluge that damaged crops, washed away fields, and destroyed infrastructure such as roads and bridges. To discern between the different behavioral regimes, this paper first constructs a monthly stock series for cattle using a wealth quartile. Then, panel estimation techniques are employed to investigate the existence of an asset level threshold that separates the asset smoothing regime and consumption smoothing regime, and to estimate the determinants of sensitivity to the rainfall shock for each regime.

The remainder of this paper proceeds as follows. Section 2 introduces definitions for sensitivity, resilience, and vulnerability with regard to asset fluctuations. A data description is provided in Section 3. Section 4 presents the econometric models used to estimate the determinants of the defined sensitivity and discusses the estimation results. Conclusions, including suggestions for future research, are offered in the paper’s final section.

2. Analytical Framework

2.1 Definitions

To empirically analyze asset responses to shock and the subsequent recoveries, this section introduces three concepts concerning asset dynamics: sensitivity, resilience, and vulnerability.

Figure 1 schematically presents definitions for sensitivity and resilience, following Carter et al. (2006) with regard to assets and Sakurai et al. (2010) with regard to consumption. The x-axis measures time and the y-axis measures asset stocks. At the time (t_b) when the shock occurs, disposable household income may be reduced below its normal level. In response to the shock, the

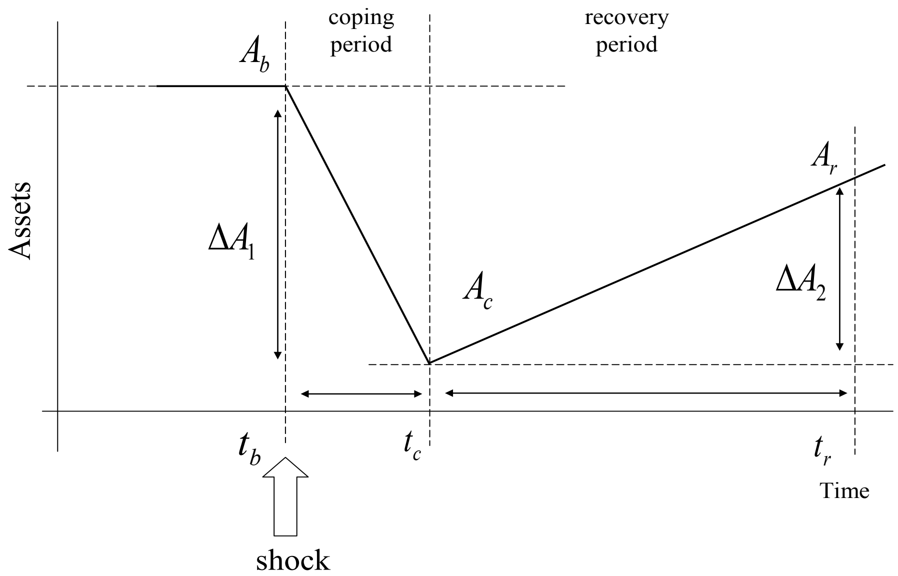

Figure 1: Schematic diagram of sensitivity and resilience

household may liquidate their assets, such as cattle, to stabilize consumption. This hypothesis is termed the buffer stock hypothesis (Rosenzweig and Wolpin, 1993). The decline in household assets is shown in Figure 1 by a drop in assets from A_b to A_c[1]. Then, the household exits from the shock and starts accumulating productive assets again for the purpose of precautionary savings or simply, production. The recovery of household assets is shown by the A_c to A_r trajectory. Sensitivity (S) and resilience (R), as shown in Figure 1, can be defined as:

$$S \equiv A_c - A_b = \Delta A_1 \quad R \equiv A_r - A_c = \Delta A_2 \qquad (1)$$

S refers to the level of impact a shock has on household assets, while R refers to the recovery level after a shock.

As shown in Figure 1, the full economic effects of an environmental shock can be traced via two stages: the coping period when households deal with the immediate losses created directly or indirectly by the shock; and the recovery period when households use coping strategies to rebuild depleted assets. To calculate sensitivity and resilience as defined above, it is necessary to identify a shock where the impact and the following coping and recovery periods can be investigated, including specific start- and stop-times for both periods.

Sakurai et al. (2010) defined sensitivity and resilience with regard to household consumption in a similar way to this study. However, in their empirical analysis they dealt with only the case of a single equilibrium, and adapted the speed of return to the steady state as a

[1] Subscript "b" refers to levels before the shock, "c" refers to levels after the coping period, and "r" refers to levels after the recovery period.

workable definition of resilience. Multiple equilibria are critical in the context of household assets and thus, in this study, different definitions are provided[2]. This point is discussed further in the following subsection.

2.2 Shocks, Asset Fluctuations, and Poverty

Previous studies on asset dynamics have suggested that at least two distinct asset thresholds exist: an asset poverty line and the Micawber threshold. The former was employed in studies investigating economic mobility using asset information (Carter and Barrett, 2006). This asset-based approach to poverty can reduce observed household economic transitions into structural poverty changes versus stochastic mobility, which is driven by temporary shocks and recovery. To distinguish between these two variants, Carter and May (2001) introduced the asset poverty line. This line is the level of assets that predicts the money metric poverty line, $\underline{c}$. In a mathematical sense, the asset poverty line, denoted by $\underline{A}$, is defined as $\underline{A} = \{A|\hat{c}(A) = \underline{c}\}$, where $\hat{c}(A)$ is a function of a vector regarding asset stocks to expected expenditure flows, termed livelihood mapping.

The asset poverty line enables us to immediately define a vulnerable household with regard to asset fluctuations as one with a high probability of falling below the asset poverty line, in an *ex-ante* sense. Vulnerability is empirically defined in this paper as a vulnerable household that has fallen below the asset poverty line after a shock, in an *ex-post* sense[3]. With a measurable definition of vulnerability and an estimated asset poverty line, we will be able to observe economic mobility with regard to assets.

The Micawber threshold, denoted by A_m, is defined as an asset level where wealth dynamics naturally bifurcate. The existence of the Micawber threshold has been suggested in several recent studies that have provided evidence of asset dynamics within a particular context as being nonconvex, compared with the standard assumption that asset dynamics are convergent (Zimmerman and Carter, 2003)[4]. The Micawber threshold theoretically influences how households cope with negative shocks: those who sit just above the Micawber threshold, but are in danger of falling below it, would choose asset smoothing rather than consumption smoothing. Hoddinott (2006), for example, found strong evidence of asset smoothing above the dynamic asset threshold among the poor in rural Zimbabwe. Moreover, Lybbert and Barrett (2010) theoretically illustrated a possibility that nonconvex asset dynamics with multiple equilibria systems could lead those just below the Micawber threshold to engage in excessive risk-taking behavior to escape the poverty trap. This asset smoothing hypothesis could offer a possible explanation for the inconsistent results regarding the use of livestock as buffer stock (Rosenzweig and Wolpin, 1993; Kurosaki, 1995; Fafchamps et.al., 1998).

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[2] The concept of resilience originated in the ecological literature. According to Gunderson et al. (2002), there are two different ways of definition, depending on the assumption of the number of equilibria: engineering resilience and ecological resilience. The former is "the speed of return to the steady state following a perturbation," conceiving ecological systems to exit close to a stable steady state. On the other hand, the latter assumes multiple stability domains and is measured by "the magnitude of disturbance that can be absorbed" before instabilities shifts or flip a system into another regime of behavior (Sakurai et al., 2010).

[3] This definition is applied by one of practical consumption vulnerability measures.

[4] Note that this finding is under the strong assumption that this threshold is the same for every household.

It is important to note that the order of the two asset levels is theoretically obscure. Thus, it is necessary to distinguish the following two cases: case 1, $\underline{A} \leq A_m$ and case 2, $\underline{A} > A_m$. For example, case 1 occurs if the asset poverty line is lower than the minimum asset threshold required to obtain high rates of return under local increasing returns to assets.

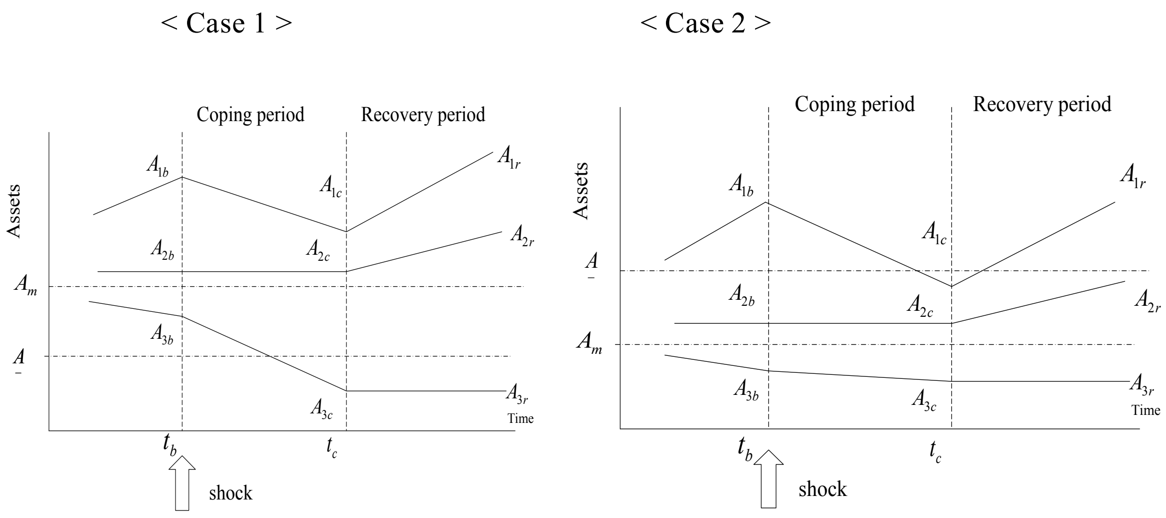

Figure 2: Asset responses to shock

Figure 2 shows asset responses to shock for households with different levels of initial asset endowment (i.e., asset levels before the shock), where A_{ip} denotes the asset level of a household (i) during a particular period (p) ($i = 1, 2, 3$, and $p = b, c, r$). As illustrated in Figure 2, households who are just above the Micawber threshold (i.e., household 2) will not draw down their assets even after the shock in both cases 1 and 2. However, distinguishing between the two cases is a useful step in considering asset vulnerability. With regard to the definition of vulnerability given above, household 3, in case 1, is recognized as a vulnerable household, as is household 1 in case 2. However, in case 2, household 3 is more problematic than household 1 because it is trapped within the lower equilibrium. Thus, it is necessary to ascertain whether the economy lies, in case 1 or case 2, as the answer will vary policy implications induced by the asset based approach toward poverty.

3. Data

This paper uses a panel data set regarding rural households in Zambia. The data were collected from October 2007 to December 2009 as part of the Research Institute for Humanity and Nature's (RIHN) Resilience Project. Zambia is situated in the Semi-arid Tropics (SAT) where people's livelihoods depend largely on rain-fed agriculture. Climatic variation, especially regarding rainfall, is a substantial covariate risk that threatens the subsistence of Zambian farmers. In Zambia the crop year runs from November to October and can be divided into a rainy season (November–April) and a dry season (May–October). Thus, the data used in this paper includes two crop years, 2007/08 and 2008/09.

The Project's study area lies alongside Lake Kariba in Southern Province, Zambia, the most drought-prone area in the country. Within the research area, the Project chose three ecologically distinctive sites for the high-frequency household survey, based on an extensive village census conducted in 2007 (Sakurai, 2008). The three sites are a lower flat lake-side area, site A, a middle escarpment area, site B, and an upper terrace on the Zambian plateau, site C. From each site, 16 households were selected to participate in the household survey, which was based on a 2007 village census (Sakurai, 2008). Thus, 48 households in total were interviewed weekly during the survey period.

The sample possesses a number of desirable properties with regard to the examination of the cattle buffer stock hypothesis. First, livestock accumulation is considered to be a store of wealth as there are no local financial institutions (e.g., banks) in which to hold money. Table 1 presents summary statistics of the respective assets for the sampled households. The ratio of livestock value, especially cattle value, to total asset value is relatively high. Second, two oxen (or cows in several cases) are needed to plough, suggesting that the ownership of two cattle may be the critical threshold perceived by farmers[5].

Table 1: Annual value of household asset holding

	2007				2008				2009			
	Mean	Percent to total value	Std. Dev	Median	Mean	Percent to total value	Std. Dev	Median	Mean	Percent to total value	Std. Dev	Median
Livestock	2601641	76.2%	3333403	1280240	1768259	79.6%	1989629	935618	2190404	72.6%	2802043	988190
large stock	1955415	57.2%	2787516	780033	1368691	61.6%	1611831	507352	1872243	62.1%	2583214	527035
small stock	646227	18.9%	1278434	203607	399568	18.0%	784262	133043	318161	10.5%	340104	247542
Durable assets	814772	23.8%	1268101	410121	453974	20.4%	748930	271985	799769	26.5%	987663	370361
productive	380471	11.1%	699725	197966	203497	9.2%	337329	91895	395444	13.1%	550040	236824
unproductive	434301	12.7%	780347	147173	250477	11.3%	457595	167123	404325	13.4%	572454	174530
Total	3416413	100.0%	4456390	2112963	2222232	100.0%	2556149	1365375	3016308	100.0%	3555639	1211994

Source: Household survey data, Resilience Project.
Note:[1] Value in Kwacha, the local currency in Zambia. The values of the respective assets in this table are deflated by the local food price index calculated by the authors using the household survey data.

The dataset is comprised of three types of data: annual, monthly, and weekly data. This paper uses both the annual and weekly data. The annual data were collected at the beginning of each crop year and contained information regarding household demographic characteristics and asset holdings, including livestock. In contrast, the weekly data were collected using weekly interviews and contained information regarding households' livestock transactions, consumption of their own livestock, and animal births/deaths[6]. Thus, by combining the initial annual livestock numbers with every livestock transaction from the weekly data, it is possible to construct a stock

[5] In the study sites, households with less than two oxen sometimes use cows to cultivate fields, although ploughing is typically done with two oxen.
[6] Although the weekly data also include household consumption, information on input/output related with agricultural activity, transfers received and sent, time allocation data of each household member and health condition of each member, this paper focuses only on livestock transactions. Future work will fully utilize this rich dataset.

series of the livestock. A further unique feature of this dataset is the collection of daily rainfall data from the land of the 48 sampled households. This will enable us to treat rainfall as an idiosyncratic shock, even though the rainfall pattern is similar throughout the study area[7].

4. Asset Sensitivity to Rainfall Shock

4.1 Coping Period and Recovery Period

To measure sensitivity, the coping and recovery periods need to be specified using the rainfall data collected from the households' land. The data were collected during the 2007/08 and 2008/09 crop years.

Table 2: Annual precipitation for 2007/08 and 2008/09 crop years[1]

		Mean annual precipitation (mm)	Standard Deviation (mm)	Coefficient of variation	Maximum (mm)	Minimum (mm)	Number of rain gauges	Percent of long-run regional average rainfall[2], 802 mm
2007/08	site A	1596	40	0.025	1699	1559	16	198.8
	site B	1574	59	0.037	1677	1488	16	196.1
	site C	1404	66	0.047	1538	1313	16	174.9
2008/09	site A	1312	78	0.059	1419	1166	16	163.5
	site B	1383	50	0.036	1478	1303	16	172.3
	site C	1378	67	0.048	1519	1262	16	171.6

Source: Household survey data, Resilience Project.

Note: [1] Not all rainfall data is complete because of technical problems with the automatic rain gauges. In the case of missing data, rainfall amount is spatially estimated from available data.

[2] There are no long-term rainfall data from the study sites. We used rainfall data from the closest weather station located in Choma, 30–60km from the study sites.

Table 2 presents summary statistics regarding annual rainfall by agricultural year and study site. The 2007/08 crop year was a year of extremely heavy rains (with a peak rainfall in December 2007), with levels higher than the long-term regional average, especially for sites A and B. The heavy rainfall damaged crops, washed away fields, and destroyed infrastructure such as roads and bridges. According to local villagers, such an event is very rare and only occurs once every several decades. Thus, the heavy rainfall in 2007/08 could be considered as an unexpected risk event that would have been a shock to villagers. Table 2 shows that the rainfall for the 2008/09 crop year was also relatively higher than the long-term average[8]. Thus, this paper categorizes the coping period as a two-year period from December 2007 to December 2009, and will focus mainly on the analysis of sensitivity.

4.2 Description

The previous sections have established that cattle are the main assets for both wealth accumulation and production in the study areas. In addition, a description has been provided

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[7] This idea follows the work of Sakurai (2006), in which plot level rainfall data were collected and used as idiosyncratic shock variables.

[8] However, less damage to field and infrastructure was observed in 2008/09 than in 2007/08, and some sampled households might recover their asset holdings after the harvest. Such scenario of resilience will be also examined.

regarding the heavy rainfall shock that occurred in the 2007/08 crop year, and how livelihoods were damaged. Thus, the focus of this paper is on the fluctuations in the number of cattle owned by the sampled households and investigates whether cattle numbers decreased in response to the rainfall shock. This subsection will use descriptive statistics regarding cattle numbers to conduct a

Table 3: Mean number of cattle holdings by quartile

Quartile	2007	2008	2009	Range (Number)	Number of Households
Q4	8.56	5.67	6.78	5〜17	9
	[3.43]	[2.74]	[5.80]		
Q3	3.22	6.11	4.56	2〜4	9
	[0.83]	[4.31]	[2.40]		
Q2	1.00	3.00	2.75	1	8
	[0.00]	[4.47]	[4.30]		
Q1	0.00	0.75	0.42	0	20
	[0.00]	[2.02]	[1.02]		

Source: Household survey data, Resilience Project.
Note: Standard deviations are in parentheses.

preliminarily investigation into the relationship between cattle number variations and rainfall.

Table 3 presents information regarding cattle inventories among the sampled households by wealth quartile. The quartile is based on the number of cattle holdings as of October 2007, at the beginning of the rainy season in the first year of the survey. As shown in Table 3, most households have no cattle in 2007. While the top quartile (Q4) experienced a decrease in the number of cattle during 07/08, and then recovered during 08/09, the other quartiles show the opposite.

Table 4: Changes in the number of cattle per household during the 2007/08 crop year

		Number of Cattle as of October 2007		Total
		Cattle≧2	Cattle<2	
Annual Rainfall in 2007/08	Above median	1.75 (5.39) N = 8	0.18 (1.55) N = 17	0.68 (3.26) N = 25
	Below median	0.60 (2.41) N = 10	1.27 (2.45) N = 11	0.95 (2.40) N = 21
Total		1.11 (3.92) N = 18	0.61 (1.99) N = 28	0.80 (2.87) N = 46

Note: The numbers represent the averages for the changes in cattle numbers and their standard deviations are in parenthesis.

The theory of consumption smoothing predicts that where households have no other means to compensate for a reduction in income, households with more crop damage (i.e., heavier rainfall) will reduce cattle in greater numbers than those with less crop damage (i.e., lower rainfall).

In addition, the asset smoothing hypothesis predicts that among the households suffering from the heavy rainfall, and with no other means to recompense, those with more cattle will liquidate greater numbers of cattle than those keeping less cattle. Table 4 provides a matrix of changes in cattle numbers during 2007/08, classified by rainfall level in the heavy rainfall year and cattle numbers as of October 2007. The criterion for cattle holdings is set at two cattle. As seen in Table 4, changes in the number of cattle held by households experiencing the heavier rainfall was less on average than that of households with the lower rainfall. Thus, households with greater damage reduced more cattle as predicted by the theory of consumption smoothing. In contrast, results also showed that households with two or more cattle increased their cattle numbers during 2007/08, a rate greater than those with less than two cattle. These results are not consistent with the asset smoothing hypothesis' prediction. This counter-intuitive result, in view of the asset smoothing hypothesis, may be caused by uncontrolled factors such as household demographic information. In addition, the assumed criterion of sample splitting could be invalid[9].

Table 5: Changes in cattle number per household during the 2008/09 crop year

		Number of Cattle as of October 2007		Total
		Cattle≧2	Cattle<2	
Annual Rainfall in 2007/08	Above median	-1.63 (5.48) N = 8	0.38 (1.86) N = 16	-0.29 (3.51) N = 24
	Below median	0.80 (3.01) N = 10	-0.85(2.54) N = 13	-0.13 (2.82) N = 23
Total		-0.28 (4.32) N = 18	-0.17(2.24) N = 29	-0.21 (3.15) N = 47

Note: The numbers represent the averages for the changes in cattle numbers and their standard deviations are in parenthesis.

Table 5 presents the same matrix for the 2008/09 crop year. In Table 5, we can observe a lagged effect for rainfall in 2007/08 on the change of cattle numbers. Furthermore, among the households with relatively small rainfall in 2007/08, those with larger cattle holdings increased more than those with less, suggesting the existence of multiple dynamic asset equilibria.

Figure 3 shows the evolution of mean numbers for cattle per household using the quartiles presented in Table 3. Q4 experienced a fall in the number of cattle holdings, while the other quartiles increased numbers during the 2007/08 crop year (see Figure 3), suggesting the existence of an asset threshold that distinguishes between the two regimes for Q4 and the other quartiles.

The above proposition requires further discussion and so we will examine the relationship between cattle number fluctuations and rainfall shock using a more rigorous method. To control for

9 A similar result was attained from the cross-section estimation. However, the degree of freedom is too small to be reliable. Thus, that result is not reported here.

other factors that may influence cattle number fluctuations, we will use panel estimation techniques to investigate the existence of an asset level threshold and estimate the determinants of sensitivity with regard to rainfall shock.

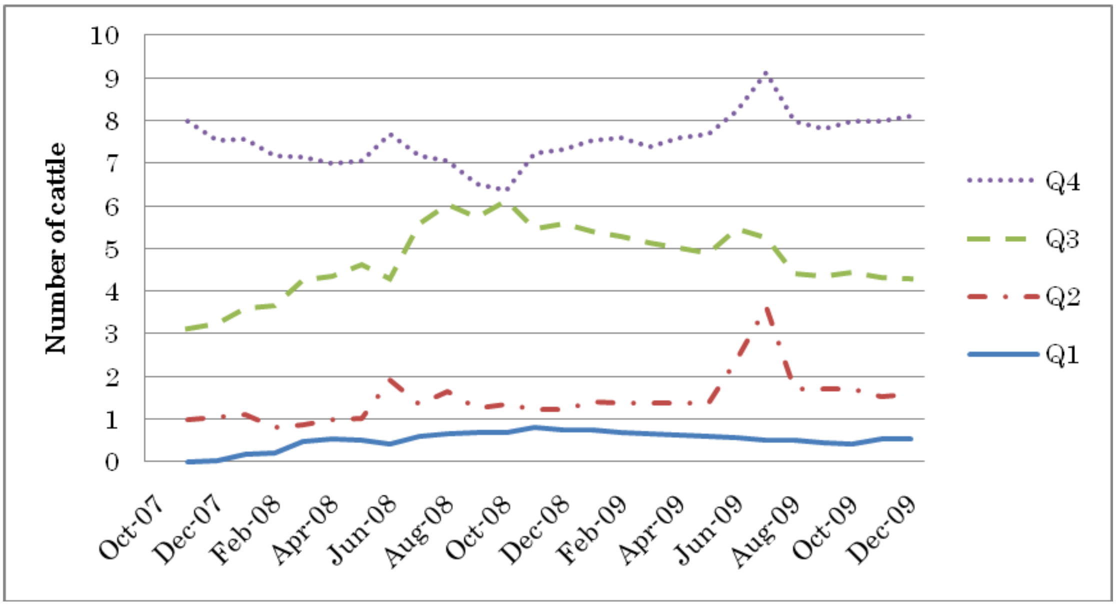

Figure 3: Monthly mean cattle numbers per household by quartile, 2007–2009

Source: Household survey data, Resilience Project.

4.3 Econometric Analysis of Sensitivity

This section presents an econometric approach in the examination of sensitivity regarding rainfall shock. Two factors influencing household sensitivity must be considered in the construction of estimation equations. First, attention should be given to a household's ability to employ alternative coping strategies such as *ex-post* labor adjustments (Rose, 2001) and non-productive asset dispositions (Udry, 1995). To capture these factors, this paper uses the ratio of working adult males to all household members and the value of small livestock such as pigs and goats. Second, the relative price of cattle to the price of food must be acknowledged. However, sufficient information regarding cattle prices was not available due to a limited number of cattle transactions. Instead, this paper uses the price of goats as a proxy variable for cattle prices.

With regard to rainfall shock, we employ two specifications based on rainfall data recorded on each household's plot: annual precipitation at plot level and monthly precipitation at plot level. The former is the total yearly rainfall, which differs among households but is constant throughout a given crop year. The latter is the total monthly rainfall, which varies both among households and during every month in the rainy season. Thus, the monthly variable is expected to capture households' immediate responses (with one or two months delay) to rainfall variability. Since we did not know in advance which specification will better explain households' responses with regard to livestock holdings in a rainfall shock, we used both rainfall shock variables together in estimation equations.

Thus, we will use the following econometric model, based on the previously defined sensitivity:

$$A_{it} - A_{it-1} = \alpha + \beta_R R_{it-1} + \beta_p p_{st} + \beta_x x_i + \mu_{it} \quad where \;\; \mu_{it} = \rho\mu_{it-1} + \epsilon_{it}, \tag{2}$$

where A_{it} is the number of cattle for a household (i) during a particular month (t); R_{it} is a vector of rainfall shocks experienced by a household (i) during a particular month (t); p_{st} is the price of goats[10] during a particular month (t) at the site (s) ; x_i is a vector of household characteristics, including working adult males ratio; and μ_{it} is a random error term assumed to follow the AR (1) process[11]. Thus, the dependent variable in this specification is the monthly change in the number of cattle owed by a household (i).

As noted above, the theory of asset smoothing predicts that productive assets drive smoothing tendencies, so this analysis aims to discern between the different smoothing regimes using cattle numbers as of October, 2007. Thus, sample households are split as follows:

$$A_{it} - A_{it-1} = \begin{cases} \alpha^h + \beta_R^h R_{it-1} + \beta_p^h p_{st} + \beta_x^h x_i + \mu_{it} & if \;\; 5 \leq A_{ib} \Leftrightarrow \;\; i \in Q4 \\ \alpha^l + \beta_R^l R_{it-1} + \beta_p^l p_{st} + \beta_x^l x_i + \mu_{it} & if \;\; 5 > A_{ib} \Leftrightarrow i \notin Q4 \end{cases} \tag{3}$$

where A_{ib} is the number of cattle of a household (i) before the shock (i.e., as of October 2007) and μ_{it} is the AR (1) error.

If livestock are used as a buffer against income shock, the coefficients of rainfall shock should be negative and significant. The first two columns of Table 6 present the full sample model (i.e., Eq. (2)) results. As shown in these columns, this coefficient is significantly positive rather than negative, suggesting that the use of cattle as buffer stock is a limited practice, consistent with the findings by Fafchamps et al. (1998)[12].

The remaining columns show results regarding the two regimes as defined by Eq. (3). While monthly changes in cattle numbers are positively responsive to total rainfall among households with lower livestock numbers in 2007, this rainfall shock variable has a significantly negative effect on changes in cattle numbers among Q4 households, implying that to prevent a reduction in consumption levels they may have sold their cattle. These results are consistent with the asset smoothing hypothesis prediction that only those with a certain level of assets pursue the traditional consumption smoothing strategy of selling assets. Furthermore, it should be noted that the sign for the ratio of working males is significantly different between the two samples: a positive coefficient in Q4 and a negative coefficient in the remaining quartiles. The positive coefficient implies that households with a weaker labor market access or simply less men are more likely to reduce cattle numbers, suggesting that such households may smooth consumption by selling cattle. However, the negative effect of working males in the lower quartiles may be

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[10] The prices of goats used here are deflated by the local food price index calculated by the authors using Household Survey data.

[11] The data in this estimation have many time periods for relatively few households, needing methods for stationary errors. In fact, the null hypothesis that there is no first order correlation in the Wooldridge test is rejected for each quartile at the 5% or less significance level. The same conclusion is reached by the test for serial correlation using fixed effect estimation. Thus, this specification assumes that the random error follows the AR (1) process.

[12] The significantly positive coefficient means that households with heavy rainfall increased the number of cattle, other things being equal. For this counterintuitive result, one possible explanation is that cattle are less liquid than small livestock, since distress sale after a covariate shock lead to a much reduced price if cattle markets are thin and fairly inactive (Fafchamps, et al., 1998). This paper leaves this as a topic for future work.

interpreted using the concept of human capital. If human capital is considered a critical productive asset influencing household welfare, households with less male labor would protect cattle numbers to smooth productive assets[13]. Table 6 also shows that the price of goats does not significantly influence cattle retention, suggesting that cattle transactions might not be particularly price responsive in the study sites.

Table 6: Determinants of sensitivity regarding rainfall shock on cattle numbers

	Pooled		Q4				Excluding Q4	
	FE	FE	FE	RE	FE	RE	FE	FE
Rainfall Shocks								
Total amount of rainfall (mm)	0.0003	0.0003	-0.0011	-0.0009	-0.0008	-0.0009	0.0005	0.0005
	[2.04]**	[1.99]**	[-1.47]	[-1.98]**	[-0.86]	[-1.76]*	[3.63]***	[2.99]***
Rainfall deviation from the	0.1588		0.2627	0.2861			0.0197	
village mean at t-1	[4.21]***		[4.98]***	[5.62]***			[0.36]	
×Site A dummy	-0.1283		-0.1806	-0.1856			-0.0269	
	[-0.71]		[-0.41]	[-0.44]			[-0.14]	
×Site B dummy	-0.1492		-0.0673	-0.1224			-0.0160	
	[-3.19]***		[-0.29]	[-0.54]			[-0.26]	
Rainfall deviation from the		-0.0468			-0.0724	-0.0458		0.0073
village mean at t-2		[-1.23]			[-1.27]	[-0.86]		[0.13]
×Site A dummy		0.0621			-0.2816	-0.1509		0.0158
		[0.34]			[-0.21]	[-0.13]		[0.09]
×Site B dummy		0.0517			-0.0533	-0.0596		0.0010
		[1.02]			[-0.16]	[-0.18]		[0.02]
Control Variables								
Monthly price of goats (10000K)	0.0100	0.0156	-0.0049	-0.0101	0.0358	0.0180	0.0186	0.0152
	[0.60]	[0.91]	[-0.12]	[-0.27]	[0.81]	[0.44]	[1.04]	[0.84]
Household Variables								
Value of small livestock (10000K)	0.0000	0.0000	0.0008	0.0003	0.0001	0.0005	0.0004	0.0005
	[-0.02]	[0.02]	[0.46]	[0.51]	[0.05]	[0.85]	[0.83]	[1.07]
Total Area for cropping (ha)	-0.0776	-0.0826	-0.2089	-0.0900	-0.228	-0.0777	-0.0571	-0.0683
	[-4.29]***	[-4.45]***	[-2.99]***	[-1.59]	[-2.99]***	[-1.30]	[-3.04]***	[-3.57]***
Value of Assets (10000K)	0.0000	-0.0001	-0.0002	0.0000	-0.0005	-0.0001	-0.0003	-0.0003
	[0.05]	[-0.83]	[-1.35]	[0.05]	[-2.27]**	[-0.98]	[-1.00]	[-0.88]
Rate of working males	-0.7420	-0.6632	0.7978	1.3142	0.6835	1.6127	-1.7860	-1.6948
	[-2.24]**	[-1.94]*	[1.25]	[2.59]***	[0.99]	[3.00]***	[-4.37]***	[-4.07]***
Rate of working females	-0.6833	-0.7180	-0.7451	-0.9840	-0.4819	-0.9587	-1.1242	-1.1602
	[-2.13]**	[-2.18]**	[-0.74]	[-1.23]	[-0.41]	[-1.14]	[-3.16]***	[-3.18]***
Constant	0.1784	0.1683	2.1251	3.5122	2.0261	3.5370	0.1102	0.2309
	[0.81]	[0.69]	[1.93]*	[2.98]***	[1.38]	[2.83]***	[0.50]	[0.95]
F-statistics	4.50	3.20	4.34		1.63		4.08	4.03
Chi-square statistics				101.00		68.14		
Level of Significance	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Hausman Statistics	22.98	20.56	-4.96[a)]		3.90		20.66	21.21
Number of Observations	913	865	168	176	159	167	745	706

* p<0.1, ** p<0.05, *** p<0.01

Notes: 1. The dependent variable is the monthly change in the number of cattle owed by the household.
2. t-statistics are in parentheses. The panel data is unbalanced because of missing data from household interviews.
3. With regard to random effects specifications, a number of variables were included but were not reported: rainy season dummies, cattle numbers as of October 2007, age of household head, years of education for household head, sex of household head, and site dummies.
4. With regard to fixed effects specifications, rainy season dummies were included as a variable but were not reported.
a). The negative Hausman statistic implies that the random effects model was not rejected due to the similarity of the covariance matrices. Thus, the Hausman test supports the use of the random effects model over the fixed effects model.

[13] Such a multidimensional view of assets, as stressed by Hoddinott (2006), should be taken into account in future research on intertemporal smoothing behavior and poverty dynamics.

4.4 Lagged Effect of Rainfall Shock on Cattle Numbers

The results presented in the previous sub-section suggest that wealthier and poorer households have different smoothing behavior. However, the effect of the heavy rainfall shock in 2007/08 may have also elicited a different response in 2007/08 than it did for 2008/09. For example, households who had experienced the heavy rainfall and decreased cattle numbers in the first year may have increased cattle numbers in the second year, an example of resilience as defined earlier in the paper. In addition, other households who had smoothed or increased cattle numbers in the first year were unable to retain cattle the following year[14]. To test these scenarios, this section performs individual specifications for each crop year and then runs a comparison between Q4 and Q3 (compared with the previous evaluation between Q4 and Q1–3)[15]. These results are presented in Table 7.

With regard to the 2007/08 crop year, both rainfall shock variables (rainfall deviation from the village mean value and annual precipitation) had a negative significant effect on the stock series for cattle among households of Q4 and no significant effect on the same among households of Q3. This result is consistent with the previous specification results. Moreover, while household specific variables have a significant influence on cattle retention for both Q4 and Q3, the coefficients signs are different between the two regimes in some instances. For example, the value of household assets in Q4 significantly increases cattle numbers. This result suggests that households in Q4 suit typical consumption smoothing tendencies, because wealthier households with additional income have the ability to save more.[16] In contrast, the value of assets reduces the number of cattle in Q3, suggesting asset smoothing tendencies. These findings constitute evidence of wealth-differentiated behavior.

Table 7 also presents aspects of resilience to rainfall shocks. If the coefficient of rainfall shock variables in Q4 is positive and significant in 2008/09, this result represents a recovery from rainfall shock. As shown in Table 7, however, the estimation result does not offer robust evidence regarding resilience in Q4 because the signs for the two rainfall shock variables are different. In contrast, as can be seen in the two rightmost columns of Table 7, rainfall shock variables for 2007/08 have a significantly negative effect on cattle numbers in Q3 for the following crop year, suggesting that those who maintain their cattle numbers in the flood-year may be affected by lagged rainfall shocks. This also indicates a long-term relationship between asset dynamics and economic mobility.

5. Conclusion

This paper introduced measurable definitions for sensitivity, resilience, and vulnerability

[14] This possibility was also suggested by Sakurai et al. (2011). They showed that food price increased during the rainy season of 2008/09 more than during the rainy season of 2007/08 probably due to the reduction of agriculture production in 2007/08 and that average household consumption is much lower during the rainy season of 2008/09 than the previous year.

[15] Q1 and Q2 are not included in the analyses because households in these quartiles had zero or one cattle as of October 2007 and their change in the number of cattle during a short period, i.e. one year, is too small to obtain statistically significant estimates.

[16] Assets include farming equipments (ex; ox-drawn ploughs and hand hoes), durables (ex; hand hammer mills and radios) and houses including animal stalls and storages for grain. Thus, assets in this context are less liquid than small livestock and grain storages.

with regard to asset fluctuations. Using the specified sensitivity definition, this study employed

Table 7: Random effect estimates of determinants of sensitivity for each crop year

	2007_2008				2008_2009			
	Q4		Q3		Q4		Q3	
	RE	RE	RE	RE	RE	RE	RE	RE
Rainfall Shocks								
Rainfall deviation from the	-24.615		-4.538		9.614		-7.964	
village mean , 07/08	[-2.51]**		[-1.36]		[1.66]*		[-3.27]***	
Rainfall deviation from the					14.485		5.574	
village mean , 08/09					[4.35]***		[2.42]**	
Total amount of rainfall, 07/08 (mm)		-0.473		0.001		-0.005		-0.003
		[-2.51]**		[0.87]		[-1.48]		[-3.23]***
Total amount of rainfall, 08/09 (mm)						-0.001		0.003
						[-0.19]		[2.35]**
Rainfall deviation from the	0.257	0.257	0.005	0.019	0.330	0.330	0.288	0.288
village mean at t-1	[3.22]***	[3.22]***	[0.03]	[0.12]	[4.79]***	[4.79]***	[1.70]*	[1.70]*
×Site A dummy	-0.253	-0.253	-0.022	-0.061	-0.305	-0.305	-0.143	-0.143
	[-0.49]	[-0.49]	[-0.03]	[-0.08]	[-0.26]	[-0.26]	[-0.23]	[-0.23]
×Site B dummy	-0.172	-0.172	0.006	-0.006	-0.076	-0.076	-0.252	-0.252
	[-0.45]	[-0.45]	[0.03]	[-0.04]	[-0.26]	[-0.26]	[-0.88]	[-0.88]
Control Variables								
Monthly price of goats (10000K)	0.013	0.013	-0.051	-0.026	-0.020	-0.020	0.024	0.024
	[0.18]	[0.18]	[-0.94]	[-0.44]	[-0.52]	[-0.52]	[0.67]	[0.67]
Household Variables								
Value of small livestock (10000K)	-0.001	0.055	0.008	0.009	0.005	0.009	0.001	0.000
	[-1.91]*	[2.51]**	[2.32]**	[2.51]**	[3.38]***	[2.60]***	[0.25]	[-0.06]
Total Area for cropping (ha)	-0.595	-49.996	-0.160	-0.067	-8.221	6.514	-1.136	-0.866
	[-2.85]***	[-2.52]**	[-1.78]*	[-0.80]	[-2.81]***	[1.23]	[-1.93]*	[-1.42]
Value of Assets (10000K)	0.003	0.129	-0.011	-0.005	-0.264	0.145	-0.132	-0.174
	[3.09]***	[2.53]**	[-2.71]***	[-1.37]	[-2.58]**	[0.97]	[-2.36]**	[-2.57]**
Rate of working males	-3.697	-143.677	-0.574	0.094	-0.001	-0.004	-0.002	-0.001
	[-2.88]***	[-2.53]**	[-0.52]	[0.09]	[-0.89]	[-2.05]**	[-2.15]**	[-0.75]
Age of HH head	0.033	4.246	-0.042	-0.024	0.044	-0.009	-0.008	0.008
	[2.47]**	[2.52]**	[-3.05]***	[-2.38]**	[2.88]***	[-0.56]	[-1.92]*	[1.29]
Education years of HH head	-0.044	2.718	-0.171	-0.035	0.191	0.019	-0.078	-0.025
	[-1.22]	[2.53]**	[-1.78]*	[-0.50]	[3.53]***	[0.52]	[-3.48]***	[-1.53]
Constant	-0.097	631.128	4.446	0.698	0.023	7.220	1.641	-0.026
	[-0.19]	[2.51]**	[2.33]**	[0.28]	[0.08]	[0.77]	[2.87]***	[-0.02]
Chi-square statistic	21.13	21.13	51.99	50.14	93.67	93.67	36.37	36.37
Level of Significance	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Hausman Statistics	0.14	0.14	6.17	2.60	1.35	1.35	-1.29	-1.29
Number of Observations	75	75	83	83	114	114	109	109

* p<0.1, ** p<0.05, *** p<0.01

Notes: 1. The dependent variable is the monthly change in the number of cattle owed by the household.
2. For the poorer quartile, this estimation only uses samples of Q3 because a significant result was not obtained using this specification when Q2 and Q1 were included.
3. t-statistics are in parentheses.
4. The panel data is unbalanced because of missing data from the household interviews.
5. The negative Hausman statistic implies that the random effects model is not rejected due to the similarity of the covariance matrices.

high-frequency panel data from Southern Province, Zambia to estimate the determinants of sensitivity to rainfall shocks and to investigate the existence of an asset threshold, marking a shift from asset to consumption smoothing. The data covered the period between the 2007/08 and 2008/09 crop years, which included a heavy rainfall year within the study sites. The results revealed patterns of asset smoothing or protection among the poorer households and asset liquidation or consumption smoothing among the wealthier, which suggests wealth-differentiated behavior regimes. In the context of the study sites, the Micawber threshold, an asset level that represents an unstable equilibrium at which dynamic behavior bifurcates, may sit at approximately five cattle rather than two cattle, the common number of cattle used for cultivation. This finding is consistent with the dynamic asset smoothing hypothesis predicted in previous studies. Our analysis also revealed that those who smooth assets in the first year may be affected in the second year by lagged rainfall shocks, probably through market price increases, suggesting a negative impact by environmental shocks on asset smoothers. In contrast, results for resilience, regarding those who decreased cattle numbers during the heavy-rainfall year, are diverse, suggesting that any recovery period might not even begin in the second year. Asset recovery experiences will be investigated in future work.

The present analysis has been unable to fully resolve the complexities of asset dynamics in rural Zambia. First, while this paper has found evidence that the wealthy have a greater ability to smooth consumption than the poor, the criteria for distinguishing between them may be ad hoc. This matter requires further investigation. Second, this paper does not examine vulnerability; future research will provide clarification of the Micawber threshold and the asset poverty line, promising tools with which to induce rich policy and development implications. Third, it would seem that future investigation is also required to better understand the relationship between asset-based analysis and traditional poverty analysis with regard to consumption or income level. In addition, giving micro foundations to the approach of this study based on dynamic household models is also left for a future study.

While future research to answer outstanding issues is always desirable, the main contribution of this paper is the provision of empirical evidence regarding wealth-differentiated tendencies using stock series data. Furthermore, the concepts of sensitivity and resilience, as defined in this paper, can be used in future studies regarding household *ex-post* coping strategies and the accumulation and liquidation of other productive and non-productive assets (e.g., land and small livestock).

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Seasonal Consumption Smoothing in Rural Zambia

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Abstract

The purpose of this article is to investigate how farmers smooth their consumption level against fluctuating income. We discuss several issues using household survey data collected in rural Zambia from November 2007 to October 2009. First, we demonstrate that farmers smooth their consumption levels of staple foods, and vegetables and fruit, and that they use animal/fish products and non-food items as buffers. Second, we illustrate that cash in hand plays a critical role in smoothing consumption levels of staple foods, and vegetables, and fruit. Finally, we show that wild food items collected from the bush are also important in smoothing the consumption levels of vegetables and fruit when these are not available from the farmers' own land.

1. Introduction

It is widely recognized that while rural farmers face a number of income risks, they have developed a variety of strategies to mitigate these, including the diversification of income sources, risk-sharing with friends and relatives, and settlement in safe areas (Fafchamps, 2003). From the viewpoints of economics, farmers will improve their welfare if they smooth their consumption levels. However, a change in consumption and its sources are in themselves important strategies to manage unexpected falls in income, although consumption levels do not appear to be smoothed by such strategies (it is possibly their utility that may be smoothed). Nevertheless, existing literature provides little empirical evidence regarding changes farmers may make to their consumption to mitigate income shocks during and after a shock event. One explanation for a lack of evidence is that there is no dataset available to enable such an empirical study. However, household survey data sourced from the Resilience Project includes high-frequency panel data regarding household consumption during a period when farmers suffered through heavy rainfalls. This data provided us with a rare opportunity to investigate the consumption adjustment behavior of farmers when they experienced income fluctuations. Thus, the aim of this article is to describe how surveyed households change the composition and source of consumption over a two-year period, to better enable us to develop an empirically testable hypothesis for future research.

2. Survey Outline and Methodology

The household survey data used in this paper were collected in rural Zambia as part of the Resilience Project. The study area is located in Choma and Sinazongwe districts, Southern Province, Zambia, and is divided into three ecological zones: site A (a lower flat land zone near Lake Kariba), site B (a middle slope zone), and site C (an upper land zone on the plateau). Five villages were selected for the household survey; two villages are in site A (Sianemba and Siameja), two are in site B (Chanzika and Kanego), and one is in site C (Siachaya). Sixteen households were chosen from each study site and were subject to weekly interviews beginning November 2007 (Sakurai 2008).

This article uses data from a two-year period, November 2007–October 2009, and employs a descriptive statistics analysis. The total value of household consumption per week was divided by adult equivalent household size, and then averaged for each site and each month. The monthly consumption per week per adult equivalent for each site was further deflated by a site-specific price index obtained from our survey data. Thus, we have a series of real consumption covering a two-year period for each site. However, due to flaws in the survey data, we omitted data regarding June 2008 for all sites, and January and April 2008 for site C. In addition, site C data from November 2007 to October 2008 are unreliable and the figures are presented for reference only.

3. Results and Discussion

First, in this section, we will illustrate the overall seasonal consumption changes to enable a better understanding of seasonal consumption smoothing. Second, we examine the role of non-food goods in smoothing food consumption levels. Finally, we divide food items into three categories (staple foods, vegetables and fruit, and animal products) and examine each category.

3.1. Overall seasonal consumption change

Table 1 shows the monthly consumption level per week per adult equivalent averaged over a two-year period for each study site. Comparisons among the three sites show that consumption per adult equivalent is highest in site B and lowest in site A. With regard to consumption composition, average consumption levels for food range from 83.7% to 88.5% for the three sites and 11.5% to 16.3% for non-food items (e.g., household goods and services). Moreover, the average consumption levels for cereals (non-processed and processed staple foods) range from 50.5% to 52.6%, 12.8% to 20.1% for vegetables, and animal products range from 8.2% to 9.6%. Although site C does not have the highest total consumption rate, its consumption share for household goods and services is the highest among the three sites.

Table 1. Average Value of Consumption per Week per Adult Equivalent[1]

	non-processed staple foods	vegetables	fruits	processed staple foods	animal products	food items collected in the Bush	Industrial Food Products	Household Goods	Service	total
SITE A	11775	6959	186	5677	3305	234	2474	2506	1447	34563
	34.1%	20.1%	0.5%	16.4%	9.6%	0.7%	7.2%	7.3%	4.2%	100.0%
SITE B	18825	5953	383	5750	5756	823	3493	3935	1745	46663
	40.3%	12.8%	0.8%	12.3%	12.3%	1.8%	7.5%	8.4%	3.7%	100.0%
SITE C	13626	7299	207	8651	3607	561	2817	5308	1832	43908
	31.0%	16.6%	0.5%	19.7%	8.2%	1.3%	6.4%	12.1%	4.2%	100.0%

1 Numbers are in ZMK deflated by price index (=1 as of November 2007 in site A)

Figure 1, presents monthly changes in average consumption per week per adult equivalent. Although most households are farmers and obtain their main income only at harvest time, average consumption levels appear to be smoothed. However, when we examine each consumption category individually, consumption levels seem to fluctuate. We will discuss each consumption category in the remainder of this section.

Figure 1. Monthly Changes in Consumption Levels and Composition


SITE A (07/08)
(KW)
80000
70000
60000
50000
40000
30000
20000
10000
0
2007/11 2007/12 2008/01 2008/02 2008/03 2008/04 2008/05 2008/06 2008/07 2008/08 2008/09 2008/10
SITE A (08/09)
(KW)
80000
70000
60000
50000
40000
30000
20000
10000
0
2008/11 2008/12 2009/01 2009/02 2009/03 2009/04 2009/05 2009/06 2009/07 2009/08 2009/09 2009/10
SITE B (07/08)
(KW)
80000
70000
60000
50000
40000
30000
20000
10000
0
2007/11 2007/12 2008/01 2008/02 2008/03 2008/04 2008/05 2008/06 2008/07 2008/08 2008/09 2008/10
SITE B (08/09)
(KW)
80000
70000
60000
50000
40000
30000
20000
10000
0
2008/11 2008/12 2009/01 2009/02 2009/03 2009/04 2009/05 2009/06 2009/07 2009/08 2009/09 2009/10
SITE C (07/08)
(KW)
80000
70000
60000
50000
40000
30000
20000
10000
0
2007/11 2007/12 2008/01 2008/02 2008/03 2008/04 2008/05 2008/06 2008/07 2008/08 2008/09 2008/10
SITE C (08/09)
(KW)
80000
70000
60000
50000
40000
30000
20000
10000
0
2008/11 2008/12 2009/01 2009/02 2009/03 2009/04 2009/05 2009/06 2009/07 2009/08 2009/09 2009/10
Services
Household Goods
Industrial Food Products
food items collected in the Bush
animal products
processed cereal
fruits
vegetables
non-processed cereal

3.2. Comparison of food and non-food consumption

Figure 2 shows the diremption of monthly consumption levels from the mean consumption levels[1] for each site. This figure demonstrates that there is a positive correlation between diremption of total consumption and that of non-food consumption. Moreover, compared with the diremption of total consumption food, the diremption of non-food consumption fluctuates more widely. These points imply that non-food item may be serving as a buffer for food consumption.

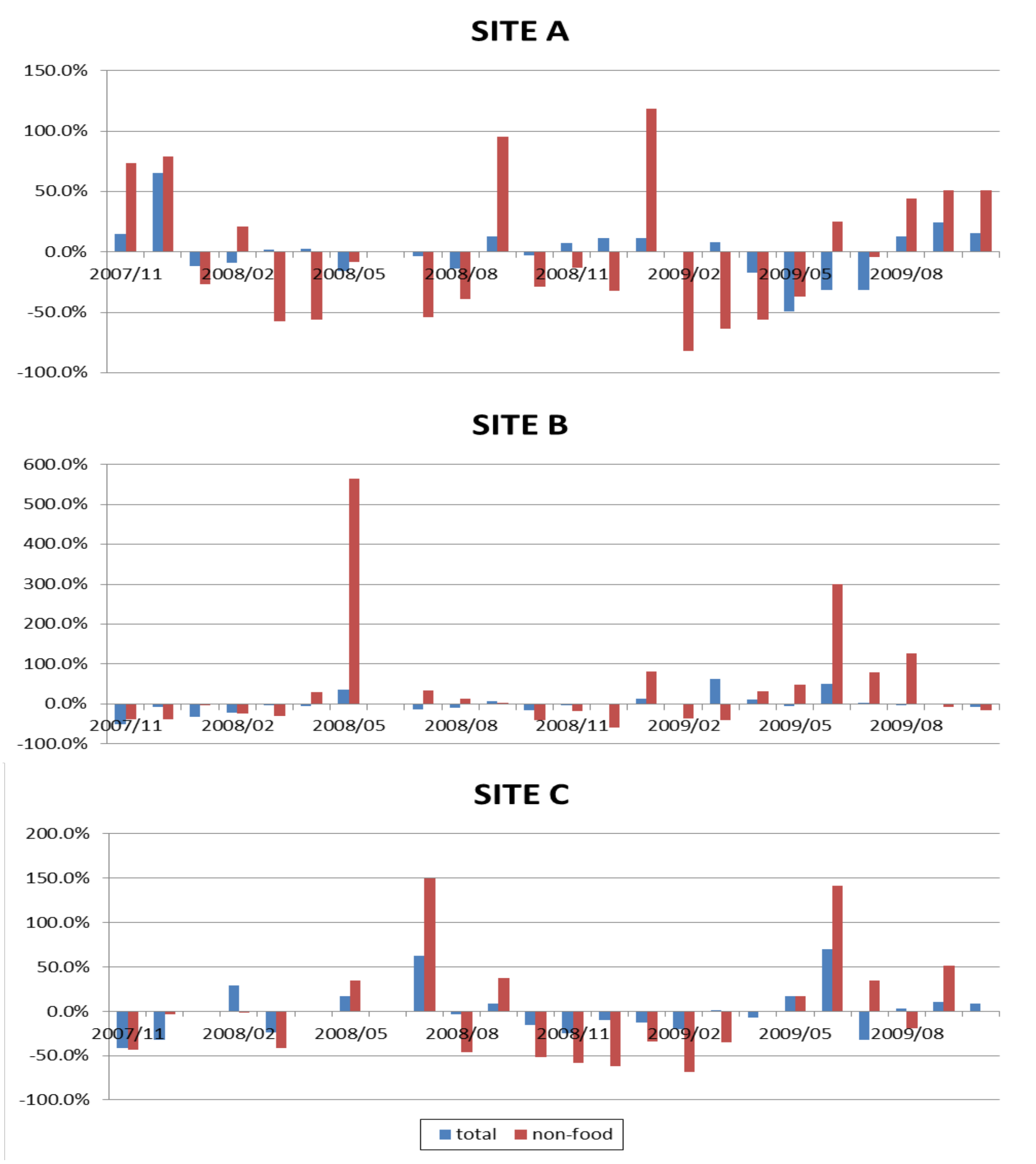

Figure 2 Diremption of Total and Non-Food Consumption from the Means

[1] Diremption = (consumption level–average consumption level)/average consumption level × 100. The average level is based on monthly data from November 2007 to October 2009.

3.3. Food consumption and food sources

3.3.1 Staple foods

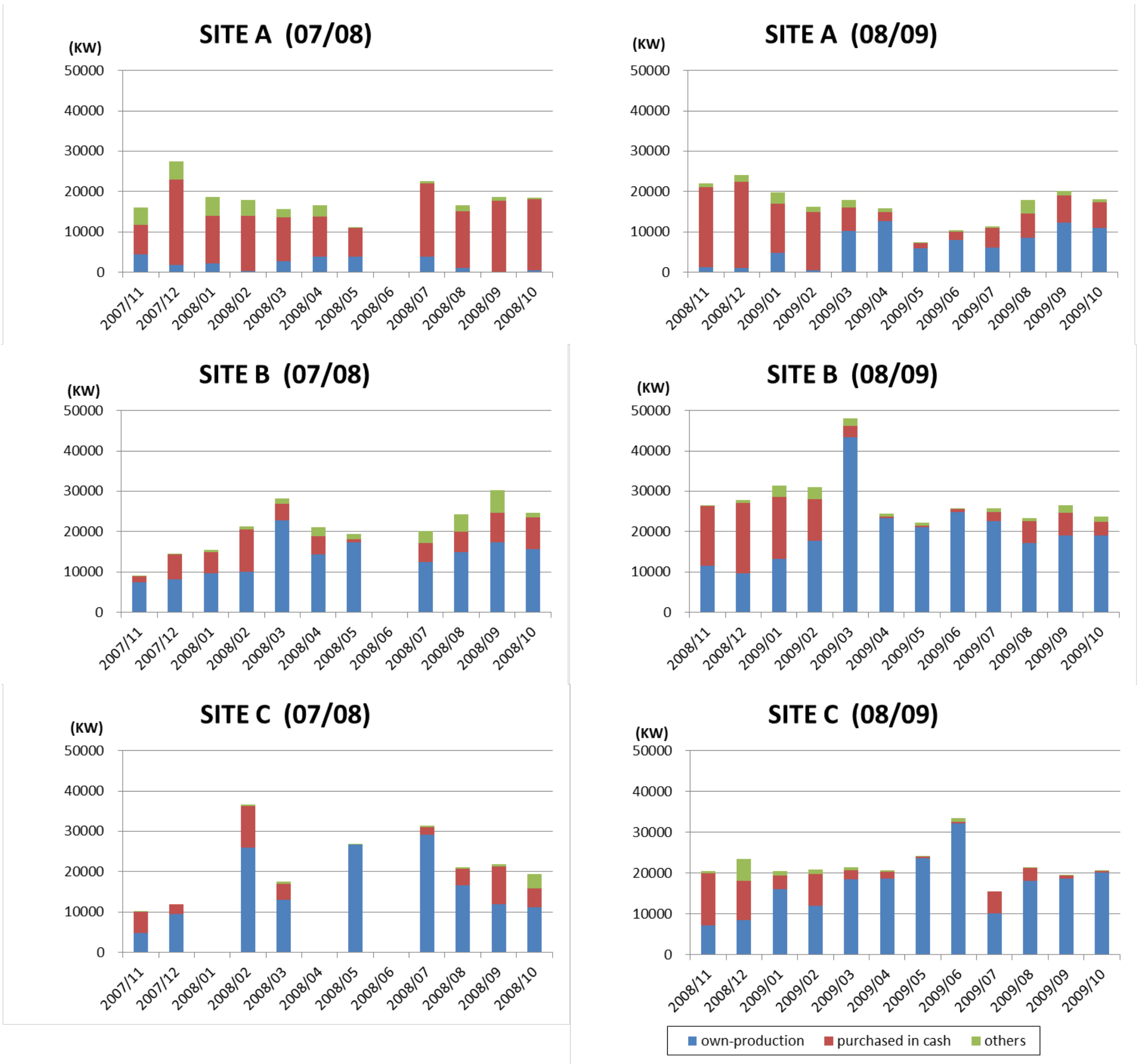

Figure 3. Monthly Staple Food Consumption and Food Sources

Figure 3, illustrates monthly real values for staple food consumption (cereal, beans, and potatoes) and the source of the items (please note, maize constitutes more than two-thirds of staple food consumption in the study sites). The following salient points are shown in Figure 3. First, while households in sites B and C use mainly self-produced staple foods, households in site A rely more on cash purchases than on self-produced food items. This suggests that cash earning activities, such as non-agricultural businesses, livestock sales, and cotton production, play critical roles in obtaining staple food items for site A households. Second, aside from a couple of exceptions, total consumption levels regarding staple foods appear to be smoothed throughout the survey period. Third, cash purchases play an important role in smoothing staple food consumption. For example, in sites B and C, even though consumption levels for self-produced items vary each month during the 2008/09 crop year, total consumption remains relatively stable year-round because households purchase staple foods using cash. In contrast, if we compare staple food consumption in site B between the two crop seasons, i.e., between November and February 2007/08 and again in 2008/09, the consumption level for self-produced items is relatively stable but the total consumption level is much higher in 2008/09 than in 2007/08. One explanation for these results is that these farmers failed to purchase staple food items using cash during the 2007/08 crop season for some unknown reason. Finally, we observed food obtained from "other" sources, especially from November 2007 to April 2008 at site A and from July to October 2008 at site B. The majority of food sourced in this manner was wheat distributed as food aid. However, judging from the source of consumed staple foods, farmers in site B appear to have already owned sufficient quantities of staple foods in July–October 2008. This suggests that food aid may not have been distributed when it was really needed.

Figure 4. Monthly Vegetable and Fruit Consumption and Sources

3.3.2 Vegetables and fruit (including wild food items collected from the bush)

Figure 4, illustrates the monthly consumption of vegetables and fruit and their sources. Interestingly, from February to April each year during the harvest period, farmers consume large quantities of self-produced vegetables (and lesser amounts of fruit). With the exception of this period, consumption levels regarding vegetables and fruit are virtually smoothed year-round, with self-produced items representing a significant share. Considering the perishable nature of vegetables and fruit, self-production implies that farmers (at least some of them) have access to water even in the dry season and are able to grow produce. However, to smooth their consumption levels, the collection of wild food items is also important. For example, from December to February during the rainy season, the collection of wild vegetables and fruit comprises the majority of consumed items in sites A and B. Please note, all natural plants, including mushrooms, are classified as vegetables and fruit in this study and only a small number are considered to be a staple food item (e.g., a wild tuber).

Figure 5. Monthly Consumption of Animal/Fish Products

3.3.3 Animal and fish products

Figure 5, illustrates the monthly consumption of animal and fish products (e.g., animal/bird meat, milk and eggs, and fish) and their sources. In contrast to other food items, the total value of consumption does not appear to be smoothed. The December 2007 peak for site A represents a high level of meat consumption during the Christmas season. Consumption levels show a reduction for Christmas 2008, possibly due to economic hardship after a poor agricultural season in 2007/08. Similar consumption patterns are observed in site B to some extent, but are not seen for site C, although they also celebrate Christmas as Christians. In contrast, there is a peak in June 2009 (we are unable to confirm if there was a peak in June 2008 due to missing data) for sites B and C. We are unable to provide any explanation regarding these high meat consumption levels as those surveyed commented that the consumption was "usual".

Figure 6, shows the diremption from the mean consumption levels at each site. Like non-food items, there is a positive correlation between the diremption of total consumption and that of animal/fish consumption. In addition, compared with the diremption of total consumption, the diremption of animal/fish consumption fluctuates in a wider region. These results imply that animal/fish products are a buffer for the consumption of staple foods, and vegetables and fruit.

4. Conclusion

This article has discussed how farmers in rural Zambia adjust consumption levels and its composition to mitigate the impact of income fluctuations. First, we demonstrated that farmers smooth their consumption level of staple foods, and vegetables and fruit, and that they use animal/fish products and non-food items as buffers. Second, we illustrated that cash purchases played a critical role in smoothing consumption levels regarding staple foods, and vegetables and fruit. Finally, we showed that the collection of wild food items also played an important role in the smoothing of consumption levels for vegetables and fruit.

In this article, we focused on descriptive analyses for consumption, while fluctuations in income levels occurred naturally in the study sites. Thus, further studies are required to examine the relationship between consumption and income. Moreover, this article does not examine how farmers obtain their money. As the surveyed farmers have varying abilities to earn money, it would be wise to investigate this further to determine which households are better able to smooth consumption. Lastly, farmers are not only receiving income from non-agricultural sources, but may also be smoothing their income by agricultural means. Further work is required to determine how farmers are in fact smoothing their income.

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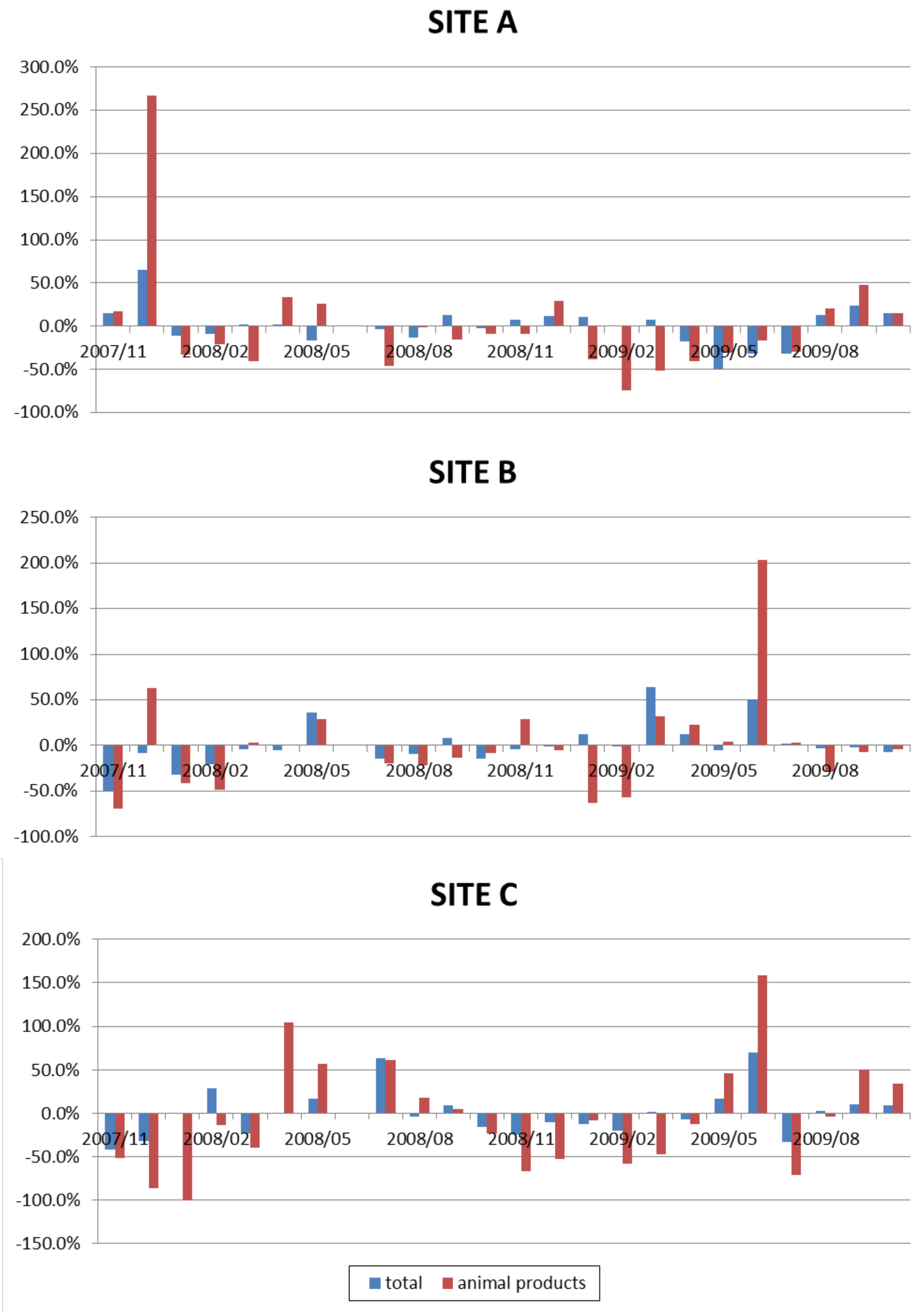

Figure 6 Diremption of Total and Animal/Fish Consumption from Mean Values

Analysis of Impact of Heavy Rainfall Shocks on Time Allocation Changes in Rural Zambia

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Abstract

This paper examines the effect of rainfall variability on people's time allocation using weekly household survey data sourced from rural Zambia. The data collection period was November 2007 to November 2009, during which an extremely heavy rainfall occurred. Changes in time allocation are examined among various activities using time use data from a weekly household survey. The data show that people worked longer hours after the heavy rainfall. These results were robust for activity categories, gender, and comparisons between children and adults.

1. Introduction

Labor supply is considered to be one of the many coping strategies employed after a shocking event. For example, Rose (2001) analyzed off-farm labor supply for agricultural households under risk of unusual rainfall in India, and showed that households with greater reliance on rainfall (i.e., with greater risk) were more likely to participate in the labor market (*ex ante* response). In addition, that study showed that unexpected low rainfall also increased labor market participation (*ex post* response). Further, Beegle et al. (2006) used data from a household panel survey in Tanzania and that found that disasters resulted in income shocks to agricultural households and significantly increased the incidence of child labor. However, previous studies have generally only conducted before-and-after comparisons of shock events to capture its impact, because of the limited availability of long-term time use data. In contrast, the household survey from the Resilience Project provides us with a high-frequency panel data covering a two-year period (this period is long enough to capture fluctuations in labor supply). With the use of this dataset, this paper examines the effects of a heavy rainfall shock in December 2007 on households' time allocation. Specifically, we focus on labor activities.

2. Data

In this study we used data (from to November 2007 to November 2009) collected in the above-mentioned household survey. The survey (which is ongoing) was initiated in November 2007 in three ecologically distinct sites located on the banks of Lake Kariba, as part of RIHN's Resilience Project (Sakurai, 2009 and Sakurai et al., 2010). One component of the household survey was a weekly interview regarding the allocation of each household member's daily time use over the past week. Thus, the dataset was collated to form individual-level weekly panel data for the two-year period, although there is some imbalance because of, for example, emigration, immigration, births and deaths. Unfortunately, the dataset is too detailed to conduct any panel data analysis presently. Instead, we will conduct descriptive analyses.

Another important feature of our data is that it includes daily rainfall data recorded on the land plot of each sample household. As such, we have the same number of daily rainfall variations as we do sample households. However, for the descriptive analyses in this paper, we will use the difference in average rainfall between only two of the three ecologically distinct study sites: site A located in the low-lying areas of Lake Kariba and site B located on an escarpment between Lake Kariba and the Zambian plateau.

It has been reported that the study sites experienced an extremely heavy rainfall during the 2007 rainy season and that it severely damaged agricultural crops, particularly in site A. This event is confirmed by our rainfall data collected from the farmers' fields—monthly precipitation in site A was on average 100 mm higher than in site B for December 2007. Thus, this paper examines how people varied the allocation of their time use in response to the heavy rain shock. Taking advantage of the data structure we will conduct an intertemporal comparison within the fixed area, as well as, a cross-sectional comparison using fixed time. Moreover, the samples will be classified as either male and female or adults and children to control for variable characteristics.

3. Characteristics of Individuals

Of the activities that may be affected by the heavy rain shock, we are particularly interested in children's education and non-agricultural activities. Therefore, we will first summarize the characteristics of the individuals from the sample households using a baseline survey conducted with the first weekly interviews in November 2007. Similar surveys were also conducted in November 2008 and November 2009. The results of each survey are not identical because household members changed during the survey period, but we are able to confirm that on average central characteristics remained similar. The 2007 survey was employed as baseline data in this paper.

3.1. School Attendance and Education Level

From the baseline survey, we are able to classify all individuals residing at the sample households as of October 2007 into those who are and are not currently attending school. Although this question was asked of all individuals regardless of his/her age, we have only analyzed school-aged individuals of between 6 and 18 years of age.

Tables 1 and 2 summarize the classification of children by the status of formal school attendance for sites A and B, respectively. Children from each site are further classified by sex and age. Among primary school children (6–12 years of age) school enrollment rates are at 62% in site A and 56% in site B, while for secondary school children (13–18 years of age) it is 86% for site A and 100% for site B. In both sites the current enrollment rates are higher among secondary school age children than among primary school age children, particularly in site B where the latter is 100%. This result may appear surprising but the reality is that many children in the study sites delay starting school and most secondary school age children still attend primary school.

Nonetheless, the results indicate that enrollment rates are relatively high in the study sites. In addition, the rates are not significantly different because statistical tests for inequality in enrollment rates for the two sites cannot be rejected for either primary school or secondary school age children.

With regard to gender difference, enrollment rates for all children are 68% for male children and 72% for female, with primary age children at 59% for males and 57% for females. Neither result is statistically significantly different according to statistical tests for inequality in enrollment rates.

Table 3 shows the education levels attained by adults (18 years of age and over) in sites A and B. In Site B, approximately 40% of people have not received any formal education. In contrast, adults with no formal education is only 10% in site A, much lower than in site B. Furthermore, the majority of educated people completed grades 4–7 in site A, but site B adults attained lower grades on average. As shown in Table 4, the average years of education for adults is significantly higher in site A than in site B.

With respect to gender, differences between education levels are not so obvious in Table 4. Although male adults received on average more years of education (4 years) than females (3.1 years), the difference is not statistically significant. If the test is conducted for sites A and B separately, the results are the same: no gender difference in education is found (not shown in Table 4). Thus, we can conclude that in the study sites there is no gender difference in schooling with regard to both school age children and adults. Interestingly, education levels may be improving, as the current enrollment rate is very high even though there are illiterate adults in the study sites.

Table 1 : Formal school attendance (Site A)

	age 6-12			age 13-18			
	male	female	Total	male	female	Total	Total
yes	8	5	13	8	4	12	25
no	4	4	8	2	0	2	10
Total	12	9	21	10	4	14	35

Table 2 : Formal school attendance (Site B)

	age 6-12			age 13-18			
	male	female	Total	male	female	Total	Total
yes	8	7	15	3	7	10	25
no	7	5	12	0	0	0	12
Total	15	12	27	3	7	10	37

Table 3 : Education level (age over 18)

	Site A			Site B		
	male	female	Total	male	female	Total
None	1	3	4	8	10	18
Sub-standard A or B; Grade 1	0	2	2	2	2	4
Standard 1; Grade 2	1	0	1	2	0	2
Standard 2; Grade 3	1	0	1	2	1	3
Standard 3; Grade 4	2	7	9	1	2	3
Standard 4; Grade 5	2	2	4	1	1	2
Standard 5; Grade 6	1	2	3	3	1	4
Standard 6; Grade 7	5	3	8	3	0	3
Standard 7; Grade 8	0	0	0	0	1	1
Standard 8; Grade 9	5	2	7	0	1	1
Standard 9; Grade 10	0	0	0	0	0	0
Standard 10; Grade 11	0	0	0	1	0	1
Total	18	21	39	23	19	42

Table 4: Comparison of Average Years of Education by Site and Gender[1]

Classification	Site		Gender	
Group	Site A	Site B	Male	Female
Mean (S.D.)	4.7 (2.8)	2.6 (2.8)	4.0 (3.0)	3.1 (3.0)
Number of Obs.	45	51	51	45
t value	3.76		1.39	
Significance	0.00		0.17	

[1] t-values are based on two-sample t-test with equal variances.

3.2. Occupation

The baseline survey conducted in November 2007 asked all individuals residing at the sample households to list primary and secondary (if any) occupations, including those of school age and pre-school age children. In this section, occupations for adults (18 years of age and older) are summarized for each site in Tables 5 and 6.

In both sites A and B, agriculture is the primary occupation for virtually all adults, both male and female, as shown in Table 5. There are those that are employed in an agricultural primary occupation in site B, but they live separately from the sample households and do not appear in Table 5. In addition, there are some who are self-employed in non-agricultural positions. In addition, several respondents in site A are students. Students that are living in the study site are high school students, because no higher level of schooling exists within commutable distance. The baseline survey shows that two-thirds to three-quarters of adults do not have any secondary occupations, including those who refer to agricultural or domestic work as their secondary occupation. This result indicates that there is little diversification among income sources within the study sites. However, six adults in site A and 16 in site B reported that they engage in non-agricultural, self-employed activities. Gender and site-wise, males in site B are most likely to have non-agricultural jobs. The most popular job for these males is logging in forested areas, which are found in site B.

Table 5 : Primary Occupation (age over 18)

	Site A			Site B		
	male	female	Total	male	female	Total
agriculture	16	22	38	23	20	43
student	2	1	3	0	0	0
Total	18	23	41	23	20	43

Table 6 : Secondary Occupation (age over 18)

	Site A			Site B		
	male	female	Total	male	female	Total
no 2nd job	9	9	18	7	7	14
agriculture	2	5	7	0	4	4
non-agri. jobs, self-employment	4	2	6	13	3	16
employed in agricultural sector	1	0	1	1	0	1
employed in non-agricultural sector	2	0	2	0	0	0
domestic work/ helping household	0	6	6	1	6	7
student	0	1	1	0	0	0
Total	18	23	41	22	20	42

4. Time Allocation

4.1. Time Use Data

Time use data were obtained from the weekly household survey by asking individual household members how many hours they spent on any of the seven activity categories: agriculture (WAG), non-agriculture (WNG), domestic/home help (WHH), school (WED), social (WSC), natural resource collection (WNR), and stock grazing (WGR), with the sum of work hours recorded as total work time (WLT). All individuals from each sample household, including both adults and children, recorded their daily time use for a week. Thus, the time use data structure is on daily and individual levels. To investigate the relationship between rainfall and time use, this paper aggregated monthly data to obtain average work hours per day for each activity category with controls for differences in site, gender, and age. The results are presented using a series of graphs from Figures 1.1 to 4.8 at the end of this paper, where the vertical axis on the left indicates monthly precipitation (ml) and the vertical axis on the right indicates hours per day.

4.2. Differences between Sites A and B

In both sites WAG labor hours during the rainy season were longer in 2007/08 than in 2008/09, as shown in Figures 1.1 and 2.1. Thus, the heavy rainfall impacted on self-employed labor activities. In addition, as expected, the impact was more significant in site A where the rainfall in December 2007 was higher. Because agricultural production was severely reduced after the heavy rain (these data are not shown in this paper), a return to self-employed labor was very low for the 2007/08 crop season, particularly in site A.

With regard to WNG, as presented in Figures 1.2 and 2.2, the monthly pattern corresponds with that for WAG. As discussed in Section 3.3, average hours spent in non-agricultural employment during the dry season were longer in site B where more adults were engaged in such activities. However, total hours per day were less than 1 hour on average for both sites, which is significantly smaller than the fluctuations in daily work hours for agriculture. In contrast, people in site A spent more hours in WGR activities than in site B, particularly during the dry season (Figures 1.7 and 2.7). As livestock is an important income source in addition to agriculture, the results show that site A depends more on livestock than on non-agricultural activities.

When we compare Figures 1.3 and 1.4, results show that hours spent in WHH activities fluctuate more in site A than in site B: in Site B, this pattern appears to be independent of rainfall, while in Site A (particularly for 2007/08) it moves almost counter-cyclically to hours of WAG labor. However, in 2008/09, this relationship between WHH and WAG disappeared in site A. Thus, the counter-cyclical movement of WHH and WAG can be regarded as an impact of the heavy rain shock.

Despite both the complementary and counter-cyclical fluctuations of work hours among activities during the rainy season of 2007/08, WTL hours in both sites is greater for 2007/08 than for 2008/09, as shown in Figures 1.8 and 2.8. This difference is more significant in site A where the December 2007 rainfall was much heavier than in site B. WTL in site A is greater even in the 2008/09 rainy season. Therefore, this significant difference in working hours during the 2007/08 rainy season can be attributed in part to the basic difference observed between the two sites in normal years. A further explanation for this difference could be the longer working hours for WHH in site A than in site B as shown in Figures 1.3 and 1.4.

4.3. Gender Differences

In this section, we will examine whether the heavy rainfall had a differential impact on gender. Figures 3.1 and 4.2 show average daily working hours for WAG activities by gender for sites A and B. The graphs indicate that male WAG mirrors female WAG hours throughout the survey period: that is they are parallel. However, the difference between male and female daily working hours during the rainy season is significant in site B, while site A shows virtually no difference. This result indicates that adult males and females are equally engaged in WAG during the crop season in site A., because this tendency is observed for both 2007/08 and 2008/09, the disappearance of the male–female gap does not appear to be due to the heavy rain of 2007/08.

With regard to WNG, however, the working hours for males and females do not mirror each other so strongly, as shown in Figures 3.2 and 4.2. Furthermore, the gender gap exists both in sites A and B, indicating that males are more likely work in non-agricultural sectors during the dry season. WGR activities also appear to be performed by males during the dry season (Figures 3.7

and 4.7). In contrast, the opposite is always observed for WHH (in Figures 3.3 and 4.3) where females feature as the dominant worker, showing the greatest gender gap among the seven activity categories. As discussed in the previous section, the numbers of hours spent in WHH fluctuate greatly in site A, with such fluctuations existing equally for both males and females. In contrast, for site B, female WHH does not appear to be subject to seasonality, while male WHH is generally performed during the dry season.

Hours spent in WNR are limited on average compared with other activities (Figures 3.6 and 4.6), and are performed generally by women throughout the year because its objective is to obtain food items to supplement self-produced vegetables. However, in site A, males also engaged in this activity quite significantly during the 2007/08 dry season, but not in the 2008/09 dry season. This irregular performance of WNR by adult males is likely to be a response to the heavy rain shock.

Unlike other activities that indicate gender gaps, WSC is the only activity showing no gender difference with regard to hours spent, although time allocation for WSC fluctuated over the year (Figures 3.5 and 4.5).

WTL represents the sum of hours spent for all activities. Figures 3.8 and 4.8 show that in sites A and B male and female WTL hours moved in a similar pattern throughout the survey period and that females' working hours were always significantly longer than males. However, if we compare the two sites, the gender gap is larger for site B than in site A and co-movement is weaker in site B than in site A. As a result, the heavy rain increased working time for both males and females in site A, but affected only females in site B. Further investigation is still required regarding whether the different responses between the two sites are due to the differing impacts of heavy rain damage, income sources, custom or culture.

4.4. Adults and Children

Similar analyses were conducted to compare adults (19 year of age and above) and children (between 6 and 18 years of age). As shown in Figures 5.1 and 6.1, the hours children spent in WAG increased during the 2007/08 rainy season for both sites A and B, with a greater increase in site A than in site B. The results for WED (Figures 5.4 and 6.4) show that children's labor in WAG had little effect on WED as the heavy rain occurred during the holiday season. However, Figure 5.4 does show that WED at the beginning of the 2007/08 rainy season decreased to some extent. Thus, the heavy rain shock had a negative impact on the children's education via an increase in demand for household labor, but the impact was marginal. Since 2007/08, children's hours spent in WAG and WED exhibit normal seasonal movements.

Comparisons between sites A and B show that children in site A spent more hours engaged in WHH and WGR than those in site B (Figures 5.3, 6.3, 5.7, and 6.7). As a result, and as presented in Figures 5.8 and 6.8, WTL for children is also higher in site A than in site B, with children's working hours closer to site A adults than site B (i.e., the work time gap between adults and children is smaller in site A). Moreover, WTL hours for both adults and children move in a similar pattern in site A, with a weaker co-movement seen for site B.

Thus, the above analyses show us that children in site A are integrated to a greater extent in household economic activities and their working hours fluctuate in a pattern similar to adults. As a result, children in site A are required to spend more hours working in WAG, WHH, and WGR. These activities can affect their schooling but according to the time allocation data the impact on education is very small. This finding is consistent with the baseline survey results that the current enrollment rate in the study sites is relatively high and that there are no enrollment differences between the sites or gender.

5. Conclusion

We analyzed the impact of heavy rainfall on respondents' time use using weekly household survey data collected in rural Zambia. Our results showed that people, both adults and children, worked greater hours during the 2007/08 rainy season when a heavy rainfall occurred. Analyses were performed for male and female adults separately, to identify gender-differentiated impacts. A work response to the shock was confirmed for male and female adults in site A, and for females adult in site B. These results show that adult males in site B did not work longer hours (nor work less) in spite of the heavy rainfall shock. The difference may be attributed to the fact that crop damage from the heavy rainfall was less significant in site B, but the true reason is not yet known and needs to be studied in future research. Comparisons of time use between adults and children revealed that children in site A worked longer hours than those in site B. Because children worked more after the heavy rain, the shock may have affected the children's school attendance. In fact, children appear to have reduced schooling hours during the 2007/08 rainy season, but we believe this impact to be insignificant from the shape of the relevant graphs.

We used the same household data as Sakurai et al. (2011), who showed in their study that the heavy rain in December 2007 reduced food consumption per capita and the body weight of respondents significantly. The present paper contributes to the topic by identifying a further negative impact of the heavy rain, that is, longer working hours. Body weight loss may have been a result of not only reduced food intake but also due to a heavier workload. The welfare implications of fluctuations in work time and its determinants remain open to future study.

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Figure 1.1 Agriculture: Site A Full Sample

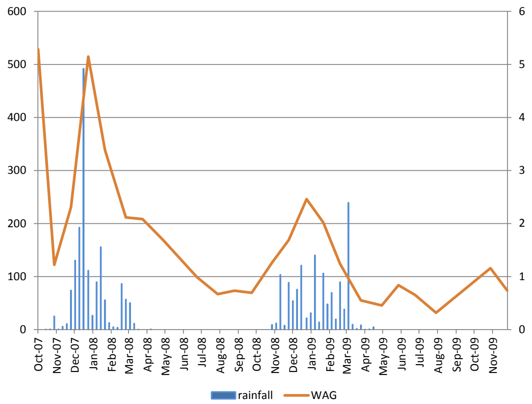


Figure 2.1 Agriculture: Site B Full Sample

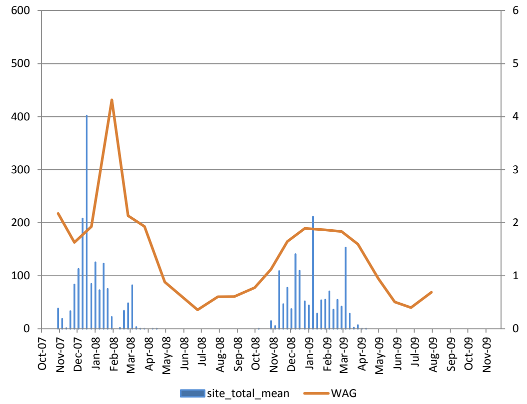


Figure 1.2 Non-Agriculture: Site A Full Sample

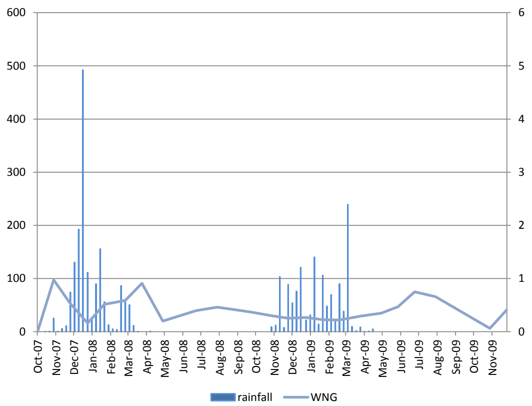


Figure 2.2 Non-Agriculture: Site B Full Sample

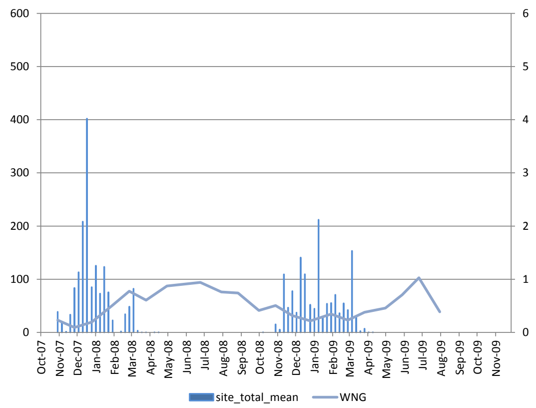
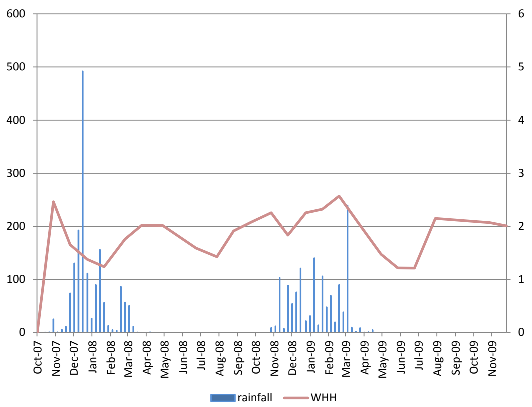


Figure 1.3 Domestic/help: Site A Full Sample



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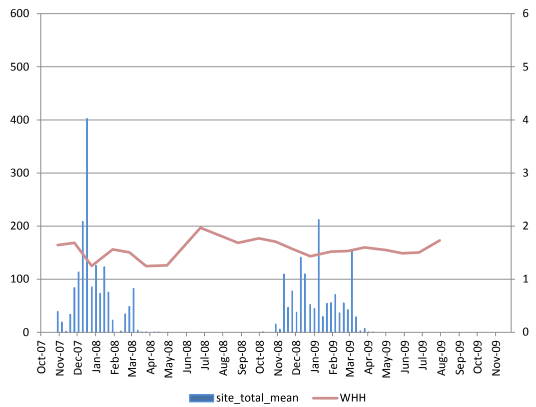
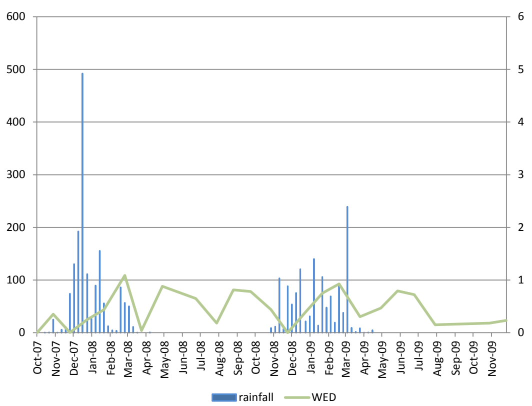


Figure 1.4 School: Site A Full Sample



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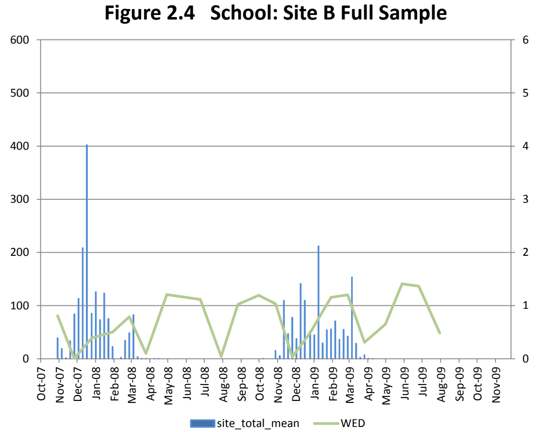


Figure 1.5 Social Activities: Site A Full Sample

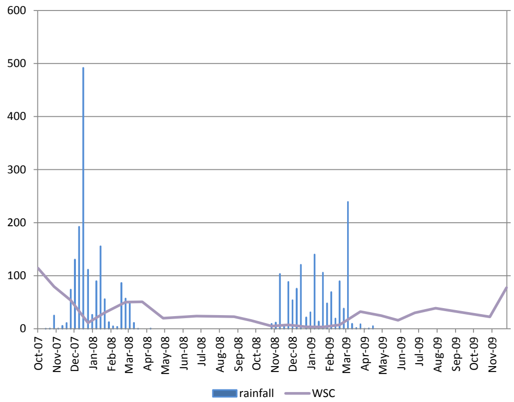


Figure 2.5 Social Activities: Site B Full Sample

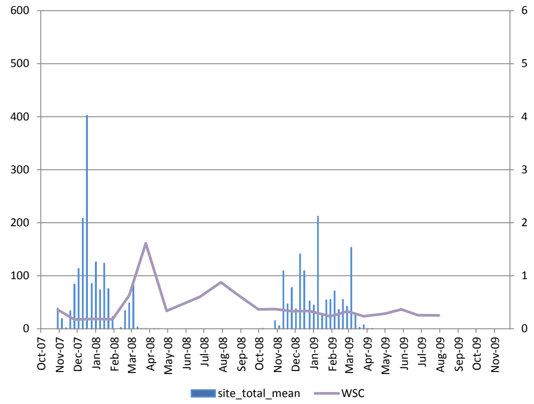


Figure 1.6 Natural Resource Collection: Site A Full Sample

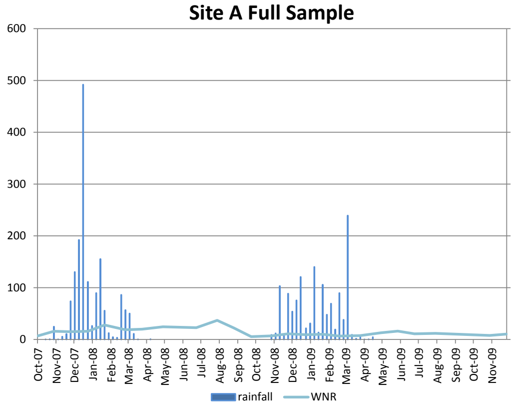


Figure 2.6 Natural Resource Collection: Site B Full Sample

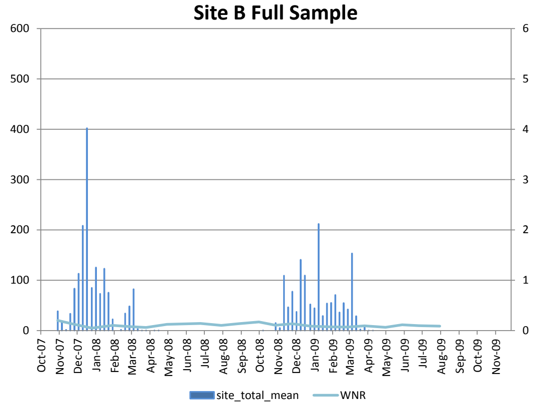


Figure 1.7 Grazing: Site A Full Sample

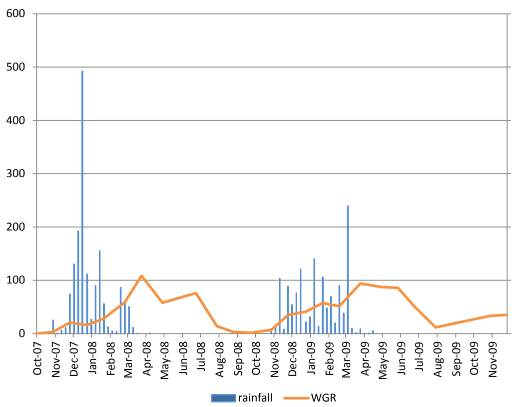


Figure 2.7 Grazing: Site B Full Sample

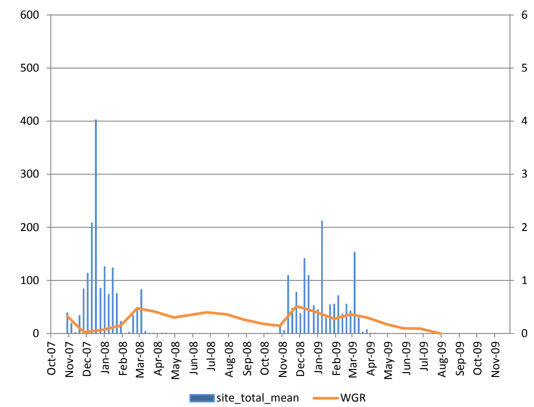


Figure 1.8 Total Work Time: Site A Full Sample

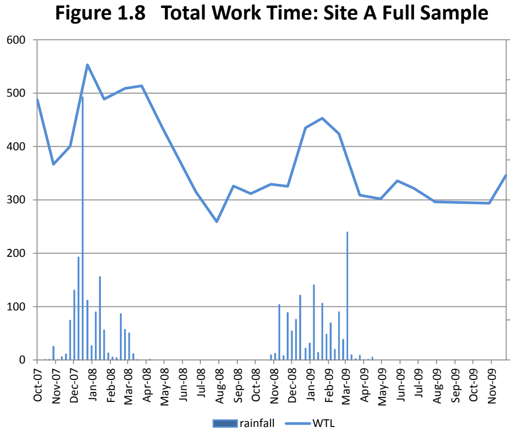


Figure 2.8 Total Work Time: Site B Full Sample

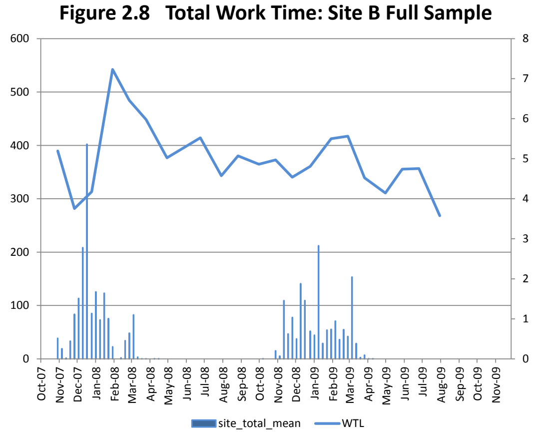


Figure 3.1 Agriculture: Site A Adult Sample

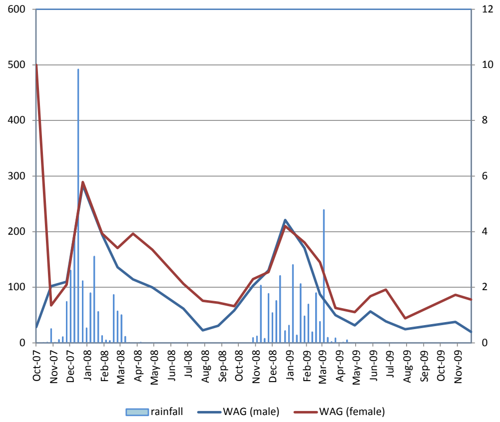


Figure 4.1 Agriculture: Site B Adult Sample

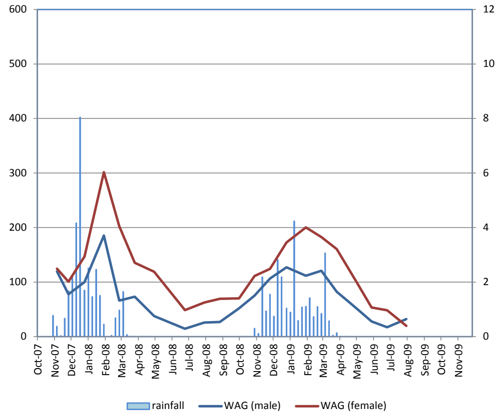


Figure 3.2 Non-Agriculture: Site A Adult Sample

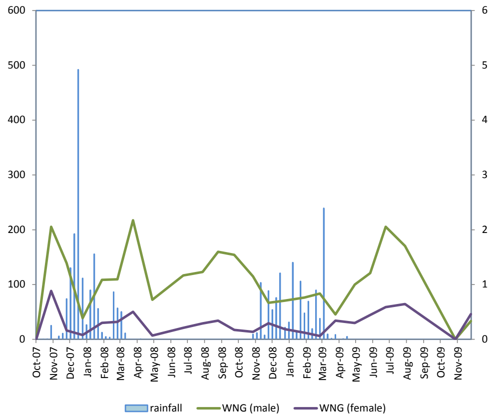


Figure 4.2 Non-Agriculture: Site B Adult Sample

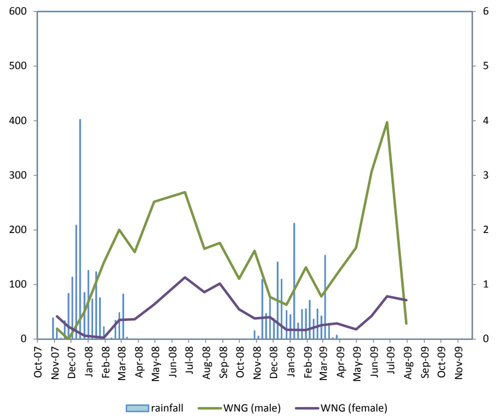
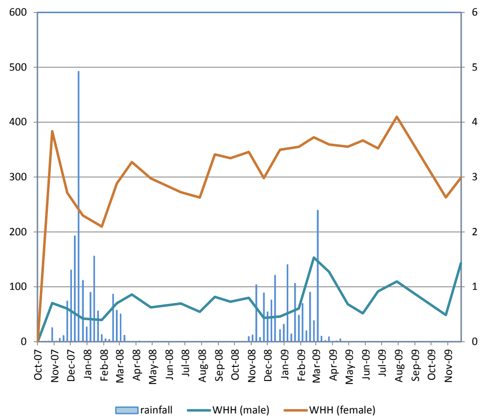


Figure 3.3 Domestic/help: Site A Adult Sample



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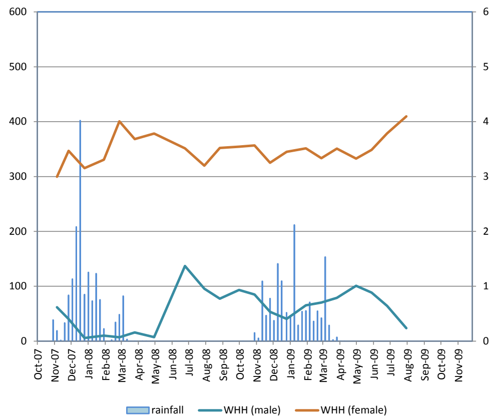


Figure 3.4 School: Site A Adult Sample

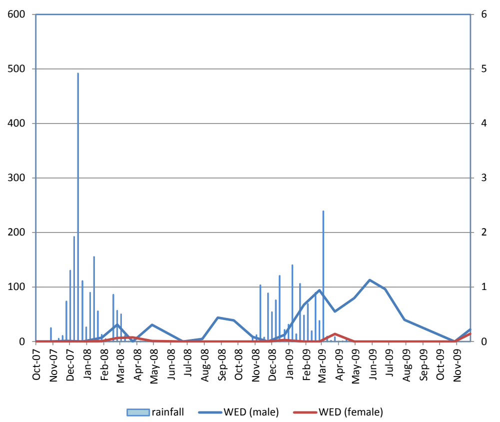


Figure 4.4 School: Site B Adult Sample

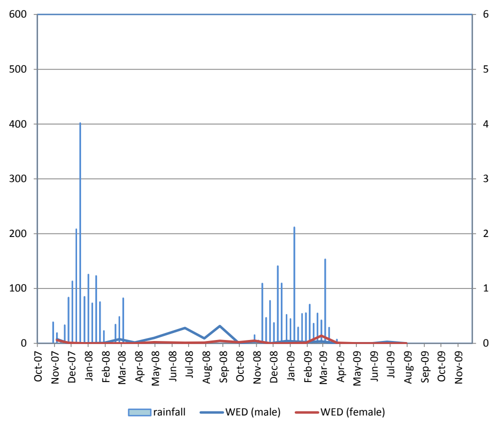
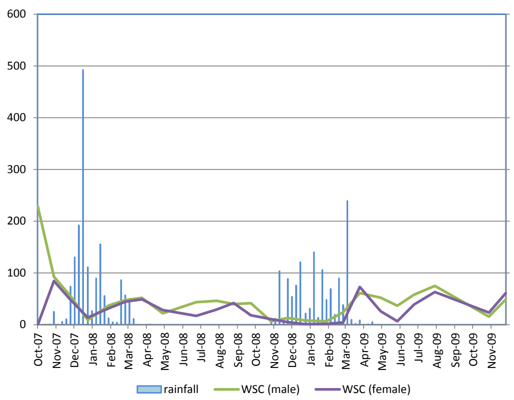


Figure 3.5 Social Activities: Site A Adult Sample



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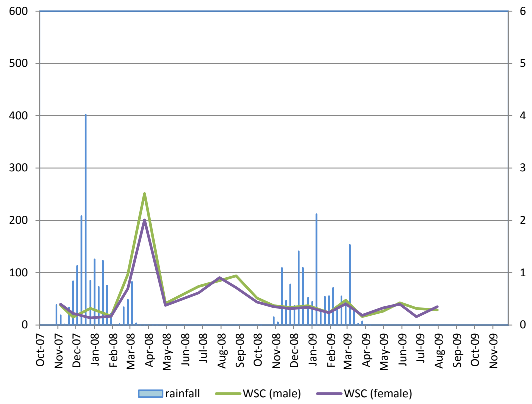


Figure 3.6 Natural Resource Collection: Site A Adult Sample

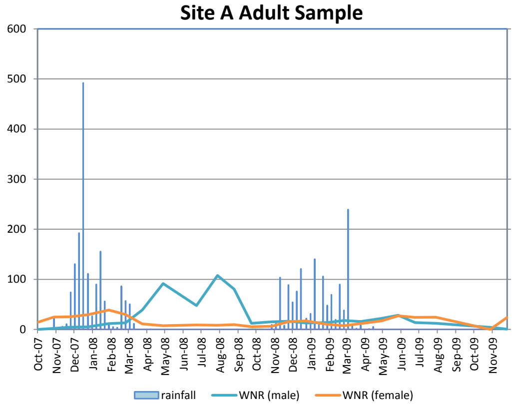


Figure 4.6 Natural Resource Collection: Site B Adult Sample

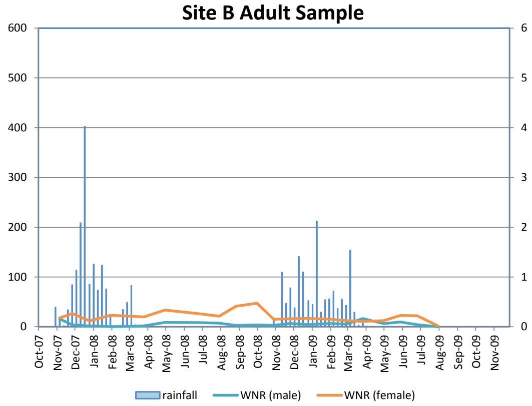
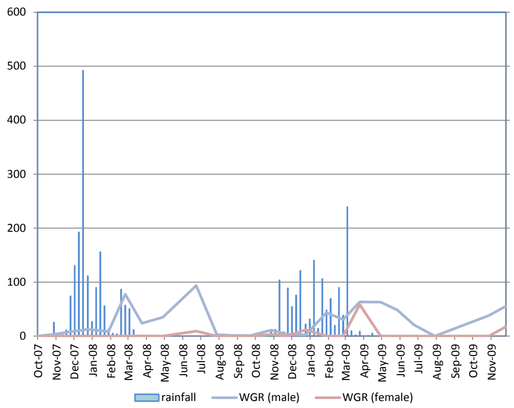


Figure 3.7 Grazing: Site A Adult Sample



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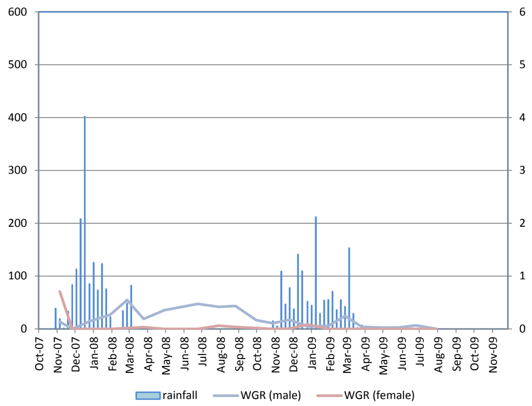


Figure 3.8 Total Work Time: Site A Adult Sample

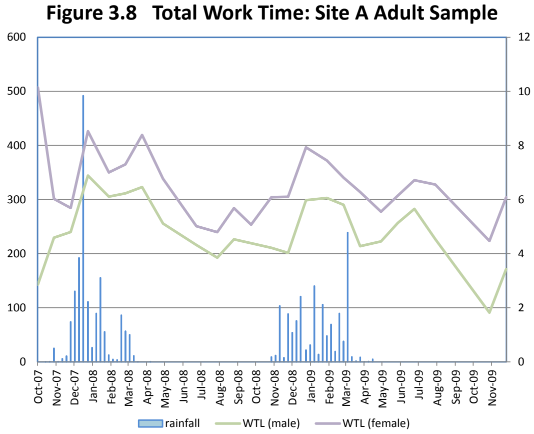


Figure 4.8 Total Work Time: Site B Adult Sample

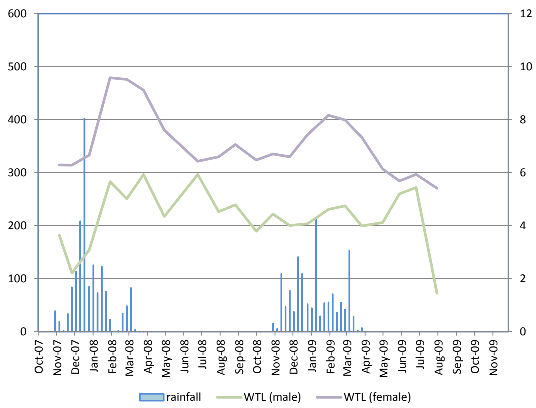
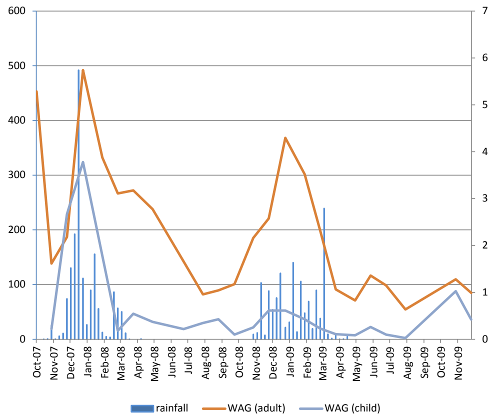


Figure 5.1 Agriculture: Site A Full Sample



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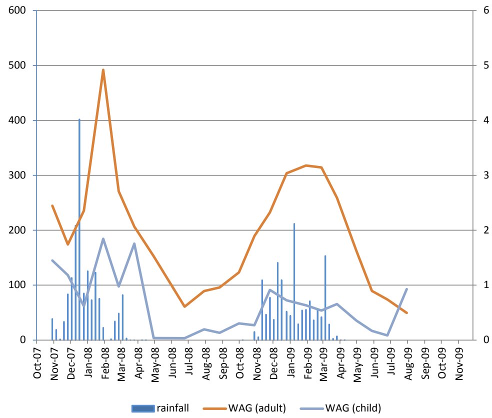

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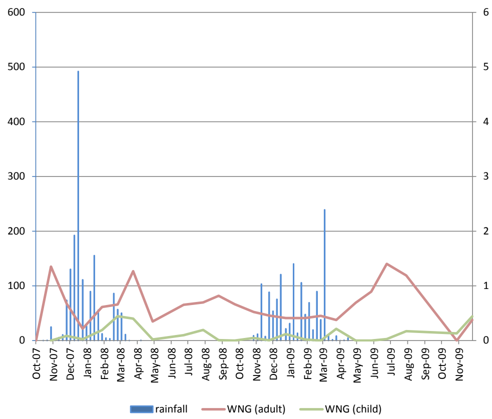

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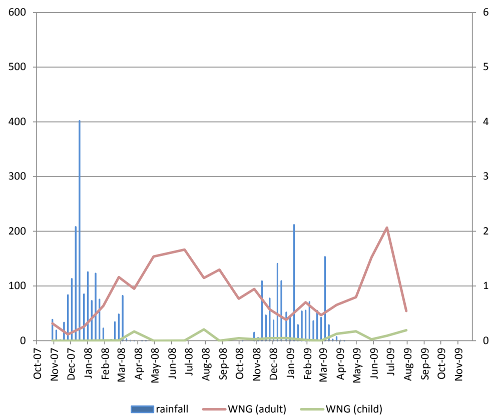

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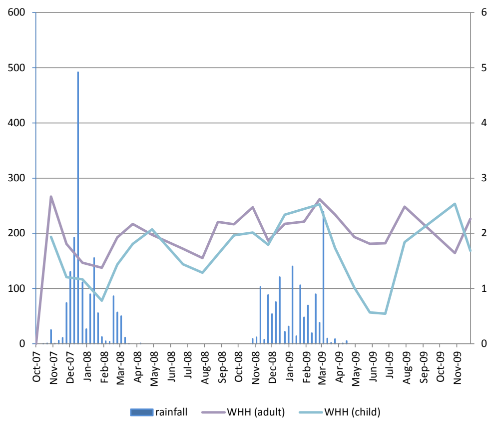

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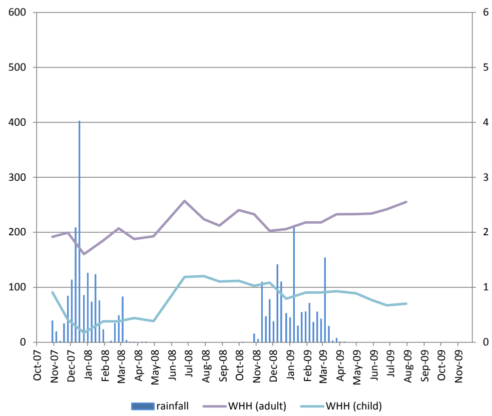

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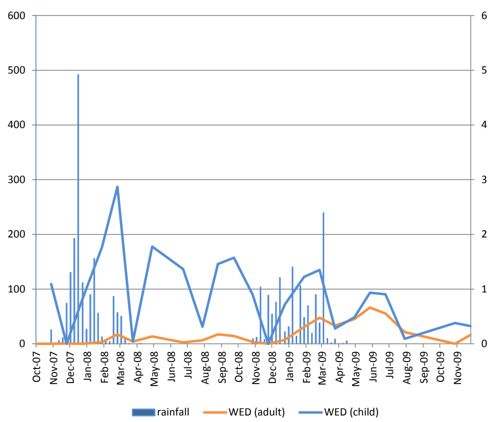


Figure 6.4 School: Site B Full Sample

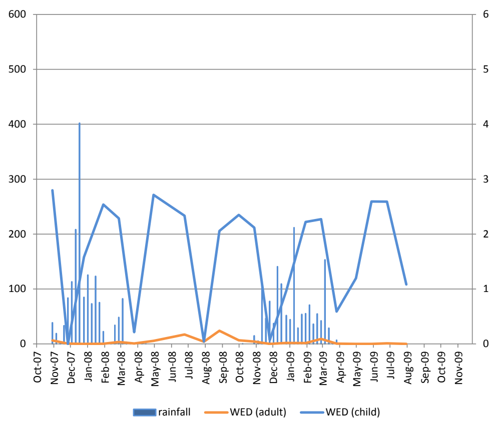


Figure 5.5 Social Activities: Site A Full Sample

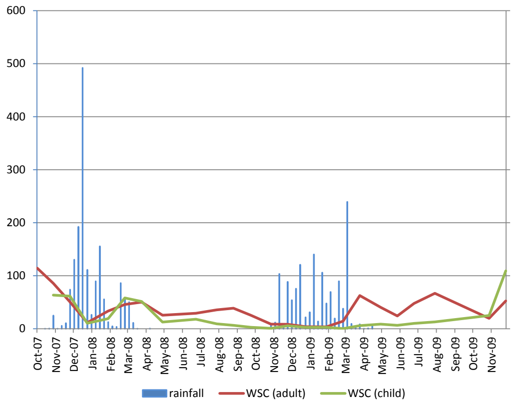


Figure 6.5 Social Activities: Site B Full Sample

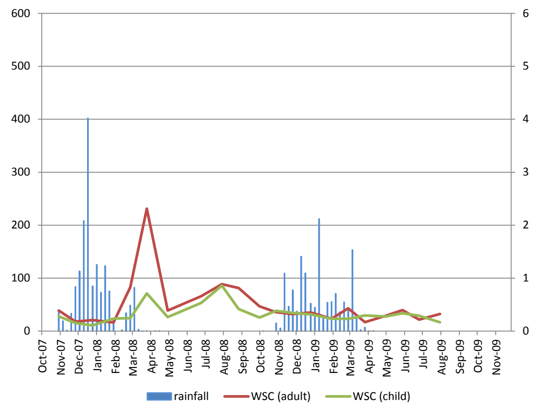


Figure 5.6 Natural Resource Collection: Site A Full Sample

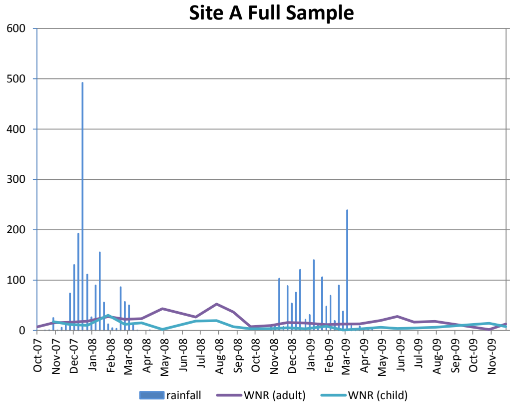


Figure 6.6 Natural Resource Collection: Site B Full Sample

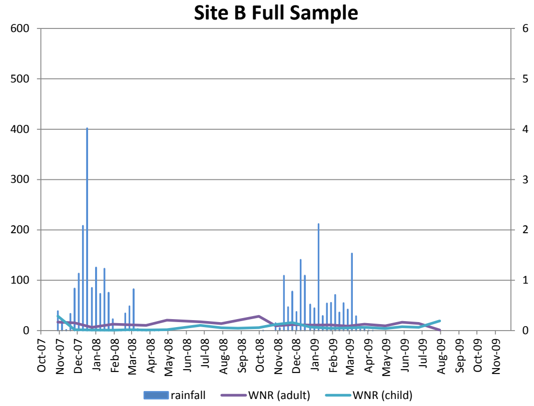


Figure 5.7 Grazing: Site A Full Sample

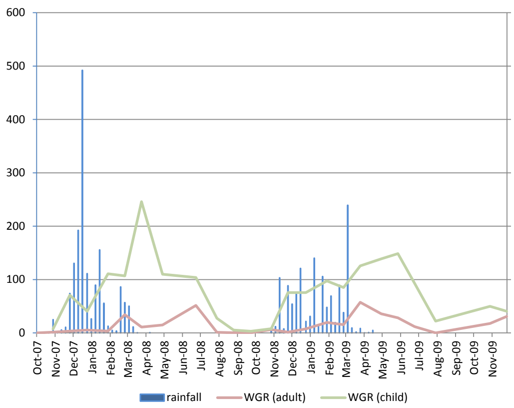


Figure 6.7 Grazing: Site B Full Sample

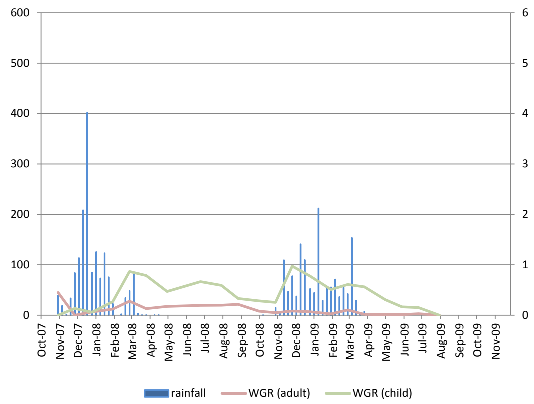


Figure 5.8 Total Work Time: Site A Full Sample

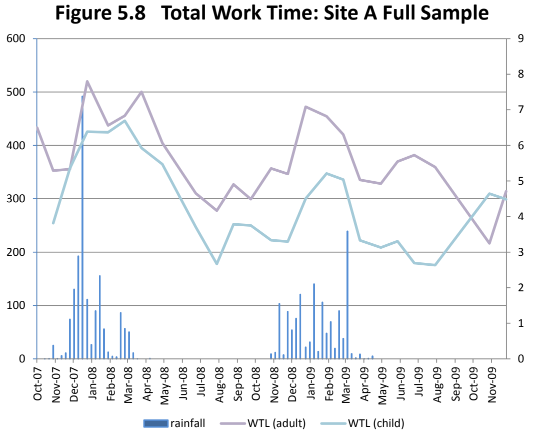
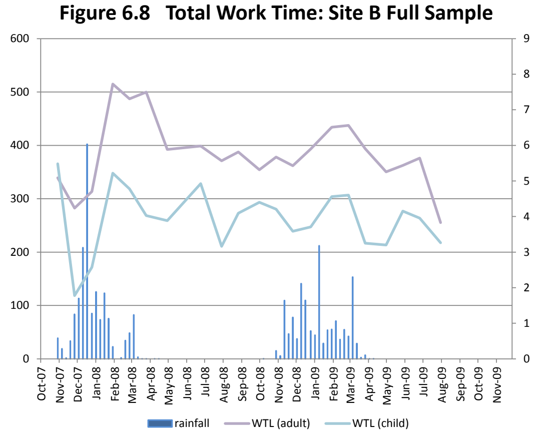


Figure 6.8 Total Work Time: Site B Full Sample



Growth and Nutritional Status of Tonga Children in Rural Zambia
-Longitudinal Growth Monitoring over 26 Months-

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Abstract

Objective: This study aimed to evaluate growth and nutritional status of children in rural Zambia by analyzing 26 months of longitudinal data on height and body weight data, with a special emphasis on sex and age differences.

Participants and Methods: Participants were 218 children (106 boys, 112 girls) from 48 households. Between November 2007 and December 2009, height was measured monthly and body weight was measured weekly. Weekly body weight was averaged over each month. Body mass index (BMI) was calculated using the height and body weight. Growth curves of height and body weight were drawn for each sex using all data measured over the 26-month period, and were evaluated against percentile curves of the National Center for Health Statistics (NCHS) reference population. Nutritional status was assessed using calculated Z-scores, and the rate of malnutrition such as stunting (low height-for-age Z-score), underweight (low weight-for-age Z-score), wasting (low weight-for-height Z-score), and thinness (low BMI-for-age Z-score) were determined.

Results and Discussion: Similar to the results of previous studies in Zambian children, the rate of stunting was high. However, based on the BMI Z-score or the weight-for-height Z-sore where influences of height and weight are offset, it is suggested that nutritional status of these children is generally good. Distinct variations in nutritional status by age were observed in the children, and were possibly due to the approximately 2-year delay of puberty compared to the reference US population. Further studies are needed to assess nutritional status comprehensively by examining the children's diet and physical activity in addition to anthropometry. It would be desirable to develop local reference growth curves instead of using international reference data based on Western populations in order to evaluate growth and nutritional status of the Zambian children adequately.

1. Introduction

Child growth is an important, internationally recognized public health indicator for monitoring nutritional status and health in populations (de Onis and Blössner 2003). From an ecological viewpoint, environmental changes in an ecosystem affect the conditions of fauna and flora, which consequently cause a decrease in body weight and body fat in general and growth retardation in children, through decreasing food availability and nutritional intake among the local population.

Multiple factors affect the nutritional status of children including dietary intake, infection, breast feeding and weaning, seasonality, and socio-economic status (Waterlow 1992). Malnutrition in childhood increases the risks for infectious diseases (Waterlow 1992), cardiovascular disease in adulthood (Stein et al. 2006), and lower mental development (Grantham-McGregor 1995), as well as reduce work capacity (Thomas et al. 2002). It is thus important to assess and ensure adequate nutritional status and growth in children.

In October 2007, we started a longitudinal survey to monitor the growth and nutritional status of local people living in five villages located in the Sinazongwe district in the Southern province of Zambia (Yamauchi et al. 2008). We have reported the nutritional status of adults and children, as well as the growth status of children, in the initial stages of a longitudinal survey of people living in three ecologically contrasting zones: the upper flat land zone on the plateau, the middle slope zone, and the lower flat land zone near Lake Kariba (Yamauchi 2009), and variation in the nutritional status of adults (Yamauchi and Kon 2010).

In this study, we report the results of nutritional status and growth evaluation in children following analysis of 26 months of longitudinal data of monthly height and weekly body weight data obtained between November 2007 and December 2009, with a special emphasis on sex and age differences.

2. Subjects and Methods

2.1 Study populations and subjects

The slope area around Lake Kariba can be divided into three ecological zones: the upper flat land zone on the plateau ('upland'), the middle slope zone ('hillside') and the lower flat land zone near Lake Kariba ('lowland') (Sakurai 2008). We chose five villages in the area: two (Sianemba and Siameja) from the lower zone, two (Chanzika and Kanego) from the middle zone, and one (Siachaya) from the upper zone. Forty-eight households were selected, 16 from each of the three zones: 4 in Sianemba, 12 in Siameja, 8 in Chanzika, 8 in Kanego, and 16 in Siachaya.

The anthropometric data of 218 children (106 boys, 112 girls) from the 48 households were analyzed. Height data were available for 213 individuals (103 boys, 110 girls), while weight data were available for 212 (101 boys, 111 girls), with both height and weight data available for 207 children (100 boys, 107 girls) (cf. Table 1, total number of stunting [height], underweight [weight], thinness [height and weight]).

2.2 Anthropometric measurements

Details of the anthropometric measurements are given elsewhere (Yamauchi et al., 2008). Briefly, height was measured monthly to the nearest 1 mm using a portable stadiometer (SECA 214, Germany). Body weight was measured weekly to the nearest 0.1 kg using battery-operated digital scales (Tanita HD-654, Japan). Weekly body weight was averaged over each month. The body mass index (BMI) was calculated using the height and body weight for each subject.

2.3 Growth curves

Growth curves of height and body weight were drawn for each sex using all data obtained between November 2007 and December 2009. The total height data obtained monthly amounted to 1473 and 1362 for boys and girls, respectively. The total data of body weight (monthly averaged) amounted to 1493 and 1579 for boys and girls, respectively. The growth curves were drawn on the percentile curves of the National Center for Health Statistics (NCHS) reference population, which is commonly used for the evaluation of growth and nutritional status (Hamill 1977, Frisancho 1990).

2.4 Nutritional status

Using NCHS reference data, the measured values were standardized. The formula for calculating the Z-score is:

Z-score = (observed value - median reference value) / standard deviation of reference population

There are four Z-scores which are commonly used for assessing nutritional status of children, where malnutrition is defined by a Z-score below -2.

Height-for-age Z-score (HAZ) < -2: 'Stunting'

Weight-for-age Z-score (WAZ) < -2: 'Underweight'

Weight-for-height Z-score (WHZ) < -2: 'Wasting'

BMI-for-age Z-score (BMIAZ) < -2: 'Thinness'

The sex-age specific rate of malnutrition was determined for the four indices of 'stunting', 'underweight', 'wasting', and 'thinness'.

3. Results and Discussion

3.1 Growth curves

Figures 1 and 2 show the height and weight growth curves, respectively, of the study population against the percentile curves of the US NCHS reference population (Hamill et al. 1977, Frisancho 1990). Compared to the reference population, the Zambian children were short and light. The age-sex−specific mean values of height and weight corresponded to lower percentiles (i.e., 5th −15th percentiles) before puberty, declined 5 percentiles after onset of puberty, and recovered to the pre-puberty level at the end of puberty.

As for the height growth curves, the age-specific mean values were between the 5th and 15th percentiles of the reference curves for both boys and girls from 1 - 11 years old, except for 10-year-old girls. After 11 years, the mean height was decreased below the 5th percentile, before rising to reach the 10th percentile at 16 years of age in girls (Fig. 1B) but remaining below the 5th percentile in boys (Fig. 1A). As to body weight, boys' mean weight values were on the 10th−15th percentiles curves for age 1 - 10 years (Fig. 2A), before starting to decline at 11 years old and then increased again at 13 years old, reaching the 10th percentile at 17 years old. The body weight of girls, on the other hand, was lower than that of boys (Fig. 2B). The mean weight values were around the 5th percentile for 1 - 7 years old, and weight started to decline after 8 years old and was lower than the 5th percentile of the reference population. Similar to boys, it rose again at 13 years old, reaching the 10th percentile at 16 years old.

The findings that the growth rates of weight and height declined at the onset of puberty and fell below the 5th percentile curve of the reference population and rose again to recover to pre-puberty levels are discussed later with the results of age variation in nutritional status.

3.2 Nutritional status

Table 1 shows the sex-region−specific rate of malnutrition based on the 4 indices of stunting (low height-for-age), underweight (low weight-for-age), wasting (low weight-for-height), and thinness (low BMI for age). The rate of stunting was relatively high for the malnutrition indices. Previous studies also reports high rate of stunting in Zambian children (Gernaat et al. 1996, Gillett et al. 2002). The rate of underweight was lower than that of stunting. Moreover, the rates of wasting and thinness which consider both height and weight were considerably low for the four malnutrition indices. No children were categorized into some age-region groups. Combining the results for the rate of malnutrition together with those for the growth curve indicate that the nutritional status of Zambian children was generally good even though the children were significantly short and light when compared with the reference age- and sex-matched Western population.

In regard to regional differences, the rate of malnutrition was higher in upland regions and lower in lowland regions. This corresponds to our previous findings that adults living in lowland regions had the largest body size and body mass index (BMI) among the three subgroups (Yamauchi 2009, Yamauchi and Kon 2010). These findings suggest that among the three regional populations, both children and adults living in the lowland regions have relatively good nutritional status. However, since no statistical significant regional difference was observed except in the case of girl's stunting ($P < 0.01$), the regional subgroups were combined and the relationship between age and nutritional status was examined for boys and girls separately (Fig. 3).

3.3 Age variation in nutritional status

Figure 3 shows the age-specific mean Z-scores of HAZ, WAZ, WHZ, and BMIAZ for boys (Fig. 3A) and girls (Fig. 3B) aged 1 - 17 years. WHZ and BMIAZ were relatively high at -1 - 0 for all ages, whereas HAZ and WAZ were relatively low at -2 - -1. The Z-scores tended to decrease at around 11 years old and increase at around 16 years old for both sexes, which is consistent with the findings of the growth curves for height (Fig. 1) and weight (Fig. 2).

One of possible reasons for this phenomenon is the difference in growth pattern between Zambian children and the reference population (Western children). Previous studies demonstrate that timing of pubertal maturation (onset and end) is later in Zambian rural children than that in Western children: 10.0 - 15.9 and 10.0 - 15.5 years old for US boys and girls, respectively, compared to 12.4 - 17.1 and 13.2 - 17.0 year olds for rural Zambian boys and girls, respectively (Campbell et al. 2004, Gillett-Netting et al. 2004, Herman-Giddens 2006). In other words, the timing of puberty for rural Zambian children is delayed by about 2 years compared with that for US children. This gap in the timing of puberty may cause the variation in Z-scores observed in the Zambian children after onset of puberty (Fig. 3). In agreement with the present study, similar age variation in Z-scores was observed in Zambia (Crooks 2007) and in the neighboring country

Malawi (Zverev and Gondwe 2001), suggesting a common tendency in southern Africa. It is thus recommended that standard growth curves based on a Zambian national sample or Zambian ethnic sample be developed in order to evaluate nutritional status adequately.

4. Summary and Future Perspective

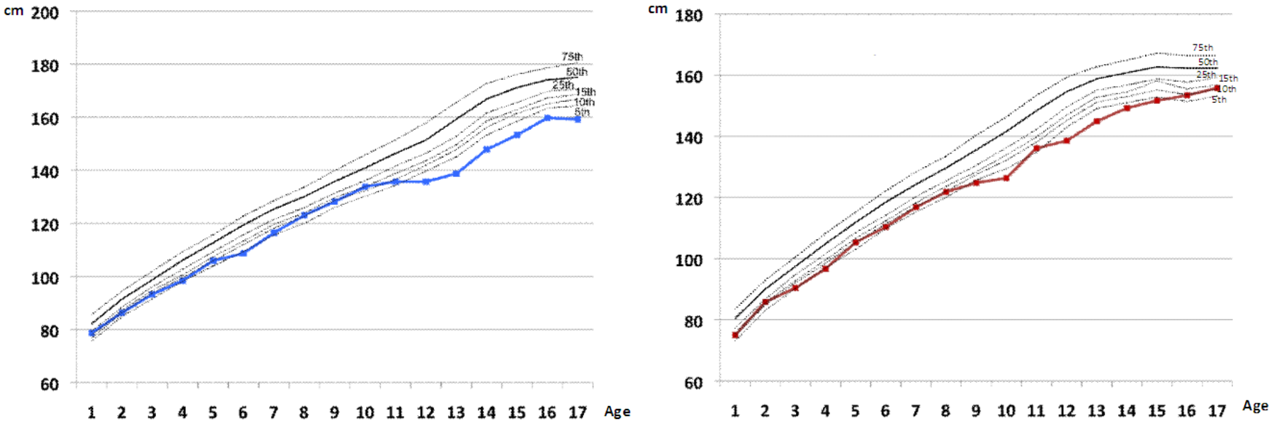
Similar to the results of previous studies, the rate of stunting (low height-for-age) was high in rural Zambian children. However, according to the Z-scores for BMI or weight-for-height where influences of height and weight are offset, it is suggested that the nutritional status of rural Zambian children is generally good. Distinct age variations in nutritional status were observed in Zambian children, possibly due to the approximate 2-year delay in puberty compared to the reference US population. Further studies are needed to assess nutritional status comprehensively by examining the diet and physical activity of children in addition to anthropometry. It would be desirable to develop local reference growth curves instead of using international reference data based on Western populations in order to evaluate growth and nutritional status of the Zambian children adequately.

Table 1. Rate of malnutrition in rural Zambian children

		Stunting		Underweight		Wasting		Thinness	
		N	%	N	%	N	%	N	%
Boys	Lowland	27	29.6	26	7.7	22	0.0	27	3.7
	Hillside	39	33.3	38	7.9	35	2.9	38	0.0
	Upland	37	37.8	37	16.2	34	2.9	35	2.9
	All	103	34.0	101	10.9	91	2.2	100	2.0
Girls	Lowland	35	14.3	35	0.0	32	0.0	35	0.0
	Hillside	35	31.4	35	14.3	29	3.4	33	0.0
	Upland	40	47.5	41	7.3	34	11.8	39	5.1
	All	110	31.8*	111	7.2	95	5.3	107	1.9

*Significant reginal difference (P < 0.01) by Kruskal-Wallis test

A: Boys
B: Girls

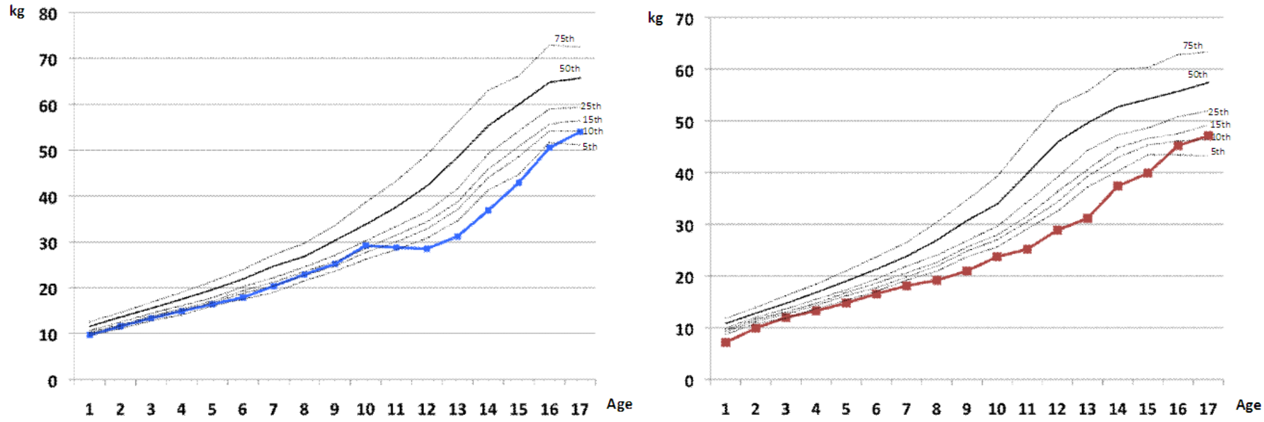


Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
N	69	116	137	121	100	99	95	101	99	93	89	110	81	59	52	27	25	1473

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
N	124	111	99	113	121	101	89	88	92	66	57	75	74	39	45	41	27	1362

Fig. 1. Height growth curves by sex for 1–17 year olds

A: Boys
B: Girls



Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
N	92	116	134	129	100	98	104	83	85	91	93	104	84	57	45	38	40	1493

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
N	108	169	136	112	104	128	110	82	109	95	82	57	77	86	48	32	44	1579

Fig. 2. Body weight growth curves by sex for 1–17 year olds

A: Boys
B: Girls

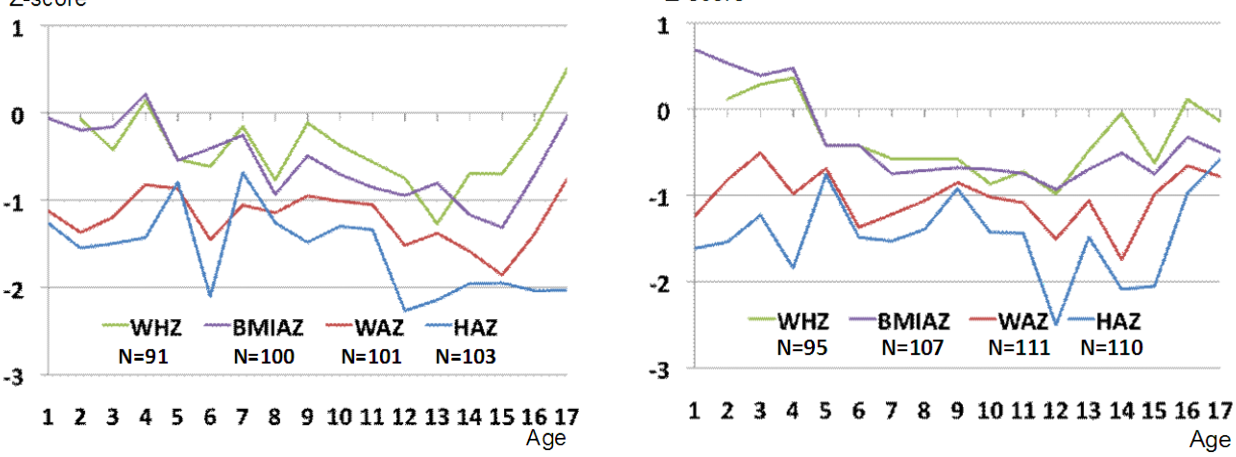


Fig. 3. Nutritional status based on Z-scores by sex for 1–17 year olds

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Nutrient Intake, Physical Activity, and Behavioral Patterns of Adults Living in Three Contrasting Ecological Zones in Rural Zambia

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Abstract

We reported in a previous project seasonal variations in the body weight of adult villagers living in three contrasting ecological zones (Lowland, Hillside, and Upland) in the southern province of Zambia. The report revealed differences in the nutritional status of adults and in patterns of seasonal variation in body weight between the three zones, suggesting characteristic lifestyles of the people living in each zone even though the zones were not geographically distant. Based on these findings, we conducted a field survey on diet, physical activity, and behavioral patterns to investigate the lifestyles of the three populations between August 2010 and September 2010. The subjects were chosen from participants of the preceding growth monitoring survey. This article describes differences in lifestyle, from the viewpoints of diet, physical activity, and behavioral patterns, of adult men and women living in the three zones, with special attention paid to regional and sex differences.

Daily energy intake (neither absolute values nor standardized ones by fat-free mass) did not differ between the three regional groups for either sex. However, regional characteristics of dietary patterns were observed from the results on nutrient intake, energy percent of macronutrients, the proportions of specific food groups contributing to energy, and all macronutrients. Moreover, regional differences in physical activity and behavioral patterns were observed.

Significant sex differences were found in the diet and physical activity patterns in the Lowland group, which can be explained by the fact that many men living in the lowlands had a side occupation besides farming and spent most of their time outside the home in the dry season. The contribution of fish consumption to dietary intake was highest in the Lowland group because of its geographical proximity to Lake Kariba. The lowland men also consumed a home-made fermented alcoholic drink. As for the Hillside group, their behavioral area used in daily life was the largest and their physical activity the highest, the latter particularly so for the women. Only the Upland group consumed sweet potato. The men and women living in the Uplands showed similar patterns in both space use and level of physical activity as the couples work together farming during the dry season.

1. Introduction

Seasonal variation in food availability is said to influence the nutritional and health condition of populations in many developing countries (Wandel and Holmboe-Ottesen 1992).

Schofield reported that seasonality affects food intake especially in areas where the distribution of rainfall is unimodal (Schofield, 1974). Moreover, it was revealed that the factors affecting the food and nutritional situation are not only pre-harvest food shortages but high agricultural workloads (Chambers et al. 1979).

Some studies of African rural populations have demonstrated that food intake decreased and physical activity increased during the rainy season when agricultural work output is at a peak, and physical activity decreased after the harvest season (Schofield 1974; Wandel et al. 1992). It was also shown that the post-harvest body weight of adults was heavier than the pre-harvest body weight (Wandel and Holmboe-Ottesen 1992).

In a project report last year, based on longitudinal anthropometric data, we reported seasonal variation in the weight of adult villagers living in three contrasting ecological zones in the southern province of Zambia (Yamauchi and Kon 2010). We found distinct patterns of seasonal variations: weight peaked around June during the dry season and was lowest in February to March during the rainy season. These variations were similar to those for adult Tanzanians reported by Wandel and Holmboe-Ottesen (1992). In addition, we found differences in nutritional status and patterns of seasonal variation in weight between the three zones.

The results raised some questions. First, it cannot be said the differences in nutritional status are attributable to geographic distance because two villages which are located within these areas and farthest each other are at least about 20km away. Moreover, the results of seasonal variations in weight which showed parallel patterns between the sexes in each area and showed a difference in patterns between the three zones may suggest that the residents in each zone have a characteristic lifestyle. Thus, studying the lifestyle of populations living in different ecological zones that are in close geographical proximity will help us to learn how the people, especially those living with unsteady agricultural production, maintain their health and nutritional condition.

We conducted surveys of the diet, physical activity, and behavioral patterns to investigate the lifestyle of the three populations; individual subjects were chosen from the samples participating in longitudinal anthropometric surveys. This article describes the result of these surveys focusing on differences in lifestyle by zone and sex.

2. Subjects and Method

2.1 Research Area & Subjects

The study was conducted at four villages (Sianemba village, Siameja village, Kanego village, and Siachaya village) located in Sinazongwe district of the southern province of Zambia. These villages can be divided into three contrasting ecological zones: Sianemba and Siameja are in the lower flat land zone (Lowland), Kanego is in the middle slope zone (Hillside), and Siachaya is in the upper flat land zone (Upland). Eight households comprised the sample for the Lowland group, and 7 households each comprised those from the Hillside and Upland groups. A total 26 men and 30 women aged over 18 years old in sample households were examined.

2.2 Measurements

1) *Anthropometry*

Height, weight, mid-upper-arm circumference, and the triceps and subscapular skinfold thickness were measured. Body mass index (BMI; kg/m^2) was calculated as weight in kg / (height in m)^2. Sum of the two-site skinfold thickness was put into the equation of Durnin and Womersley (1974) to calculate body density, then the equation of Siri (1956) was used to estimate body-fat percentage (%fat). Mid-upper-arm muscle area (MUAMA) was calculated using the triceps skinfold thickness and mid-upper-arm circumference (Frisancho 1990).

2) *Food Consumption*

Food intake was recorded using a weighed dietary record. We visited sample households to measure their meal before preparing breakfast (generally at 07:00) and stayed until subjects had eaten their supper (generally between 20:00 and 21:00). Food consumption data were converted into quantities of energy and nutritional intakes using the Zambia Food Composition Tables, 4th edition (The National Food and Nutrition Commission of Zambia 2009). In addition, percentages of energy and macronutrients as derived from 7 food groups were calculated.

3) *Physical Activity*

Physical activity was monitored using a uniaxial accelerometer sensor. Subjects attached the device to their waist during 5 consecutive weekdays and data recorded during the middle 3 days were analyzed. Physical activity recorded by the device was categorized into one of 11 activity levels (0, 0.5, and 1–9) based on accelerometric signal patterns. Total energy expenditure was calculated using these activity levels.

4) *Behavioral Area*

Behavioral area used in daily life was investigated using portable GPS. Subjects wore portable GPS with accelerometer sensors for 3 days corresponding to the middle 3 days of wearing the aforementioned accelerometer sensor. Latitude, longitude, and elevation of each subject’s location, and distance from last point, cumulative distance, movement bearing, and speed of movement were recorded. Behavioral tracks were identified using Google Earth software, then behavioral radius, the center of which was the subject’s home, was measured.

2.4 Data analysis

All data are expressed as means and SDs. Regional differences were examined by ANOVA and multiple comparisons. Gender differences were examined using the unpaired t-test. All analysis was performed with the JMP 8.0.2J software package (SAS Japan), with statistical significant set at $P<0.05$.

3. Results and Discussion

3.1 Anthropometry

Age and anthropometric measurements are given in Table 1. Age, body size, and body

Table 1 Age, body size, and body composition of adults living in three contrasting ecological zones of Zambia

a) Male

	Lowland (n = 7)		Hillside (n = 10)		Upland (n = 9)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	47.3	18.1	36.9	13.1	36.7	18.6
Height (cm)	171.5	4.7	169.3	6.0	165.5	6.6
Weight (kg)	61.1	2.4	58.4	2.0	57.8	2.2
BMI (kg/m^2) [1]	20.7	2.2	20.4	1.5	21.0	1.8
%fat (%) [2]	20.0	4.5	16.8	3.2	19.4	6.1
MUAMA (cm^2) [3]	427.2	57.0	438.2	55.9	422.5	95.7

[1] Body mass index : weight (kg) / height $(m)^2$

[2] The equation of Siri (1956) and Durnin & Womersley (1974) was used.

[3] Mid-upper-arm muscle area : The equation of Frisancho (1990) was used.

b) Female

	Lowland (n = 10)		Hillside (n = 9)		Upland (n = 11)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	36.5	15.2	37.9	8.2	35.9	11.9
Height (cm)	159.9	5.2	157.0	4.3	156.8	5.6
Weight (kg)	60.0*	9.8	50.3	4.0	54.2	7.4
BMI (kg/m^2) [1]	23.4	3.9	20.4	1.2	22.1	2.9
%fat (%) [2]	33.5	5.5	28.7	3.9	32.5	4.2
MUAMA (cm^2) [3]	346.5	43.4	362.0	45.7	322.8	44.4

[1] Body mass index : weight (kg) / height $(m)^2$

[2] The equation of Siri (1956) and Durnin & Womersley (1974) was used.

[3] Mid-upper-arm muscle area : The equation of Frisancho (1990) was used.

* Significantly higher than in Hillside and Upland ($P<0.05$)

composition did not differ significantly between the three zones for either sex. Average BMI in all zones and for both sexes were classified as 'normal' ($18.5 \leq$ BMI ≤ 25.0) according to WHO criteria (WHO 2000). Among men and women of the Hillside group, because BMI and %fat were the lowest and MUAMA was the highest of the three zones, they were characterized as having a 'lean' physique. BMI differences between the sexes were not identified in all zones. MUAMA was higher among men than women ($P < 0.01$), whereas %fat was higher among women than men ($P < 0.001$) in all zones.

3.2 Food Consumption

Table 2 shows the energy and nutrient intakes of men and women in the three zones. Daily energy intake and daily energy intake per fat-free mass did not differ between the three zones for either sex. Fat intake and fat energy percent among men in the Lowland group were significantly lower than among men in the other two zones, while carbohydrate energy percent was the highest of the three zones. Among women, fat intake, carbohydrate intake, and energy percents of fat and carbohydrate did not differ between the three zones. Only protein energy percent was

Table 2 Comparison of daily energy and nutrient intakes of adults living in three contrasting ecological zones of Zambia

a) Male

	Lowland (n = 6)		Hillside (n = 10)		Upland (n = 8)	
	Mean	SD	Mean	SD	Mean	SD
Energy (kcal)	2266.7	465.7	3032.0	719.6	2863.4	539.2
Energy (kcal/FFM[1]kg)	48.3	10.7	62.0	11.4	61.6	10.4
Protein (g)	53.7	21.1	75.4	24.5	62.0	13.4
Energy %	9.1	2.1	9.9	1.6	8.6	0.3
Fat (g)	20.3*	6.9	56.6	17.4	46.7	13.6
Energy %	7.8*	1.5	17.1	4.9	14.9	4.2
Carbohydrate (g)	472.1	87.0	557.1	140.3	540.4	99.2
Energy %	83.8**	3.0	73.3	4.4	75.6	7.3
Calcium (mg)	299.9	210.0	432.7	299.1	634.5	405.4
Iron (mg)	16.8	3.4	21.0	5.3	20.2	4.1
Vitamin A (μg)	1850.6	2200.9	4532.7	3330.1	5163.2	2874.2
Vitamin C (mg)	44.5	28.1	26.8	24.6	32.6	21.8

[1] Fat fee mass

* Significantly lower than in Hillside and Upland (*P*<0.01)

** Significantly higher than in Hillside and Upland (*P*<0.01)

b) Female

	Lowland (n = 10)		Hillside (n = 9)		Upland (n = 11)	
	Mean	SD	Mean	SD	Mean	SD
Energy (kcal)	2681.1	602.6	2595.4	359.6	2476.9	621.4
Energy (kcal/FFM[1]kg)	68.4	16.0	72.6	9.3	68.0	15.3
Protein (g)	73.0	23.8	66.4	10.1	56.9	16.8
Energy %	10.7*	1.8	10.3	1.2	9.1	0.8
Fat (g)	35.6	18.8	43.1	10.1	42.4	20.0
Energy %	11.4	4.3	15.1	3.7	15.0	4.6
Carbohydrate (g)	505.6	74.2	487.6	78.4	464.3	102.5
Energy %	77.0	8.2	75.0	3.7	75.6	6.6
Calcium (mg)	668.0	395.3	369.5	133.0	516.6	416.8
Iron (mg)	26.1**	11.7	20.3	5.7	16.6	3.7
Vitamin A (μg)	6140.4	6881.8	5044.9	2697.3	3819.1	2199.7
Vitamin C (mg)	75.5***	39.2	26.3	17.1	21.1	16.7

[1] Fat fee mass

* Significantly higher than in Upland (*P*<0.05)

** Significantly higher than in Hillside and Upland (*P*<0.05)

*** Significantly higher than in Hillside and Upland (P<0.001)

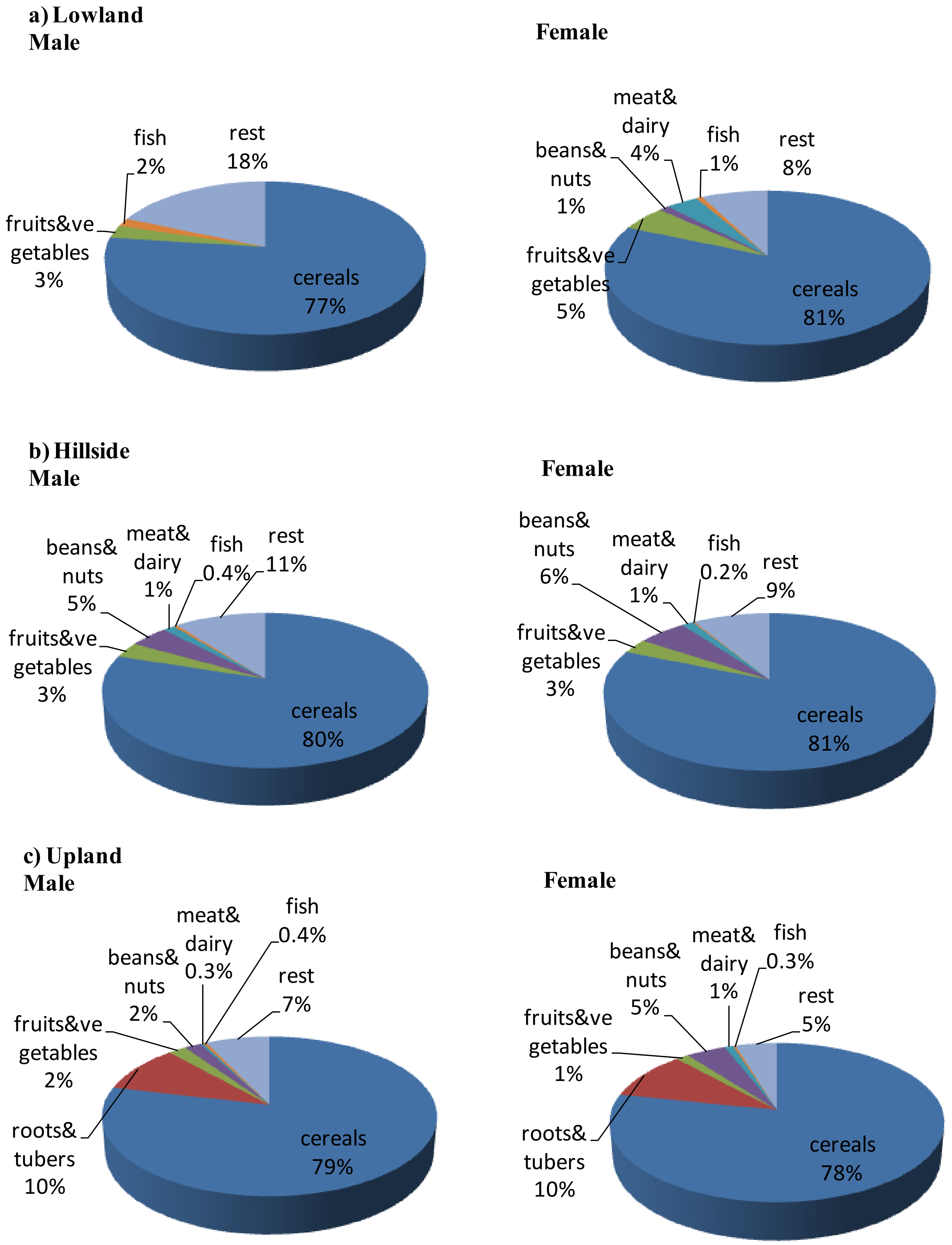

Figure 1 Contribution of specific food groups to daily energy intake

lower in the Upland group compared to the lowland group. Gender differences were not found in the intakes of energy and all nutrients at any of the zones. Figures 1 and 2 show the proportional contribution of specific food groups to the daily intake of energy and protein, respectively, at the three zones and for each sex separately. The proportion of specific food groups contributing to the intakes of energy and all macronutrients were significantly different for all zones, suggesting that there are regional characteristics in dietary patterns. On the other hand, gender differences were not

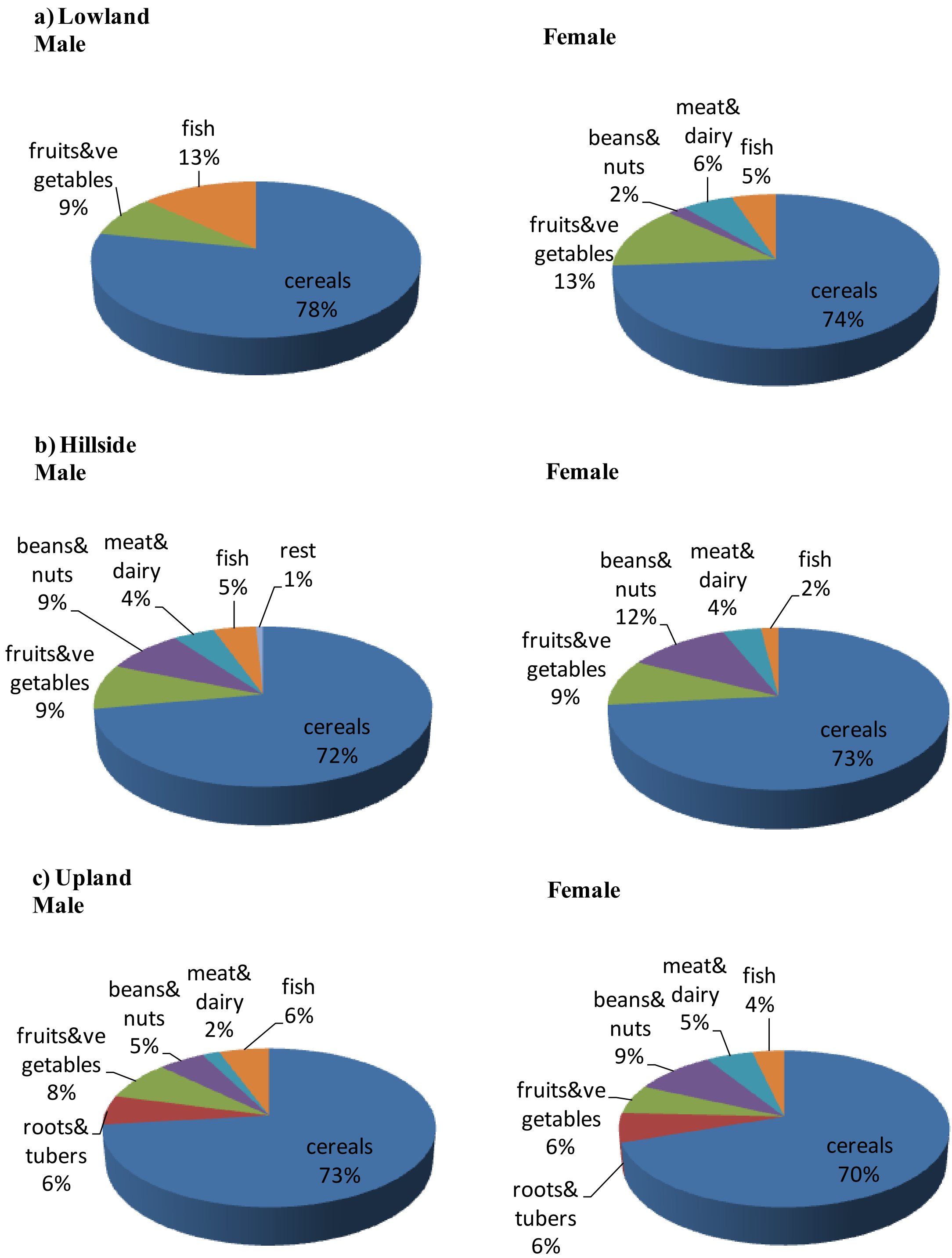

Figure 2 Contribution of specific food groups to daily protein intake

found in the hillside and upland groups, but the proportional contribution of food groups to the daily intake of protein, fat, and carbohydrate were significantly different between men and women in the Lowland group.

These results imply that men and women in the Hillside and Upland groups have similar dietary patterns, but there is gender difference in the dietary pattern of the Lowland group. The occupation of men in the Lowland group may account for this gender difference. Many adult men in the Lowland group work in the kapenta (small fish caught in Lake Kariba) industry and stay overnight near the lake in the dry season when there is less agricultural work to do at home. This resulted in the absence of the male head of the household in the Lowland group during our survey. A few male subjects who were at home during the survey mostly had a second occupation (i.e. job at a local clinic, day laborer). They spent most of the daytime outside the home and ate meals at their workplace, and this might account for the clearer gender difference in diet in the Lowland group compared to the Hillside and Upland groups where subjects of both sexes eat meals together. In addition, some subjects in the Lowland group consumed a home-made fermented alcoholic drink made from tea leaves, yeast, and a high amount of sugar. The food composition of sugar is all carbohydrate. Sugar is classified into 'rest' in this study. This would explain the high proportional contribution of 'rest' to carbohydrate intake (data not shown) and the high intake of carbohydrate (Table 2) among men in the Lowland group.

As to other specific regional dietary patterns, there was a high proportion of consumption of 'roots & tubers' to intakes of energy and protein among both men and women in the Upland group (Figures 1, 2). This is attributed to the intake of sweet potato only in the Upland zone, where sweet potato was eaten for breakfast in almost all cases. The proportion of 'fish' consumption to protein intake was highest among both sexes in the Lowland group compared to other two zones. Although kapenta caught in Lake Kariba were processed and eaten in all zones, fresh fish was sold only in the lowlands close to the lake and were cooked and consumed by the sample households in this group, thus accounting for their high proportion of 'fish' consumption to dietary intake.

3.3 Physical activity & behavioral area

Table 3 shows the estimated basal metabolic rate and indices of physical activity and behavioral area. TEE, energy balance, and PAL did not differ significantly between the three zones for either sex. Energy balance was within the proper range (± 1MJ = 239kcal) for men in the Hillside group and men and women in the Upland group. A minus energy balance was found among men in the Lowland group, and women in the Lowland and Hillside had excess energy intake. Mean PAL was classified as 'active' (FAO/WHO/UNU 2004) for all zones and both sexes.

Although there was no significant difference in daily steps or daily total moving distance between the three zones for either sex, the behavioral radius was significantly larger for both men and women in the Hillside group (Table 3). However, 5 male subjects in this group attended a major Christian meeting in Batoka town about 35 km away from their village, where many Tongan Christians met during the survey period. This may have expanded their behavioral area compared to other subjects who did not attend the meeting or who attended another such meeting outside the survey period. If we calculate the mean behavioral radius of the 5 male subjects excluding the day they attended the meeting, the mean value and SD is 8.2 ± 8.9. Performing the statistical comparison again, we find no difference between the three zones. The mean behavioral radius among men in the Hillside group was still the largest of all groups despite the re-calculation, that among the women was also significantly larger than for the other sites. Both this finding and those of daily steps and daily total moving distance show that the behavioral area of hillside subjects is the largest and that their degree of activity is also the highest, especially for the women.

Table 3 Basal metabolic rate and indices of physical activity and behavioral area of adults living in three contrasting ecological zones of Zambia

a) Male

	Lowland (n=7)		Hillside (n=10)		Upland (n=9)	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	61.1	2.4	50.3	4.0	57.8	2.2
BMR[1]	1479.0	225.1	1552.7	122.3	1513.5	148.0
TEE (kcal)[2]	2535.4	471.9	2790.3	302.5	2728.6	279.4
Balance[3]	-345.2	699.4	241.7	649.4	177.0	534.2
PAL[4]	1.71	0.08	1.79	0.09	1.81	0.13
Steps (steps/day)	12111	3980	15828	4932	17226	7208
Distance (km/day)	9.5	6.3	20.6	13.0	11.3	5.5
Behavioral radius (km)	4.9	3.7	21.8*	15.4	2.6	2.1

[1] Estimated basal metabolic rate (FAO/WHO/UNU 2004)

[2] Total energy expenditure

[3] TEI - TEE

[4] Physical activity level; TEE / BMR

* Significantly higher than in Lowland (P<0.01)

b) Female

	Lowland (n=10)		Hillside (n=9)		Upland (n=11)	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	60	9.8	50.3	4	54.2	11.9
BMR[1]	1307.1	128.9	1249.5	36.6	1288.7	62.3
TEE (kcal)[2]	2224.2	253.9	2241.6	113.1	2280.3	152.0
Balance[3]	456.9	494.4	353.8	395.9	196.6	584.0
PAL[4]	1.70	0.11	1.79	0.08	1.77	0.05
Steps (steps/day)	13681	7589	18643	5604	16414	3004
Distance (km/day)	8.6	5.4	11.6	3.4	9.6	1.7
Behavioral radius (km)	1.8	1.8	4.7*	3.3	2.9	1.6

[1] Estimated basal metabolic rate (FAO/WHO/UNU 2004)

[2] Total energy expenditure

[3] TEI - TEE

[4] Physical activity level : TEE / BMR

* Significantly higher than in Lowland (P<0.05)

Among the women in the Lowland group, PAL, behavioral radius, and daily steps were the lowest of the three zones, although not significantly so. Women in the Lowland group are likely to be more sedentary than those in the other two zones. Moreover, while male subjects in the Lowland group had a minus energy balance, the women there showed a plus value, which was also the highest of the three zones.

Among the Upland subjects, there was no gender difference in daily steps, daily total moving distance, or behavioral radius. In fact, most of the sample households in this group farm even during the dry season and we found many couples working together in their fields during the survey. This working together of spouses differs from the situation in the other two zones, suggesting that men and women in the Uplands have similar patterns of both use of place and amount of physical activity expended.

4. Summary

The findings suggest gender differences in dietary and physical activity patterns in the Lowland population because many of the adult men have a second occupation and spend most of the daytime outside the home in the dry season. In the Lowland group, the proportion of 'fish' consumption to dietary intake was higher in both sexes because of the geographical proximity to the lake, and some male subjects consumed a home-made fermented alcoholic drink. The subjects in the Hillside group had the largest behavioral area and highest rate of physical activity, especially among the women. The unique dietary characteristic of the Upland group was that they ate sweet potato. Moreover, as many couples work together farming in the rainy season in the Upland group, it is suggested that they have similar patterns of both use of place and amount of physical activity expended.

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Analysis of meteorological measurements made over three rainy seasons in Sinazongwe District, Zambia.

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1. Introduction and method: Meteorological observations in 2009/2010

Local meteorological observations have been made in the Sinazongwe District, Zambia, from September 2007. Detailed analysis of observations from the 2007/08 rainy season was reported in Kanno and Saeki (2009), and that of the 2008/09 rainy season was summarized in Kanno et al. (2010). In this paper, we summarize the characteristics of the 2009/10 rainy season and compare these to the 2007/08 and 2008/09 rainy seasons.

Two meteorological observation stations (weather stations) were installed at Siachaya Village (site ***C***; high elevation, 1090 m) and Sianemba Village (site ***A***; low elevation, 515 m). The stations were powered by a solar-charged battery and installed in a wide open area devoid of vegetation in the center of each village. Meteorological observations of air temperature, air pressure, relative humidity, solar radiation, precipitation, wind direction and wind speed were made at 30 min intervals and stored by a data logger. Wind direction was recorded as instantaneous values, whilst the other meteorological elements were recorded as mean values over a 30 min period (the 30 min prior to the time of data logging). Equivalent potential temperature and absolute humidity were calculated from air temperature, relative humidity and air pressure.

Separate to these observation stations, a total of 48 rain gauges were installed at sites ***A*** and ***C*** as well as at an additional location in Kanego and Chanzika villages (Site ***B***; mid elevation, 720-986 m), with 16 gauges at each site. Precipitation data was recorded at 30 min intervals and automatically stored in the data logger, and hourly and daily precipitation means were calculated from this data.

In the 2009/2010 season, the condition of the rain gauges was generally poor, especially at site ***A***. Some data loggers were broken and others recorded zero in the middle of the rainy season (the cause being that the water hole in the rain gauge was clogged with mud). Consequently, the number of rain gauges with data over the whole rainy season was: 4 at site ***A***, 7 at site ***B***, and 10 at site ***C***, respectively. The number of data loggers that collected data over the whole measurement period varied in each of the three rainy seasons at each station. We therefore interpolated the precipitation at missing data points using the precipitation data at the nearest three gauges and these interpolated time series were then used to calculate the mean precipitation data.

2. Temporal variation of precipitation at each site

Precipitation data recorded by the weather stations for the three rainy seasons, 2007/08, 2008/09, and 2009/10, were compared for sites ***A*** and ***C***. Figure 1 shows the accumulated daily precipitation at the two weather stations. In the 2007/08 rainy season, there was a lot of rain in December, and in 2009/10 season, there was much rain around late February to early March, and 2008/09 experienced a stable increasing rate of precipitation throughout the rainy season. At site ***A***, the difference in the accumulated precipitation between the 2007/08 and 2008/09 rainy seasons was very large until mid February. However, much precipitation fell in late February and the difference in the total amount of precipitation over these two rainy seasons was not large: 1437-1258 = 179 mm. Interestingly, the time variation in precipitation differed amongst the three rainy seasons, and the accumulated precipitation over time in the 2008/09 rainy season shows a constant increasing rate. At site ***C***, the variation in precipitation over time in each of the three years was similar to site ***A***, but the precipitation difference between the 2007/08 and 2009/10 rainy seasons were smaller than at site ***A***. This indicates that the volume of precipitation in the highlands (site ***C***) is more stable over a rainy season than the lowlands.

Figure 2 shows the daily and accumulated precipitation for the three rainy seasons at site ***A***. Precipitation was averaged over the 16 rain gauges, which comprised a combination of observation and interpolated data. The difference in precipitation between the first and third rainy season precipitation was distinct until early March. The maximum accumulated precipitation difference was 1030 mm on February 1. In the 2009/10 rainy season, precipitation suddenly increased in early and late March. Interestingly, there was a distinct break with almost no rain for ten days in mid February 2010. After this break, over 1000 mm of precipitation was observed in a short period and the total amount of precipitation for the season reached nearly the same value as in the 2007/08 rainy season. In the other two rainy seasons, there was not much rain after late February, and the dry spell and rain late in the season in 2010 are distinct inter-seasonal variations. These may have importance for understanding the nature of precipitation variations in the 2009/10 season.

Figure 3 shows the daily and accumulated precipitation for each of the three rainy seasons at site ***B***. Whilst the nature of the temporal variations for each of the three rainy seasons were similar to those at site ***A***, the difference between the seasons was a little lower than at site ***A***. The precipitation graph for Site ***C*** is shown in Fig. 4. The maximum difference between two rainy seasons was 680 mm, which is the smallest difference amongst the three sites. Also, the total amount of precipitation was nearly the same in each of the three years at site ***C.*** The dry period in mid February 2010 can be seen distinctly at all three sites.

Next, we consider the causes responsible for the precipitation differences amongst the three rainy seasons. Interestingly, in spite of the time variations, the total amount of precipitation in each of the three rainy seasons was the nearly the same at sites ***B*** and ***C***, and in 2007/08 and 2009/10 rainy seasons, were almost the same at site ***A***. Major events in

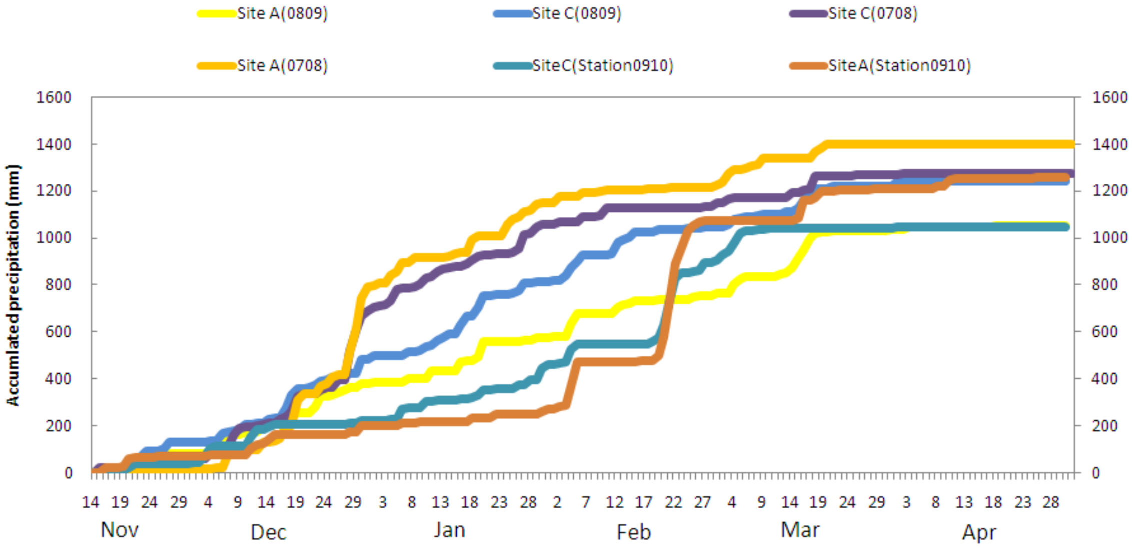

Fig. 1 Daily accumulated precipitation (mm) at sites *A* and *C* from November 14 to April 30 for the three rainy seasons (2007/08, 2008/09, and 2009/10). Data were observed by meteorological weather stations.

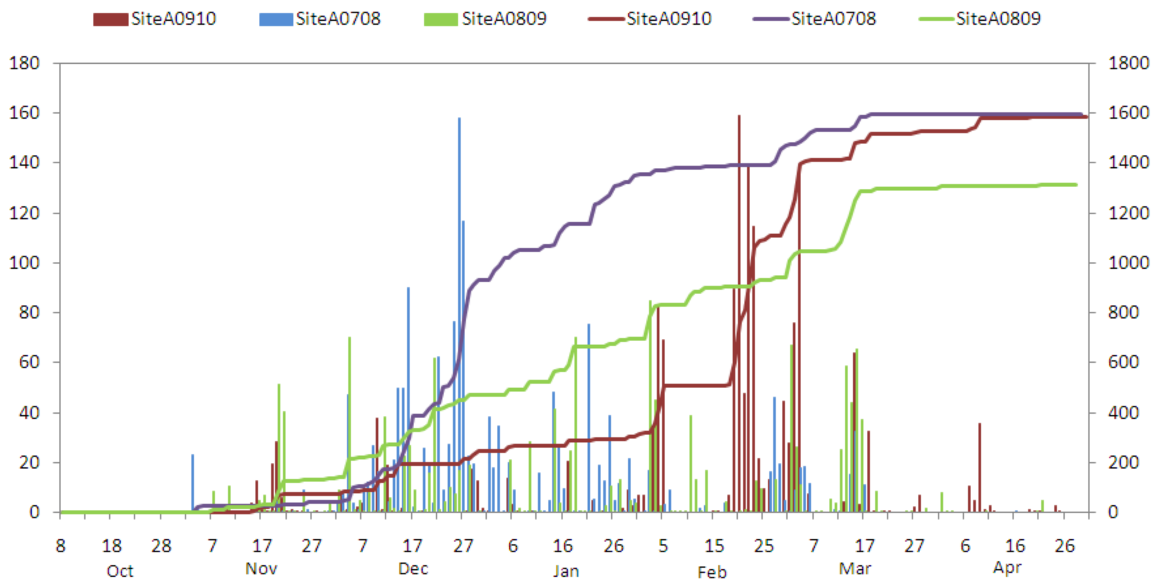

Fig. 2 Daily mean and accumulated precipitation (mm) at site *A* from November 1 to April 30 for the two rainy seasons (2007/08 and 2008/09). Precipitation was averaged over the 16 rain gauges.

regards to the global atmospheric field occurred during these periods. An *El Nino* event occurred from Spring 2007 to Summer 2008 and a *La Nina* event occurred from Summer 2009 to Spring 2010 (seasons for the northern hemisphere). These events affect global weather conditions, causing, for example, unusual rainfall and flooding, drought and forest fires, warm winters, cool summers.

So, the difference in the timing of rainfall in the two rainy seasons was possibly affected by these *El Nino* and *La Nina* events, and we now have measurements for three different cases: *El Nino*, *La Nina*, and the common (2008/2009 season) year.

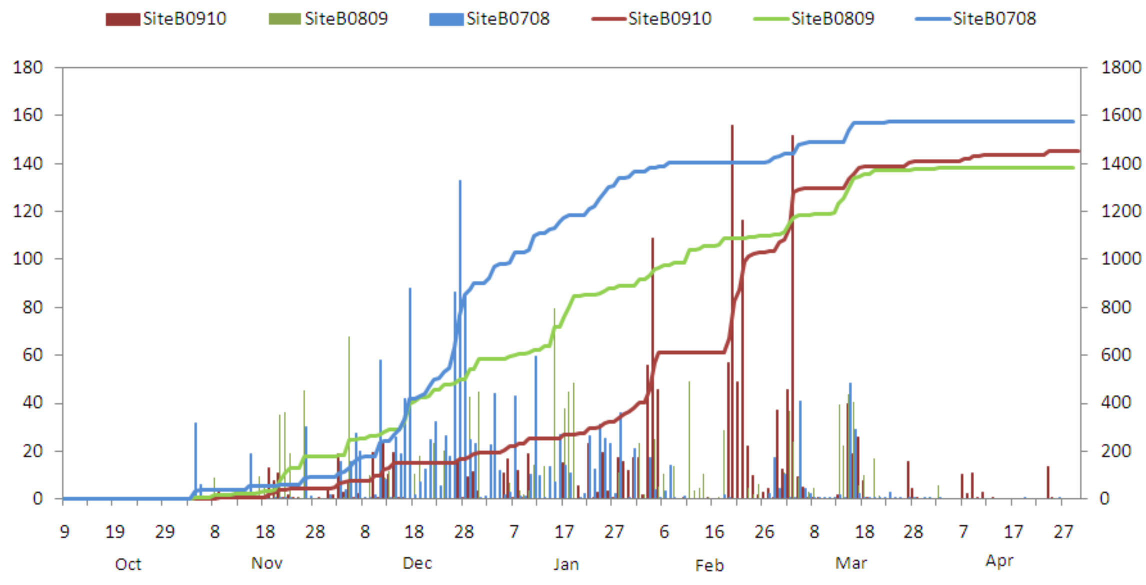

Fig. 3 As in Fig. 2 except for site *B*.

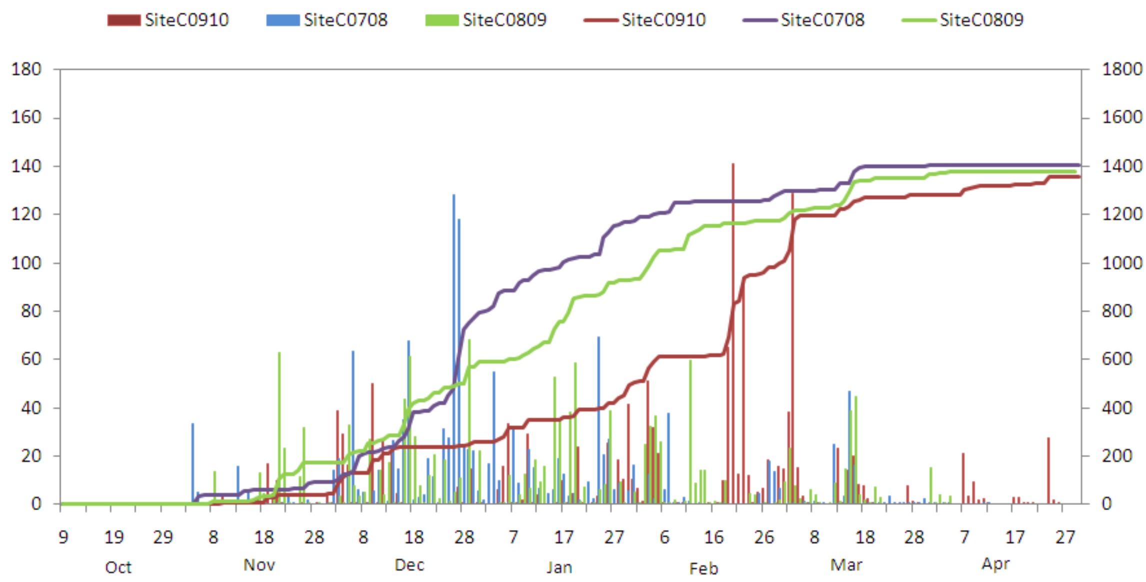

Fig. 4 As in Fig. 2 except for site *C*.

Distinct diurnal variations are present in the hourly precipitation values in the 2009/10 rainy season (Fig. 5), with high precipitation occurring between 1700 and 0200 hours at all sites. In comparison to the previous two rainy seasons, the two peaks in rainfall at 2100-2200 and 2400-0100 at site ***A*** are unique features. In the morning, site ***A*** has an indistinct peak around 0500, site ***B*** has a distinct peak at 0600 and ***C*** has a peak at 0700-0800. It seems that the morning rain moves from site ***A*** (lowland) to site ***C*** (highland). In the daytime from 1000 to 1500, there was little rain at each of the three sites. In a comparison of the three rainy seasons, there was little daytime rain observed in the 2008/09 and 2009/10 seasons; however, in the 2007/08 rainy season, distinct daytime rain was observed. Since the 2007/08 rainy season was an *El Nino* year, the atmospheric circulation may have been different from the other two rainy seasons. In conclusion, midnight rain around 2000-0100 was common in all three rainy seasons, but daytime rain was observed only in the 2007/08 rainy season, which may be attributable to the *El Nino* phenomenon occurring at this time.

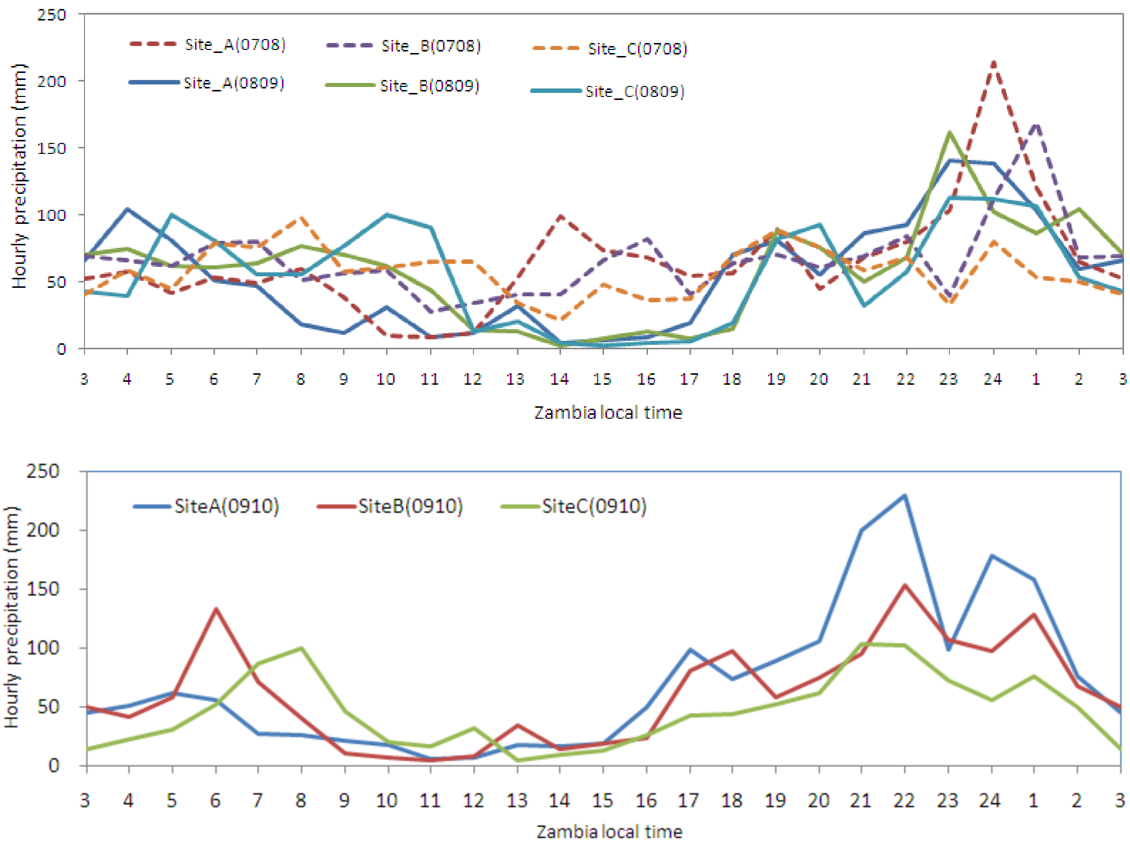

Fig. 5 Hourly precipitation (mm) from November 1 to April 30 for three rainy seasons (upper: 2007/08 and 2008/09, lower: 2009/10) at sites *A*, *B* and *C*.

3. Meteorological observation station data

In this section, daily and hourly variations of meteorological parameters other than precipitation at site ***A*** are discussed. The analysis period is from September 2007 to August 2010, and the annual features will be discussed. Analysis of data from site ***C*** was not conducted due to poor data recovery owing to instrument failure.

3.1. Temperature and humidity

Figure 6 shows the time variation of temperature and relative humidity at site ***A***.

Temperatures reach a maximum value from October to December, just before and following the onset of the rainy season. In the rainy season (from November to March), temperatures gradually decrease, and after the rainy season, this rate of decrease becomes large and temperatures fall until June-July.

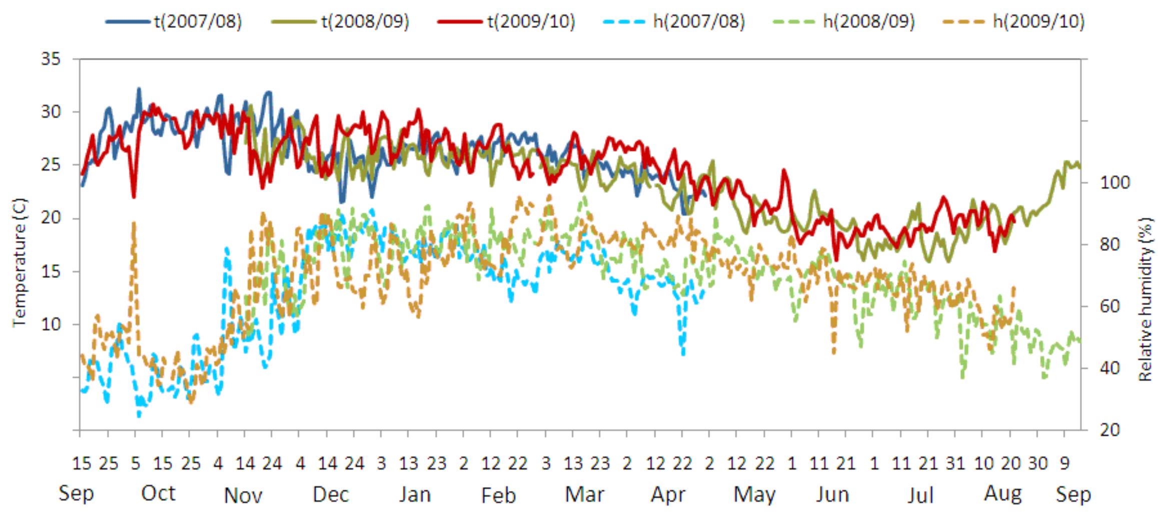

Fig. 6 Time series of temperature (t) and relative humidity (h) at site *A* in three rainy seasons (2007/08, 2008/09 and 2009/10).

Relative humidity shows minimum values of around 30-40 % from September to October, and then rises rapidly with the beginning of the rainy season. After December, humidity is maintained at 60-80 % until April, and then gradually decreases. The relative humidity was distinctly lower around December to January in the 2009/10 rainy season (*La Nina* year) than for the other two rainy seasons, during which period there was little rain. Also, the relative humidity from late March to April 2010 maintained higher values than during the other two rainy seasons. On the other hand, humidity from February to April in 2007/08 season (*El Nino* year) was lower than the other rainy seasons, and there was a little rain after February 2008. Consequently, humidity showed different temporal variations in the *El Nino* and *La Nina* years, which indicates that the difference in precipitation between those seasons may have been produced by large atmospheric variations.

3.2. Equivalent potential temperature and mixing ratio

Figure 7 shows the time variation of equivalent potential temperature (θe) and mixing ratio (x) over the three rainy seasons. These values simultaneously rise in early November, indicating the arrival of the air mass that produces the rainy season around this period. Therefore, in spite of the interannual variations in precipitation, the air mass movement may occur at nearly the same time in each of the three years. On the other hand, a distinct difference is seen in the period from late March to April, whereby θe and x in 2007/08 and 2008/09 seasons rapidly drop at the end of the rainy season, but in 2009/10, they maintain a high value, same as that in the rainy season, until April. These differences might be produced by the large-scale atmospheric variations peculiar to the *La Nina* year.

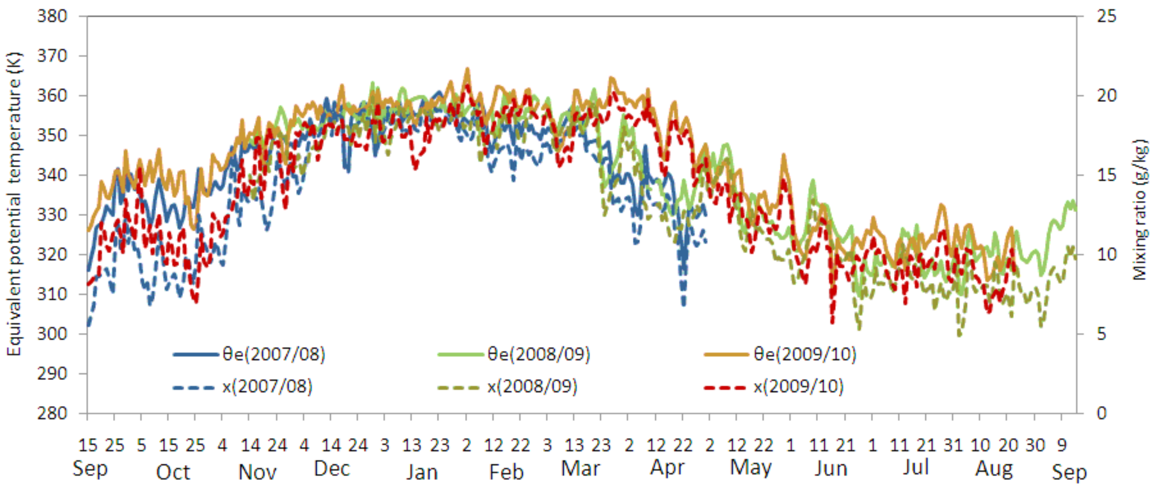

Fig. 7 Time series of equivalent potential temperature (*θe;* K) and mixing ratio (*x*; g/kg) at site *A* in three rainy seasons.

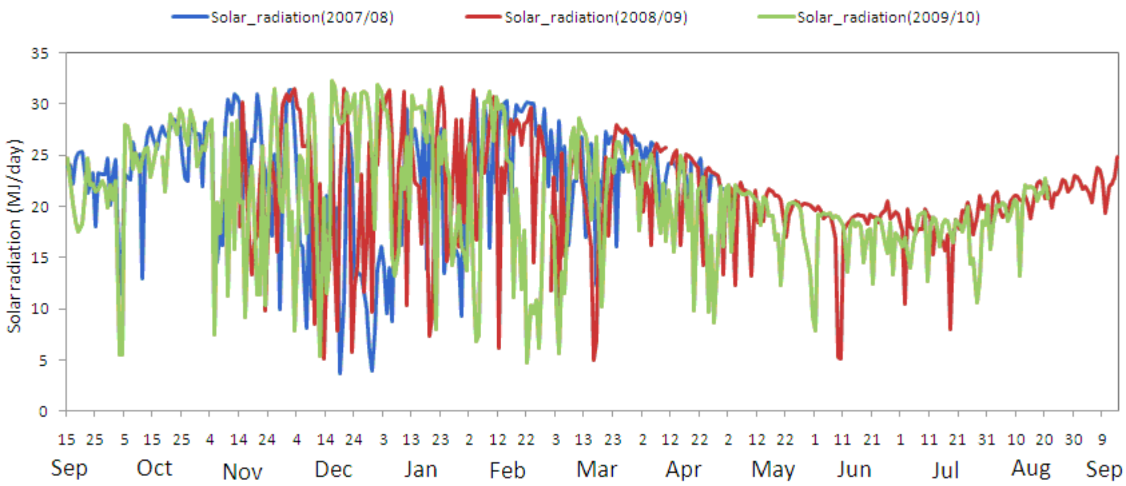

Fig. 8 Time series of daily solar radiation (MJ) at site *A* for three rainy seasons.

3.3. Solar radiation

Figure 8 shows the time series of daily solar radiation over each of the three rainy seasons. The value on a clear day indicates the annual cycle in solar radiation: the maximum values were observed in the rainy season from December to February, and the minimum were around June and July. In the rainy season, the values of solar radiation in each of the three years indicate the characteristic inter-seasonal change. Around mid December and late January, all values dropped simultaneously, likely coinciding with cloudy and rainy weather. On the other hand, solar radiation in 2007/08 fell in early January, but did not in the other two years. Also, solar radiation was low around late February 2010. These differences might coincide with the precipitation differences in the *El Nino* and *La Nina* years, respectively. We thus identify that these climate events affect a range of meteorological elements.

4. The relation between the dry spell and the large-scale atmospheric field in the 2009/10 rainy season

As discussed in Section 2, the time series of precipitation show unique features in each rainy season. In this section, we focus on the dry period in the 2009/10 rainy season and analyze the contemporaneous moisture field, and then consider the relation between them. The data used in this section is NCEP/NCAR reanalysis data (Kalnay et al., 1996).

Figure 9 shows the surface precipitable water distribution over southern Africa from January 27 to February 5, 2010. At our observation sites, about 200 mm of rain fell in this period. The high precipitable water area is shaped like a band from the equatorial Indian Ocean to the southern part of the African continent, and around the equator on the western side of Africa, which are part of the ITCZ. Also, there is another band-like area from the southeastern coast to the western equatorial coast through the southern part of Zambia. The value at our site is ca. 37-38 kg/m^2. Therefore, the rain experienced in this period may have been brought by this moisture band. Surface precipitable water for the period from February 6 to 15 is shown in Fig. 10. In this 10 day period, there is no rain and it is recognized as a clear break in the rainy season. The band-like area across the African continent seems to be interrupted, and the value at our site is ca. 30 kg/m^2. Surface precipitable water from February 16 to 25 is shown in Fig. 11. In this period, a lot of rainfall over 500 mm was experienced. The band-like moist area extended from the Indian Ocean to our site. The value around our site is ca. 40 kg/m^2 and this may have been sufficient to produce much rain.

Consequently, the break in the 2009/10 rainy season was associated with the variation in the large-scale moisture field, that is, the inter-seasonal variation of the ITCZ. Therefore, it is possible that the variation in precipitation at the three study sites is a local phenomenon, but that the global atmospheric variation also affects them. A numerical meteorological model experiment using the global objective analysis data as input should be effective for the analysis of the variation in the distribution of local precipitation.

5. Numerical simulation experiments

In this section, a numerical meteorological model was used for the simulation of the spatial distribution and temporal variation of local precipitation at the study site. The model used in this study was the Weather Research & Forecasting Model (WRF) ver. 3.2. The input data sources were as follows: the objective analysis data were NCEP/NCAR reanalysis data, the vegetation data were supplied via the MODIS (MODerate resolution Imaging Spectroradiometer) product, soil data were from the World Soil Resources Map Index, and the topography data were sourced from U.S. Geological Survey's GTOPO30.

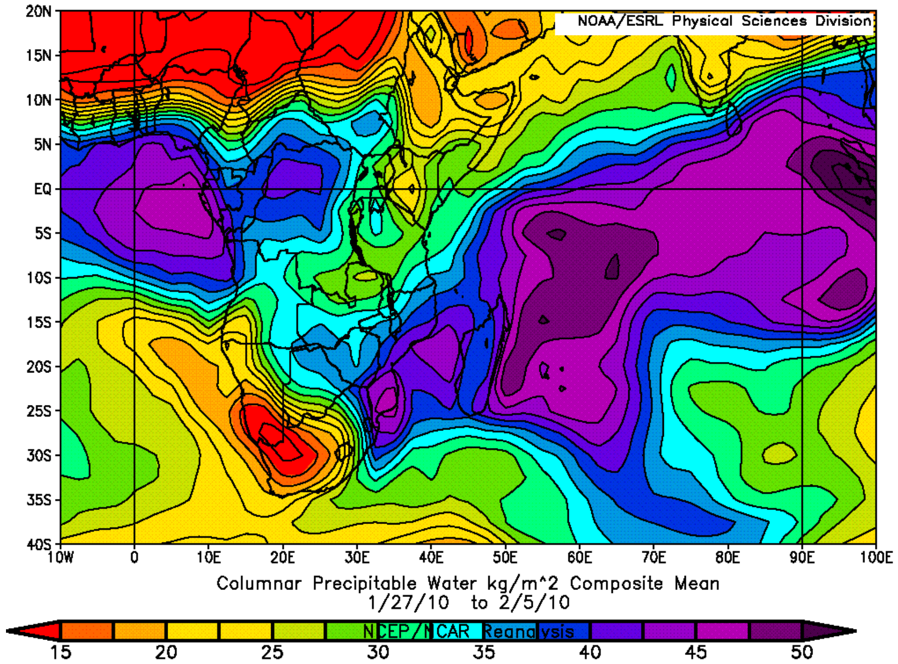

Fig. 9 Surface precipitable water distribution over southern Africa from January 27 to February 5, 2010.

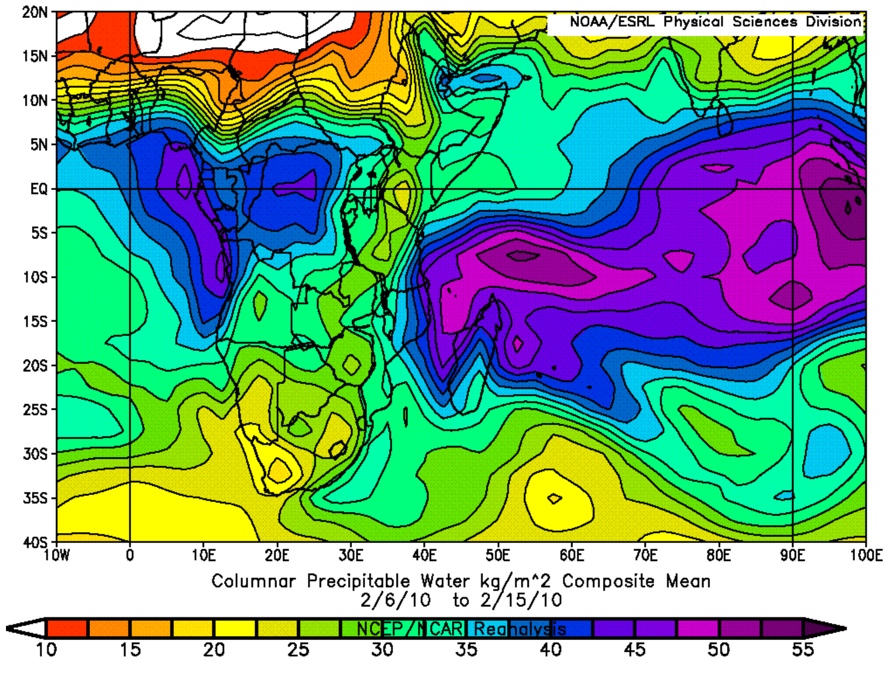

Fig. 10 As in Fig. 9 except from February 6 to 15, 2010.

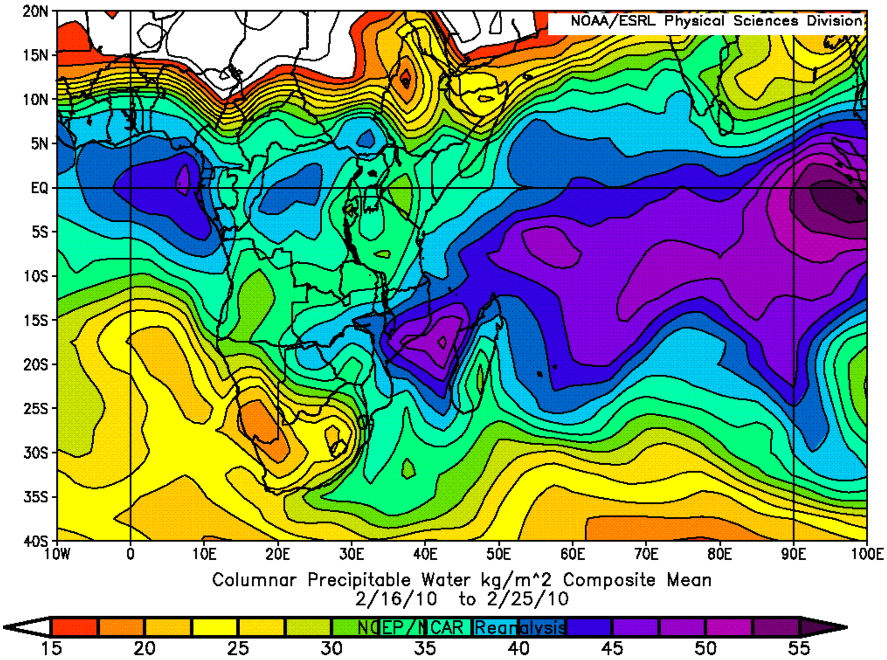

Fig. 11 As in Fig. 9 except from February 16 to 25, 2010.

Figures 12, 13 and 14 show the daily mean distribution of precipitation in December in 2007, 2008 and 2009, respectively. As already mentioned, a lot of rain fell in December in 2007 and little rain in 2009 at our sites. The results of the model simulation agree with these observations. In 2007, much precipitation was seen in the simulation results around the northern highland area and our site experienced relatively high precipitation extending from the north along the southwestward-facing slope. In 2008, precipitation was less than in 2007, and in 2009, there was the least precipitation of the three years in the vicinity of our sites.

Figures 15, 16 and 17 show the daily mean distribution of precipitation in February 2008, 2009 and 2010, respectively. According to the observations at our sites, precipitation was low in 2008 and high in 2010. The simulated distribution of precipitation in 2008 shows few rainfall areas around 16.5-18.0ºS latitude (Fig.15), and around our sites, precipitation was the lowest of the three rainy seasons. On the other hand, in February 2009 and 2010, a large precipitation area was located in the northern area, and the precipitation was highest in 2010 of the three rainy seasons around our sites (Figs.16 and 17).

Consequently, the numerical model was found to well simulate the observed distribution of precipitation in the three rainy seasons. Thus, the other simulated meteorological elements should be useful for gaining an understanding of the factors producing these weather variations. We are continuing the simulation of further meteorological elements over a longer time range, and these will be presented in a subsequent report.

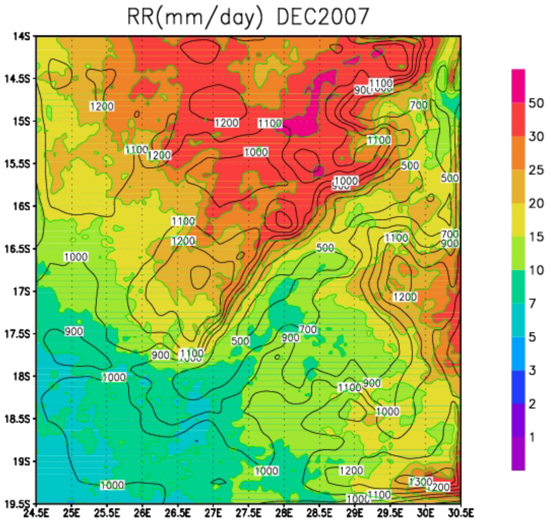

Fig. 12 Daily mean precipitation distribution in December in 2007 in Sinazongwe District, Zambia. The colorscale indicates the amount of precipitation, lines and numerals in the figure are the contour line and value. The contour interval is 100 mm.

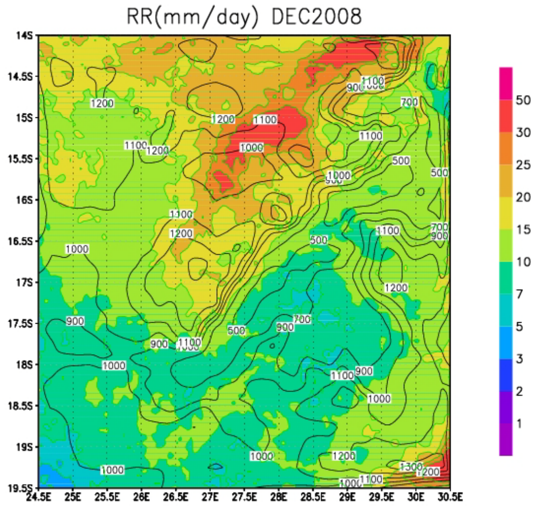

Fig. 13 As in Fig. 12 except for 2008.

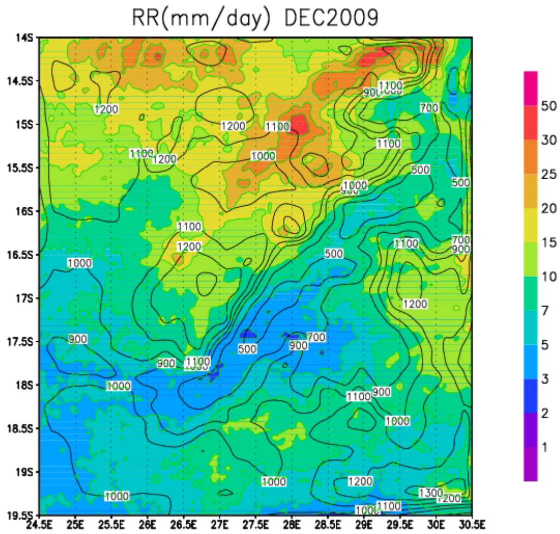

Fig. 14 As in Fig. 12 except for 2009.

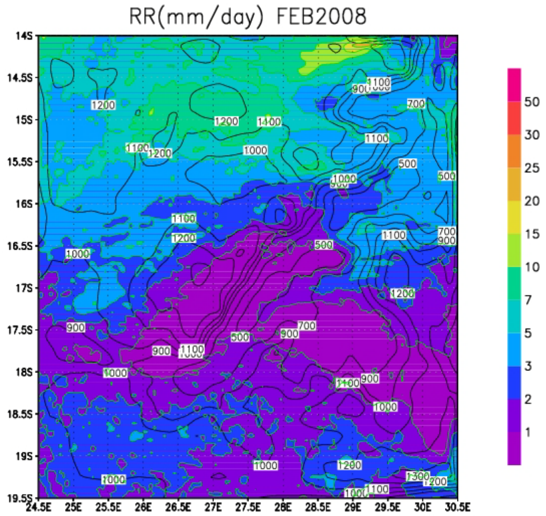

Fig. 15 Daily mean precipitation distribution in February in 2008 in Sinazongwe District, Zambia.

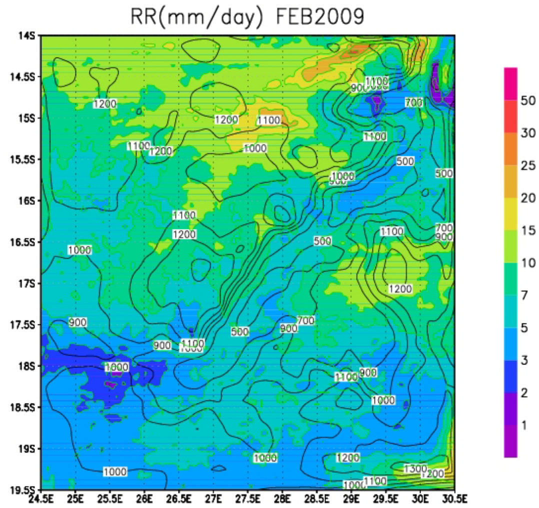

Fig. 16 As in Fig. 15 except for 2009.

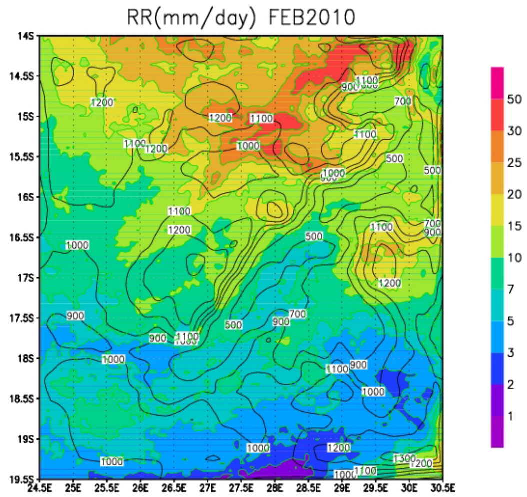

Fig. 17 As in Fig. 15 except for 2010.

6. Conclusions

Local meteorological observations were made at three research sites in the Sinazongwe District, Zambia, from September 2007 onward. The observation data were analyzed and compared over three rainy seasons: 2007/08, 2008/09, and 2009/10. The results of this analysis are summarized as follows:

1) The time series of precipitation over the three rainy seasons show distinct variations: the early stage of the 2007/08 rainy season experienced a lot of rain, but the late stage of the 2009/10 season experienced much rain. Since the 2007/08 rainy season occurred in an *El Nino* phase and the 2009/10 rainy season occurred in a *La Nina* phase, these differences were possibly produced by the differences in large scale circulation.

2) Hourly accumulated precipitation showed distinct diurnal variations, with high

precipitation between 1700 and 0200 hours at all sites throughout the three rainy seasons. In the 2009/10 rainy season, morning rain seems to have moved from the lowlands to highlands. In the 2007/08 season, there was distinct precipitation in the daytime, which may be related to the *El Nino* event.

3) Temporal variations in temperature showed a common seasonal change, but those in relative humidity showed variable characteristics. Exemplifying the difference between the *El Nino* and *La Nina* years, humidity around December to January of the 2009/10 rainy season (*La Nina* year) was distinctly lower than in the other two seasons. Also, humidity from late March to April 2010 maintained a higher value than the other two seasons. On the other hand, humidity from February to April in 2007/08 season (*El Nino* year) was lower than the others.

4) The temporal variations of equivalent potential temperature and mixing ratio show a simultaneous rise around early November, which indicates that the air mass producing the rainy season arrives around this period. In the 2009/10 season, these parameters maintain a high value until April, same as in rainy season. These differences may be produced by the large-scale variations peculiar to the *La Nina* year.

5) Around mid December and late January, solar radiation dropped in all years, which likely coincides with cloudy and rainy weather. Solar radiation fell in early January 2007/08, but not in the other two years, and in late February 2010, solar radiation was low. These differences might coincide with the temporal differences in precipitation in *El Nino* and *La Nina* years, respectively.

6) According to the large-scale precipitable water analysis, the break in the 2009/10 rainy season was likely affected by the variation of the large scale moisture field, that is, the inter-seasonal variation of the ITCZ. It is possible that the variations in precipitation at three sites are local in nature, but also affected by the variation in global atmospheric circulation.

7) The numerical meteorological model was found to well simulate the distribution of precipitation over the three rainy seasons. Thus, other simulated meteorological elements should be useful in providing an understanding of the factors producing these weather variations, and this will be investigated in a subsequent study.

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Effects of planting timing on maize productivity in Zambia

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Abstract

Optimal planting date is essential to attain high maize (*Zea mays* L.) productivity despite environmental variation in low-input agriculture in Zambia. Local farmers generally plant maize as soon as possible after the rainy season begins, but there is no scientific evidence that this timing is optimal for attaining high productivity using local practices. To test this, we grew maize at three planting dates (normal timing, then 10 and 20 days later) in six fields of Zambia's Southern Province in the 2008/09 and 2009/10 growing seasons. Grain yield was reduced by delayed planting, by an average of 19% for all years and locations combined. The reduction resulted from decreased biomass production and harvest index. The yield was closely correlated with the mean air temperature and wind speed during the 30 days after planting; cooler and windier conditions increased the magnitude of the yield reduction due to delayed planting. These results support the early planting used by local farmers.

1. Introduction

Maize (*Zea mays* L.) is a major food source in southern Arica, including Zambia, but its productivity is low compared to yields obtained elsewhere in the world; the mean yield in Zambia (1742 kg ha^{-1}; 10-year average from 1999 to 2008) is only 37% of the world average (4671 kg ha^{-1}), and the coefficient of variation in Zambia is roughly twice that in other countries (FAO, 2010). A slight decline in maize productivity can have detrimental effects on the lives of local farmers and their families, jeopardizing both their health and their lives. Stabilization of maize productivity in Zambia is therefore essential, particularly given current prospects for future climate change (IPCC, 2007).

The precipitation pattern is one of the most critical factors that affects maize production in Africa (Cane *et al.*, 1994; Phillips *et al.*, 1998; Stige *et al.*, 2006), where precipitation occurs primarily during the wet season. Choosing the most appropriate planting date is therefore essential for increasing crop productivity by taking advantage of the available climatic resources under conditions in which farmers have no access to inputs such as synthetic fertilizers or pesticides.

To analyze the impact of planting date on maize productivity, simulation models have proven to be a powerful option (Tsubo *et al.*, 2005ab; Abraha and Savage, 2006). These models have shown that too-early planting before the rainy season begins increases the risk that severe drought will prevent germination and establishment when young plants do not have root systems to absorb enough soil water. On the other hand, too-late planting might reduce the total growing period and total biomass by limiting crop absorption of solar radiation. Most simulation models, however, were developed based on data obtained from experiments conducted under well-fertilized conditions and well-controlled management practices. Unfortunately, huge gaps exist between the potential productivity and the actual productivity achieved by farmers due to differences in several key factors, such as fertilizer, pesticide, and herbicide inputs. Sileshi *et al.* (2008) analyzed the published maize yield data, and showed that actual maize productivity was almost half of the productivity obtained under well-fertilized conditions, with a high coefficient of variation for yield under field conditions. Thus, it is necessary to test the effects of planting date on maize productivity under local environmental and cultivation conditions to calibrate the predictions of simulation models.

There have been few field studies of the effects of planting timing on maize productivity in Africa (Tsubo *et al.*, 2003, for South Africa; Tittonell *et al.*, 2008, for Kenya; Kamara *et al.*, 2009, for Nigeria), leading to weak scientific evidence for the optimal planting date that will maximize maize yield by smallholders in southern Africa. In the present study, we examined the effects of planting date on maize productivity at six smallholder fields in Zambia, at three altitudes that differ in weather conditions.

2. Materials and Methods

In Zambia's Southern Province, the local maize cultivar 'Jileile' was planted in six fields of villages at three different altitudes: A = Sianemba and Siameja villages (17°05'S, 27°30'E, 517 m in altitude, two fields), B = Chanzika village (17°05'S, 27°20'E, 769 m in altitude, one field), and C = Siachaya village (16°59'S, 27°20'E, 1075 m in altitude, three fields). Planting was conducted on three dates from late November to early December in 2008 (starting on the normal date, then at ca. 10-d intervals) to produce a final density of 33.3×10^3 plants ha^{-1} (1 m between rows × 0.3 m between plants; planting two to three seeds per spot for an initial density of from 67×10^3 to 100×10^3 plants ha^{-1}). The plants were thinned after emergence, leaving only a single plant per spot. Table 1 summarizes the planting dates and other key dates. We defined the normal planting date based on the decision of the local farmers as the control, then chose planting dates that were approximately 10 and 20 days later as the delayed planting treatments; at some sites, we used only one of the two treatments and at other sites we used both. Farmers in Zambia's Southern Province have learned from experience to plant maize a few days after the second large rainfall of the year, which is judged to represent the start of the wet season. The plot size in the control treatment was 20 × 20 m, whereas those in the 10-d-later and 20-d-later plots were about 10 × 20 m. Agronomic practices followed local methods: weeding by hand, and no irrigation, fertilizer, herbicide, or pesticide application in any field. A similar experimental design was used in 2009/10, but the planting was delayed in two plots (to 47 days later in ASn1 and 31 days later in CSa1).

Table 1. Growth stages and grain yield of maize sown on different dates in the 2008/09 and 2009/10 growing seasons in Zambia.

Season	Site	Field ID	Treatment	Sowing		Emergence		Flowering		Period from sowing to flowering	
2008/09	A	ASn1	Control	4-Dec		7-Dec		30-Jan		57	
			10d later	13-Dec	(+9)	17-Dec	(+10)	7-Feb	(+8)	56	(-1)
			20d later	23-Dec	(+19)	27-Dec	(+20)	19-Feb	(+20)	58	(+1)
		ASm2	Control	4-Dec		-		30-Jan		57	
			10d later	13-Dec	(+9)	-		-		-	-
	B	BCh2	Control	29-Nov		-		17-Jan		49	
			10d later	8-Dec	(+9)	-		5-Feb	(+19)	59	(+10)
	C	CSa1	Control	28-Nov		-		2-Feb		66	
			10d later	7-Dec	(+9)	13-Dec		27-Feb	(+25)	82	(+16)
			20d later	17-Dec	(+19)	23-Dec		20-Mar	(+46)	93	(+27)
		CSa2	Control	28-Nov		-		2-Feb		66	
			10d later	7-Dec	(+9)	13-Dec		27-Feb	(+25)	82	(+16)
		CSa3	Control	28-Nov		-		1-Feb		65	
			10d later	7-Dec	(+9)	13-Dec		27-Feb	(+26)	82	(+17)
2009/10	A	ASn1	Control	17-Dec		21-Dec		1-Feb		46	
			10d later	30-Dec	(+13)	5-Jan	(+15)	16-Mar	(+43)	76	(+30)
			20d later	2-Feb	(+47)	6-Feb	(+47)	2-Apr	(+60)	59	(+13)
		ASm2	Control	17-Dec		22-Dec				-	-
			10d later	30-Dec	(+13)	3-Jan	(+12)			-	-
	B	BCh2	Control	12-Dec		17-Dec		26-Jan		45	
			10d later	22-Dec	(+10)	29-Dec	(+12)			-	-
	C	CSa1	Control	8-Dec		13-Dec		28-Jan		51	
			10d later	18-Dec	(+10)	23-Dec	(+10)	16-Feb	(+19)	60	(+9)
			20d later	8-Jan	(+31)	13-Jan	(+31)	12-Mar	(+43)	63	(+12)
		CSa2	Control	8-Dec		13-Dec		28-Jan		51	
			10d later	18-Dec	(+10)	23-Dec	(+10)	16-Feb	(+19)	60	(+9)
		CSa3	Control	8-Dec		13-Dec		28-Jan		51	
			10d later	18-Dec	(+10)	23-Dec	(+10)	16-Feb	(+19)	60	(+9)

Values in parenthesis indicate differences from the control. -, data not available.

We recorded the emergence and flowering dates in each plot. At harvesting time (in early April), maize yield was determined for the whole control plot (divided into 12 subplots of 5×6 m, for a total area of 360 m^2), but we used four subplots (2×2 m, for a total of 16 m^2) at each site in the 10-d-later and 20-d-later plots. The yield was expressed as the oven-dried (70°C) seed weight. The 100-grain weight was also measured. From the 100-grain weight and grain yield, the grain density was estimated. Total oven-dried aboveground biomass was also measured. We calculated harvest index by dividing the total grain yield by the total aboveground biomass of an oven-dry basis.

Solar radiation, wind speed, and relative humidity were measured at sites A and C, at one location per site, using a CMP3 solar radiation sensor (Campbell Scientific Inc., Logan, UT, USA), a 034B-Lx wind set (Campbell Scientific Inc.), and a CS215-Lx temperature and relative humidity sensor (Campbell Scientific Inc.) covered by a 41303-5A radiation shield (Campbell Scientific Inc.), respectively. Air temperature was measured at three locations at sites A and B and four locations at site C, at 1.2 m in height, with a TR-52 sensor (T&D Corporation, Nagano, Japan) covered by a 41303-5A radiation shield. Precipitation was measured at 16 locations at each site using CTK-15PC tipping-bucket rain gauges (Climatec Inc., Tokyo, Japan). All measurements were conducted at 30-minute intervals.

We used Excel statistics to perform simple linear regression analysis of the relationship between yield and environmental parameters, and to calculate Pearson's correlation coefficient between total grain yield and the yield and weather parameters.

3. Results

3.1. Weather

The total precipitation was greater in 2009/10 than in 2008/09, but did not differ between locations (Table 2). The seasonal precipitation trend differed between years; the precipitation was greater during the early growing season in 2008/09, but was greater during the late growing season in 2009/10. The precipitation during the early growing season (December and January) was higher at site C than at sites A and B in both years. Figure 1 illustrates the changes in daily precipitation at the three sites around the maize planting dates (from November to December) and during the rest of the growing season. The precipitation started earlier in the 2008/09 season than in the 2009/10 season.

The seasonal mean air temperature (December to March) was lowest at the high elevation of site C (average 21 to 23°C, maximum 26 to 27°C, minimum 18 to 19°C), followed by site B at an intermediate elevation (average 23 to 24°C, maximum 28 to 29°C, minimum 19 to 20°C), and was highest at the low altitude of site A (average 25 to 26°C, maximum 30 to 31°C, minimum 21 to 22°C) (Table 2). Air temperature in the 2008/09 was about 1°C lower than that in 2009/10, and decreased during both growing seasons. Wind speed was faster at site C than site A (by 60%) throughout the growing season in both years. Relative humidity was generally higher at site C than site A. Solar radiation at site C was only about 90% of that at site A. Thus, the weather at the higher altitude of site C was cooler, windier, and wetter, with less solar radiation, and the 2008/09 season was cooler and wetter than the 2009/10 season.

Table 2. Climate conditions at the three study locations in Zambia during the 2008/09 and 2009/10 growing seasons. Elevations: site A < site B < site C.

Season	Year	Month	Precipitation (mm)			Air temperature (°C) Average			Maximum			Minimum			Relative (%)		Solar (MJ m^{-2} d^{-1})		Wind speed (m s^{-1})	
			A	B	C	A	B	C	A	B	C	A	B	C	A	C	A	C	A	C
2008/09	2008	Dec.	339	365	397	25.4	23.5	22.3	29.9	27.7	26.6	21.9	20.2	19.2	79.0	84.1	20.5	18.9	0.7	1.4
	2009	Jan.	225	348	358	25.7	23.6	22.2	30.5	27.9	27.0	22.0	20.3	18.9	80.7	87.1	22.9	20.2	0.8	1.2
		Feb.	234	211	246	25.4	23.2	21.7	30.6	28.3	26.9	21.1	19.5	18.0	80.3	86.2	24.9	21.4	0.8	1.2
		Mar.	369	274	180	23.9	21.9	20.5	29.4	27.0	25.5	20.0	18.4	17.0	83.0	87.2	20.8	18.9	0.7	1.1
	Seasonal mean		***292***	***300***	***295***	***25.1***	***23.1***	***21.7***	***30.1***	***27.7***	***26.5***	***21.3***	***19.6***	***18.3***	***80.8***	***86.1***	***22.3***	***19.8***	***0.8***	***1.2***
	SD		***73***	***71***	***100***	***0.8***	***0.8***	***0.8***	***0.5***	***0.5***	***0.7***	***0.9***	***0.9***	***1.0***	***1.7***	***1.4***	***2.0***	***1.2***	***0.1***	***0.1***
2009/10	2009	Dec.	176	150	219	26.8	24.9	23.4	31.8	29.7	28.3	22.3	21.0	19.5	73.5	78.8	23.9	22.4	1.1	1.4
	2010	Jan.	64	194	243	27.0	24.6	23.1	32.5	29.3	28.0	22.7	21.0	19.7	72.9	82.0	23.6	20.7	0.9	1.2
		Feb.	848	650	478	25.6	23.7	22.4	30.4	28.4	26.5	22.2	20.6	19.6	83.3	88.0	19.1	17.6	0.5	1.1
		Mar.	450	375	301	25.3	23.3	21.8	30.8	28.7	26.7	21.1	19.4	18.2	82.7	86.9	21.7	19.0	0.5	1.0
	Seasonal mean		***384***	***342***	***310***	***26.2***	***24.1***	***22.7***	***31.4***	***29.0***	***27.4***	***22.1***	***20.5***	***19.2***	***78.1***	***83.9***	***22.1***	***19.9***	***0.8***	***1.2***
	SD		***349***	***227***	***117***	***0.8***	***0.7***	***0.7***	***1.0***	***0.6***	***0.9***	***0.7***	***0.7***	***0.7***	***5.7***	***4.3***	***2.2***	***2.1***	***0.3***	***0.2***
	Relative value 1		*0.76*	*0.88*	*0.95*	*0.96*	*0.96*	*0.96*	*0.96*	*0.96*	*0.97*	*0.96*	*0.96*	*0.95*	*1.03*	*1.03*	*1.01*	*1.00*	*1.01*	*1.04*
	Relative value 2		-	*0.95*	*0.90*	-	*0.92*	*0.86*	-	*0.92*	*0.88*	-	*0.92*	*0.87*	-	*1.07*	-	*0.90*	-	*1.60*

Relative value 1 = mean in 2008/09 divided by mean in 2009/10 (i.e., annual difference). Relative value 2 = mean at site A in both years divided by mean at sites B or C (i.e., regional difference).

3.2. Cropping schedule and growth stage

The planting date in the control plots in 2008/09 (30 November ± 3.0 d, mean ± standard deviation) was an average of 11 days earlier than that in 2009/10 (11 December ± 4.4 d) (Table 1) because the rainy season started earlier (Fig. 1). The planting date was earlier at the high-elevation site C than at the lower elevations of sites A and B (Table 1). The flowering date in the control was earlier at sites A and B than at site C, even though the planting date was earliest at site C.

The delayed planting date did not affect the duration from planting to seedling emergence

(Table 1). The period from planting to flowering was prolonged by 10 to 27 days in 2008/09 as a result of the delayed planting, except at site A, where there appeared to be no significant difference. In 2009/10, flowering was delayed by 9 to 30 days compared with the control.

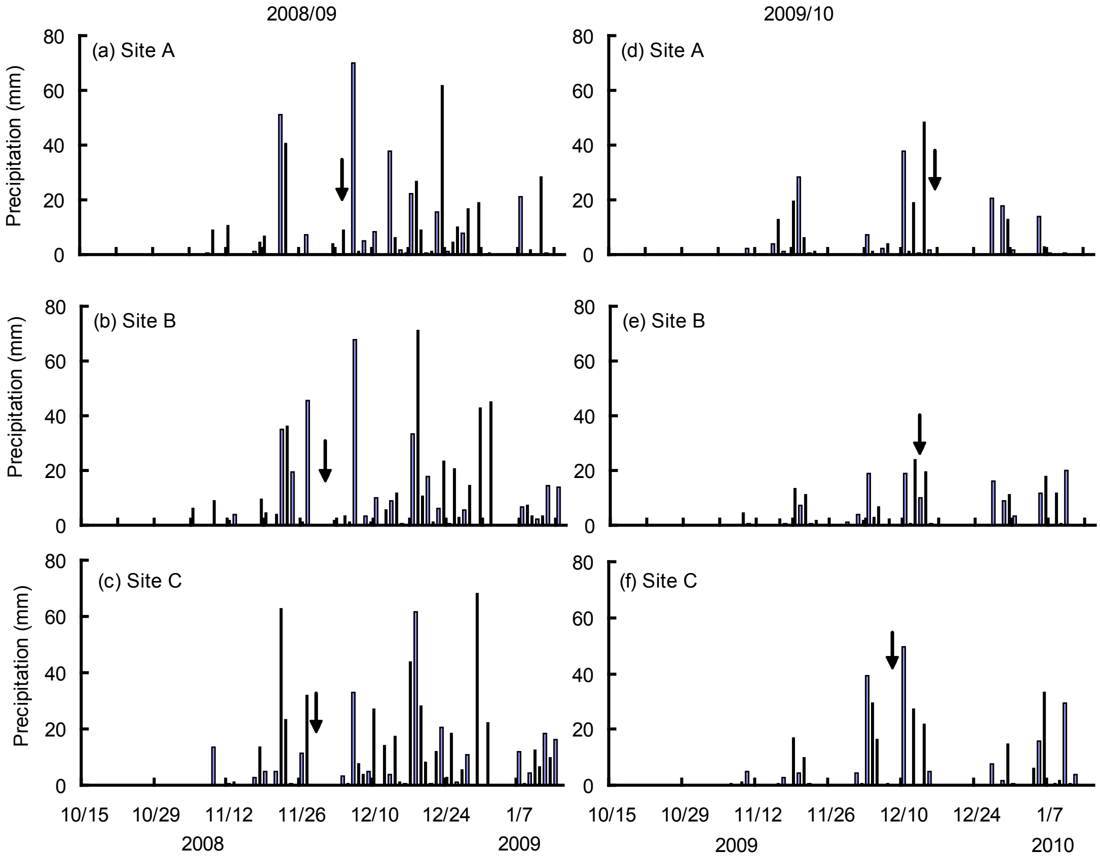

Fig. 1 Daily precipitation pattern at three villages in Zambia in (a, b, c) 2008/09 and (d, e, f) 2009/10. Arrows indicate the planting date in the control.

3.3. Grain yield

Grain yield in the control at sites A and B was greater than 1100 kg ha^{-1} in 2008/09 and greater than 700 kg ha^{-1} in 2009/10 season, with the exception of field ASm2 in 2009/10 (480 kg ha^{-1}) (Table 3). However, the yield at site C was less than 300 kg ha^{-1} in both years. The delayed planting date reduced grain yield significantly (P < 0.001), by an average of about 19% for all years and locations combined (Fig. 2).

The changes in biomass and harvest index also explained the variation in grain yield (r > 0.65, P < 0.001; Table 3). Of the yield components, the grain yield variations were explained best by grain density (r = 0.956, P < 0.0001), but individual grain size was also significant (r = 0.529, P < 0.01). No significant relationship between grain yield and the number of plants per hectare was observed (r = 0.240, ns).

Table 3. Grain yield, biomass yield, and harvest index of maize sown on three dates in the 2008-2009 and 2009-2010 growing seasons in Zambia. Elevations: site A < site B < site C.

Year	Site	Farmer's field ID	Treatment	Grain yield (kg ha^{-1})			Plant establishment (10^3 ha^{-1})		Individual grain weight (g 100-grains^{-1})		Grain density (10^3 ha^{-1})		Biomass (kg ha^{-1})			Harvest index	
2008/09	A	ASn1	Control	1157	±105		26.8		33.7		3430		2263			0.51	
			10d later	1205	±207	(1.04)	30.0	(1.12)	29.1	(0.86)	4144	(1.21)	4497	±682	(1.99)	0.27	(0.52)
			20d later	1214	±115	(1.05)	37.5	(1.40)	18.6	(0.55)	6537	(1.91)	11594	±633	(5.12)	0.10	(0.20)
		ASm2	Control	1117	±137		23.7		29.9		3729		2765			0.40	
			10d later	740	±162	(0.66)	45.0	(1.90)	23.0	(0.77)	3215	(0.86)	3794	±166	(1.37)	0.20	(0.48)
	B	BCh2	Control	1956	±166		24.6		32.8		5966		3733			0.52	
			10d later	1375	±261	(0.70)	30.0	(1.22)	28.2	(0.86)	4875	(0.82)	4324	±484	(1.16)	0.32	(0.61)
	C	CSa1	Control	197	±71		22.6		31.7		622		1161			0.17	
			10d later	10	±9	(0.05)	26.3	(1.16)	7.3	(0.23)	134	(0.22)	891	±139	(0.77)	0.01	(0.06)
			20d later	0	±0	(0.00)	17.5	(0.77)	0.0	(0.00)	0	(0.00)	501	±217	(0.43)	0.00	(0.00)
		CSa2	Control	252	±45		17.0		21.9		1149		1096			0.23	
			10d later	138	±67	(0.55)	33.8	(1.98)	19.0	(0.86)	728	(0.63)	1482	±140	(1.35)	0.09	(0.40)
		CSa3	Control	286	±87		18.9		25.4		1127		1002			0.29	
			10d later	26	±11	(0.09)	34.4	(1.82)	14.5	(0.57)	177	(0.16)	1209	±164	(1.21)	0.02	(0.07)
2009/10	A	ASn1	Control	766			15.7		32.7		2342		2153			0.36	
			10d later	478	-	(0.62)	35.0	(2.23)	24.7	(0.76)	1937	(0.83)	1207		(0.56)	0.40	(1.11)
			20d later	530	±0	(0.69)	23.8	(1.51)	24.3	(0.74)	2179	(0.93)	1654		(0.77)	0.32	(0.90)
		ASm2	Control	480			18.7		30.7		1565		1384			0.35	
			10d later	492	±109	(1.02)	23.8	(1.27)	26.0	(0.85)	1897	(1.21)	1099		(0.79)	0.45	(1.29)
	B	BCh2	Control	885			26.3		-		-		3169			0.28	
			10d later	996	±0	(1.13)	23.1	(0.88)	26.2		3801		3100		(0.98)	0.32	
	C	CSa1	Control	642			26.1		24.7		2600		2054			0.31	
			10d later	467	±61	(0.73)	23.8	(0.91)	22.0	(0.89)	2127	(0.82)	1511		(0.74)	0.31	(0.99)
			20d later	510	±97	(0.79)	28.1	(1.08)	24.7	(1.00)	2063	(0.79)	1954		(0.95)	0.26	(0.83)
		CSa2	Control	90			10.9		29.7		304		354			0.26	
			10d later	184	±46	(2.03)	19.4	(1.77)	22.2	(0.75)	828	(2.72)	1125		(3.18)	0.16	(0.64)
		CSa3	Control	58			23.0		24.7		236		857			0.07	
			10d later	103	±59	(1.76)	29.4	(1.28)	21.7	(0.88)	472	(2.00)	1153		(1.35)	0.09	(1.30)
	r			-			0.240	ns	0.529	**	0.956	***	0.656	***		0.662	***

Values in parentheses indicate the treatment value divided by the value in the control. Grain yield ± SE (n =12 plot for the control plots, n = 4 plot for the 10-d-later and 20-d-later plots). *r*, correlation coefficient with grain yield. ***, *P < 0.001* ; **, *P < 0.01* ; ns, not significant.

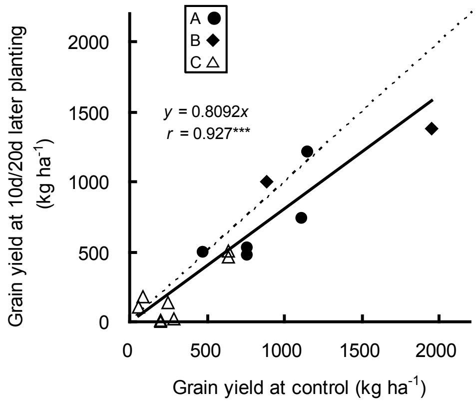

Fig. 2 Relationship between grain yield in the control (normal planting date) and grain yield in the delayed-planting treatments (ca. 10 or 20 days later). The dashed line represents the line y = x. ***, P < 0.001

To clarify the factors responsible for the yield decrease in response to the delayed planting, we plotted the ratio of grain yield in the delayed planting treatments to that in the control (the "relative yield") as a function of the mean weather conditions from planting to 30 days after planting (Fig. 3). The 30-day period after planting was chosen based on the duration of the most greatly delayed planting (ca. 20 d) and the period from planting to emergence (ca. 10 d). Note that because the CSa2 and CSa3 plots in 2009/10 showed extremely high relative values (>1.7) due to the exceptionally low yield in these plots (less than 100 kg ha^{-1}), which would have introduced excessive noise in the analysis (Table 3), we excluded these data from the regression analysis (circled points in the figures). To confirm that this approach was acceptable, we repeated the regression analysis with these data points included, and found weaker but still linear regressions (data not shown). Although precipitation, solar radiation, and relative humidity were not significantly correlated with relative yield (Fig. 3), wind speed and air temperature were both significantly correlated with the variations of the yield response; windier and cooler conditions both significantly decreased the relative yield.

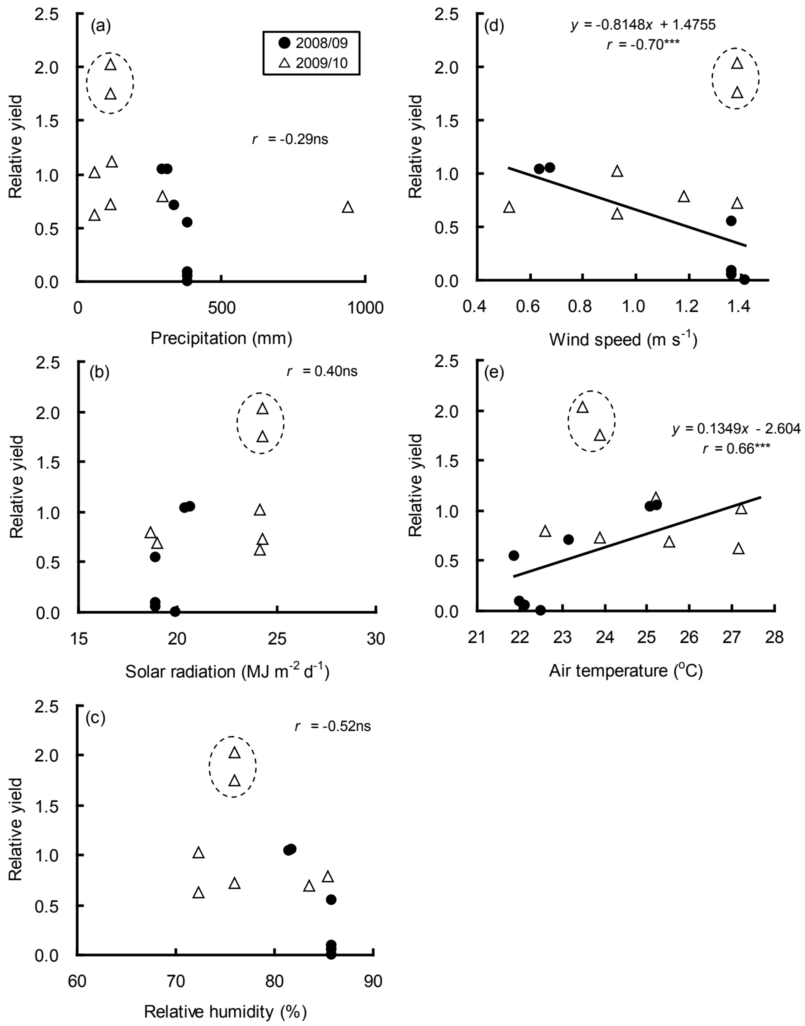

Fig. 3 Relationship between relative yield (defined as the ratio of the yield in the 10-d-later and 20-d-later treatments to that in the control) and mean weather conditions during the 30 days after planting.

***, P < 0.001; ns, not significant. Circled data was excluded from the regression analysis.

4. Discussion

Our study results demonstrated that the normal planting date, which smallholders have traditionally chosen, produced higher grain yields than the delayed planting dates, which had yields that averaged 19% lower than those in the control for all sites and years combined (Fig. 2, Table 3). We did not examine planting before the normal planting date, but the observed precipitation pattern (Fig. 1) suggested that because of low rainfall before the control date (i.e., the high risk of drought during seed germination and seedling establishment), the normal planting date in the control represents the early limit for planting at the study sites. Thus, our field trials in two seasons confirmed that the smallholders chose the optimal planting schedule for high productivity of maize in their part of Zambia under the current low-input management practices. However, the current grain yield for all villages in the present study was much lower than the national average (1742 kg ha^{-1}) at all sites except BCh2 in 2008/09 (Table 3).

The reduction of yield due to the delayed planting was attributed primarily to the reduction of grain density (number per hectare; Table 3). Because grain density is known to be determined by biomass production (Uhart and Andrade, 1995; Paponov *et al.*, 2005; Sadras, 2007), the reduced biomass production that resulted from delayed planting appears to be the key factor responsible for the smaller yields in these treatments. We initially assumed that water availability would be one of the most important factors that limits maize production in Zambia, but precipitation during the 30 days after planting did not significantly explain the yield variation (Fig. 3). Instead, wind speed and air temperature proved to be the most significant factors that determined the response to delayed planting. Because C_4 plants (including maize) grow better at higher temperatures, lower temperatures and windy conditions (which can decrease plant surface temperature) can both reduce growth (Lafitte *et al.*, 1997; Soldati *et al.*, 1999). Soldati *et al.* (1999) examined the effects of low temperature during vegetative growth of maize on final leaf number, and showed that low temperatures decreased the final leaf number. Lower temperatures during the vegetative stage in the present study might therefore have had a direct negative impact on biomass production. At the same time, the growth reduction caused by lower temperatures would decrease canopy development, resulting in a lower ability to compete with weed species that are adapted to those conditions. Tollenaar *et al.* (1997) examined the effects of weeding under different levels of N input, and showed that the yield losses caused by weed competition were greater at low N input (a 48 to 64% reduction) than at high N input (a 17 to 20% reduction). In our experiment, we did not apply any fertilizers or manure, and this would have decreased the ability of the corn to compete with weeds, resulting in decreased growth. However, we did not measure the weed biomass and therefore cannot confirm this hypothesis.

We used a single local cultivar in the present study, but genotypic variations in plant responses to environmental differences will be an important issue to consider both to optimize crop yield at the study sites and to preserve food security in the face of global climate change, particularly given the limited resources available to farmers in southern Africa. Paponov *et al.* (2005) tested the response of grain production per unit N uptake in two maize genotypes, and found that one cultivar had 34% higher N-use efficiency for producing grain of sink capcity. The use of such efficient cultivars might increase the harvest index under the conditions of limited biomass production observed at the study sites, resulting in higher grain yield.

Accurate prediction of future maize productivity is essential to let nations ensure food security during a time of global climate change. The yield responses observed in the present study correspond well to model predictions (Tsubo *et al.*, 2005ab; Abraha and Savage, 2006). However, the prediction of changes during developmental stages differed from model predictions. Models of maize growth usually predict that later planting would decrease the growth period and decrease canopy radiation capture, thereby decreasing plant biomass and yield (Tsubo *et al.*, 2005ab; Abraha and Savage, 2006). However, it is interesting that in the present study, the delayed planting generally increased the period from sowing to flowering (Table 1), though despite that increase, biomass and yield were both reduced.

Ongoing global climatic change will have a strong impact on African maize productivity and food security (Lobell *et al.*, 2008). To increase the accuracy of predictions of the future impact on African maize productivity, more detailed measurements using local farmers and their common cultivation practices will be required.

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Notes on Recent Changes in Vulnerability in a Village in Zambia

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Abstract

This paper discusses two remarkable changes in organizing of groups in a village in Central Zambia, where I have conducted a field study since 1991. First, the burgeoning of small-scale group saving and credit, and second, an increase in the practice of lending a 'set' of cows and plow to be used for cultivation or weeding in the rainy season.

The burgeoning of small-scale savings and credit, referred to as Own Saving for Assets and Welfare Creation (OSAWE), started after 2007, following the failure of a credit and savings program initiated by an NGO. Despite the combined efforts of leaders in the village, the first credit and savings program in the village almost went bankrupt because of the deaths of prominent members, and the consequent failure in management and re-organization.

The second change—an increase in the practice of lending a 'set' of cows and a plow—was a gradual transition, related to the weakening of group farming. In the rainy season, upland cultivation is usually undertaken by group farming, which is organized and managed within extended families. This is a mutually beneficial system, that operates without any transaction of money or goods. However, in the new lending system, farmers receive money or goods, such as fertilizer or maize seed, for lending the 'set'.

The implications of these two changes are ambiguous from the perspective of the vulnerability of villagers, with two negative and two positive outcomes. First, the weakening of the practice of group farming, which helped farmers who were not equipped with a farming 'set', suggests that the vulnerability of non-equipped farmers has increased. Second, the failure of the initial small-scale savings and credit scheme also had a negative impact on those who consequently failed to benefit from it. There has been an increased feelings of mistrust among farmers who felt betrayed by the executives of the scheme, which may have a negative impact on future projects in the village.

Third, the burgeoning of new small groups, for savings and credit, indicates that a new channel of access to resources has opened up in the village, which could strengthen human networks. Fourth, the increase of 'set' lending can also mitigate the increased vulnerability of non-equipped farming families.

This study suggests that the vulnerability of a farmer or household cannot be defined by a single index that shows a cross section of social change, but should be examined by a group of indices. In daily life, people are affected by multiple complex factors, some of which increase vulnerability and some of which reduce it. Thus, it is important to determine ways of evaluating integrated vulnerability with a group of indices, each of which measures a single factor for analysis.

Understanding Agricultural Vulnerability, Human Behavior and Relief in Southern Province:
Thinking of Rural Farmer's Resilience

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1. Preface of Understanding Agricultural Vulnerability, Human Behavior and Relief

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A vicious cycle of poverty and environmental degradation is a major issue of global environmental problems. Especially in semi-arid tropics (SAT) including Sub-Saharan Africa and South Asia where the majority of the poor is concentrated, poverty and environmental degradation is widely prevalent. People in this area largely depend on rain-fed agricultural production systems and their livelihoods are vulnerable to environmental variability. The environmental resources such as vegetation and soil are also vulnerable to human activities. In order to solve these global environmental issues, a key factor is a recovery from, or a resilience of human society and ecosystems to, the impacts of environmental variability. The general concept of vulnerability expresses the multidimensionality of disasters by focusing attention on the totality of relationships between the social situations and environmental forces, produces a disaster. The major research question of vulnerability is methodology, such as: measuring and assessing vulnerability, including finding appropriate indicators for various aspects of vulnerability, up- and downscaling methods, and participatory methods. Especially in the social vulnerability, it is focus on the problems of complex human interactions, vulnerability of groups' people, and shocks like natural hazards, climate change, and other kinds of disruptions. Our final goal is to identifying factors affecting resilience and the ways to enhance the resilience of rural people to various horrible environments. Human activities are affected by both social and ecological environments. Conversely, human activities themselves affect both social and ecological environments. Thus there is a cross-interaction among them. Especially social and ecological environments are vulnerable to human activities. And sometimes total system including human activities recover or does not recover from any shocks.

From the mentioned backgrounds, we have been conducting various field investigations at Southern province, Zambia in order to understand what rural farmer's resilience is. As one of the common results of FY2009, we had established the approach to resilience. For an empirical approach to resilience, we focus on the mechanism and the speed of recovery in food consumption and livelihoods of agricultural households after shocks such as drought and flooding. The theme 4 has been conducting the visualization of spatial pattern of resource use from the agricultural household point of view.

Figure 1-1 shows our study area is located in Sinazongwe district, Southern province of Zambia. Here is located in Semi-Arid Tropics climate zone. The long term averaged annual rainfall in Sinazongwe is 695mm/yr. As for the field investigation, we set the study sites A, B and C where are located in the lower terrace, middle escarpment and upper terrace, respectively. This is the common study sites for our research project; thus many rain-gauges were installed at Sites A, B and C. The targets of field survey are total five villages; ASn and ASm (Site A), BKa and BCh (Site B) and CSa (Site C)

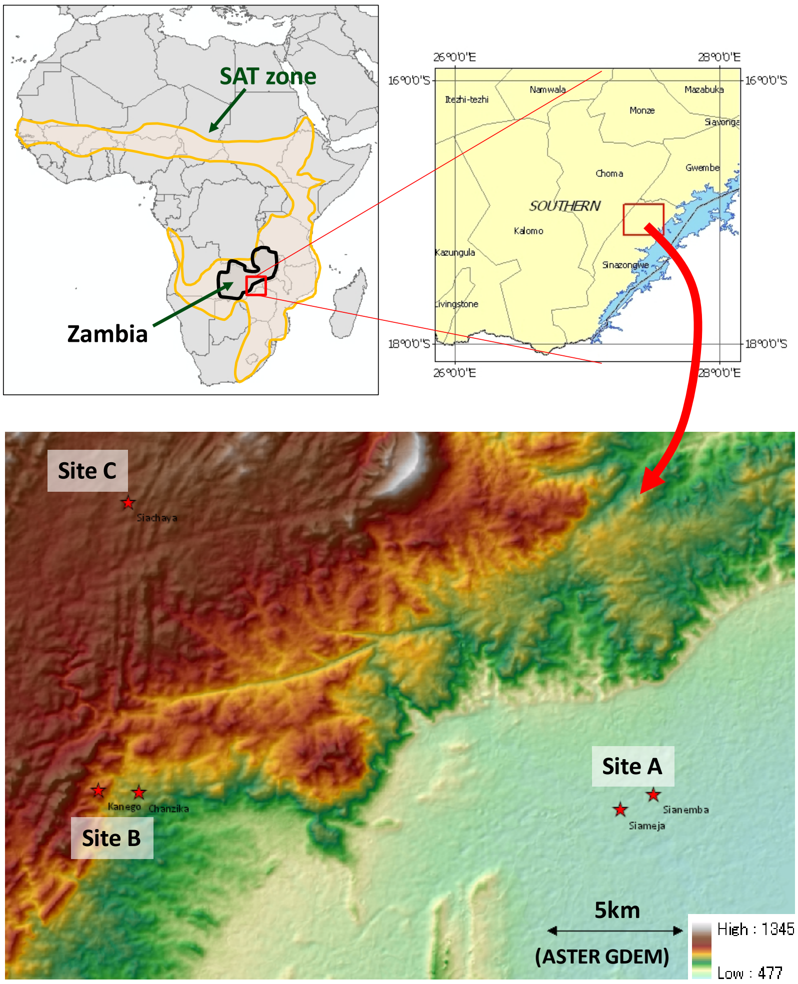

Figure 1-1. Our field sites in Southern province of Zambia

In this year, we conducted the field investigation data integration focus on understanding an agricultural vulnerability, human behavior and relief in Southern province in order to think the rural farmer's resilience. At the beginning of this year, we had discussed the concept of resilience in human activities and how to clarify the capacity at the household livelihood level. According to discussed approach which is illustrated in Figure 1-2 as the conceptual diagram of transition in potential production and behaviors to the climate change effects. In this paper's the climate change effect was the extreme heavy rain.

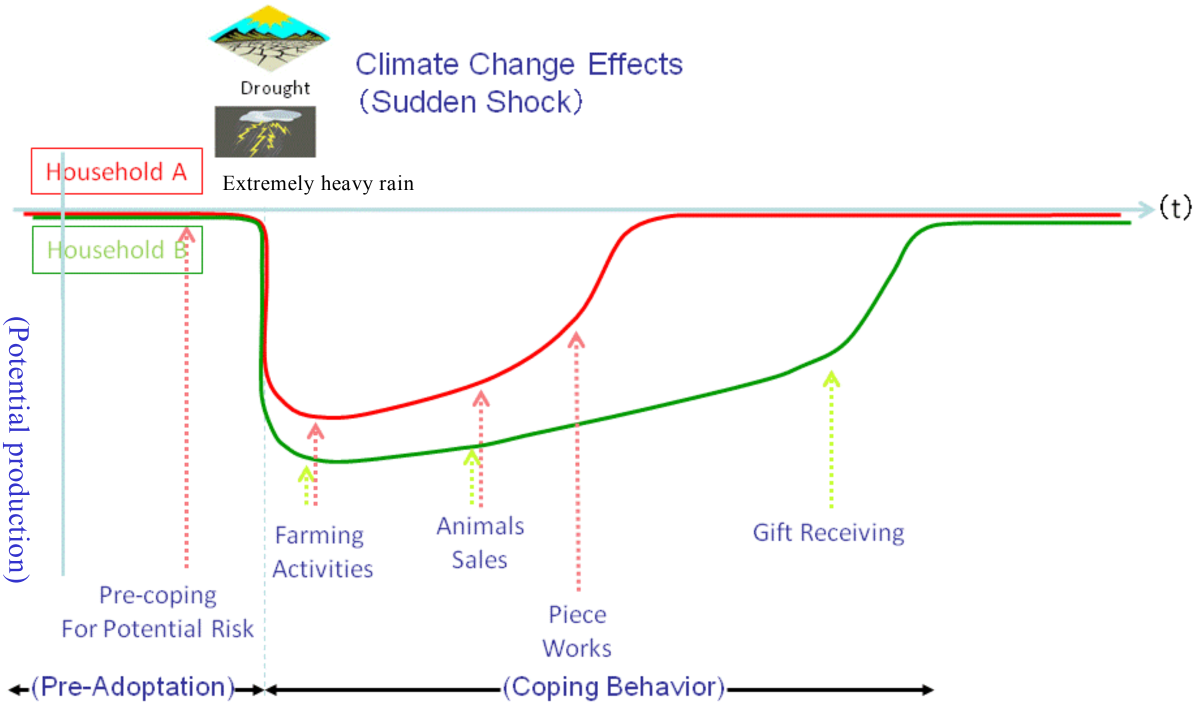

Figure 1-2. The Concept Diagram of Transition in Potential Production and Behaviors

In this figure, pre-adaptation for potential climate change risks and coping behavior of Household A and B are compared. Household A has much asset and labor, and Household B does not have. The horizontal axis corresponds to the time and the vertical axis corresponds to the potential production of all livelihoods activities. Detailed considerations are discussed in Chapter 2. The subsequent chapters discuss the various behaviors depicted in Figure 1-2. In Chapter 3, the multi-spatial and temporal data integration is discussed as the potential risk, an adaptation in land use and coping behavior in pre- and post shocks periods in farm activities is discussed in Chapter 4, and supports and requests for receiving gifts through mobile phone as social networks coping behavior is discussed in Chapter 5 respectively. In Chapter 6, we focused on the social institution and resilience for food shortage risk. In final Chapter 7, we conclude the results of understanding agricultural vulnerability, human behavior and relief as Postface.

2. Resilience of Rural Farmers and Approaches for Clarifying Capacity:
The Level of Household Livelihood

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Abstract

Resilience, in the context of this study, refers to insusceptibility to damage and the ability to recover after damage. Insusceptibility has two aspects, comprising robustness and flexibility in response to shock. This study sought to clarify the relationships between resilience and several other important concepts. Here, I describe an approach for clarifying the capacity for resilience. In addition, I examine the sequence of adaptation and coping behavior in the time period following a specific shock, with a particular focus on the resilience of rural farmers at the level of household livelihood.

2.1. Introduction

Resilience, in the context of this study, refers to insusceptibility to damage (Holling et al., 1995) and the capacity to recover after damage (Ellis, 2000). Insusceptibility is comprised of two aspects; robustness, and flexibility in response to shock.

Section 2.2 clarifies the relationships between resilience and several other important concepts which are discussed in resilience and vulnerability studies (Adger, 2000; Resilience Alliance, 2007; Terner et al., 2003; Watts and Bohle, 1993); capacity, external factors, exposure, assets, vulnerability, shock, disturbance and risk. Section 2.3 describes an approach for clarifying the capacity for resilience. Finally, section 2.4 discusses the sequence of adaptation before and coping behavior following a specific shock. This study has a particular focus on the resilience of rural farmers at the level of household livelihood.

2.2. Relationships between resilience and other concepts

Figure 2-1 and 2-2 illustrate the relations between resilience and several other important concepts at the level of household livelihood. This section describes the relationships between resilience and other concepts, providing examples to illustrate each concept.

In this study, resilience consists of three components; capacity, external factors and assets. The term exposure is used as a substitute for external factors in vulnerability studies (Bohle, 2001; Chambers, 2006). Household risk is composed of potential risk and manifested risk. Emergent risk may lead to a change in the properties of potential risk. Potential risk can be thought of as vulnerability, emergent risk can be restated as disturbance.

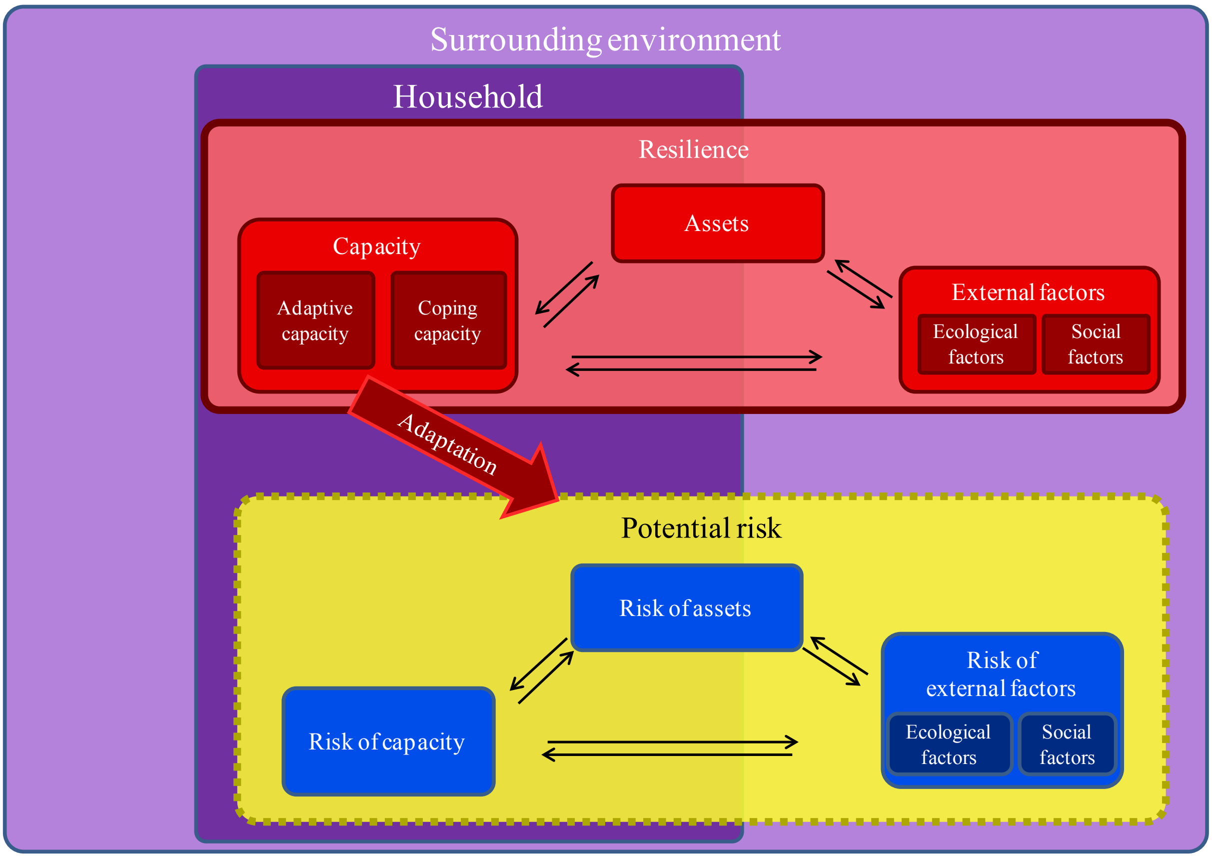

Figure 2-1. Relationship between resilience and other concepts

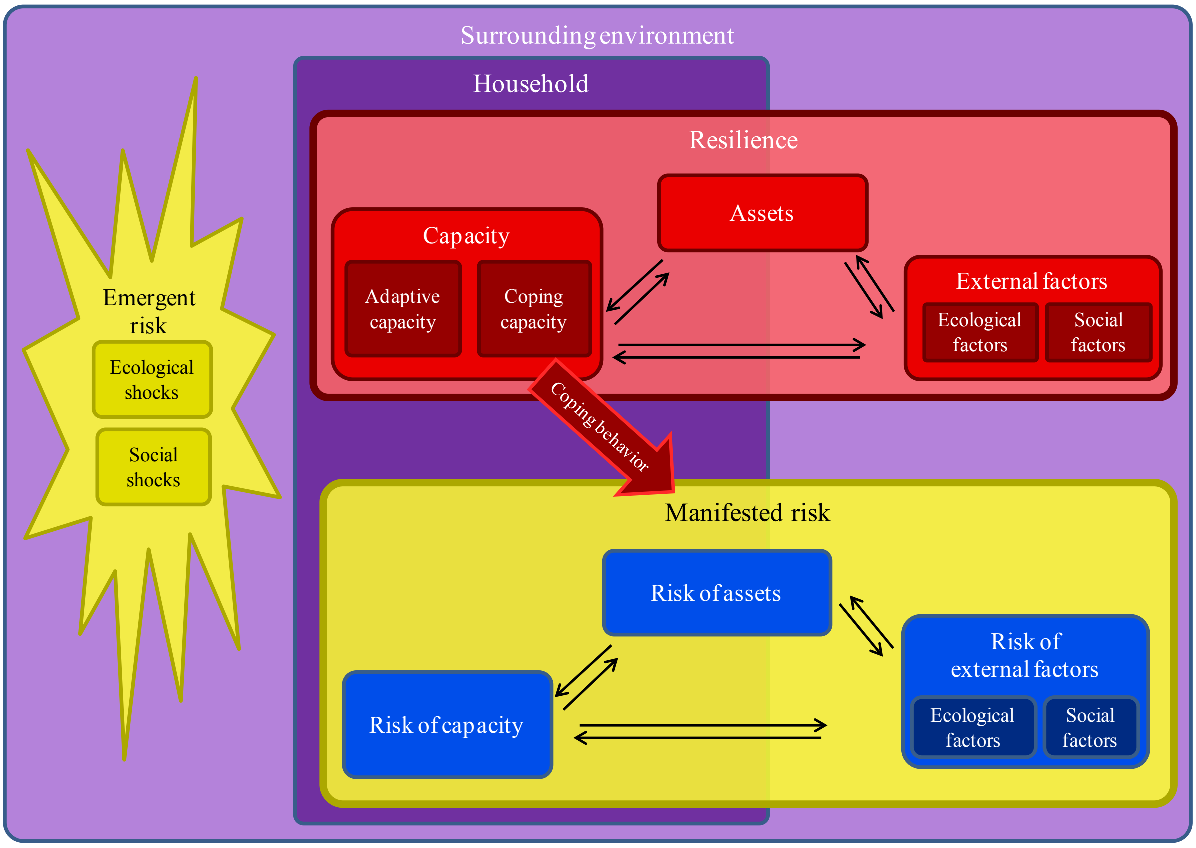

Figure 2-2. Relationship between resilience and other concepts: changed properties of potential risk by emergent risk

Various potential risks are related to each component of resilience; low capacity, negative external factors and insufficient assets. When emergent risk is more extensive than expected, potential risk is manifested; that is, Figure 2-1 shifts to Figure 2-2. Emergent risks can be divided into ecological shocks and social shocks. Ecological shocks include light rain, heavy rain, disease epidemic, insect damage, bird damage, other animal damage, and so on. Social shocks include political, economic, cultural and legal changes etc.

External factors can be divided into ecological factors and social factors. Ecological factors include geographic and climatic factors, etc. Social factors include political, economic, legal, historic and cultural changes etc.

Capacity is divided into adaptive capacity to potential risk before shock and coping capacity with manifested risk after shock.

Three components determine whether resilience is in a high or low state at the level of household livelihood: capacity, external factors and assets. In cases where capacity is high, external factors are positive and assets are sufficient, the state of resilience is high.

Figure 2-3 shows a conceptual diagram representing resilience of rural farmers at the level of household livelihood. In the figure, the X-axis represents assets, the Y-axis represents external factors, the Z-axis represents assets, and the volume of the cube on sides X, Y and Z-axes represents resilience. As each component improves, each axis lengthens, and as volume increases, resilience also increases.

For example, if rainfall (an external factor) is extremely bad (i.e. drought or flooding), agricultural production may fall to a low level. However, if people with a high capacity for resilience can practice suitable farming technology to offset the rainfall conditions, the reduction in agricultural production may be absorbed or cancelled out.

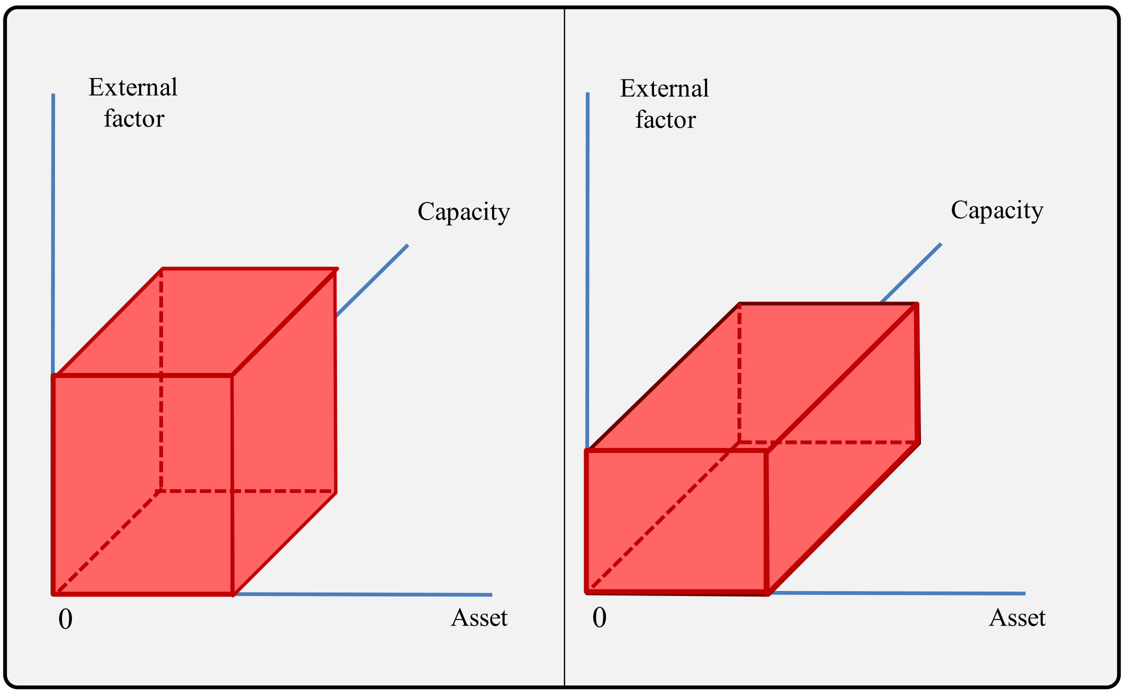

Figure 2-3. Three components determining whether resilience is in high or low state.

2.3. Approach to clarify capacity

The quality of prediction and analysis of external factors has been significantly increased in recent years with improvements in meteorological data, satellite image data and socioeconomic data. Meanwhile, a standardized method of analysis for determining capacity as an internal factor has not yet been established (Shimada, 2008). As such, this study focuses on capacity as one component of resilience.

Capacity itself is difficult to measure and observe. However, when capacity is considered in terms of the behavioral adaptation of farmers to potential risks before a shock occurs, and the ability to cope with the manifested risk after shock, it can be measured and observed. The current report empirically analyzes evidence of adaptation and coping behavior by farmers in the Southern Province of Zambia, located in a semi-arid tropical region with fluctuating rainfall, as a case study for clarifying the mechanisms underlying capacity.

2.4. Adaptation and coping behavior in time series

Adaptation and coping behavior varies according to the nature of a shock. The current report focuses on extremely heavy rain as an ecological shock, and analyzes farmers' behavior across time, in terms of how they adapt and cope at the level of household livelihood.

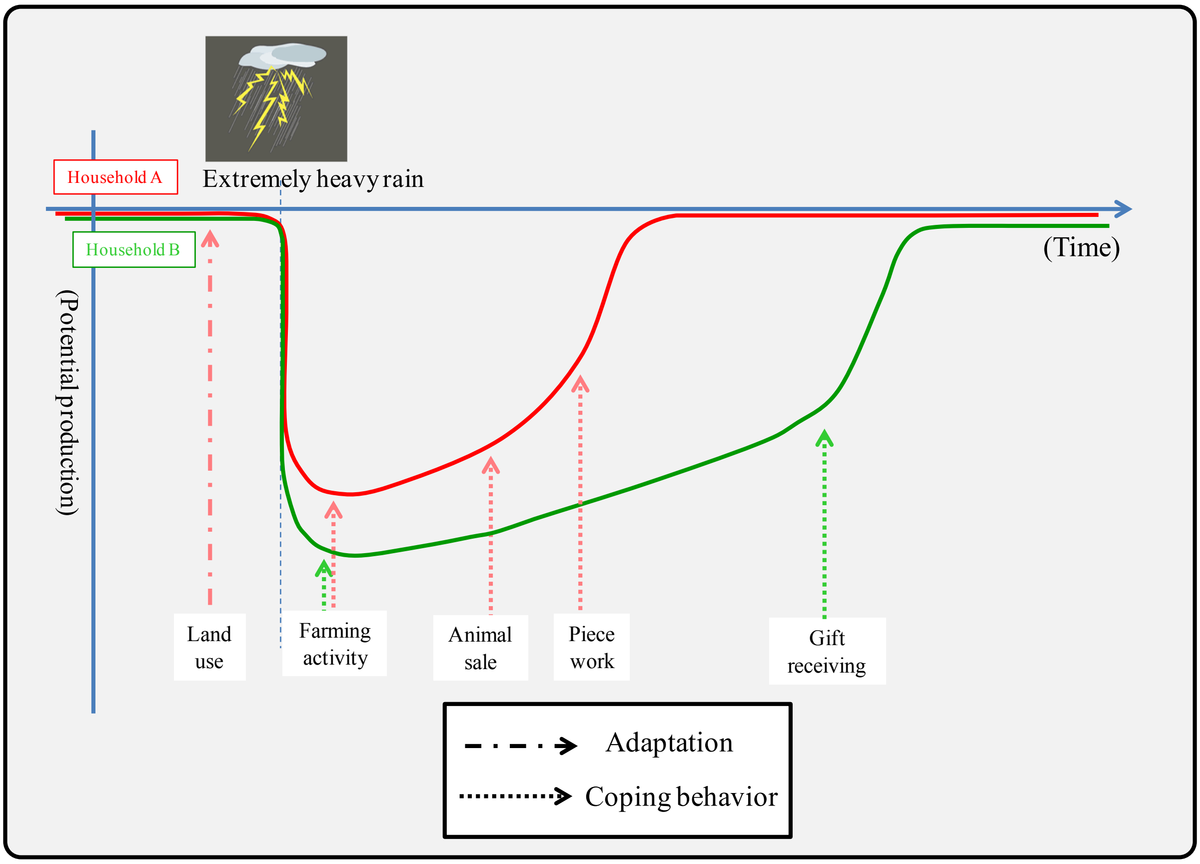

Figure 2-4. Conceptual diagram of transition in potential production and behaviors to extremely havy rain

Figure 2-4 shows a conceptual diagram of the transition in potential production and behaviors in response to extremely heavy rain. In this figure, the adaptation and coping behavior of Household A and B are compared. Household A has a relatively large amount of assets and labor, both of which are lacking for Household B. The horizontal axis represents the time, and the vertical axis represents the potential production of all livelihood activities Figure 2-4.

As shown in Figure 2-4, Household A adapts to the potential risk of geographical factors with land use, in contrast with Household B, which does not. Following the extreme rain event, Household A suffers less of a decline in potential production relative to Household B. Household A copes with the post-shock decline by undertaking additional farming activity, animal sale and piecework, so that potential production reaches pre-shock level. Meanwhile, Household B copes by undertaking additional farming activity, but cannot sell any animals or practice piecework. Eventually Household B is compensated by gifts through a social network.

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3. Multi-spatial and Temporal Data Integration for Understanding Agricultural Activity and Vulnerability:
A case study of rural farmer's villages

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Abstract

This chapter describes field investigations and geo-spatial/temporal analysis of livelihood at the village level, with a particular focus on agricultural activities, using a multi-disciplinary approach. As a basic analysis, the integration of all data collected so far has been carried out to understand the situation at the level of the household or village, in terms of adaptation and capacity to cope with a risk caused by an unexpected ecological or social shock.

3.1. Introduction

This research sought to clarify the relationships between social-ecological vulnerability and human activities from a multi-disciplinary point of view using geo-spatial information in combination with social and economic analyses. To this end, it was necessary to collect geo-spatial and temporal data relevant to people's livelihood and the environment in which they live.

We collected crop and field data by conducting field investigations, aerial photographs and satellite images, and integrated and analyzed the data to understand agricultural activity and its vulnerability to risks.

The study area covered sites A, B and C, located in Sinazongwe district, Southern province.

3.2. Data collection and analyses

3.2.1. Obtained and collected data list

Table 3-1 shows a list of all geo-spatial data we have obtained and collected so far. Since FY2007, we have carried out a field investigation to document the boundaries of all crop fields of all households in five villages. We also obtained aerial photographs taken around our study area in 1970, 1980 and 1991 by the Survey Department of Zambia. Additionally, we obtained satellite images obtained by optical sensors with middle-high resolution to identify seasonal changes in the pattern of land use / land cover and the effects of natural vegetation and cultivated land from 1972_3 to the present. These satellite images cover our study area (including Site A, B and C). Data were processed to have the same map coordinates using the universal transverse mercator (UTM) system (Zone35 South, WGS84) map projection.

Pre-processing and analysis were conducted in FY2010, for the data obtained and collected mainly after 2006.

Table 3-1. Geo-spatial data for our study site area

Aerial photos/ crop allocation data	Satellite images						
	Satellite/Sensor		Resolution (m)	Obs. Date	Season	Remarks	Geometric correction
1970 Aerial photos	Landsat	MSS	80	1972/11/23	From dry to rainy		
	Landsat	MSS	80	1973/3/11	Rainy		
1980 Aerial photos	Landsat	TM	30	1986/11/17	From dry to rainy		
	Landsat	TM	30	1987/2/21	Rainy		
1990 Aerial hotos	Landsat	TM	30	1990/3/1	Rainy		
	Landsat	TM	30	1995/1/26	Rainy		
	Landsat	ETM	30/15	2001/8/30	Dry		
	Landsat	ETM	30/15	2001/10/1	End of Dry		
	Landsat	ETM	30/15	2001/12/20	Rainy		OK
	Terra	ASTER	20	2002/2/6	Rainy		OK
	Landsat	ETM	30/15	2002/2/22	Rainy		
	Landsat	ETM	30/15	2002/5/13	Harvesting		
	Landsat	ETM	30/15	2002/8/17	Dry		
	Landsat	ETM	30/15	2002/10/20	End of dry		
	Landsat	ETM	30/15	2002/11/21	From dry to rainy		
	Terra	ASTER	20	2002/11/21	From dry to rainy		OK
	Terra	ASTER	20	2003/4/30	End of Rainy	Cloud coverage 10%	OK
	Terra	ASTER	20	2003/6/1	After Harvest		OK
	Terra	ASTER	20	2003/7/3	Dry		OK
	Terra	ASTER	20	2003/11/24	From dry to rainy		OK
	Terra	ASTER	20	2004/1/11	Rainy	Cloud coverage 10%	OK
	Terra	ASTER	20	2004/7/21	Dry		OK
	Terra	ASTER	20	2004/8/22	Dry		OK
	ALOS	PRISM	2.5	2006/7/19	Dry	Covering siteA only	OK
	ALOS	AVNIR-2	10	2006/9/3	Dry		OK
Rainy crop data 2007/8	ALOS	AVNIR-2	10	2007/9/6	Dry		OK
	ALOS	AVNIR-2	10	2007/10/22	End of dry		OK
	ALOS	AVNIR-2	10	2008/4/23	Harvest	Cloud coverage 10%	OK
Dry crop data 2008	ALOS	AVNIR-2	10	2008/6/8	End of harvest		OK
	ALOS	AVNIR-2	10	2008/9/8	Dry		OK
Rainy crop data 2008/09	ALOS	PRISM	2.5	2008/10/24	End of dry	DEM / covering siteB and C	OK
	ALOS	AVNIR-2	10	2008/10/24	End of dry		OK
	ALOS	AVNIR-2	10	2009/3/11	End of rainy	Cloud coverage 10%	
	ALOS	AVNIR-2	10	2009/4/26	Harvest		OK
Dry crop data 2009	ALOS	AVNIR-2	10	2009/9/11	Dry		OK

3.2.2. Crop allocation map

Field investigations for crop allocation mapping were carried out for more than 220 households in the villages of ASn, ASm (Site A), BKa, BCh (Site B) and CSa (Site C) in two rainy seasons of 2007_08 and 2008_09 and two dry seasons of 2008 and 2009.

To generate the crop allocation map, we used a portable global positioning system (GPS) to measure boundaries at a sub-field level that recognized different crops at Sites A, B and C. In addition, we conducted interviews with all households to obtain information about field names, topography, soil type, crops, cultivated varieties and types of fertilizer, to understand households' coping strategies related to climate variations. The boundaries of crop fields and attributes such as the names of crops and their owners were converted to the general geographic information system (GIS) data format with a Shape file (.shp).

Furthermore, we determined whether each crop field had been damaged by a natural disaster, such as drought or flood, and which crops were replanted after damage.

3.2.3. Generation of Digital Elevation Model

To generate a Digital Elevation Model (DEM) and ortho aerial photo images of the large scale of our study area, we used aerial photos taken in 1991 with a scale of approximately 1 : 30,000. However, because an area around site C was not completely covered, we also used a stereo pair of ALOS/PRISM images taken on 2008/10/24 from nadir, forward and backward views.

We processed the stereo pairs of both aerial photos and ALOS/PRISM images. We used XYZ coordinates of UTM (Zone35 South, WGS84) read from Google Earth as the ground control points (GCPs) for extra orientation. Figure 3-1 shows the Digital Elevation Model (DEM) around our study sites. The grid size of the DEM was 5 m.

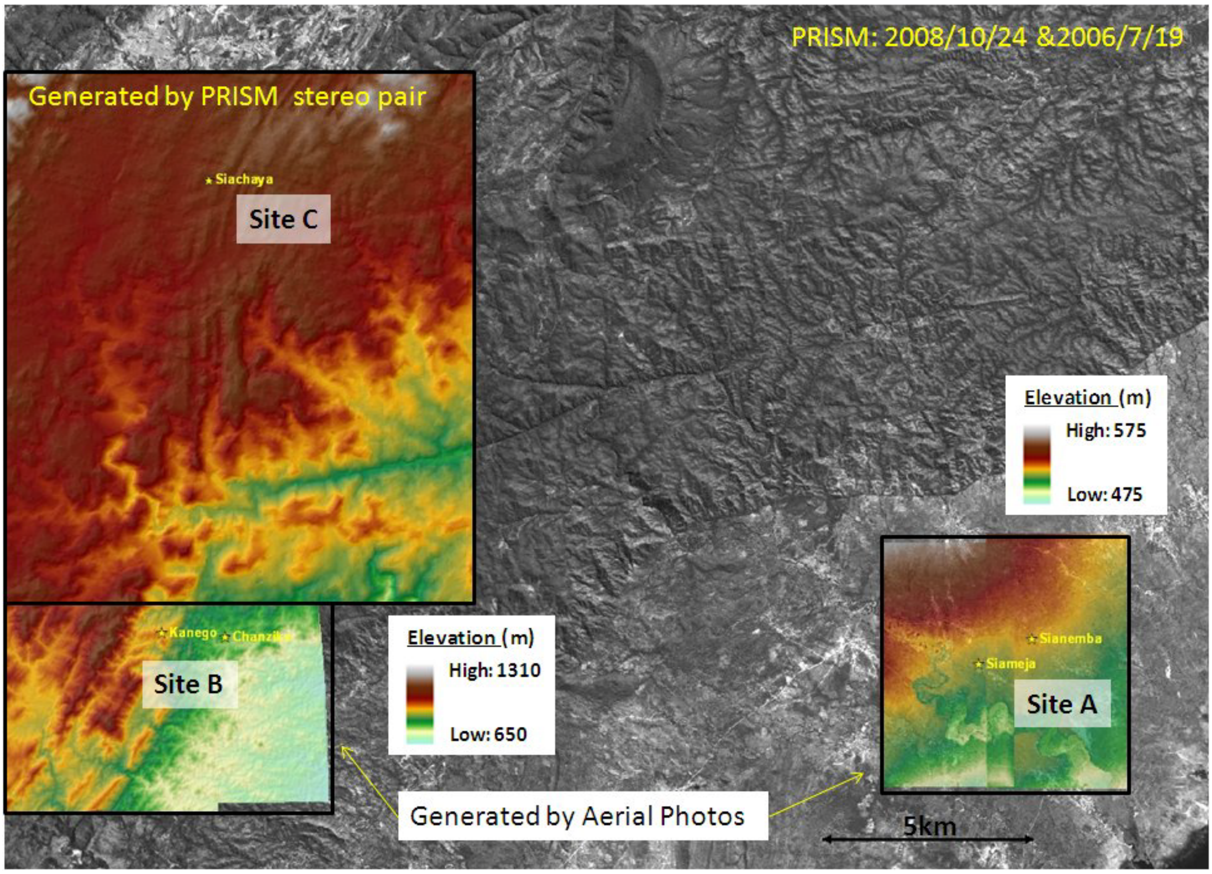

Figure 3-1. DEM generated by aerial photos and ALOS/PRISM stereo pair

3.2.4. Geometric correction for satellite images

Multi-spectral satellite images are useful for recognizing seasonal land surface conditions. In FY2010, we processed the geometric correction for all ALOS/AVNIR-2 images. The AVNIR-2 sensor has four spectral bands of visible Blue (band1), Green (band2), Red (band3) and Near Infrared (band4). Here, we used the same map coordinates from Google Earth as the ground control points (GCPs) for geometric correction. The location accuracies of the geometric corrections for all images were less than one pixel (10 m).

Figure 3-2 shows the results after geometric correction of ALOS/AVNIR-2 false color images taken on 2008/9/8, 10/24, 2009/9/11 in the end of dry season and 2009/4/26 at the end of the rainy season. These images are different visually between the ends of the dry and rainy seasons.

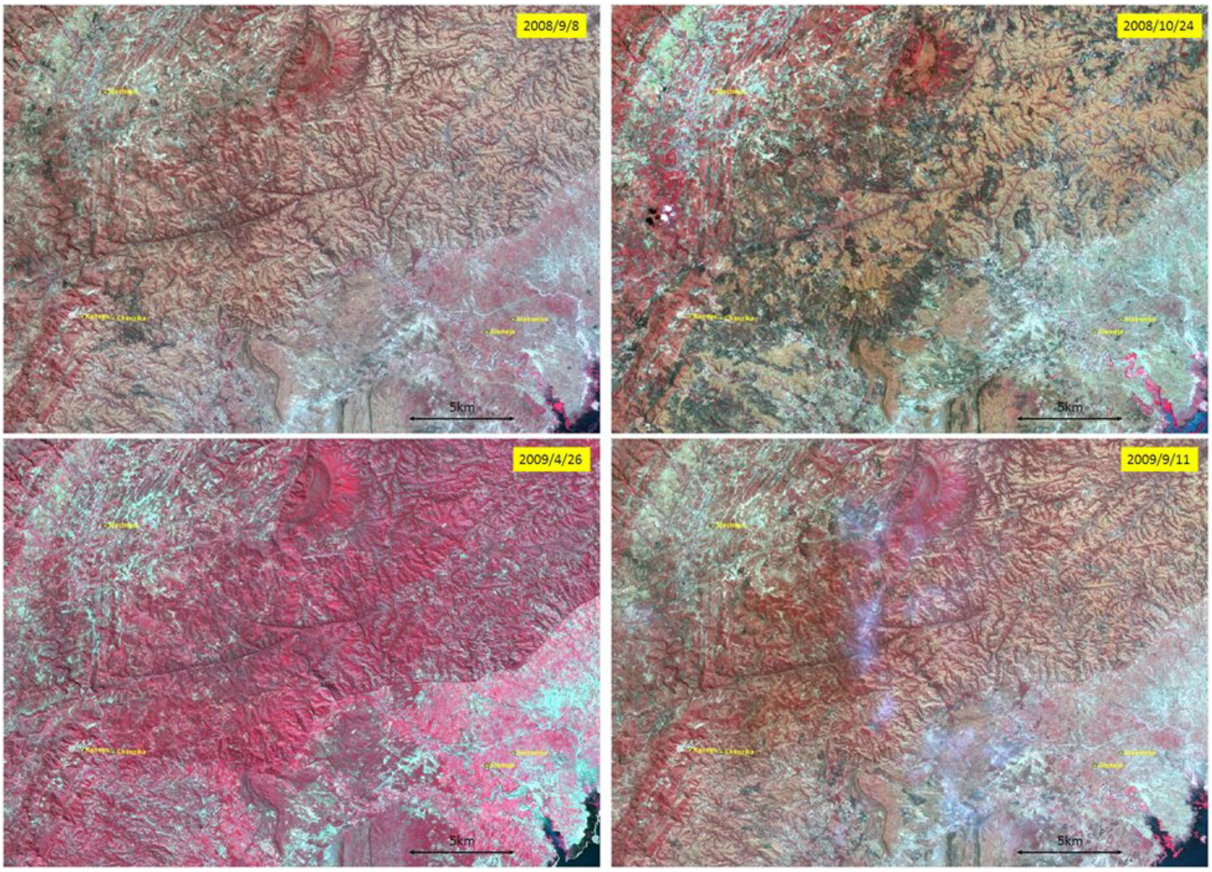

Figure 3-2. Samples of geometric corrected ALOS/AVNIR-2 false color images (RGB:b432)

3.2.5. Additional data

We also collected location data for all of the households we examined, and other facilities such as schools, churches, watering points, water pumps and markets/shops, using portable GPS. Data regarding the main roads and streets commonly used in these areas were also measured with GPS and entered by visual interpretation on the aerial photographs and the ALOS/PRISM ortho images.

Figure 3-3 illustrates the distribution of the households and other commonly used facilities. These kinds of location data can be used to analyze the relationship between the locations of households and crop fields and accessibility to facilities and natural resources. The accessibility of facilities in BKa and BCh (site B), which were established in the 1990's, is more difficult than access at other sites. However, the forest resource has been largely retained in site B, providing an advantage over some other areas. Therefore, some of households in site B have another livelihoods such carpenter, plank and so on.

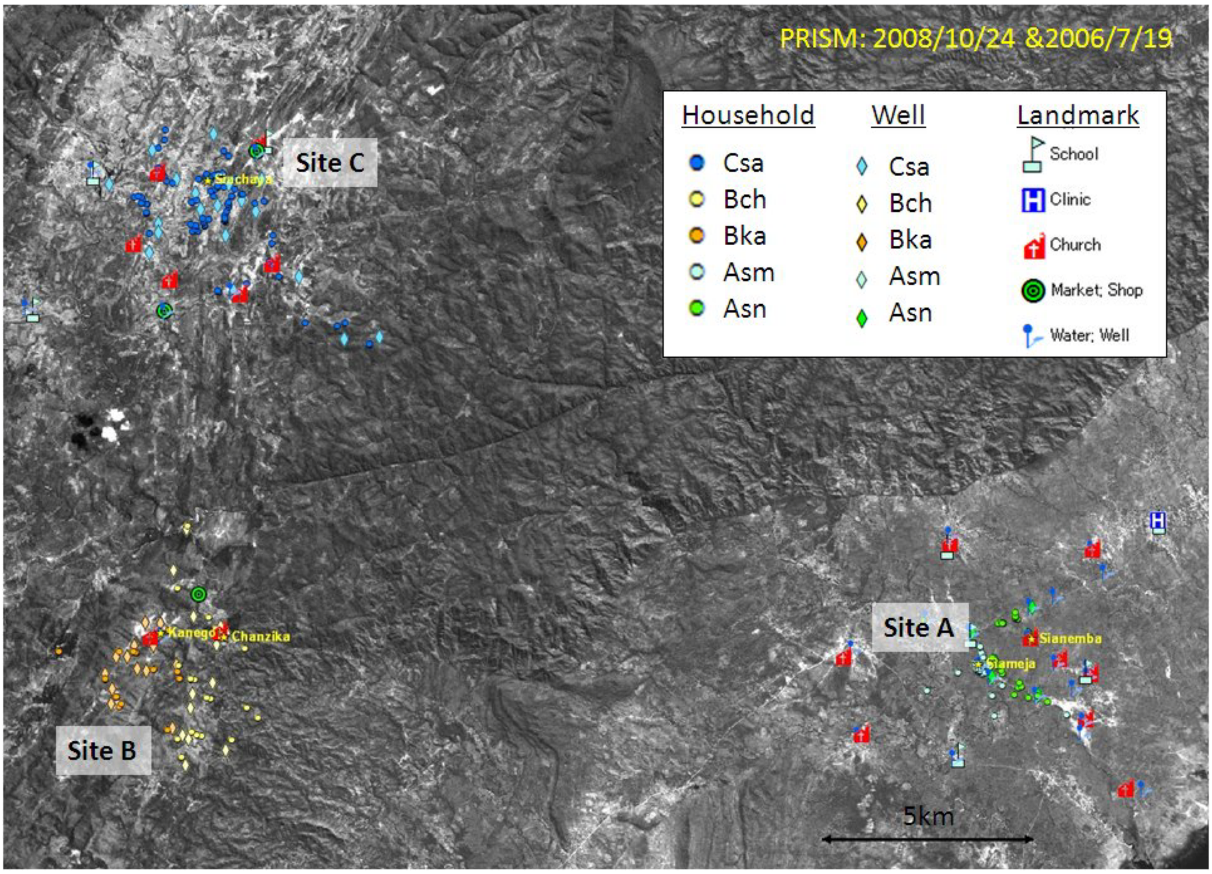

Figure 3-3. The locations of the examined households and commonly used facilities

3.3. Results and discussion

3.3.1. Rainy crop area from 2007_08 to 2008_09

The characteristics of the crop field location were different at each study site. At site C, almost all of the crop fields were distributed along the mountain ridges and the gentle slope of the hill. The crop fields at site B were distributed around very steep hillsides. The terrain at site A is basically flat, and the soil is more fertile than that at sites B and C.

Figure 3-4 shows the crop allocation map at site A during two rainy seasons of 2007_08 and 2008_09. The ALOS/PRISM image is shown in the background. The areas shown in green indicate the overlapped fields of both rainy seasons in 2007_08 and 2008_09.

Figure 3-5 shows a graph of the total crop field area in five villages during two rainy seasons of 2007/2008 and 2008_09. Total crop area in the 2008_09 rainy season appeared to decrease compared to the rainy season of 2007_08. More than 67% of rainy season crop fields in 2008_09 overlapped with the crop fields of the 2007_08 rainy season.

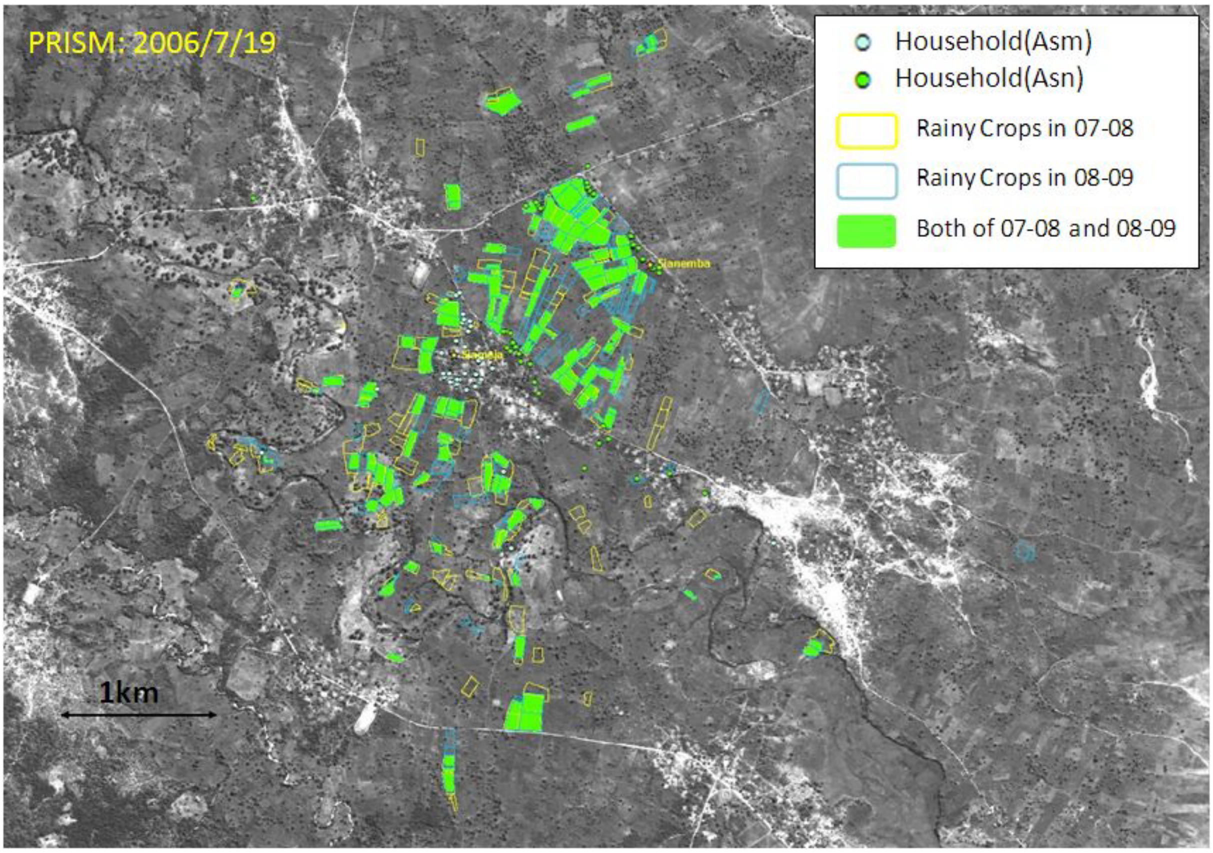

Figure 3-4. Crop field distribution at site A during two rainy seasons of 2007_08 and 2008_09

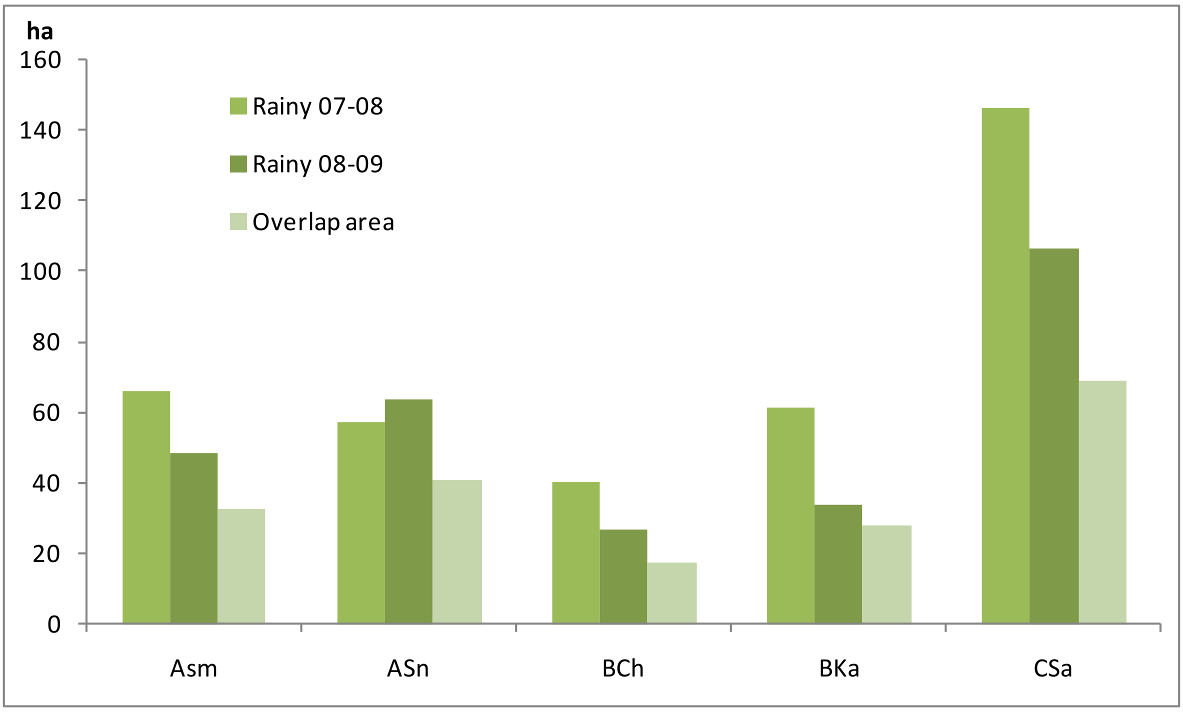

Figure 3-5. Total crop field area during two rainy seasons of 2007_08 and 2008_09

3.3.2. Topographical features of agricultural land use

To examine the topographical conditions of each households' crop fields, the slope was calculated from the DEM and classified into seven classes: Flat (0-1, units: degree), very gently sloping (1-3), gently sloping (3-8), sloping (8-15), steep (25-40), very steep (more than 40), in accord with the Handbook for soil survey (Japanese Society of Pedology, 1978). The mountain ridges and small valleys or thalwegs were detected with the method of water flow accumulation (Jackson and Domingue, 1988).

Figure 3-6 shows the results of slope classification. It is easy to recognize the flat, gently sloping and steep areas at each site.

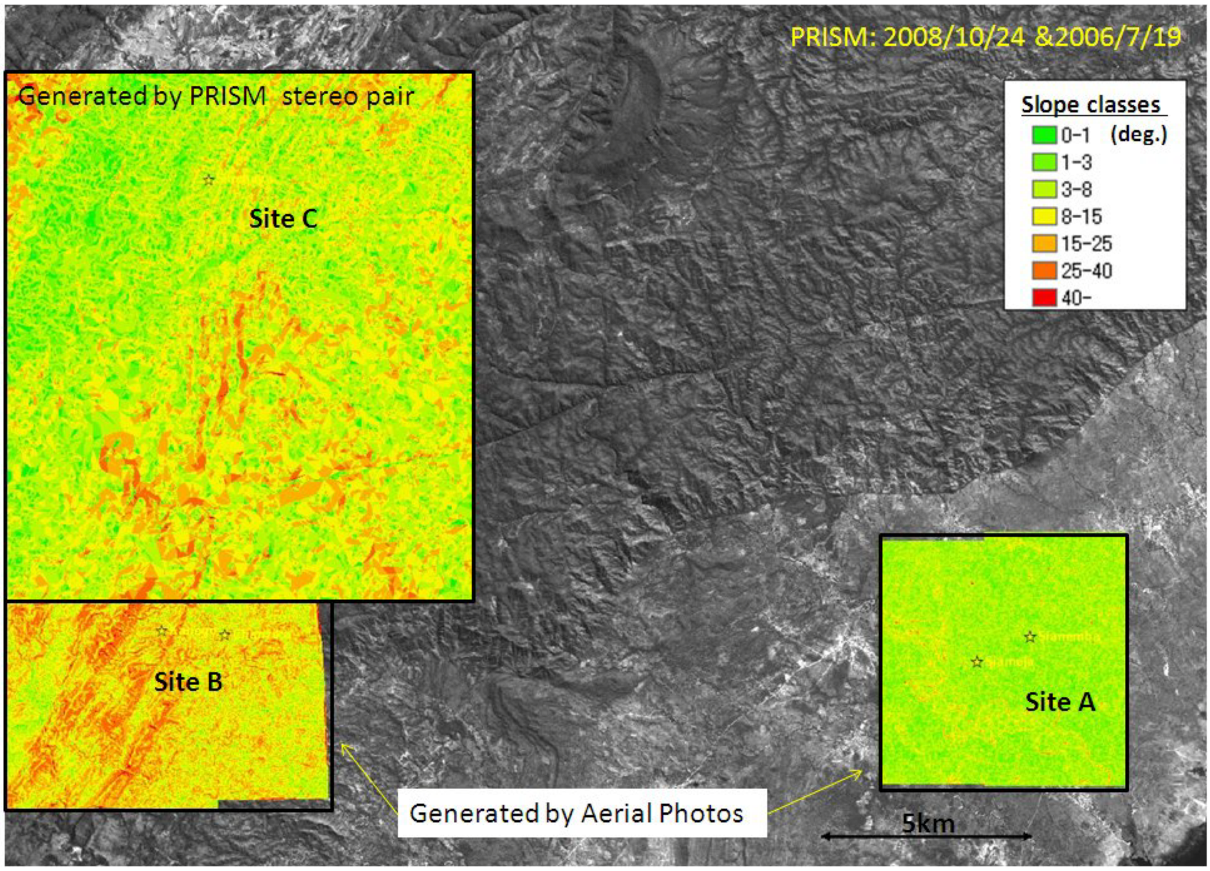

Figure 3-6. Slope classification

Figure 3-7 shows the topographic features of mountain ridges and valleys / thalwegs and the crop field distributions at site B as an example. At site B, all crop fields were located in topographical areas featuring mountain ridges, hill sides and valleys / thalwegs. We analyzed the areas of seven slope classes, mountain ridges and valleys / thalwegs for each crop field. Therefore, we were able to determine the topographical situation of the crop fields of each household in assessing *ex ante* adaptation for ecological risks such as drought and heavy rain. Adaptation at the household level is discussed in Chapter 4.

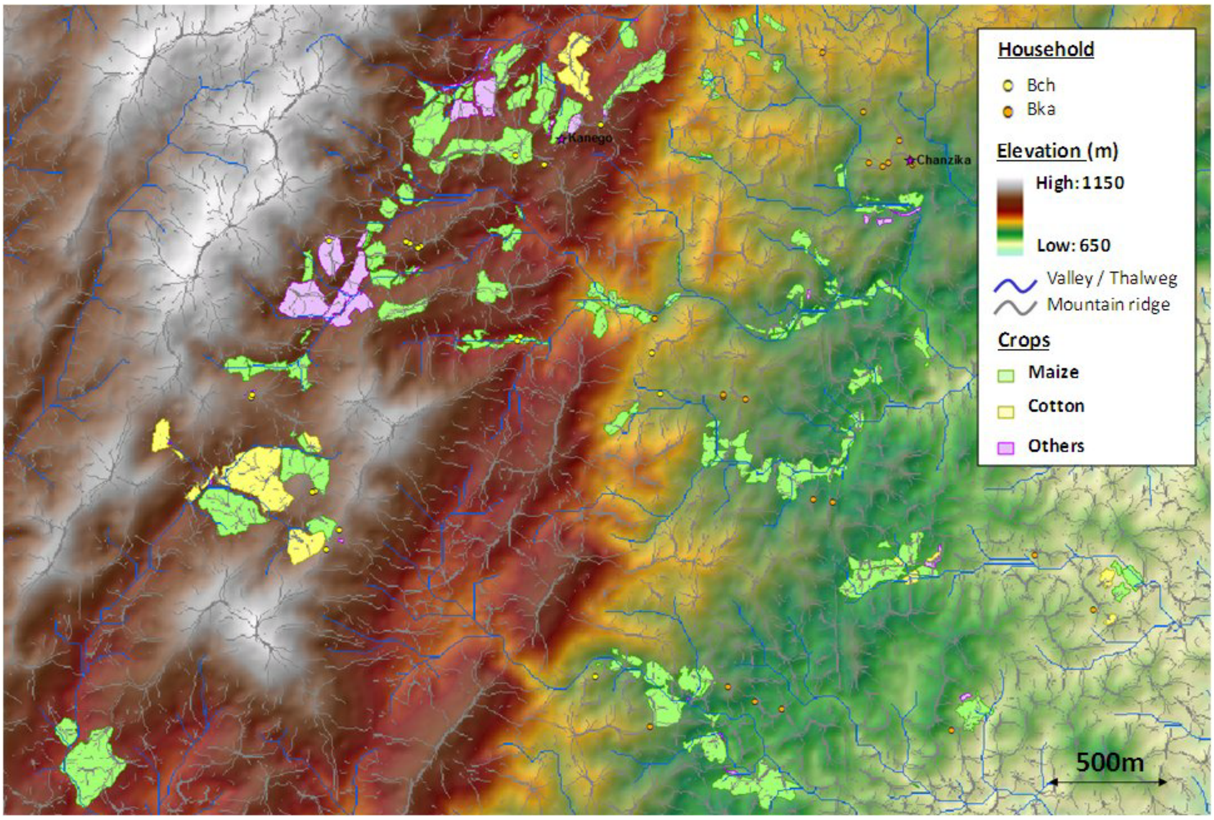

Figure 3-7. Topographic structures and crop fields in part of site B

3.3.3. Seasonal land use / cover characteristics

According to the crop calendar constructed from Miyazaki's interviews about periods of land preparing, planting weeding and harvesting at three sites, the land preparation involved clearing and burning rainy crop fields, performed from September until the beginning of November. In addition, many pictures were taken in the various seasons at three study sites. Figure 3-8 shows samples of the pictures taken on 2007/9/13 in the dry season at Bka.

Figure 3-8. Samples of pictures taken on 2007/9/13 in BKa (by Miyazaki)

Comparing field data with the geo-corrected ALOS/AVNIR-2 images shown in Figure 3-2 allows the characteristics of land use / land cover in each season to be understood. In Figure 3-2, the false color images taken on 2008/9/8 and 10/24 show the charcoal color. These areas show the land cover situation after the burning. In addition, smoke and haze can be seen in the image taken on 2009/9/11. The image taken on 2009/4/26 appears redder than other images on the whole, and the areas around our study sites reveal brightness at that location. The brightness areas on this image show the crop fields after harvesting. These findings suggest that it might be possible to automatically distinguish between cropland and natural vegetation fields using these seasonal characteristics.

3.4. Predicted results in FY2011

We plan to collect and analyze various types of multi- spatial and temporal data in FY2011.

First, the classification of land cover/use in rainy and dry seasons around three study sites will be carried out using ALOS/AVNIR-2 images, crop calendar and field pictures as ground truth data. Second, spatial analysis of the land cover/use and topographical features will be performed. We will then examine the potential risks and ecological shocks at the level of villages or study sites.

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Yamashita M., Miyazaki H., Ishimoto Y. & Yoshimura M. 2010. Multi-temporal and spatial data integration for understanding the livelihood in village level. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVIII, Part 8, 827-830.

4. Adaptation and Coping Behavior of Farmers during Pre- and Post-Shock Periods

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Abstract

Farmers use both on-farm and off-farm-based coping strategies to mitigate the impact of heavy rain. The choice of coping behaviors tends to vary with access to resources. As an example of on-farm-based coping behaviors, farmers can change land use patterns by switching crops. As an example of off-farm-based coping behaviors, heavy rain affected farmers can compensate for lost income by selling livestock and fishing.

4.1. Introduction

When assessing farmers' adaptation and coping behavior as elements of household resilience, it is important to clarify how farmers actually adapt to climate variability during the pre-shock period, and how they cope during the post- shock period.

In this chapter we describe adaptation strategies in land use, and coping behavior in terms of on- and off- farm activities.

4.2. Adaptation to climate variability

Figure 4-1 illustrates the relation between maize harvest and three characteristic rainfall amounts. Figure 4-1 a), b) and c) show an adequate rainfall year, a drought year and a heavy rainfall year, respectively. Maize fields are distributed around different topographic positions including ridges, slopes and valley bottoms. In an adequate rainfall year, maize harvest is a normal harvest for each topographic position. In a drought year, we expect fields on valley and slope near the valley to retain an adequate harvest, while fields on ridges and slopes near ridges are unlikely to produce an adequate harvest because of a shortage of rainfall. In heavy rainfall years, however, we expect fields on ridges and slopes near ridges to acquire adequate harvest, but fields on valley and slope near the valley may not acquire adequate harvest because of flooding. These predictions were confirmed by field experience from 2007_08 to 2009_10.

Thus, the maize harvest varies every year depending on rainfall and topographic position. Thus, if a farmer possesses maize fields at each topographic position, they can avoid severe negative consequences of climate variability such as drought or heavy rainfall. However, not all farmers have access to fields at all topographic positions. Therefore, it is important to know where each household's fields are located when considering their adaptation to climate variability.

Table 4-1 indicates the potential risk of heavy rainfall for a rainy season maize field, for each household in 2007_08. The number in parentheses indicates the potential risk of heavy rainfall. We supposed that if a farmer has three maize plots of the same size, the potential risk can be estimated by three numbers as follows. The value is 1 for a ridge plot, 2 for a slope plot and 3 for a valley plot.

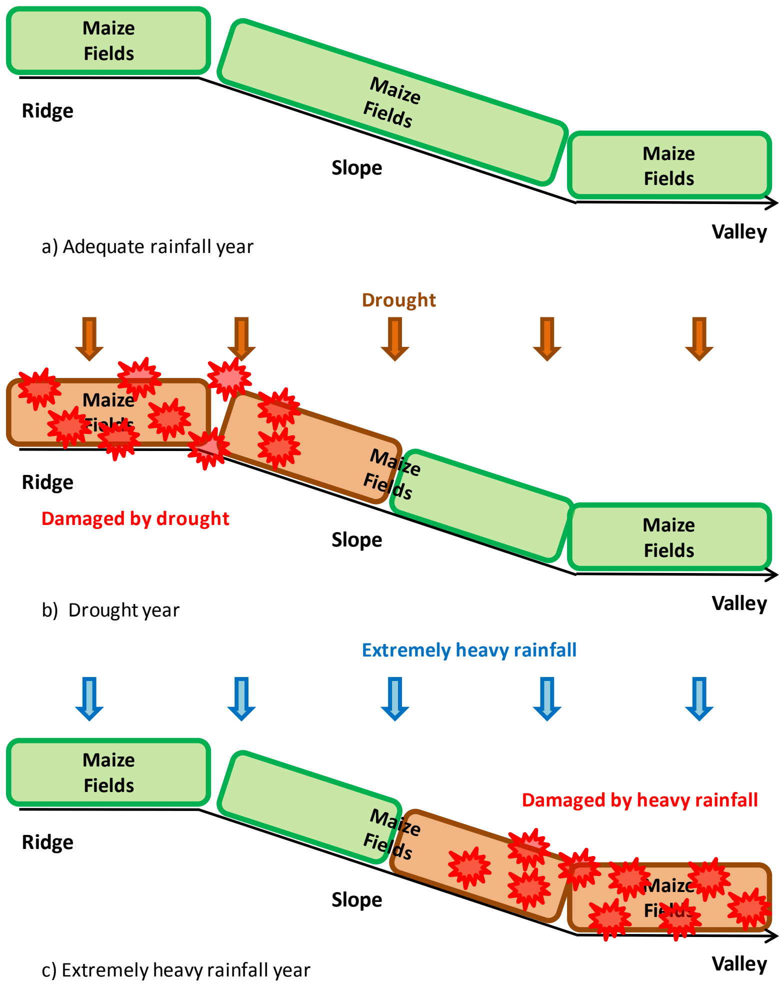


Figure 4-1 Relationship between maize harvest and three characteristic rainfall amounts, a) Adequate rainfall year, b) Drought year and c) Extremely heavy rainfall year

Table 4-1 Potential risk of heavy rain at rainy season maize fields in 2007_08

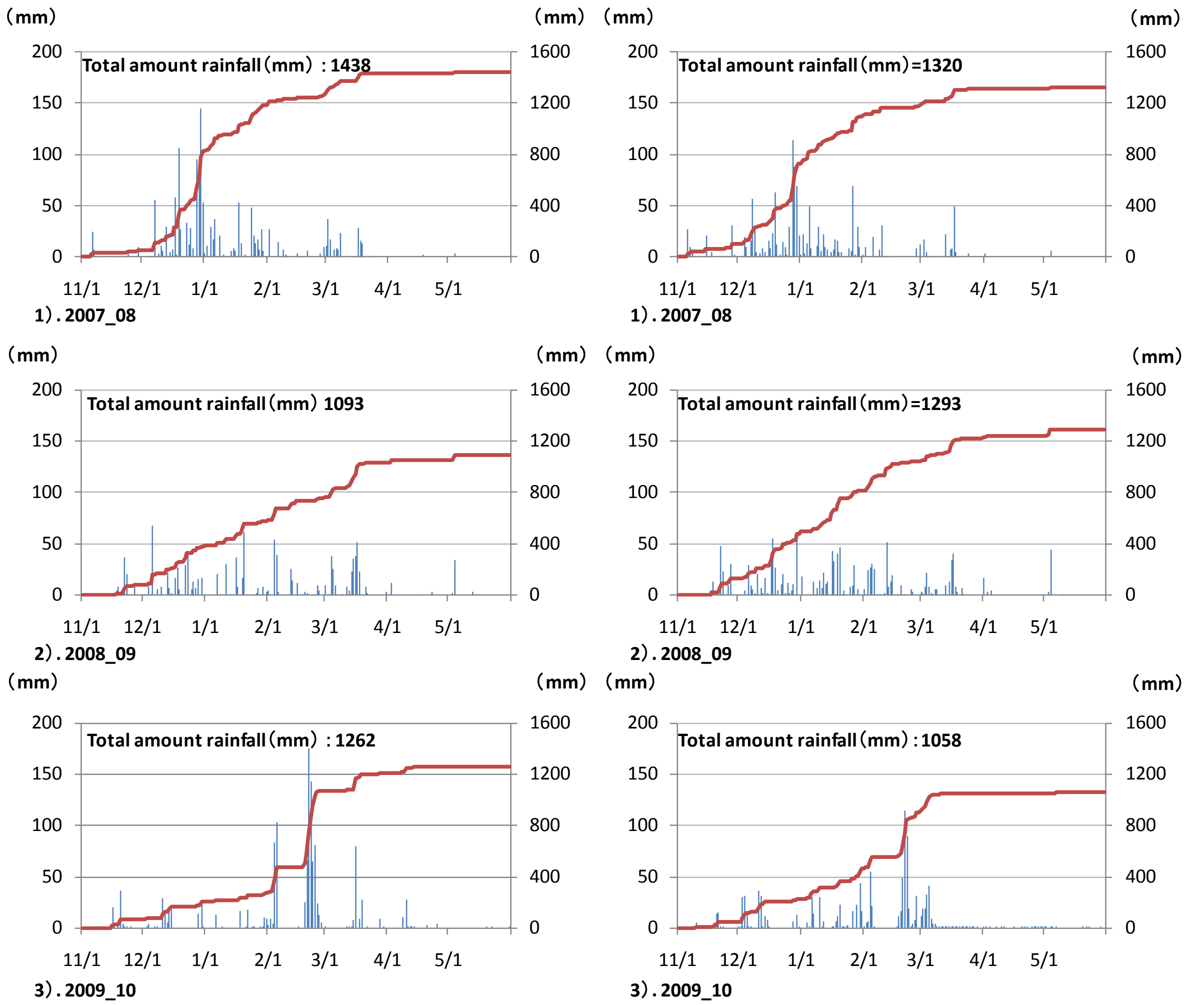
	Households Number	Valley (9.0)		Slope and valley (7.5)		Slope (6.0)		Ridge and valley (6.0)		Ridge, slope and valley (6.0)		Ridge and slope (4.5)		Ridge (3.0)	
Site B	37	0	0%	0	0%	0	0%	0	0%	35	95%	2	5%	0	0%
Site C	81	0	0%	16	20%	29	36%	1	1%	19	23%	16	20%	0	0%

If potential risks are larger, it is more likely for a crop to be damaged by heavy rain. Conversely, smaller potential risk indicates higher resilience. At Site B, almost all households possessed maize fields at all topographic positions. However, at Site C, the location of maize fields tended to be biased to a slope. Comparison of the two sites reveals that Site B has greater resilience than Site C. However, this estimation is tentative. Future studies should make topographic maize harvest classifications on the basis of topographic features, soil nutrient content and slope angle.

4.3. Coping behaviors in terms of on-farm activities during the post shock period

4.3.1. Rainfall between 2007_08 and 2009_2010

Figure 4-2 shows the daily rainfall and daily accumulation rainfall at Site A and Site C. At Site A, total amounts of rainfall of 2007_08, 2008_09 and 2009_2010 were 1,438 mm, 1,093 mm and 1,262 mm respectively. At Site C, the amounts were 1,320 mm, 1,293 mm and 1,058 mm, respectively. As is mentioned in our previous report, many of the fields at each of our study sites were damaged by heavy rain in 2007_08. Many fields were also damaged by heavy rainfall in 2009_2010. At each site, total amount of rainfall was highest in 2007_08. However, the total amount of rainfall in 2008_09 was higher than in 2009_2010 at Site C. This means that the damage to fields caused by heavy rainfall was not determined by the total amount of rainfall alone, but rather the rainfall pattern, as can be seen at the end of December in 2007_08 and the end of February in 2009_10.

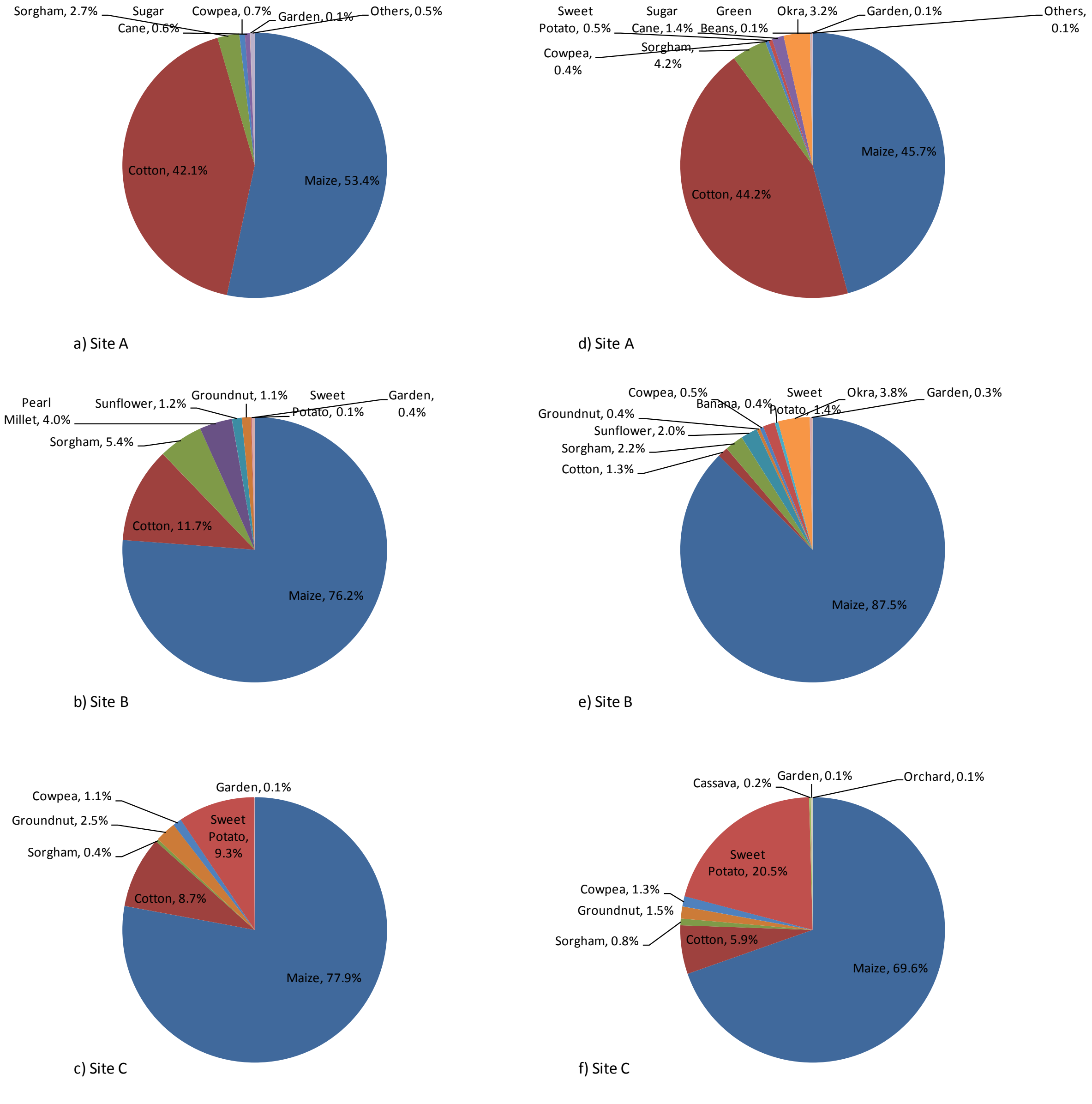


a). Site A b). Site C

Figure 4-2 Daily rainfall and daily accumulated rainfall at a) Site A, and b) Site C

4.3.2. On-farm activities at each site from 2007_08 to 2008_09

Figure 4-3 shows on-farm activities at each site from 2007_08 to 2008_09. At all sites, maize was most dominant staple food crop. At site A, cotton was the second most common crop in both years. In 2007_08, cotton was second, but in 2008_2009 the ratio of cotton grown was decreased due to the additional labor and chemical inputs required compared to other crops, leading to a selling off of cotton crops at site B. Sweet potato is the second-most dominant crop at site C. At this site, sweet potato is a more important cash crop than cotton. These differences of on-farm activities among three sites depend on meteorological conditions, soil conditions and access to the market and the main roads.



1) 2007_08 2) 2008_09

Figure 4-3 On-farm activities at each site from 2007_08 to 2008_09

4.3.3. Coping behaviors related to on-farm activities during the post shock period

Approximately 20% of maize fields were damaged by heavy rainfall in 2007_08. As a coping response to heavy rain damage, between 30% and 80% of damaged fields were abandoned. (Figure 4-4) In some fields, farmers switched or replanted crops. At site A, many farmers sowed maize seeds again. In site B, many farmers switched to planting groundnuts and maize during the dry season. At site C, many farmers switched to sweet potato. Thus, coping behaviors in response to heavy rain damage were markedly different at each site.

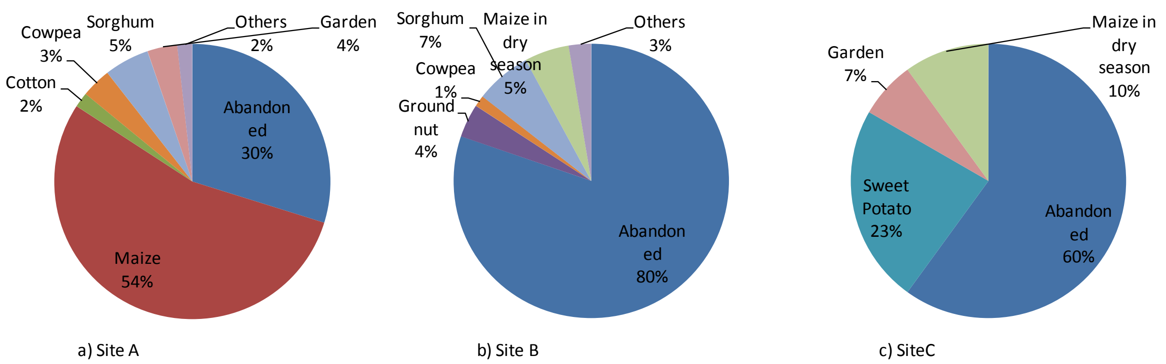


Figure 4-4 Coping behaviors related to on-farm activities following heavy rain damage

4.4. Coping behaviors in off-farm activities during the post-shock period

4.4.1. Coping behaviors in off-farm activities at the site-level

Table 4-2 shows site-level coping behaviors to damage from heavy rain through non-agricultural activities. The table shows the number of households that started new non-agricultural activities because they could not sell maize due to a shortage of maize production in 2008. 65% of households sold animals as a coping behavior. (Figure4-5) At site A, elderly households commonly asked for financial assistance from relatives. At site B, the number of households selling planks increased.

Table 4-2 New non-agricultural activities for households that were unable to sell maize due to the shortage of maize yields in 2008

	Housholds	Animal	Poultry	Fish	Local Beer	Plank	Others
SiteA (n=69)	16	10	1	1	0	0	4
SiteB (n=33)	7	6	1	0	0	5	0
SiteC (n=91)	6	2	0	1	1	0	0
Total	29	19	2	2	1	5	4

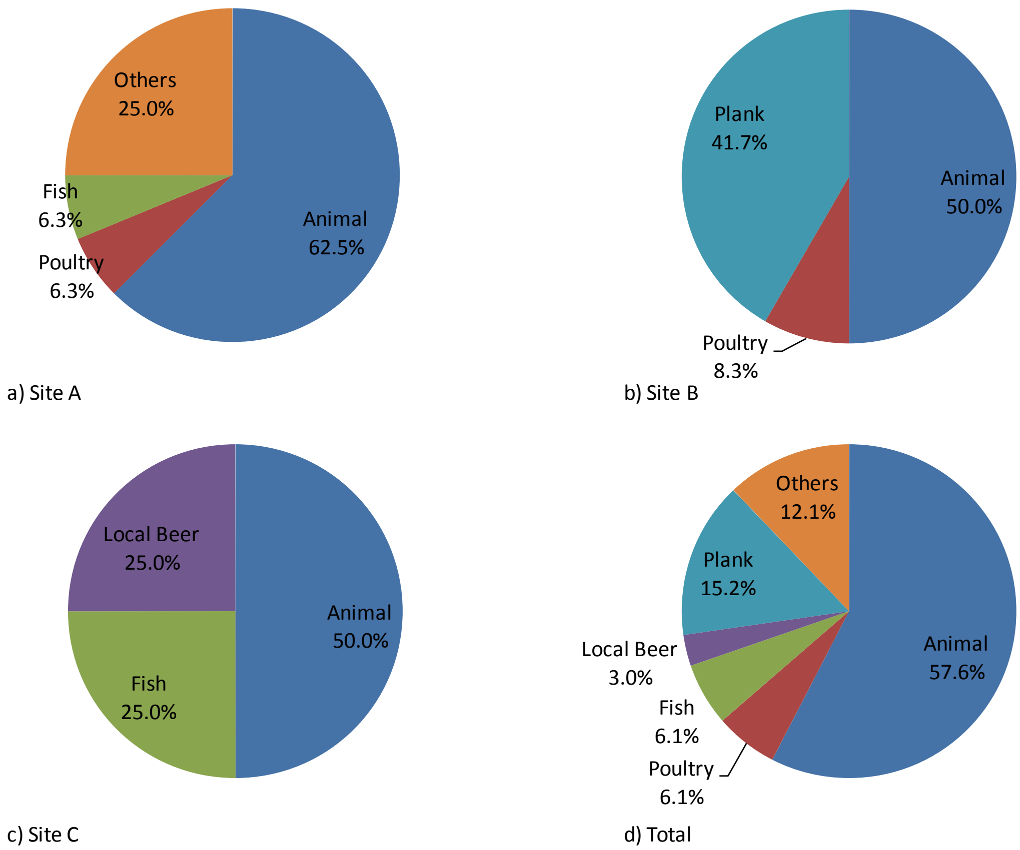


Figure 4-5 Coping behaviors in off-farm activities at the site-level for households that were unable to sell maize due to the shortage of maize yields in 2008

4.4.2. Coping behaviors related to off-farm activities by household-level

Table 4-3 shows household-level coping behaviors. Table a) shows data for 2007. Table b) shows data for 2008. The numbers in each row indicate the percentage distributions of cash income sources in each year, summing to 100%. After the fields were damaged, income was obtained by selling animals, fish, and local beer in 2008.

a) 2007

2007	Maize	Cotton	Vegetable	Animal	Poultry	Gathering	Fish	Local Beer	Carpenter	Plank	Piece Work
Csa 5	20.0	30.0	20.0		15.0						15.0
Csa 21	15.0		50.0		15.0						20.0
Csa 24	5.0	20.0	20.0		5.0						50.0
Csa 33	11.1		5.6		11.1	16.7			38.9		16.7
Csa 59	5.0		10.0	45.0	5.0					35.0	
Csa 85	10.0	30.0	15.0	20.0	10.0						15.0

b) 2008

2008	Maize	Cotton	Vegetable	Animal	Poultry	Gathering	Fish	Local Beer	Carpenter	Plank	Piece Work
Csa 5				100.0							
Csa 21			100.0								
Csa 24		10.0	10.0	70.0	5.0		5.0				
Csa 33			20.0		15.0	15.0		50.0			
Csa 59		1.0		95.0	4.0						
Csa 85		70.0	15.0	5.0	10.0						

Table 4-3 The cash income situation in 2007 and 2008 for households experiencing crop damage from heavy rain at Site C

5. A Preliminary Report on Support and Requests for Gifts via Mobile Phones:
A Case Study of Rural Tonga People in the Southern Province of Zambia

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Abstract

In Zambia, the penetration and prevalence of mobile phone use has dramatically increased in recent years. This study focused on the mobile phone as a rapidly spreading tool for communication, and sought to clarify how rural Tonga people utilize mobile phones to receive support.

The results revealed several key findings regarding support and requests for gifts via mobile phones among Tonga people: 1) People with insufficient funds for making calls on their mobile phones often encourage others to call them by "paging" others' phones. 2) In cases where a household member has no mobile phone, they can often access the mobile phone of another household. 3) Cash and food are often requested via mobile phones. 4) Most requests are made over a long distance. 5) Many requests occur between parents and children boarding elsewhere, and between villagers and urban relatives.

5.1. Introduction

The prevalence and penetration of mobile phone use in Africa has rapidly increased in recent years. Figure 5-1 shows growth in the number of subscribers and penetration of mobile phones in Africa over the 6-year period from 2002 to 2007 (Blycroft Limited. 2008). The number of mobile phone subscribers grew from 49.10 million in 2002 to 280.69 million in 2007. A similar tendency has been seen in Zambia, a country in southern Africa.

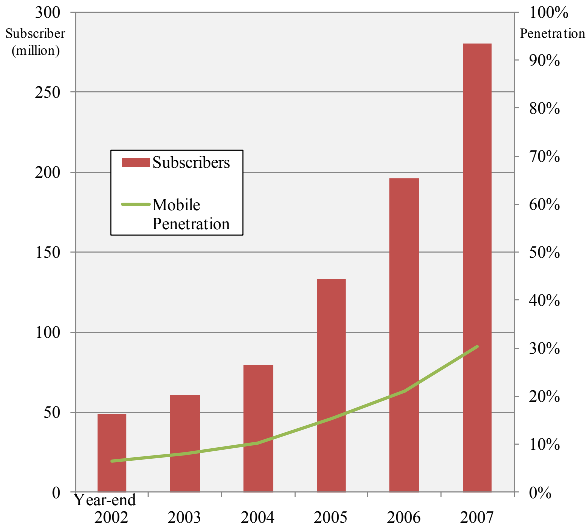

Figure 5-1 Mobile subscribers and penetration in Africa

Source: Blycroft Limited. (2008) *African Mobile Factbook 2008*, Blycroft Publishing, Craven Arms.

Figure 5-2. Tonga woman using a mobile phone

Ecological factors cause fluctuations in food production and income in rural villages in the semi-arid tropics (SAT). The Tonga people live in the SAT region in the Southern Province of Zambia. In addition to difficulties created by ecological factors, rural Tonga people have limited or no access to insurance markets or administrative social security.

If problems such as poor harvest occur in this context, they may be compensated via social networks, which function as a kind of insurance. The present study focused on the use of mobile phones as a rapidly spreading tool for communication, and sought to clarify how rural Tonga people utilize mobile phones to receive support. This preliminary report is part of an ongoing research project.

5.2. Research Outline

The research sites were located in areas of lower flat land ("Site A"), middle slope ("Site B"), and upper flat land ("Site C") in the Sinazongwe area, Southern Province, Zambia. Tonga people constitute the majority of residents at each of these sites.

Interviews were conducted through a questionnaire, administered on alternating weeks. The research period covered 168 days, from early August 2009 to early July 2010. The specific research topics of interest were the details of calls and short message service (SMS) messages, including the reason for contact, and information about the person contacted.

5.3. A Case Study of Household E at Site A

This section examines the mobile phone use of the householder of Household E (Householder E) at Site A, and discusses the features of cell phone use in the study area.

Over the entire study period, Householder E's mobile phone was utilized 355 times for calls, and eight times for SMS messages. Of these calls, 272 were received, while 83 were made from Householder E's phone. Of the SMS messages sent, seven of the messages were received from others, and only one was sent from Householder E's phone. Thus, Householder E's phone was predominantly used to receive calls and messages.

5.3.1. "Paging"

This section discusses the use of "paging" of mobile phones. Paging is a technique of mobile phone use, where a number is dialed but the phone is left to ring only once. In Zambia, most mobile phones are prepaid, meaning that it is not possible to make a call unless sufficient funds have been paid in advance. However, paging requires little phone credit, so can be used to alert another person that contact is desired. Paging thus allows a person with insufficient funds to encourage another phone user to call them.

Figure 5-3 shows the frequency of Householder E's phone calls involving conversations, in comparison with the number of calls used for paging. The monthly ratio of paging relative to calls ranged from 14.3-28.1% across months. A total of 281 calls involving conversations and 74 paging requests were made. Thus, the ratio of paging was 20.8% over the entire study period.

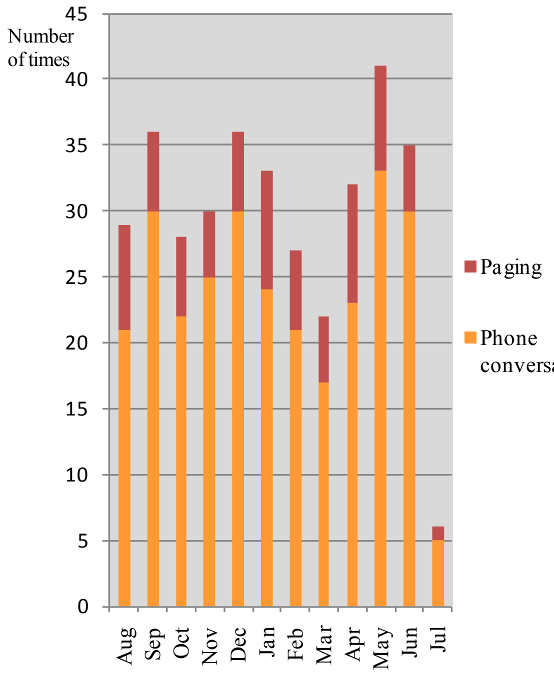

Figure 5-3. Breakdown of phone calls

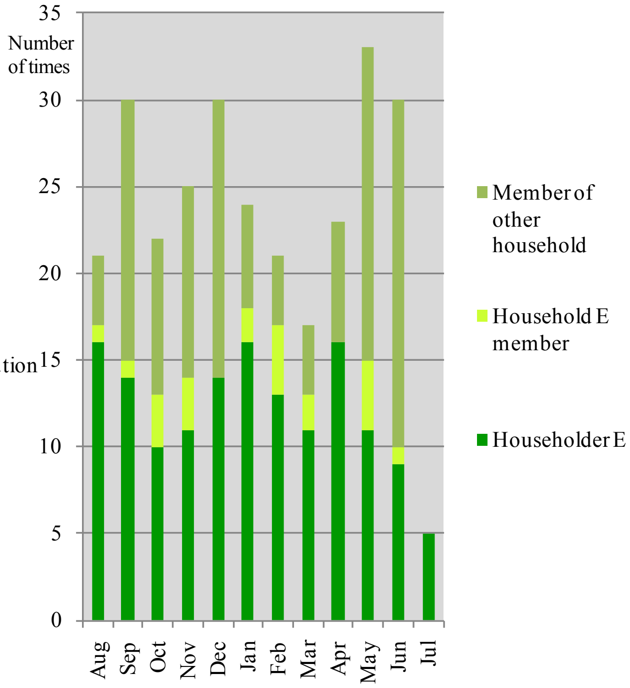

Figure 5-4. Breakdown of attribution for user of Householder E's phone conversations

5.3.2. Borrowing mobile phones

This section discusses the practice of borrowing mobile phones. Figure 5-4 shows the number phone conversations held by Householder E, Household E members and people who were not members of Household E, using Householder E's phone. Monthly ratios varied widely. Of 281 phone conversations, 146 were held by Householder E, 21 by other members of Household E, and 114 by people who were not members of Household E. The ratio of use by people who were not Household E members relative to all phone users was 40.5%. Thus, in cases where household members have no mobile phone, they are commonly able to access mobile phones of other households.

5.3.3. Requests for gifts via mobile phones

This section discusses the practice of requesting gifts using mobile phones. Figure 5-5 shows the frequency of phone conversations that were made to request a gift. Requested gifts commonly consisted of cash, food and other items. These requests were divided into cases where the user of Householder E's phone made the request, and cases where a gift was requested from them. The total frequency of phone conversations involving a request was 20 of 281. Requests for cash were the most common, occurring 14 times (70% of requests).

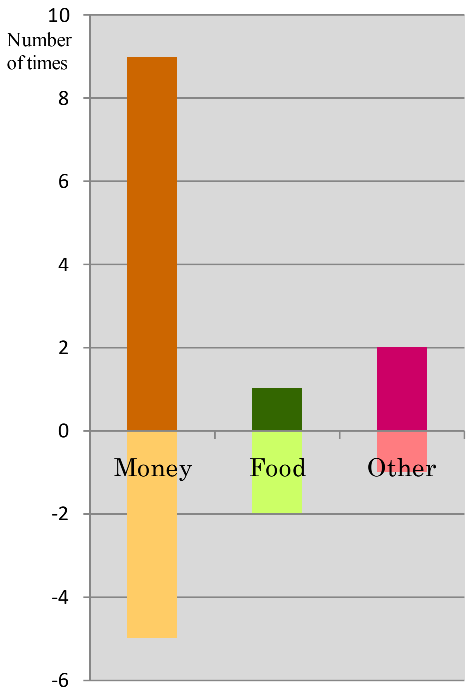

Figure 5-5. Types of gift items requested via Householder E's mobile phone

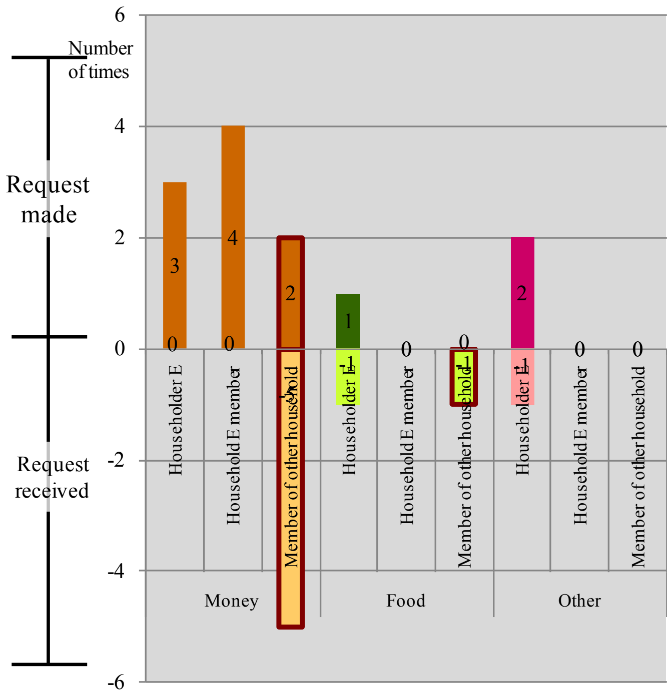

Figure 5-6. Breakdown of requests made and received by users of Householder E's mobile phone

Figure 5-6 shows a breakdown of for the requests made and received by users of Householder E's mobile phone. Requests for gifts occurred eight times in conversations involving Householder E, four times in conversations of other Household E members and eight times in conversations of people who were not members of Household E. Thus, 40% of requests involved phone users that were not Household E members, and seven of these were requests for cash.

Figure 5-7 shows the spatial distribution of people who made requests via Householder E's mobile phone. The left section of the figure shows a neighborhood map around Household E, while the right section shows a large-scale map. These maps indicate that most requests were made over long distances.

Finally, the details of distant requests were analyzed. In all cases where something was requested of the person using Householder E's phone, an item was requested from parents living within the study area by children who were boarding elsewhere. In cases where requests were made by the person using Householder E's phone, an item was requested of an urban relative by a person living in the study site. These requests usually involved close relatives such as brothers, sisters, parents and children.

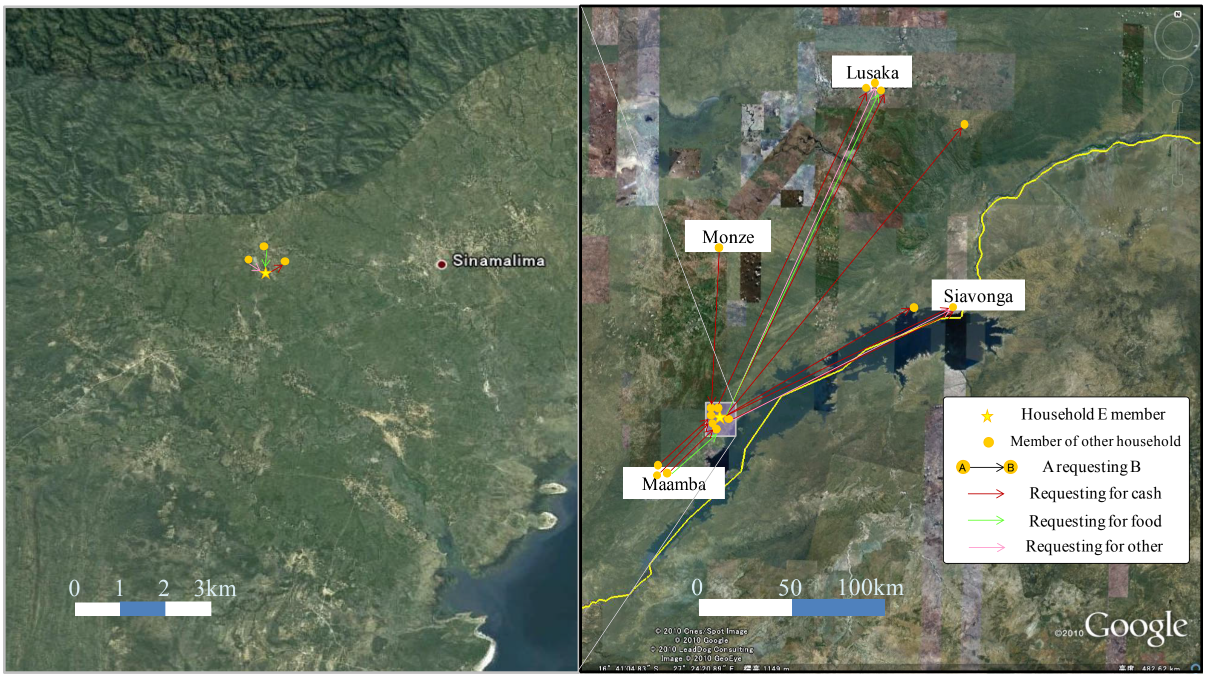

Figure 5-7. Spatial distribution of people requesting and being requested gifts via Householder E's mobile phone

5.4. Key Findings

The current study revealed several key findings regarding support and requests for gifts via mobile phones among Tonga people:

1) People with insufficient mobile phone funds can encourage others to call them using the paging technique.
2) In cases where household members have no mobile phone, they can often access the mobile phone of another household.
3) Cash and food are often requested via mobile phones.
4) Most requests occur over a long distance.
5) Many requests are made between children boarding elsewhere and their parents in the village, and between villagers and urban relatives.

Reference

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6. Social Institutions and Resilience for Food Shortage Risk:
Food Relief Activities in Southern Province, Zambia

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Abstract

To mitigate the impact of natural disasters, the Zambian government and non-governmental organizations instituted several types of food relief program. This paper examines these activities in terms of resilience for rural farmers, particularly focusing on a case in the Sinazongwe district between 2005 and 2008. The case study reveals that the relief food was extensively distributed by the government and NGOs to the population, seeking to avert a food shortage. However, at the same time, it was clear that the timing and targeting of the food aid was far from well-managed. To enhance the resilience of rural farmers, it is necessary for aid providers to respond in timely fashion to food crises, and to help farmers recover from the most vulnerable situations. The case in Sinazongwe, however, suggests that food relief programs seeking to cope with food shortage risks are severely limited, and must be reconsidered as social institutions to promote resilience.

6.1. Introduction

We conducted field research examining food relief programs in the Sinazongwe district to analyze social-ecological resilience in rural Zambia. Several types of relief programs have been implemented by the Zambian government, UN agencies and NGOs, including emergency food aid and disaster management projects. By examining these programs, we sought to determine how such policies contributed to the social-ecological resilience of rural communities, and how national and international organizations have been involved in this process. Thus, the main purpose of our research was to reveal the role of food security institutions in providing local farmers with resilience to overcome vulnerability in drought-prone areas.

To achieve this goal, it is necessary to analyze African rural communities in a multi-level context. In recent years, African agrarian communities have built an interactive network with external agencies such as the market, government policy, and NGOs, for securing resources. However, the ways in which development policies and social institutions impact on rural livelihoods remain unclear. To answer these questions, the resilience and vulnerability of African rural communities must be reconceived in terms of a wider perspective, considering government policies and the activities of NGOs, as well as households' efforts within their communities.

In this paper, we focus on a case study of food aid in the Sinazongwe district from 2005-08. By analyzing documents collected in the Sinazongwe district and the offices of NGOs, in combination with interviews with government officials, NGO staff and local farmers, we sought to reveal how relief food was delivered to villagers after the 2004/05 drought and the 2006 flash flood, and to determine the consequences of the implementation of food aid programs for rural communities.

6.2. The Government's risk assessment and food relief 2005-08

As mentioned in my annual report for FY2007, the Sinazongwe District Disaster Management Committee (SDDMC) made an appeal in December 2005, stating that an average 75% crop failure was experienced in most parts of the district, and that the southern end of the District was the worst affected due to the low rainfall (recorded below 190 mm; SDDMC, 2005). The government's Disaster Management and Mitigation Unit (DMMU) and the Vulnerability Assessment Committee (VAC) attempted to determine the population affected by the drought (for details of the DMMC and VAC, please refer to my FY2008 annual report). The VAC began an assessment in the rural areas of the southern half of Zambia from April 2005, and published a report in June 2005 (ZVAC 2005).

The VAC report concluded that a total population of 1,232,661 people in the rural areas of Zambia (excluding commercial farmers) were likely to face food insecurity, and would require 118,335 metric tons of cereal for a period of 8 months (July 2005 – February 2006) in 27 districts covering Lusaka, Central, Southern, Western and Eastern Provinces. They estimated that the cereal needs in Sinazongwe district and the number of persons at risk in the 2005/06 marketing season was respectively 667 metric tons of cereal, and 6,944 persons over the subsequent 8 months.

In contrast, the 2005/06 production season was generally good, though characterized by excessive rain in some parts of the country which resulted in the flooding of some low lying areas (ZVAC 2006a). In the Sinazongwe district, excessive rains caused flash floods to wash away some crops along riverbanks, and breached earth dams. The district office submitted damage reports to the government twice; the first on a breached earth dam in March, and the second on the district's flood damage in April. A rapid assessment was conducted by VAC in June 2006. However, Sinazongwe district was not included as a target of the survey, and no risk or needs were reported (ZVAC 2006a). Thereafter, the VAC report published in December 2006 finally estimated the food shortage risks and needs in the Sinazongwe district: it was predicted that 41,125 persons would be at risk, and 987 metric tons cereal would be required for the next two months.

Table 6-1 shows the number of people at risk and needing cereal in the Sinazongwe district, as estimated by the VAC in 2005-08. In June 2006, March 2007, August 2008 and February 2008, neither food shortage risk nor cereal requirement was reported in the Sinazongwe district. In the 2006/07 production season, production in the Southern Province increased marginally over the previous season despite experiencing prolonged dry spells during part of the growing season, while production substantially increased in valley areas including Sinazongwe (ZVAC 2007b). Although the 2007_08 rainy season started well with the southern half of the country experiencing an early onset, rainfall increased substantially from November 2007 to January 2008, resulting in widespread heavy rain that caused floods (ZVAC 2008). The VAC report of June 2008 estimated that 21,898 people were at risk, and that 1,642 metric tons of cereal would be needed for the next 6 months in Sinazongwe district (ZVAC 2008). The report noted that the maize price in Sinazongwe was abnormally high (up to

K1,900/Kg; more than twice that of April 2007) indicating a possible food shortage risk.

Table 6-1. Risk and needs assessment of Sinazongwe district from VAC reports 2005-08

Month/ Year	Number of persons at risk	Cereal requirement (metric tons)
June 2005	6,944	667 (for 8 months)
June 2006	-	-
December 2006	41,125	987 (for 2 months)
March 2007	-	-
August 2007	-	-
February 2008	-	-
June 2008	21,898	1,642 (for 6 months)

Source: VAC reports 2005-08 (ZVAC 2005, 2006a, 2006b, 2007a, 2007b, 2008)

Table 6-2. Actual food distribution by the government in Sinazongwe district 2005-08

Month/ Year	Number of beneficiaries	Distributed cereal (metric tons)
June 2005	7,926	100
September 2005	12,500	150
November 2005	4,833	58
April 2006	2,483	29.8
May 2006	6,917	83
March 2007	41,083	493
October 2007	12,500	150
August 2008	7,980	100
December 2008	14,743	182

Source: Documents collected from Sinazongwe district office and KDF

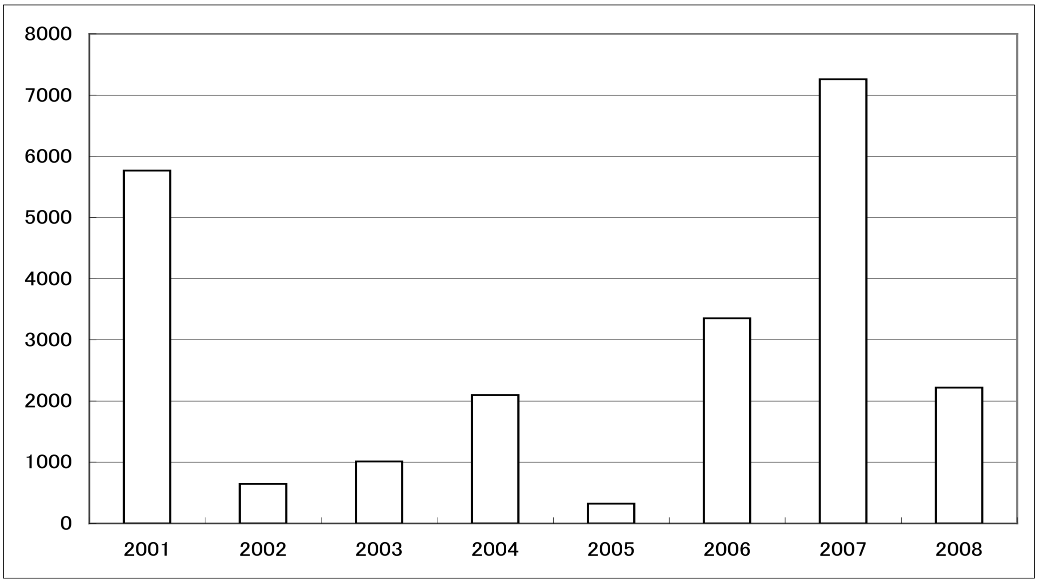

Figure 6-1. Estimated annual maize production in Sinazongwe district 2001-08 (mt)
Source: District Agriculture Coordination Office of Sinazongwe District

Table 6-2 shows the actual amount of the government relief food and the number of beneficiaries in Sinazongwe district. The food relief delivered to Sinazongwe was distributed among the population by a local NGO, the Kaluli Development Foundation (KDF). The data in Table 6-2 were derived from several documents and records in Sinazongwe district office and the KDF office.

Comparing the actual amount of food relief with the needs assessment of VAC reveals considerable gaps between them. First, the amount of distributed cereal was much less than the cereal needs estimated by the VAC. In 2005 and 2008, for example, the actual food relief was less than half and less than one fifth, respectively, of the predicted food requirement. In contrast, even though there was no reported need for cereal in 2007, especially after the harvest season (from March to April), a substantial amount of food was distributed twice in March and October.

Figure 6-1 shows the annual production of maize in Sinazongwe district estimated by the District Agriculture Coordination Office (DACO). According to this estimation, the 2007 harvest was much better than that of the other years. Even under these good agricultural conditions, the total amount of food relief in 2007 was substantially greater than that in 2005, a severe drought year. The main reason for this mismatch was that the delivery of relief was delayed to the extent that it was not completed before the harvest in 2007.

6.3. NGO food relief 2005-06

After the severe drought in 2005, several NGOs, including the Red Cross Society (RCS), Catholic Church (CC) of Maamba Parish, Christian Council of Zambia (CCZ), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), and World Vision (WV) started their own food relief programs in Sinazongwe district. All NGOs terminated their programs by July 2006.

In June 2005, GTZ initially responded to requests made by the Ministry of Agriculture and Cooperatives to assist food insecure households in Sinazongwe district (GTZ 2006). However, it was in September 2005 that the emergency appeal came into effect at the GTZ headquarters. The number of beneficiaries was targeted as 3,000 households, although the food request was dependent on the availability of financial resources of GTZ. In November, GTZ started their relief food distribution for 3,011 households with 150 mt maize gain, 75 mt maize-cassava meal mix, 7.5 mt sorghum seed, 15 mt maize seed, and 7.5 mt cowpea seed.

The response of other NGOs was also delayed. On 18 October 2005 RCS launched an appeal for emergency food in Southern African countries (RCS 2006). The food security operation of RCS sought to assist up to 1.5 million vulnerable beneficiaries in seven countries (Lesotho, Malawi, Mozambique, Namibia, Zambia and Zimbabwe) with provision of food assistance. Even by the end of March 2006, however, the registration of targeted beneficiaries in Sinazongwe was still not completed. Furthermore, due to the delay of permits to allow food entry into the country, it was not until April 2006 that RCS finally started relief food distribution to a total of 2,199 households (16,000 beneficiaries), 317.615 mt maize meal, 51.139 mt beans, 16,000 liters of cooking oil, 88.132 mt high energy protein supplements (HEPS).

Table 6-3. Relief food distributed by NGOs in Sinazongwe district 2005-06 (mt)

Month/ Year	CC	GTZ	CCZ	WV	RCS	Total
August 2005	1					226.83
September 2005		225.83				
November 2005						
December 2005	14.63					14.63
January 2006	14.63	150.55				165.18
February 2006	14.63		20			34.63
March 2006			20			20
April 2006			20	79	144.82	243.82
May 2006				78.72	172	250.72
June 2006				23.45		23.45
July 2006				138.73		138.73
Total	44.89	376.38	60	319.9	316.82	1117.99

Source: Documents collected in Sinazongwe district office (only on cereal grain and meal)

Table 6-3 shows the timing of NGO relief operations and the amount of food distributed by each NGO. More than half of the food aid was implemented after the 2005/06 harvest. This means that the relief food did not reach the affected population during the most severe period of the 2004/05 drought. Consequently, in spite of a rapidly changing situation surrounding rural households and agricultural activities, the relief of the government and NGOs continued with the same scale of food aid even after the recovery from drought or flood.

6.4. Conclusion: Social institutions and resilience for food shortage risk

Examining the relief activities of the government and non-governmental organizations after the 2004/05 drought revealed that actual relief activities were frequently delayed, and not operated in a timely manner, even when the effect of a natural disaster was recognized through risk assessments and/or emergency appeals. On the one hand, in terms of an initial response to the food shortage risk, government relief operated quickly to some extent. In contrast, it took large international NGOs such as WV and RCS much longer to start their operation at the local level. On the other hand, the government relief activities were so sporadic and poorly coordinated that there were large gaps between the initial risk assessment and actual food aid.

As Ishimoto argues in chapter two, the resilience of rural households can be defined in terms of the time taken to recover from an unexpected shock. This means that social institutions such as food aid agencies should mitigate the food shortage risk at an initial phase and enhance the resilience of rural households to recover from shocks as soon as possible. It is true that various relief programs can partially contribute to the avoidance of the disastrous consequences caused by natural hazards. The case study of Sinazongwe, however, revealed severe operational problems and inefficiency in those relief activities with a great time gap (Figure 6-2). Most importantly, to support households in recovering from a shock, it is necessary to match the coping strategies of rural farmers.

The relief program against food shortage risk in Africa is heavily dependent on food aid. As discussed above, it takes a substantial amount of time for aid organizations to provide the enormous amounts of food required by local populations, and difficulties are involved in procuring the necessary amount of food at a given time. As Miyazaki and Ishimoto point out in their chapters, individual farmers adopt various kinds of coping strategies, such as shifting crop varieties, selling livestock, temporarily working as waged laborers, and utilizing social-networks. Food shortage risk cannot always be avoided by relief food provision and agricultural development policies. In terms of the resilience of rural farmers, it can be argued that relief activities that are heavily dependent on food aid should be reconsidered. The most important goal in providing an effective relief is to support farmers' own voluntary efforts by providing opportunities that can be utilized at the time of a food shortage.

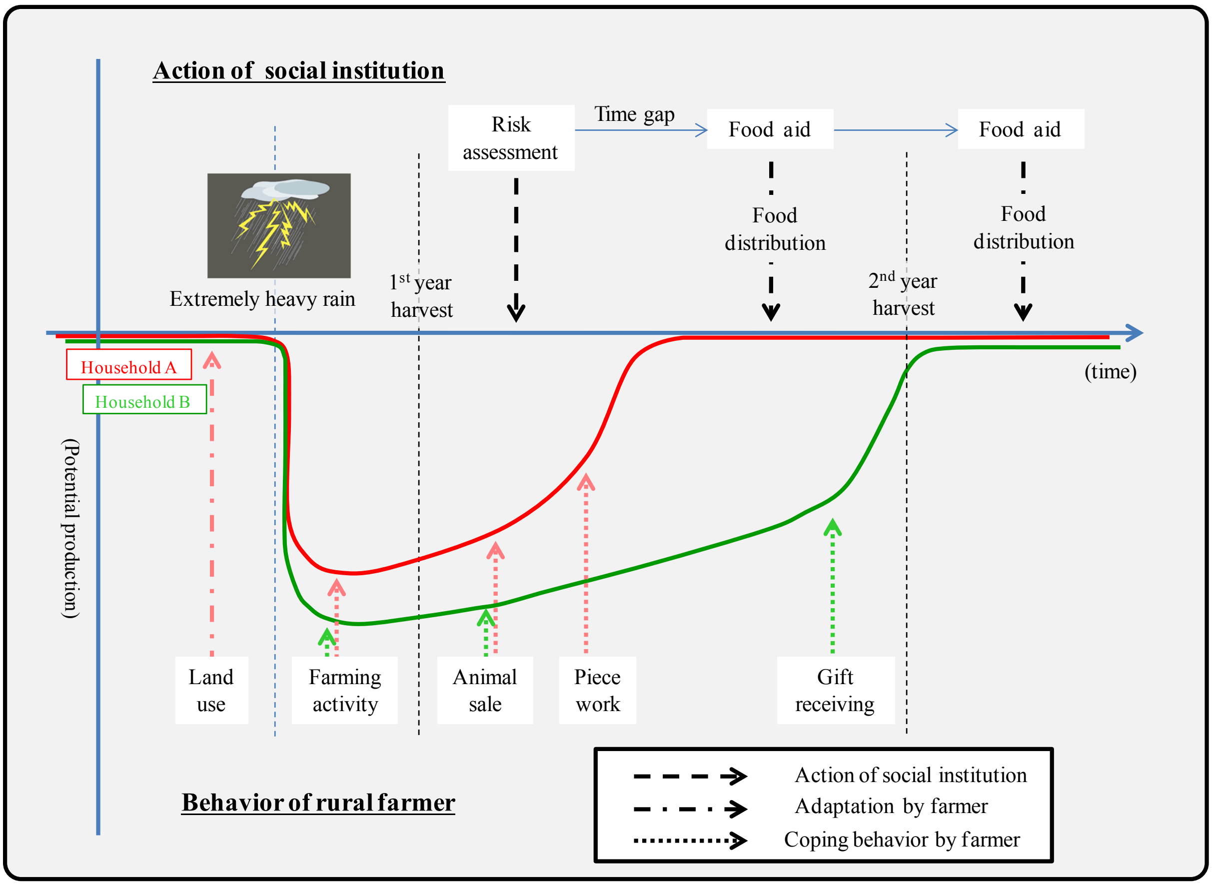

Figure 6-2. Comparison of farmer's behavior with social institution's action in response to extremely heavy rain

* This figure is revised figure 2-4 by K. Matsumura.

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7. Conclusion of Understanding Agricultural Vulnerability, Human Behavior and Relief

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Pasco Corporation

In this year, we conducted the field investigation data integration focus on thinking the rural farmer's resilience by considering an agricultural vulnerability, human behavior and relief in Southern province. Followings are the results of considerations.

As our discussion result for the concept of resilience in human activities, it consists of three components; capacity, external factor and asset. Exposure is a substitute for external factor in vulnerability studies. Risk of household is composed of potential risk and manifested risk. Emergent risk may lead to change the property of potential risk. Moreover, potential risk may be replaced by vulnerability. There are various potential risks related to each component of resilience; low capacity, bad external factor and deficient asset. When emergent risk occurs, the risk is more extensive than expected, potential risk manifests. Emergent risks are divided into ecological shock and social shock. Ecological shocks include light rain, heavy rain, epidemic, insect damage, bird damage, animal damage and so on. Social shocks include politic, economic, cultural and legal change etc. In this paper's the climate change effect was the extreme heavy rain.

From the rainfall between 2007_08 and 2009_2010 and the daily rainfall and daily accumulation rainfall in Site A and Site C, total amount rainfall at Site A of 2007_08, 2008_09 and 2009_2010 were 1438mm, Site B was 1093mm and Site C was 1262mm respectively. In Site C, those were 1320mm, 1293mm and 1058mm respectively. As is mentioned in previous report, a lot of fields in all sites were damaged from heavy rain in 2007_08. Additionally, in 2009_2010 many fields were also damaged by heavy rainfall. In each sites, total amount of rainfall were highest in2007_08. But total amount of rainfall in 2008_09 was higher than 2009_2010 in Site C. This means that fields damage by heavy rainfall coursed by not total amount of rainfall but rather rainfall pattern with much rainfall, such as end of December in 2007_08 and end of February in 2009_10.

From the total crop field area in five villages during two rainy seasons of 2007_08 and 2008_2009, it seems that total crop area in rainy 2008_09 decreases comparing with the one in rainy 2007_08. More than 67% of rainy crop fields in 2008/09 are overlapped with the crop fields of rainy 2007_08. From the topographical conditions point of view, the land preparation composed of clearing and burning at rainy crop field is performed from September to the beginning of November. Also, we have many pictures taken in various seasons at three study sites. From comparison with such field data and geo-corrected ALOS/AVNIR-2 images, the characteristics of land use / land cover in the each season might be understandable. In FY2011, firstly, the classification of land cover/use in rainy and dry seasons around three study sites will be carried out using ALOS/AVNIR-2 images, crop calendar and fields' pictures as ground truth data. Secondly, the spatial analysis for the land cover/use and topographical features will be done. Then we will discuss the potential risks and for the ecological shocks in the villages or sites level.

From the results of on-farm activities investigation in each site from 2007_08 to 2008_09, maize was most dominant crop which is staple food. In Site A, cotton was second in both years. In 2007_08, cotton was second, but in 2008_2009 it's ratio was decreased due to a lot of labor force and selling off in site B. Sweet potato is second dominant crop in site C. In this site, sweet potato is more important cash crop than cotton. These differences of on-farm activities among three sites depend on meteorological condition, soil condition and access to market and main road.

From the results of coping behaviors investigation in on-farm activities during post shock period, about 20% of maize fields were damaged by heavy rainfall in 2007_08. As coping behavior with heavy rain damages through on- farm activities, from 30% to 80% of damaged fields were abandoned. In other fields, many farmers switched or replanted crops. In Site A, they sowed maize seeds again. In site B, they switched to planting ground nuts and maize during the dry season. In site C, they switched to sweet potato. Thus coping behaviors with heavy rain damages were different in each site.

From the coping behaviors investigation in off-farm activities by site-level, the numbers are numbers of households which started new non-agricultural activities because they could not sell maize due to a shortage of maize productions in 2008. 65% of households sold animals as a coping behavior. In Site A, elderly households asked money from relatives. In site B, plank selling households increased.

Key findings on supports and requests for gift through mobile phone by Tonga people are following:

1) Person, who has not enough talk fee of mobile phone, can encourage calling by the action "*Paging*".
2) In case of household member having no mobile phone, he or she can access mobile phone of other household.
3) Cash and food are requested through mobile phone.
4) Most of requests are long distant.
5) Many cases of requests are between parent and boarding child, villager and urban relative.

The relief program against food shortage risk in Africa has ever been heavily depended on food aid. As I argued above, it takes time for aid organizations to provide an enormous amount of food to local population, and at the same time it is also difficult to procure a needed amount of food at a needed period. As Miyazaki and Ishimoto points out in their chapters, individual farmers adopt a various kinds of coping strategies such as shifting crop varieties, selling livestock, temporal working as a waged labor and utilizing social-networks. Food shortage risk cannot always be avoided by relief food provision as well as agricultural development policies. In terms of resilience of rural farmers, it can be argued that relief activities depended heavily on food aid must be reconsidered. The important thing is to support farmers' voluntary efforts with provision of opportunities they can utilize at a time of food shortage.

Zambia's Poverty and Food Security: Measurements, Trends and Decompositions

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Research Institute for Humanity and Nature

Abstract

This paper examines poverty measurement methodology and poverty situations in Zambia with a special focus on level and trends in Southern and Eastern provinces where our study sites are located. Poverty in Zambia is measured using absolute poverty approach by which households are classified as poor if their monthly consumption expenditures fall below a pre-determined cost of minimum food basket for a family of six. This consumption based poverty measurement provides a direct linkage to household food security. The implementation of structural adjustment program in 1990 coupled with a major drought in 1991/92 agricultural season have created a sharp increase in poverty in both rural and urban areas in 1993. The largest increase of poverty was in urban areas especially in Lusaka and Copperbelt. Overall poverty situation in Zambia showed sign of improvements especially during the new growth period after the year 1998. Economic growth during this new growth period appears to disproportionately benefit urban population with Lusaka enjoying significant reduction of poverty headcounts. In contrast, poverty in Southern and Eastern provinces are on a rising trend with increasing severity. The turning point was in the year 2002. The shifting poverty trends in those two provinces may be associated with a series of droughts affecting farm production during early 2000s' agricultural seasons.

1. Introduction

Once a middle-income country, Zambia is now one of the Sub-Saharan Africa's poorest. Every two in three persons lived off a daily income of less than PPP$1.25 a day. A transition into a low income country status started when price of copper, a Zambia's dominant mining industry and source of foreign currency earnings, fell sharply in 1970s. Zambia government responded by heavily relying on foreign borrowings to finance imports and ambitious social programs with a hope that copper market would recover. The long anticipated recovery of the copper market failed to come and foreign debts piled up. Unable to service the debts, IMF and the World Bank provided assistance conditioning on successful implementations of market liberalizations and structural adjustment programs. The market liberalizations and structural adjustment programs implemented in 1991 were Zambian's painful experiences. People saw their welfare as measured by real income per capita fell further. The falls of the real GDP per capita were finally over in 1998. Since then the country has entered a new era of steady growth of real income per capita (see Figure 1).

The purposes of this paper are two folds. Poverty and food insecurity are intimately linked. First, this paper provides a macro view of the dynamics of household poverty in post market liberalization and structural adjustment program period, which happened to coincide with a period of frequent droughts and dry spells threatening living standards of the rural poor. The second objective is to provide linkage across scales by extracting poverty statistics and household dynamics at a level closest to the Resilience Project's study sites in

Petauke and Sinzongwe districts. That level of analysis is not routinely published in any governments' and international organizations' reports.

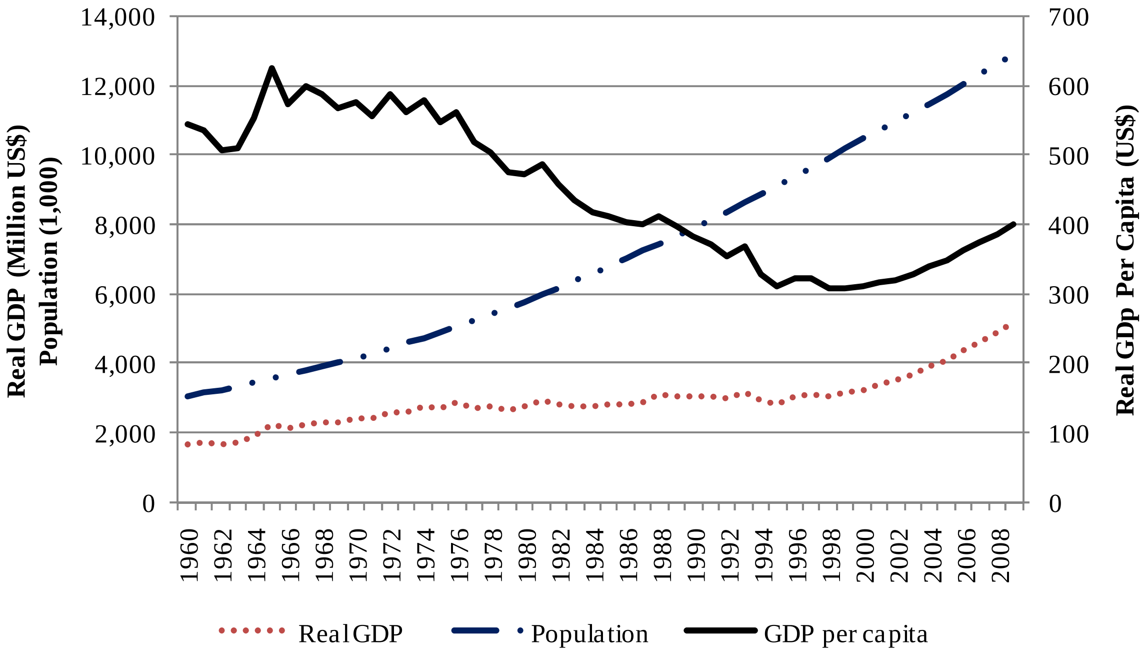

Figure 1: Real GDP and GDP per Capita, Zambia, 1960-2009
Source: IMF's World Economic Outlook Database, October 2010

2. Poverty Measurements and Food Security

Poverty is broadly defined as a deprivation of acceptable welfare. Recognizing that human welfare is multidimensional, economists choose to focus on income or consumption since they are important determinants of human welfare. The United Nations' Development Program argues for the use of multidimensional poverty index (MPI) to reflect multidimensionality of the poverty. The MPI simultaneously takes into account of health, education and living conditions. A drawback of the MPI is its insensitivity to short-run variations to external shocks. The MPI is ideal in measuring poverty in long- or mid-term situations. On the other hand, income or consumption based welfare measure is a more sensitive short-term and medium term poverty indicator.

In Zambia as in most developing countries, income data are not reliable. Consumptions can be measured more accurately. The Zambia governments routinely survey household income, consumptions and other living condition indicators to monitor their living standards through the Central Statistical Office (CSO). The CSO conducted what is called Indicator Monitoring Survey (IMS) roughly every two years starting from 1991. Up to now, a total of eight IMS has been conducted, i.e. Priority Survey (PS) 1991 and 1993 and Living Standard Monitoring Survey of 1996, 1998, 2002-2003, 2004, 2006 and 2008. In this report, data analyses cover the 1991-2006 periods because the official release of the LSMS 2008 is not yet available.

2.1 *Absolute Poverty and Minimum Food Basket*

CSO has been using a consumption based methodology to measure poverty under an absolute poverty concept. A household's consumption is defined as a sum of household expenditures and the value of home production. The absolute poverty is defined as an inadequacy of food consumption to meet human's minimum caloric requirements. CSO adopted the WHO's recommendation of 2,094 calories/adult/day as a minimum caloric requirement. The food basket that meets the caloric requirement for a family of six living in poverty is then established and converted into monetary units. A household is judged food poor or severely poor if its consumption values in adult equivalent unit fall below the food poverty line.

Table 1; Adult Equivalent Scales, Zambia

Age	Adult equivalent scale
Child 0-1 year	0.00
Child 1-3 year	0.36
Child 4-6 year	0.62
Child 7-9 year	0.78
Child 10-12 year	0.95
1 Adult female (age 13 and above)	1.00
1 Adult male (age 13 and above)	1.00

Source: CSO, LSMS Report

In actuality, lives require not only food but also some non-food items such as cooking fuel, lighting etc. to sustain a healthy life. To reflect these basic non-food needs, the minimum food basket poverty line is adjusted by adding an additional amount of non-food items to the poverty line. The amount added is determined by examining the consumption patterns of households living near poverty. It is determined that non-food consumptions of the near poverty households accounted for approximately 30 % of total consumption expenditures. That number is then used to adjust the food poverty line upward to produce what may be called basic poverty line to distinguish it from the food or core poverty line. Households living below food poverty line are considered severely poor and those that are living between the food poverty line and the basic poverty line are considered moderately poor.

Table 1 shows adult equivalent scales used in converting household members with different gender and age groups into one single adult equivalent unit.

Table 2: Zambia's Minimum Food Basket

Food/Non-Food Item	CSO		JCTR	
	1991	2002	1991	2002
Basic/Minimum Food Basket				
Roller/Mealie meal	80 Kg	90 Kg	75 Kg	75 Kg
Bread	-	-	30 Loafs	30 Loafs
Nuts/Beans			2 Kg	2 Kg
Groundnuts	1 Kg	3 Kg	NS	NS
Mixed nuts	1 Kg	-	NS	NS
Dried beans	1 Kg	2 Kg	NS	NS
Vegetable			30 day supply	
Green vegetables/Rape	1 Kg	7.5 Kg	NS	7.5 Kg
Onions	1 Kg	4 Kg	NS	4 Kg
Tomatoes	1 Kg	4 Kg	NS	4 Kg
Meat product				
Dried kapenta	1 Kg	2 Kg	-	2 Kg
Dry fish	-	1 Kg	-	1 Kg
Meat	-	-	8 Kg	4 Kg
Egg	-	-	40 Eggs	20 Eggs
Fresh milk	500 ml	2 L	-	2 L
Micellaneous				
Sugar	2 Kg	-	8 Kg	8 Kg
Salt	1 Kg	1 Kg	1 Kg	1 Kg
Cooking oil	5 L	2.5 L	5 L	4 L
Tea	-	-	500 g	500 g
Basic Non-Food Basket				
Charcoal	-	-	180 Kg	180 Kg
Soap	-	-	6 Tablets	10 Tablets
Detergent	-	-	2 Kg.	1.6 Kg
Vaseline	-	-	200 g	500 g
Electricity	-	-	-	3 bed room
Water & sanitation	-	-	-	3 bed room
Housing	-	-	-	3 bed room
Average basic food costs	5,766	387,180	6,375	324,650
Average basic non-food costs	2,514	165,930	-	504,600
Average basic foood and non-food	8,280	553,110	6,375	829,250

Source: - CSO, Priority Survey Report 1991 and Living Standard Monitoring Survey (2002).
- JCTR (2007)

Note: NS = not specified; - = not included.

Table 2 compares minimum food basket used by CSO and those of the Jesuie Centre for Theological Reflection (JCTR), a strong advocate for poverty reduction and social justice in Zambia. The two baskets differ in many ways. Firstly, the CSO's basket is based on consumption patterns of and price faced by the rural and urban poor while the JCTR's based entirely on urban markets. Secondly, specific non-food items are identified in the JCTR's but not in the CSO's baskets. Thirdly, despite including non-food items in what JCTR called the Basic Need Basket, the poverty line in 1991 is only slightly higher than the CSO's food basket (5,766 vs. 6375). Differences in prices might be a factor. Over times, gaps between the two baskets are growing.

Poverty line used by CSO to estimate poverty statistics is shown in table 3. It is interesting to note that costs of minimum food basket in Zambia have grown from ZMK 60 in 1981 to ZMK 961 in 1991 and ZMK 65,710 in 2006 respectively. Assuming that food baskets are comparable across time, such increased costs of the minimum food basket indicates an average inflation rates of 43%/year.

Table 3: Zambia Poverty Line, 1981-2006

Year	Food Poverty Line	Basic Poverty Line
1981	60	106
1991	961	1,380
1993	5,910	8,480
1996	20,181	28,979
1998	32,861	47,187
2002	64,530	92,185
2004	78,223	111,747
2006	65,710	93,872

Source: Various issues of CSO's PS and LSMS reports

3. Poverty Profile and Trend

3.1 *Poverty Profile*

Poverty measures calculated are of the FGT poverty index class (Foster, Greer, & Thorbecke, 1984). The FGT poverty index is comprised of three related indices, i.e. poverty headcount index (P0), poverty gap index (P1) and poverty gap squared index (P2). The headcount index measures prevalence of poverty in percentage of population. The poverty gap index measures severity of poverty using distance of household consumptions from the poverty threshold or poverty line. The square of the poverty gap index measures inequality of poverty. A full report of all three poverty indices from 1991 to 2006 is in Table 4. The poverty line used in these calculations is the basic poverty line which includes food and non-food items. Poverty estimations using the food poverty line are available upon request.

Poverty in Zambia remains persistently high at the lowest of 64 percent in 2006 to the highest of 74 percent in 1993 which is a year after a major continental wise drought in 1991/1992 agricultural season compounded with post policy shocks from the market liberalization and structural adjustment program mandated by the IMF and World Bank. The poverty prevalence is gradually trending down over times.

Poverty are higher in rural than in urban areas especially among the small scale and medium scale farmers. In urban area, poverty is more prevalent among the populations living in a low-cost urban. Provinces that are predominantly urban such as Lusaka and Copperbelt have the lowest poverty headcounts. Eastern, Luapula and Northern are three provinces with highest prevalence of poverty. Levels of poverty in the remaining provinces are only marginally lower.

Poverty gap is about 30%-40% below the poverty line. Given that 30% of the basic poverty line is of non-food, the observed poverty gap implies that, on average, poor households are slightly below the food poverty line. Some even argued that the 2,094 calories per adult equivalent per day is a generous amount and suggested that the lower figure of 1,774 calories better reflect real minimum nutritional requirements (World Bank, 2005).

If one is to arbitrarily defined level of inequality based on the poverty gap squared index of 0.00-0.25 as low, 0.26-0.50 as moderate and 0.50 or greater as high, the poverty inequality in Zambia may be characterized by moderate to low levels of poverty inequality varying in range from 13.9-32.5.

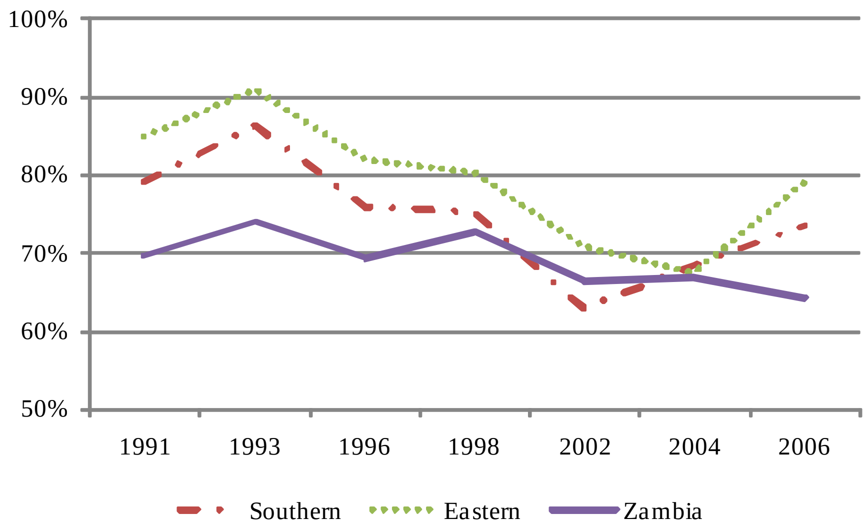

Figure 2: Poverty Headcount of Zambia, 1991-2006

Source: Own calculation.

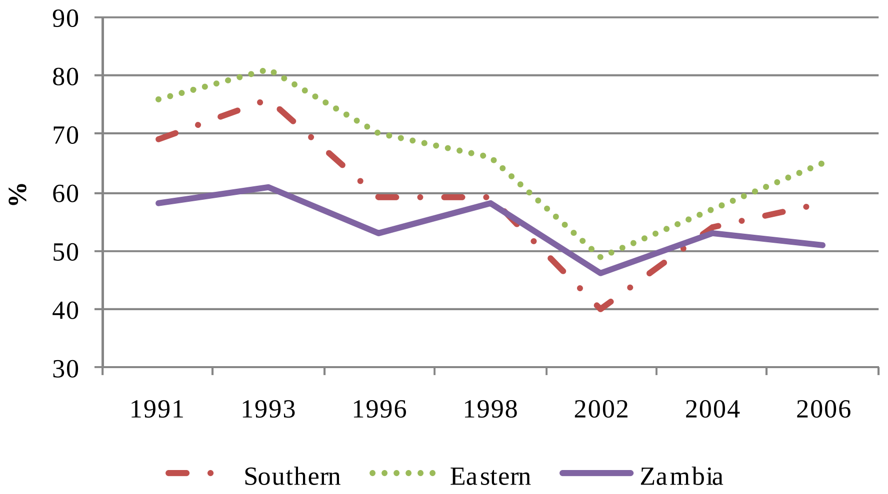

Figure 3: Poverty Headcount of the Severely Poor, Zambia, 1991-2006

Source: Various issues of CSO's PS and LSMS reports.

3.2 *Poverty Trend*

Figure 3 and 4 display poverty trends. National poverty in Zambia is on a gradual declining trend. The trend is driven by variations of the food poor. Poverty headcounts in Southern and Eastern Provinces are generally higher than the national average and follow similar national trend up to the year 2002. There appears to be a rebound of poverty in the two provinces with increasing severity as measured by the poverty gap shown in table 4.

Cautions should be exercised when interpreting the observed results of 2002. The LSMS 2002/2003 was conducted with an important change in methodology. The LSMS 2002/2003 was a panel survey with the same households being interviewed about 10 times in a year. A journal method was used to collect consumption data while a standard method of 2-weeks to one-month recalls was utilized in all other surveys which were a onetime interview survey. Such methodological changes may have influenced survey results and make cross survey comparison difficult.

3.3 *Urbanization vs. Ruralization*

Population share between the two periods of 1998 and 2006 reveals an unusual pattern of de-urbanization. The urban share fell from 37.6 to 35 percent and the rural population share increased from 62.4 to 65 percent (see Table 4). A similar ruralization trend is marginally observed in Eastern Province as shown in Table 5. The unexpected change corresponded with an increased share of small scale agriculturalists stratum and a decrease in the share of medium-cost and high-cost economic stratum of the urban.

On the other hand, Southern Province became rapidly urbanized between the two periods under examination. Rural population fell from 81 to 76 percent and the urban population rose from 18 to nearly 22 percent (Table 5). A possible shift in economic stratum from the no-farm rural to the low-cost urban is observed while other economic strata remained relatively constant. The much faster urbanization in Southern Province is not beyond expectation considering the fact that Southern Province is better endowed with road and rail road infrastructure.

Urbanization progressed at an astonishing speed in Sinazongwe district (see Table 6). Once 96 percent rural, Sinazongwe’s rural population share now stands at 78 percent with a corresponding increase of urban population from 4 percent to 22 percent. The rapid urbanization was associated with movements of the rural non-farm stratum to the low-cost urban. At the same time, small scale farm stratum slightly increased.

Petauke became more urbanized at a much slower speed than did Sinzongwe. Rural population dropped from 96 percent to 90 percent (see Table 6). However, patterns of economic stratum movements clearly differed. The urbanization in Petauke is primarily associated with a movement out of the small scale farming stratum toward the low-cost urban and, to a smaller extent, rural non-farm.

One should be cautious in interpreting all district-level statistics. The resulting estimates are generally imprecise because they are based on small sample size.

Table 4: Poverty Profile, Zambia 1991-2006

	Pop. Share	Pop. Share	Poverty Headcount (P0)							Poverty Gap (P1)							Poverty Inequality (P2)						
	1998	2006	1991	1993	1996	1998	2002	2004	2006	1991	1993	1996	1998	2002	2004	2006	1991	1993	1996	1998	2002	2004	2006
National			69.7	73.8	69.2	72.8	66.5	66.9	64.3	43.3	43.0	35.5	39.9	27.1	35.2	33.8	32.5	29.9	22.3	26.6	13.9	22.8	21.7
Rural	62.4	65.0	88.0	92.1	82.8	83.0	74.3	75.4	80.5	61.3	60.2	46.1	49.8	31.3	43.4	45.0	48.0	43.9	30.2	34.7	16.5	29.5	29.7
Small scale	54.9	59.6	89.9	92.4	84.4	84.0	75.5	76.3	81.6	63.7	60.6	47.4	50.4	32.0	44.3	45.8	89.9	44.3	31.3	35.1	16.8	30.3	30.3
Medium scale	2.4	2.3	78.5	90.8	65.1	71.7	63.9	72.0	69.6	48.7	56.6	31.4	38.3	22.8	36.0	34.5	78.5	39.9	18.6	25.2	11.5	22.4	21.2
Large scale	0.1	0.1	61.6	0.0	34.9	15.7	32.8	38.0	33.3	31.6	0.0	9.4	10.1	5.1	18.5	11.3	61.6	0.0	3.7	7.7	0.9	12.5	5.2
Non-farm	5.0	3.0	70.4	0.0	72.0	79.3	54.7	66.5	67.9	41.5	0.0	36.8	48.5	22.5	35.1	37.8	70.4	0.0	22.9	35.1	12.0	23.2	25.2
Urban	37.6	35.0	48.6	44.9	46.0	55.8	52.2	53.6	34.2	22.6	15.9	17.4	23.5	19.2	22.6	13.0	14.5	7.8	8.9	13.2	9.3	12.5	6.8
Low-cost	27.6	28.1	55.5	50.1	51.1	60.9	61.6	59.0	38.9	26.0	18.5	19.9	26.5	23.1	25.4	14.9	55.5	9.3	10.3	15.0	11.2	14.3	7.8
Medium-cost	5.2	4.2	42.6	40.9	32.4	49.4	30.3	47.3	19.1	19.7	13.0	10.4	18.5	8.6	18.5	7.1	42.6	5.9	4.7	9.6	3.5	9.6	3.7
High-cost	4.8	2.7	36.1	33.0	23.8	33.5	7.5	29.9	7.7	15.9	12.3	7.3	12.3	2.3	11.7	2.6	36.1	6.1	3.3	6.4	1.0	6.3	1.3
Province																							
Central	10.0	10.4	70.0	81.0	73.8	76.8	69.1	74.0	71.7	39.1	51.0	36.9	44.3	29.5	42.2	36.8	26.6	36.9	22.4	30.7	15.5	28.0	22.5
Copperbelt	17.9	15.2	61.1	49.2	55.6	64.7	58.8	57.2	41.9	31.9	18.8	21.3	31.4	23.1	24.6	17.5	22.7	10.0	11.0	19.1	11.6	13.8	9.8
Eastern	12.7	13.7	84.7	90.8	82.0	80.2	70.7	67.4	79.0	58.6	59.2	48.1	46.5	28.2	38.6	44.1	46.4	43.4	32.9	31.7	14.1	26.6	29.0
Luapula	6.9	7.9	84.0	88.4	78.8	80.9	70.4	76.7	72.8	53.3	53.7	42.4	47.5	29.0	41.0	39.0	39.9	37.0	27.1	32.5	15.2	26.1	24.6
Lusaka	15.0	14.0	30.6	38.8	37.9	51.8	56.3	47.3	29.0	12.2	16.9	14.7	22.3	21.6	18.5	10.5	6.7	10.2	7.8	12.9	10.9	9.9	5.3
Northern	12.1	12.7	84.0	86.1	83.9	81.1	80.5	72.5	78.5	55.9	47.7	46.2	45.9	37.7	40.3	43.2	42.0	30.7	29.7	30.9	21.1	26.9	28.2
N. Western	5.4	6.0	74.7	88.0	80.3	75.8	71.9	76.8	72.1	48.0	55.8	43.3	41.5	30.0	40.7	37.9	36.2	41.1	27.8	26.8	15.5	26.4	24.6
Southern	12.7	12.4	79.1	86.3	75.9	75.2	62.9	68.4	73.4	54.1	55.6	39.5	42.1	23.6	35.5	39.3	43.2	40.9	24.9	28.5	11.4	22.6	25.5
Western	7.4	7.5	84.3	91.1	84.3	89.1	65.4	81.4	83.6	59.3	61.2	51.0	57.4	24.0	52.0	53.4	47.0	45.8	35.3	42.3	11.7	37.8	39.0

Source: Own estimations.

Table 5: Poverty Profile of Eastern and Southern Province, Zambia 1991-2006

	Pop. Share	Pop. Share	Poverty Headcount (P0)							Poverty Gap (P1)							Poverty Inequality (P2)						
	1998	2006	1991	1993	1996	1998	2002	2004	2006	1991	1993	1996	1998	2002	2004	2006	1991	1993	1996	1998	2002	2004	2006
Eastern																							
Rural	**90.8**	**91.8**	**90.9**	**93.3**	**84.1**	**81.7**	**73.6**	**70.6**	**82.5**	**64.6**	**62.4**	**50.3**	**48.2**	**29.6**	**42.3**	**46.8**	**52.0**	**46.3**	**34.7**	**33.2**	**14.9**	**29.9**	**31.0**
Small scale	85.9	87.2	91.3	93.6	85.7	82.1	74.5	70.5	83.1	65.1	63.1	51.5	48.9	30.0	42.5	47.2	52.6	47.0	35.6	33.8	15.1	30.1	31.3
Medium scale	2.7	2.4	85.6	88.9	63.6	75.4	71.9	70.5	73.1	56.4	52.3	31.1	33.1	26.1	37.9	39.8	41.2	35.5	19.5	17.9	12.9	24.5	25.9
Large scale	0.1	0.1	87.8	-	35.7	37.7	0.0	91.3	91.7	53.6	-	0.8	18.3	0.0	67.5	36.4	32.7	-	0.0	10.7	0.0	51.0	17.4
Non-farm	2.2	2.2	75.9	-	44.5	74.1	37.2	69.9	69.7	55.0	-	26.5	43.2	13.9	37.8	39.2	43.7	-	17.6	29.5	7.5	26.5	26.0
Urban	**9.2**	**8.2**	**57.1**	**66.7**	**64.4**	**66.1**	**39.9**	**57.5**	**39.3**	**31.6**	**28.4**	**29.9**	**29.2**	**12.9**	**27.3**	**13.7**	**21.3**	**15.6**	**17.5**	**16.7**	**5.7**	**16.4**	**6.7**
Low-cost	6.0	7.5	73.0	79.5	67.5	69.3	41.5	69.2	41.4	41.6	34.0	32.3	34.2	13.5	36.1	14.6	27.6	18.5	19.2	20.5	6.0	22.7	7.2
Medium-cost	2.6	0.1	97.2	56.5	63.9	62.4	54.7	48.8	15.2	64.3	22.9	27.6	20.3	16.3	20.7	4.4	47.3	12.8	14.3	9.9	7.4	11.7	1.4
High-cost	0.5	0.5	21.6	17.6	39.5	47.7	11.4	30.3	14.8	5.9	8.2	11.6	16.3	3.1	10.6	3.3	3.0	4.7	5.4	7.6	1.0	5.3	1.1
Southern																							
Rural	**81.6**	**78.3**	**85.9**	**93.7**	**80.1**	**80.5**	**68.2**	**74.6**	**81.9**	**61.4**	**65.4**	**42.8**	**46.6**	**26.5**	**40.5**	**45.6**	**49.6**	**49.7**	**27.4**	**32.1**	**13.0**	**26.3**	**30.2**
Small scale	65.8	67.9	87.6	94.5	81.1	83.0	70.2	75.4	84.3	63.8	66.3	43.9	48.4	28.0	40.9	47.5	51.8	50.8	28.3	33.5	13.9	26.6	31.7
Medium scale	6.2	4.8	79.8	93.7	74.0	69.7	54.6	75.5	68.7	50.3	64.1	38.3	35.6	15.2	41.8	34.8	39.6	47.3	23.5	22.3	5.7	27.5	21.5
Large scale	0.2	0.1	61.2	0.0	77.1	5.0	89.3	65.1	15.1	29.8	0.0	36.3	4.7	16.8	23.9	0.1	22.4	0.0	17.1	4.4	3.2	14.8	0.0
Non-farm	9.3	5.5	73.6	0.0	76.5	72.6	51.3	54.8	64.4	53.6	0.0	38.1	42.1	15.5	30.4	32.1	42.5	0.0	23.8	29.7	6.7	20.3	19.4
Urban	**18.4**	**21.7**	**57.7**	**61.9**	**52.9**	**52.7**	**43.4**	**48.1**	**42.9**	**30.9**	**23.3**	**21.1**	**22.7**	**13.2**	**19.3**	**16.5**	**22.7**	**11.9**	**11.1**	**12.9**	**5.7**	**10.3**	**8.5**
Low-cost	8.2	16.2	59.5	61.7	57.1	72.3	52.9	55.1	49.9	30.8	23.2	23.2	33.6	15.3	23.1	19.5	22.3	12.5	12.5	19.9	6.4	12.6	10.1
Medium-cost	5.7	4.3	65.1	65.6	50.9	42.4	51.5	47.4	27.1	37.9	23.7	18.5	16.0	16.3	18.4	9.2	29.2	11.0	8.8	8.3	7.2	8.7	4.6
High-cost	4.6	1.2	24.7	47.5	26.3	30.5	14.0	17.4	5.3	8.5	22.3	8.3	11.4	5.8	3.7	2.0	4.1	12.4	3.4	6.1	2.8	1.7	1.1

Source: Own estimations.

Table 6: Poverty Profile of Petauke and Sinazongwe District, Zambia, 1991-2006

	Pop. Share	Pop. Share	Poverty Headcount (P0)							Poverty Gap (P1)							Poverty Inequality (P2)					
	1998	2006	1991	1993	1996	1998	2002	2004	2006	1991	1993	1996	1998	2002	2004	2006	1991	1993	1996	1998	2002	2004
Petauke																						
Rural	**98.43**	**93.59**	**89.8**	**99.2**	**93.5**	**91.9**	**75.7**	**84.9**	**88.1**	**71.3**	**72.4**	**63.5**	**53.1**	**31.8**	**56.7**	**49.3**	**60.9**	**56.5**	**46.9**	**35.6**	**16.1**	**41.5**
Small scale	96.42	89.96	89.7	99.5	93.8	91.9	76.1	85.5	88.7	71.3	73.1	63.8	53.4	32.0	57.4	49.7	60.9	57.2	47.3	35.8	16.2	42.2
Medium scale	0.87	0.94	92.8	94.0	88.5	93.3	46.5	70.8	30.7	76.0	61.2	48.3	49.8	17.6	35.3	12.6	65.0	43.8	30.0	29.9	7.1	19.9
Large scale	-	0.07	100.0	-	0.0	-	-	100.0	51.0	61.0	-	0.0	-	-	85.8	38.1	37.3	-	0.0	-	-	73.7
Non-farm	1.14	2.6	90.7	-	86.9	87.7	60.4	63.9	89.3	68.3	-	56.2	35.8	22.8	27.2	48.2	58.2	-	38.0	20.0	12.1	15.5
Urban	**1.57**	**6.41**	**76.7**	**71.0**	**53.4**	**54.1**	**0.0**	**69.7**	**42.1**	**54.4**	**32.5**	**27.8**	**22.2**	**0.0**	**36.5**	**12.4**	**40.9**	**19.9**	**16.7**	**13.3**	**0.0**	**23.7**
Low-cost	1.57	6.41	76.7	71.0	53.8	54.1	0.0	90.9	42.1	54.4	32.5	28.7	22.2	0.0	90.9	12.4	40.9	19.9	17.4	13.3	0.0	43.3
Medium-cost	-	-	-	-	48.0	-	-	62.0	-	-	-	17.0	-	-	62.0	-	-	-	8.5	-	-	16.6
High-cost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sinazongwe																						
Rural	**95.57**	**77.9**	**95.0**	**95.2**	**79.2**	**72.6**	**73.6**	**78.9**	**75.6**	**84.8**	**69.9**	**38.7**	**44.1**	**29.6**	**41.8**	**39.2**	**78.7**	**54.4**	**22.8**	**31.8**	**16.4**	**26.2**
Small scale	58.91	64.66	95.0	93.3	81.5	84.6	68.3	79.7	75.9	84.7	65.8	39.9	53.3	33.4	42.9	38.7	78.7	50.1	23.4	38.4	19.8	27.1
Medium scale	2.96	2.3	100.0	100.0	61.4	75.4	30.8	-	86.4	62.1	80.7	39.1	53.4	4.8	-	48.9	38.6	65.6	26.7	42.3	0.7	-
Large scale			-	-	-	-	-	60.9	-	-	-	-	-	-	16.6	-	-	-	-	-	-	5.1
Non-farm	33.7	10.93	94.2	-	64.0	51.6	85.7	-	71.2	91.3	-	22.5	27.2	22.5	-	40.3	88.7	-	12.0	19.4	10.0	-
Urban	**4.43**	**22.1**	**39.8**	**55.0**	**44.3**	**50.0**	**39.5**	**38.9**	**47.3**	**8.1**	**21.7**	**15.5**	**28.0**	**5.9**	**13.8**	**19.3**	**2.0**	**12.5**	**6.4**	**18.8**	**1.4**	**7.2**
Low-cost	1.24	19.86	34.6	86.2	-	91.8	39.5	38.9	49.7	7.4	45.3	-	61.5	5.9	13.8	20.4	1.8	30.1	-	47.1	1.4	7.2
Medium-cost	1.58	0.85	44.0	36.6	-	38.3	-	-	42.6	8.7	7.9	-	16.3	-	-	12.0	2.2	2.2	-	7.3	-	-
High-cost	1.61	1.39	-	-	44.3	29.1	-	-	15.8	-	-	15.5	13.6	-	-	7.6	-	-	6.4	8.2	-	-

Source: Own calculations.

Table 7: Growth Elasticity of Poverty Reduction, Zambia, 1991-2006

	1991-1998			1998-2006		
	Absolute Change Poverty Headcount	Growth Elasticity of Poverty Reduction	Growth Semi-Elasticity of Povety Reduction	Absolute Change Poverty Headcount	Growth Elasticity of Poverty Reduction	Growth Semi-Elasticity of Povety Reduction
National	3.153	-0.241	-0.168	-8.550	-0.738	-0.537
Central	6.715	-0.511	-0.358	-5.063	-0.414	-0.318
Copperbelt	3.649	-0.318	-0.194	-22.848	-2.217	-1.435
Eastern	-4.487	0.282	0.239	-1.263	-0.099	-0.079
Luapula	-3.113	0.197	0.166	-8.068	-0.627	-0.507
Lusaka	21.168	-3.680	-1.127	-22.852	-2.771	-1.435
Northern	-2.883	0.183	0.154	-2.656	-0.206	-0.167
N. Western	1.105	-0.079	-0.059	-3.621	-0.300	-0.227
Southern	-3.881	0.261	0.207	-1.776	-0.148	-0.112
Western	4.876	-0.308	-0.260	-5.494	-0.387	-0.345
Petauke	3.059	-0.185	-0.163	-6.120	-0.421	-0.384
Sinazongwe	-3.753	0.265	0.200	-2.326	-0.204	-0.146
Growth Real GDP/Cap.	-18.77			15.92		
Growth Real GDP/Cap./Yr	-2.7			2.0		

Source: Own calculations.

3.4 *Poverty Change and Decomposition*

An important question is whether or not economic growth lifts the poor out of poverty. Table 7 reports growth elasticity of poverty reduction and semi-elasticity is also reported side-by-side. During the 1991-1998 periods, growth of real income per capita was negative at an average annual rate of -2.7 percent. In the next period of 1998-2006, the real income per capita grew, on average, 2 percent/year.

The poverty-growth elasticities and semi-elasticities of Zambia are inelastic (less than unity) meaning that a 10 percent economic growth is associated with poverty reduction of 1.6 and 5.3 percentage point during the structural adjustment and new growth periods respectively. The fact that the elsaticities are smaller during the structural change period indicates that the Zambian economy has significant degree of shock absorptions. If the poverty-growth semi-elasticity during 1991-1998 is equal in magnitude to that in 1998-2006, absolute change in poverty headcounts would have tripled from 3.1 to 10.1 percentage point.

Predominantly urbanized Provinces like Lusaka and Copperbelt have high poverty-growth elasticities (greater than unity in absolute value) indicating that they are more affected during the structural adjustment program and benefited more from economic growth during the new growth era.

During the period of structural adjustment, Eastern and Southern Provinces were the top two provinces in reducing poverty. While poverty in Sinazongwe reduced, Petauke experienced an increase. During the growth period, however, Petauke outperformed Sinazongwe by having her poverty headcount reduced by 6 percentage points comparing to a meager reduction of 2 percentage point in Sinazongwe.

Change in poverty can be decomposed into growth and redistribution components (Datt & Ravallion, 1992). To avoid path dependent issue, Shapley approach to decomposition was used. Table 8 shows decomposition results. Changes in poverty headcounts were largely attributable to changes in growth components. No uniform patterns can be said about the redistribution components. Changes in the variance of consumption expenditures played both offsetting and supplementing roles to the growth components.

Table 8: Decomposition of Poverty Change

Period	1991-1998			1998-2006		
	Growth Componennt	Redistribution Component	Total Change in Poverty	Growth Componennt	Redistribution Component	Total Change in Poverty
	Headcount Index					
National	3.2	-0.1	3.2	-11.3	2.7	-8.6
Central	-1.6	8.3	6.7	-1.6	8.3	-5.1
Copperbelt	3.8	-0.1	3.6	-26.3	3.4	-22.8
Eastern	-4.4	-0.1	-4.5	-2.3	1.0	-1.3
Luapula	-2.3	-0.8	-3.1	-6.7	-1.4	-8.1
Lusaka	14.2	7.0	21.2	-23.4	0.5	-22.9
Northern	-2.8	-0.1	-2.9	-4.3	1.7	-2.7
N. Western	7.1	-6.0	1.1	-0.9	-2.7	-3.6
Southern	0.6	-4.4	-3.9	-8.4	6.6	-1.8
Western	10.2	-5.3	4.9	-2.5	-3.0	-5.5
Petauke	-1.0	4.1	3.1	-11.0	4.9	-6.1
Sinazongwe	-0.8	-2.9	-3.8	-2.0	-0.4	-2.3

Source: Own calculations.

To better understand how growth affects poverty, growth incidence curves were plotted for Zambia, Eastern and Southern Province, Petauke and Sinazongwe districts. The graphs are shown in Figure 5-14. For the structural adjustment periods, the growth incidence curves depict clear pictures of pro poor growth. Consumptions of the populations in lower quantiles grew faster than the mean growth rates. However, the situations reversed during the new growth period except Sinazongwe's. Consumption growth of the higher quantiles outpaced those of the lower ones indicating that gains from growth may have disproportionately benefited the better-offs which generally residing in urban areas. As a result, inequality in Zambia worsened (see Table 9). Figure 4 illustrates year-to-year movement of Gini coefficient (the lower is more equal). The movement patterns are consistent with the results reported in Table 9.

Table 9: Pro Poor Growth and Inequality, Zambia 1991-2006

	Pro-Poor Growth		Change in Gini Coefficient	
	1991-1998	1998-2006	1991-1998	1998-2006
Zambia	Yes	No	-0.081	0.032
Eastern	Yes	Neutral	-0.138	-0.003
Petauke	Yes	No	-0.292	0.073
Southern	Yes	No	-0.160	0.053
Sinazongwe	Yes	Yes	-0.200	-0.082

Source: Own calculations.

Note: Changes in Gini coefficient indicates improvement (deterioration) if negative (positive).

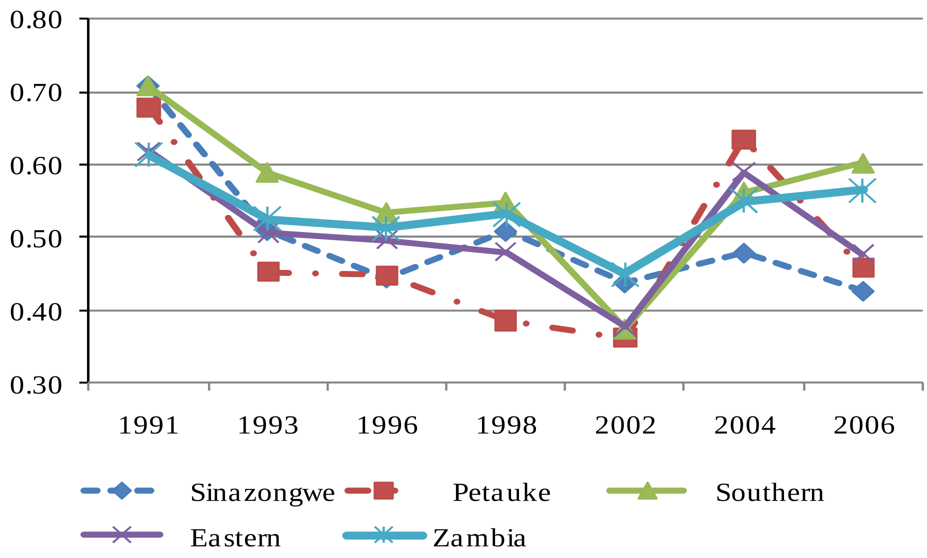

Figure 4: Trends of Gini Coefficient by Selected District, Zambia, 1991-2006

4. Conclusion

The implementation of structural adjustment program in 1990 coupled with a major drought in 1991/92 agricultural season have created a sharp increase in poverty in both rural and urban areas in 1993. The largest increase of poverty was in urban areas especially in Lusaka and Copperbelt. Overall poverty situation in Zambia showed sign of improvements especially during the new growth period after the year 1998. Economic growth during this new growth period appears to disproportionately benefit urban population with Lusaka enjoying significant reduction of poverty head counts. In contrast, poverty in Southern and Eastern provinces are on a rising trend with increasing severity. The shifting poverty trends in those two provinces may be associated with a series of droughts affecting farm production during early 2000s' agricultural seasons.

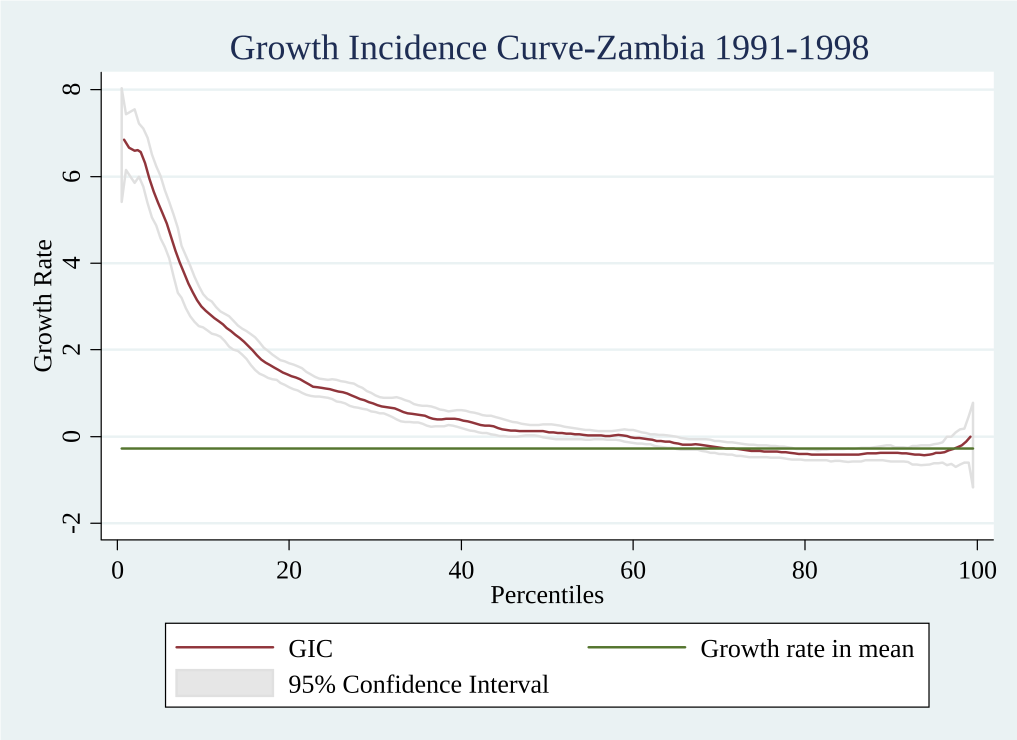

Figure 5: Growth Incidence Curve, Zambia, 1991-1998

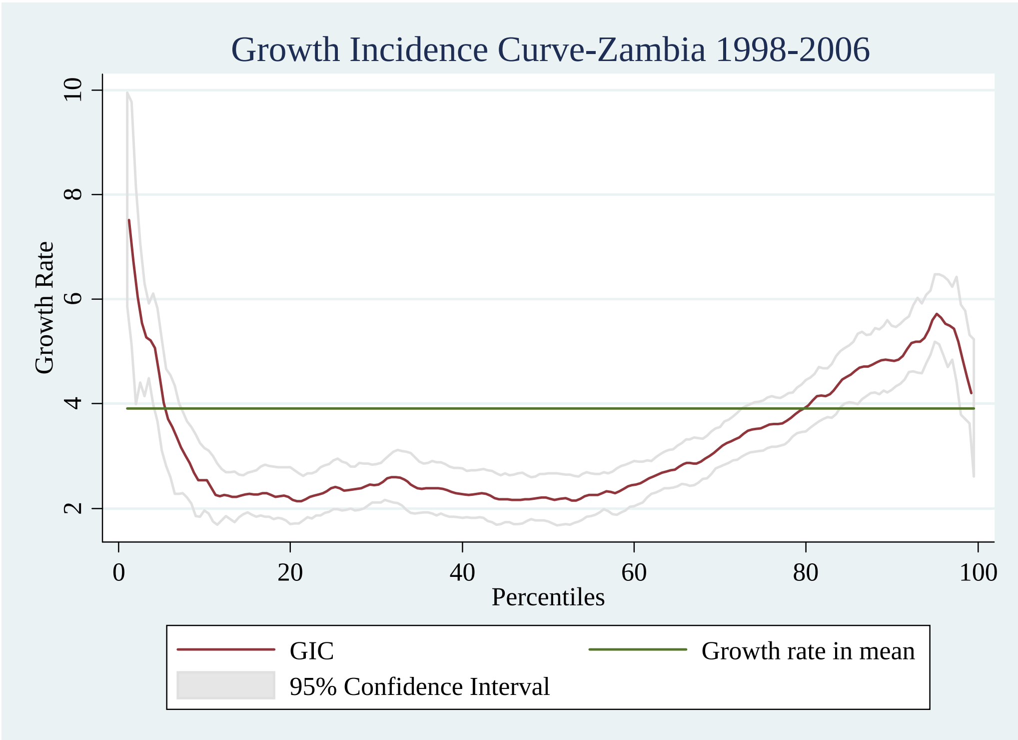

Figure 6: Growth Incidence Curve, Zambia, 1998-2006

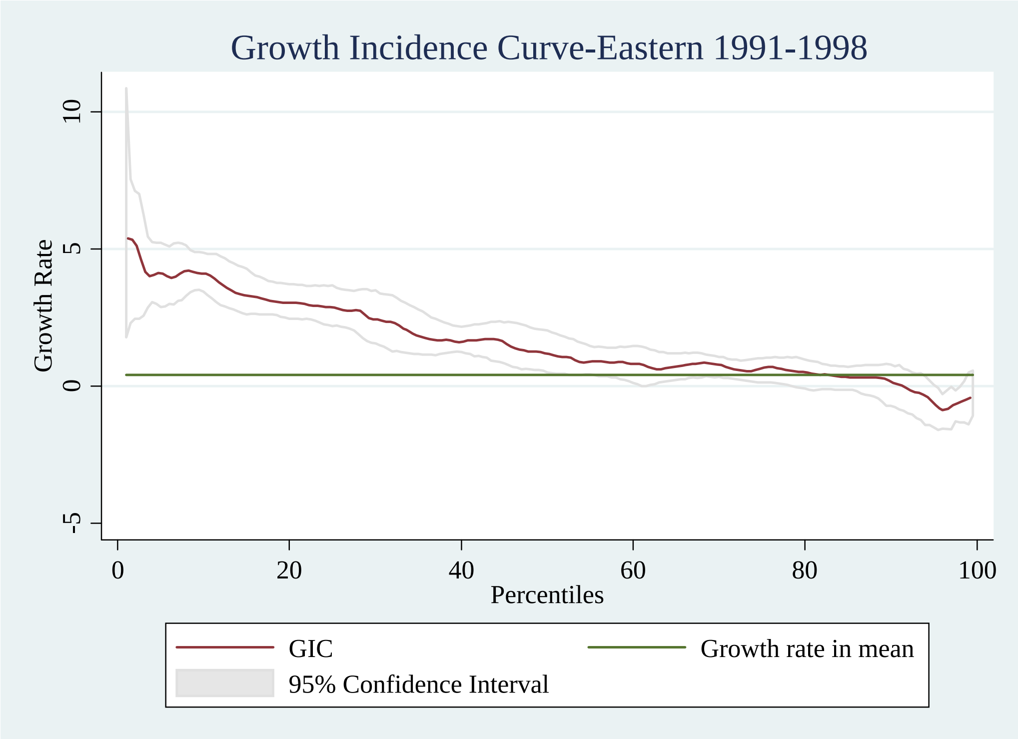

Figure 7Growth Incidence Curve, Eastern Province, Zambia, 1991-1998

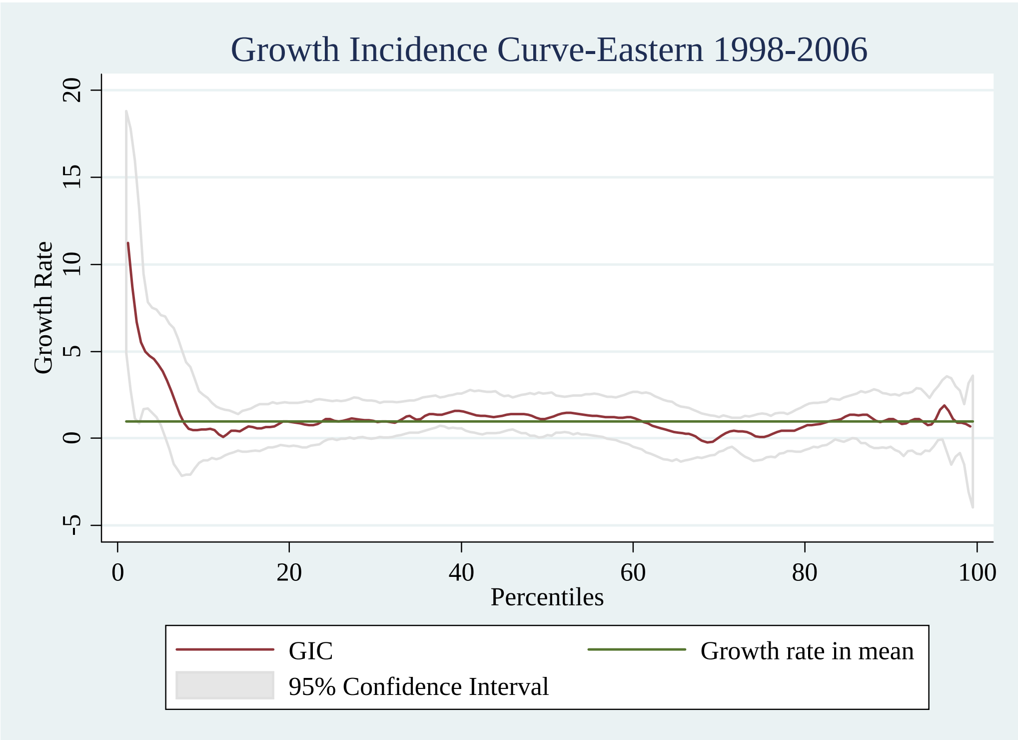

Figure 8: Growth Incidence Curve, Eastern Province, Zambia1998-2006

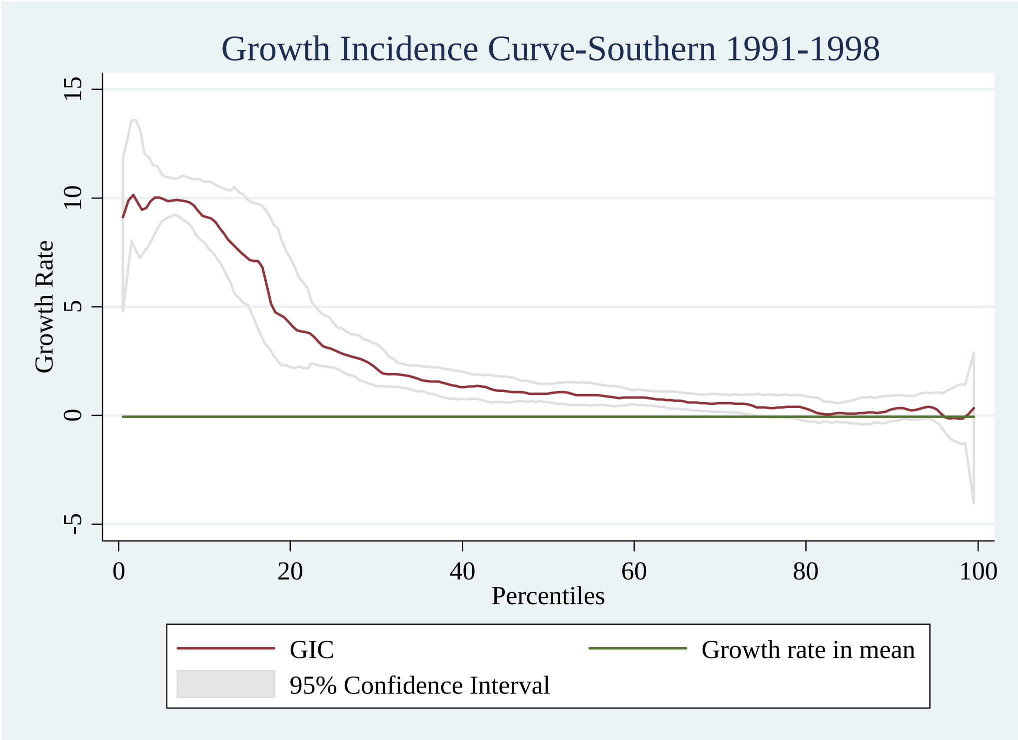

Figure 9: Growth Incidence Curve, Southern Province, Zambia, 1991-1998

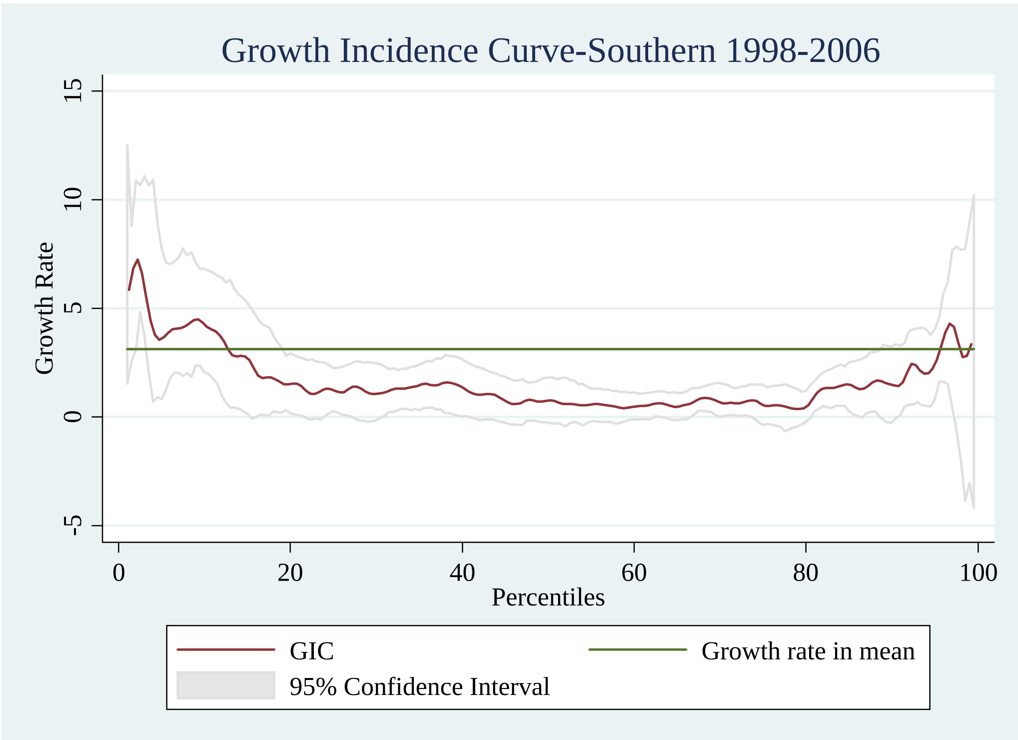

Figure 10: Growth Incidence Curve, Southern Province, Zambia, 1998-2006

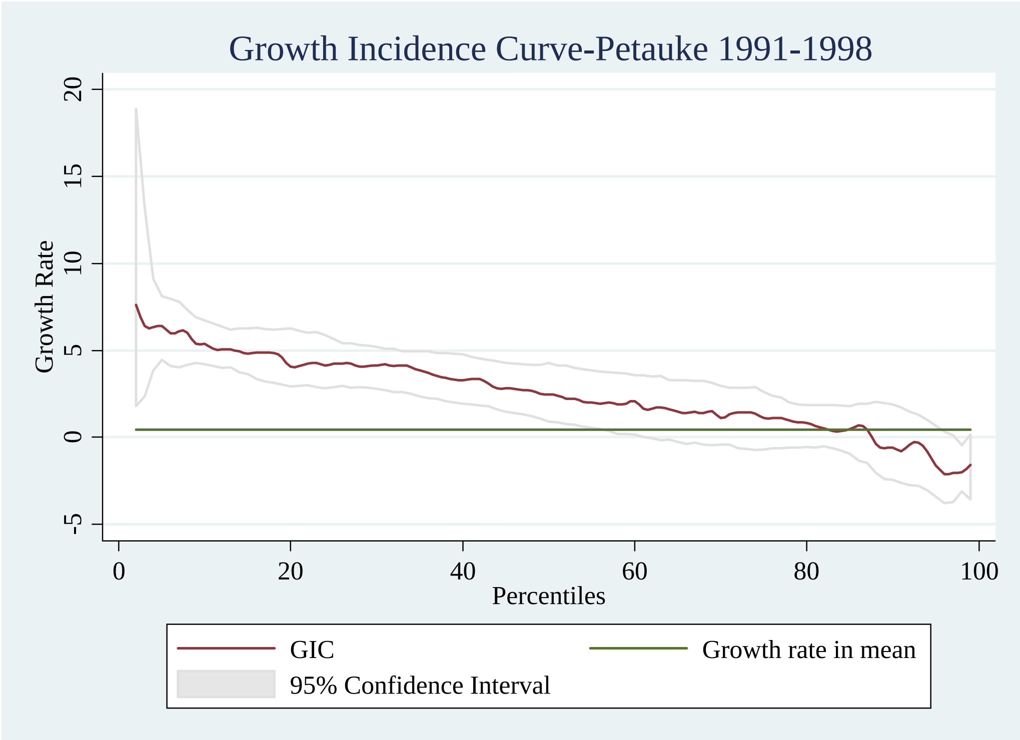

Figure 11: Growth Incidence Curve, Petauke, Eastern Province, Zambia 1991-1998

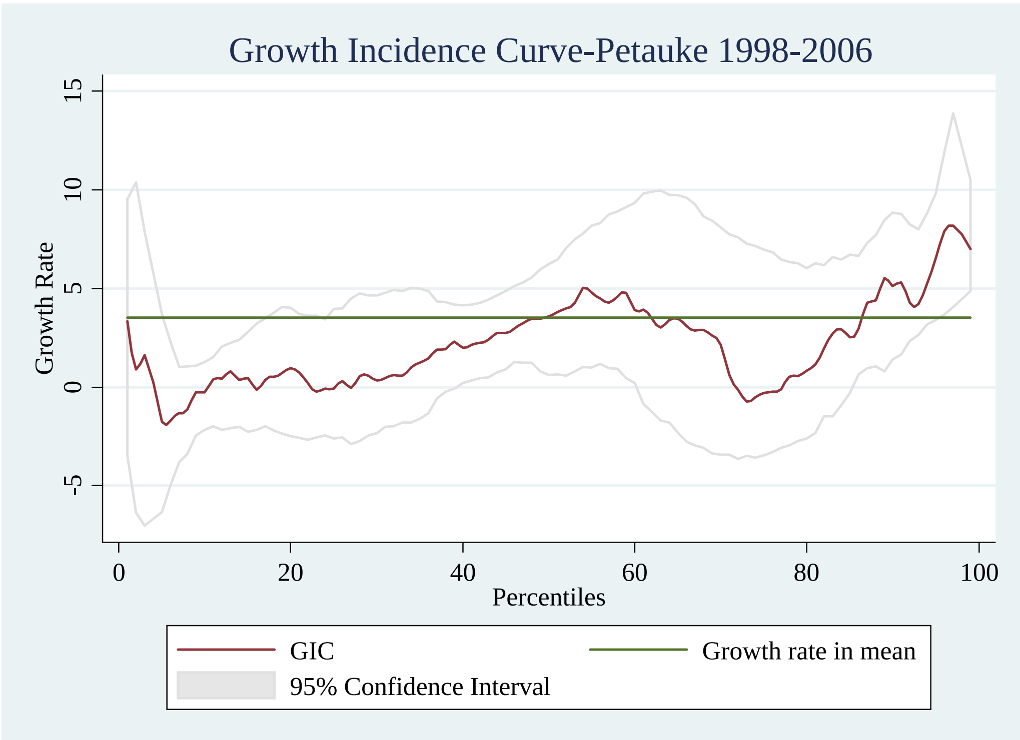

Figure 12: Growth Incidence Curve, Petauke, Southern Province, Zambia, 1998-2006

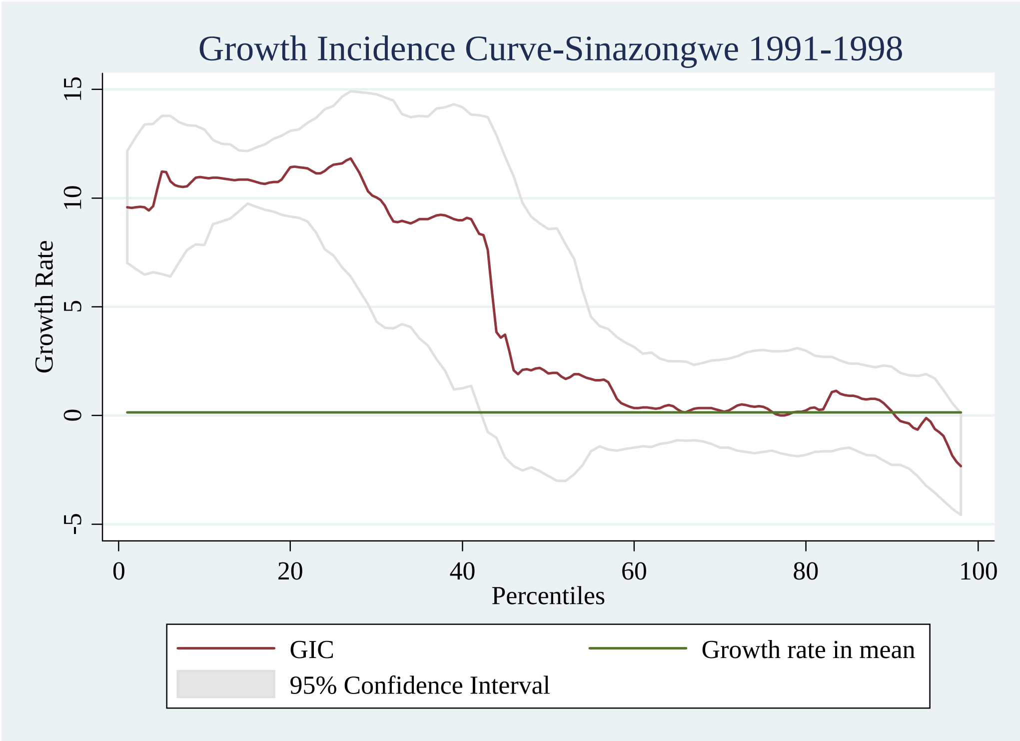

Figure 13: Growth Incidence Curve, Sinazongwe, Southern Province, Zambia 1991-1998

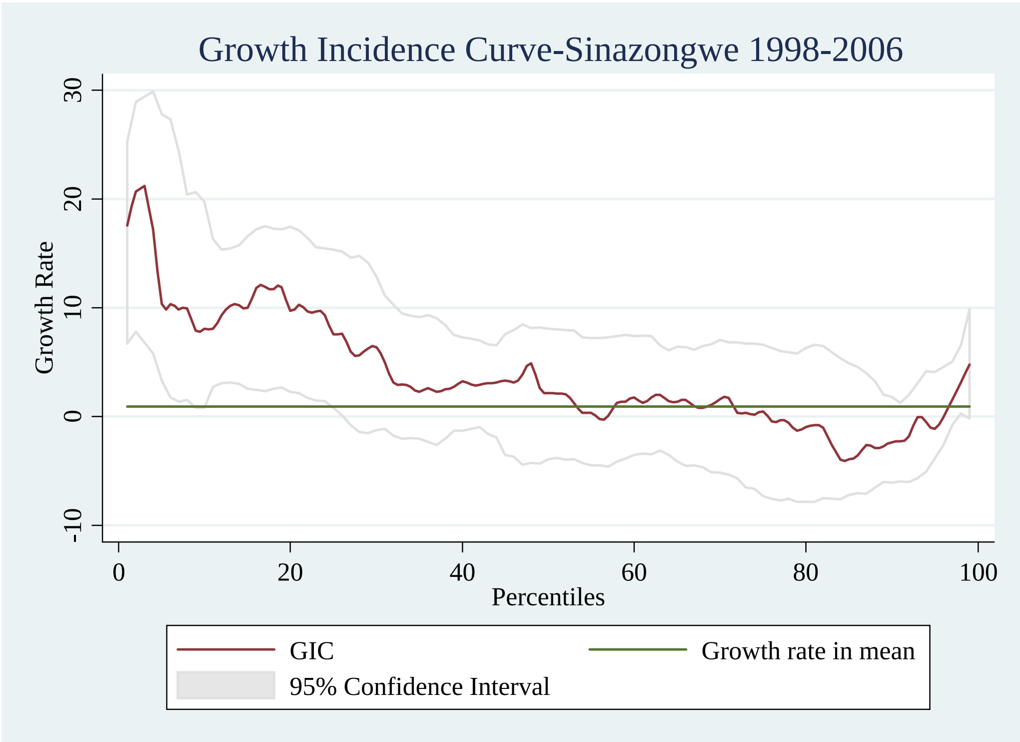

Figure 14: Growth Incidence Curve, Sinazongwe, Southern Province, Zambia 1998-2006

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Interannual variation of seasonal rainfall in South Zambia

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1. Introduction

The amount of rainfall and its seasonal characteristics are important factors in Zambia, because its economy depends on rain-fed agriculture. Therefore, analyses of historical rainfall patterns are useful from a scientific perspective, but also in terms of understanding Zambian culture. In terms of “resilience”, the responses to a previous shock event, for example, a drought, may affect current drought prevention activity and the behavior of farmers. In this paper, we describe the rainfall climatology and the rainfall trends over the last 40 years in Zambia. The final goal of this study is to evaluate the conditions over the target years of the project (2006–2011) compared with long-term conditions (over the last 50 years). This paper does not present measurement data from the current project, but instead shows rainfall data archived by the Zambia Meteorological Department. As well, we present gridded precipitation climatology data (shown in section 2.4) and satellite (radar) estimates (2.3).

2. Data

Recently, many rainfall estimates have been obtained using satellite data. However, the time-series of such estimates are not long enough to reveal long-term trends. Furthermore, these estimates need to be confirmed by comparisons with direct rain-gauge measurements, especially in desert areas. For these reasons, we have mainly used rain-gauge measurement data in this study (2.1, 2.2).

2.1 Monthly rainfall station data

The monthly rainfall station data were obtained from the Zambia Meteorological Department (ZMD).

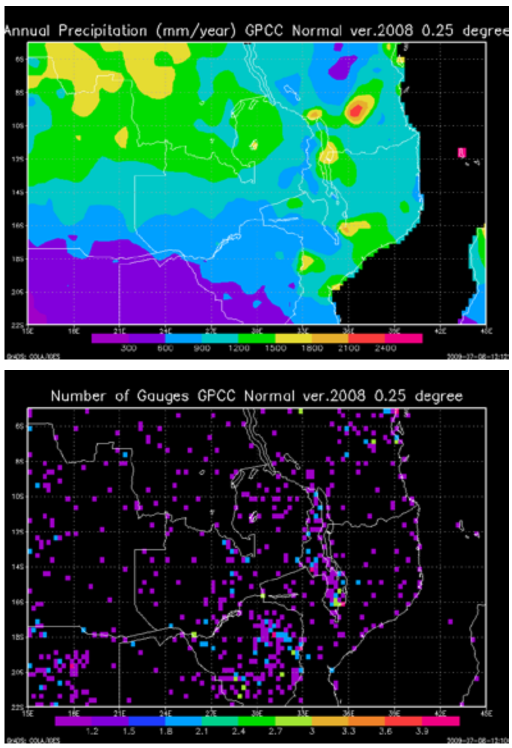

Fig. 1 Upper: Upper: Annual precipitation normal (mean) shown on a 0.25-degree grid, developed by GPCC. Lower panel shows number and location of gauges used to analyze data for top figure.

At the beginning of this project, we obtained monthly precipitation data collected from 40 stations across Zambia from 1961 to 2003. Some of the information regarding station locations appeared to be incorrect, in that some of the stations appeared to be located outside of the national boundary. These data were checked and corrected (cf. Figure 3a, Saeki, 2008). Then data updated to 2006 were obtained.

2.2 Daily rainfall data

The daily rainfall data for Zambia were compiled by the Zambia Meteorological Department. We obtained daily precipitation data for Zambia from 1978 to 2009. Some stations have data updated to 2007/2008.

2.3 Precipitation Radar (PR) of Tropical Rainfall Measuring Mission (TRMM)

TRMM/PR is a powerful tool to show rainfall patterns, including those on orographically complex terrain. We used “near surface rain” of PR2A25 path data to construct a 0.05-degree grid (approximately 5-km mesh) to show precipitation climatology data in the period from 1998 to 2007.

2.4 Global Precipitation Climatology Center (GPCC)

The GPCC is an international organization that operates within the German Meteorological Service (DWD). They produce monthly precipitation grid data. Here, we used only the climate normal values (one of their products created in 2008) and some station information.

3. Results

3.1 Climatology

Figure 1 shows annual precipitation data obtained by the GPCC. The maximum rainfall occurs in northwestern Zambia, and the amount of rainfall decreases to the southeast. The South District of Zambia receives 600–900 mm rainfall per year, and thus, this area is a semi-arid zone. The lower panel of Figure 1 shows the locations of the rain gauges across Zambia. The network of rain-gauges shown in this map, including those in surrounding countries, appears to be sufficient to study the relationship between rainfall and synoptic meteorological conditions.

TRMM/PR is one of the most powerful tools to depict rainfall patterns over land area, including orographically complicated terrain. Figure 2 shows a 10-year composite of TRMM/PR monthly rainfall patterns. Northwestern parts of Zambia receive more rainfall in October, November, and March, while there is a uniform pattern of rainfall across Zambia in December and January.

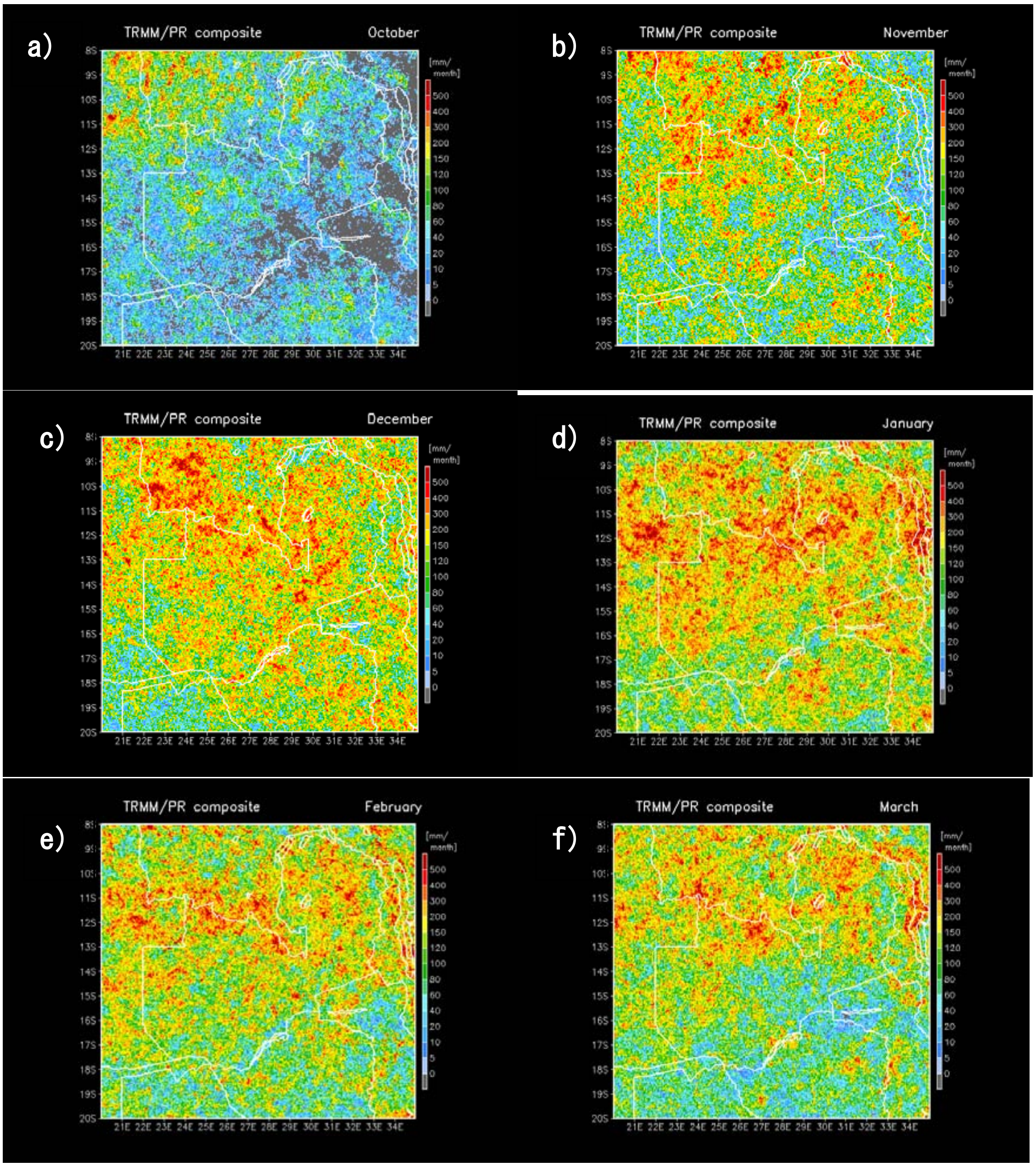

Figure 2. Monthly composite pattern (October to March) of “near surface rain” data from Precipitation Radar on board TRMM. Unit (mm/h) was converted into mm/month.

3.2 Trend of seasonal precipitation

Figure 3 shows seasonal rainfall over time during the period from 1961 to 2003. For this figure, we chose data from three stations (Chipata, Lusaka, and Livingstone) along the northeast-southwest national boundary. At all of these stations, there was a decrease in rainfall from at least the 1970s to the early 2000s. Some rainfall peaks are coincident at several stations, but they do not always match. Hence, further discussions will be focused on the South Province.

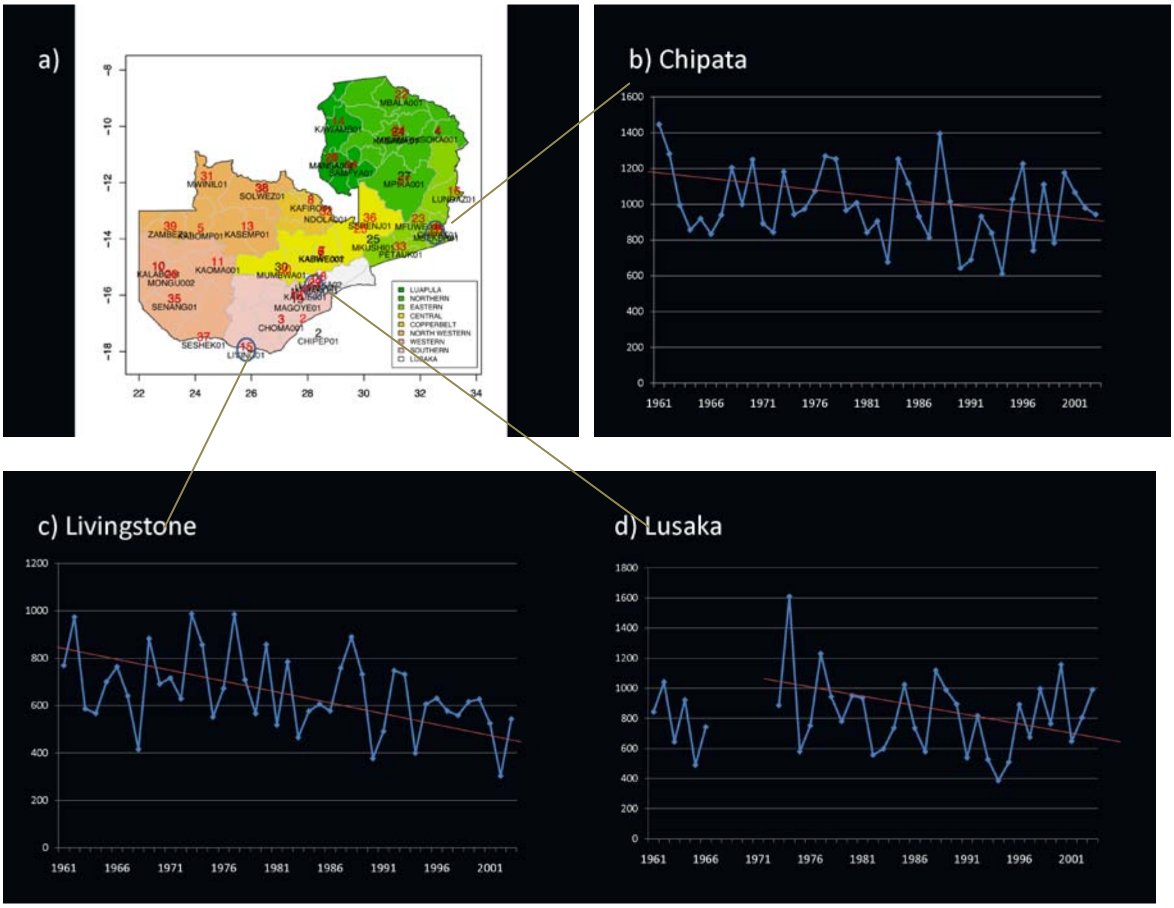

Figure 3. Seasonal (September to May) rainfall time-series (blue lines) at Chipata, Lusaka, and Livingstone from 1961 to 2003. Values shown for 1961 represent accumulated rainfall from September 1961 to May 1962. Red lines show linear trend.

3.3 Relationship with El Nino/Southern Oscillation (ENSO)

The ZMS observation station nearest to the project site is at Choma. Figure 4 shows the annual (August–July) rainfall time-series at Choma, Lusaka, and Livingstone from 1978 to 2007. The three time series show very similar patterns of fluctuations. In general, there was less rainfall at all of these sites in El Nino years, and more rainfall in La Nina years. However, this trend was not always observed. In 2006 and 2007, the time series at Choma differed from those at the other two sites. Therefore, to understand the rainfall variability and to compare it with the project observation site, it may be important to analyze rainfall patterns using satellite data.

Figure 5 shows the composite rain-rate pattern for December 2006 and December 2007. Although TRMM/PR has a large sampling bias problem, it shows clear differences in rainfall patterns. In particular, it highlights the rainfall maxima around Lake Kariba in December 2007.

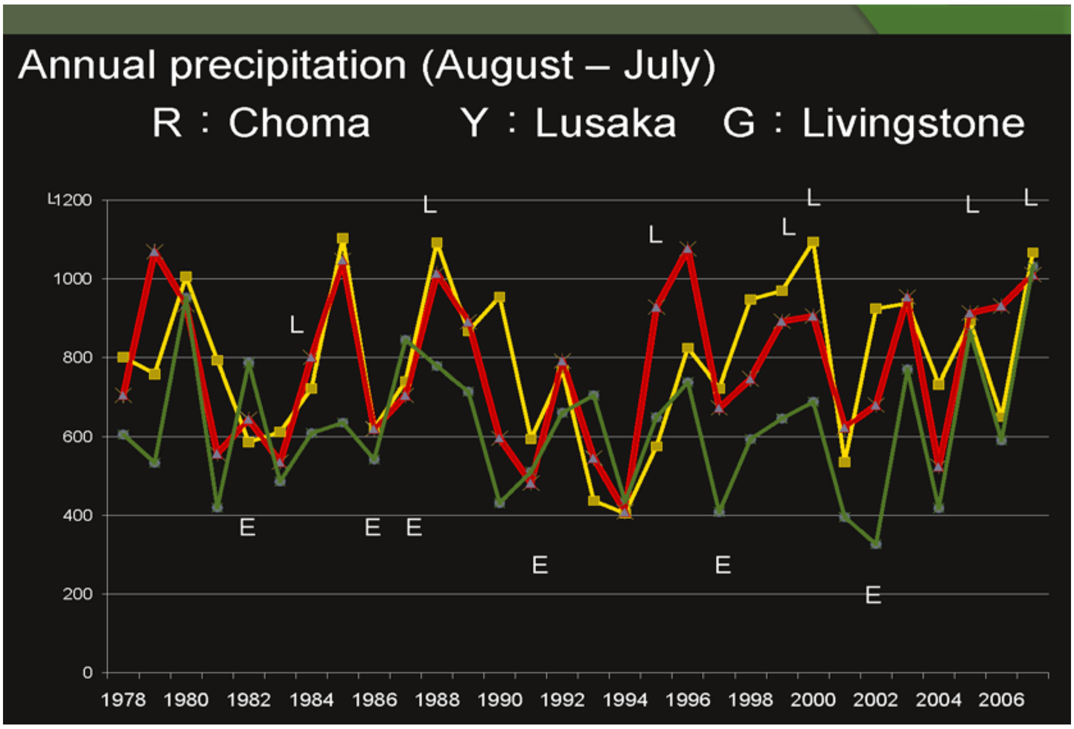

Figure 4. Annual (August–July) rainfall time series at Choma, Lusaka, and Livingstone from 1978 to 2007. Value shown for 1978 represents total rainfall from August 1978 to July 1979. E, El Nino; L, La Nina; Red, Choma; Yellow, Lusaka; Green, Livingstone.

3.4 Daily rainfall change at Choma

Figure 6 shows accumulated rainfall over time at Choma. This type of rainfall data is important for agricultural purposes. As shown in Figure 4, in general, there is less rainfall at this site in El Nino years. Hence, a severe drought period occurred in 1982/1983 and 1991/1992. However, there was also less rainfall in 1999, even though it was a La Nina year. In terms of agricultural production, it is important to clarify which patterns of rainfall are more harmful. It is also important to understand the dominant factors affecting such rainfall patterns, including climate patterns such as El Nino.

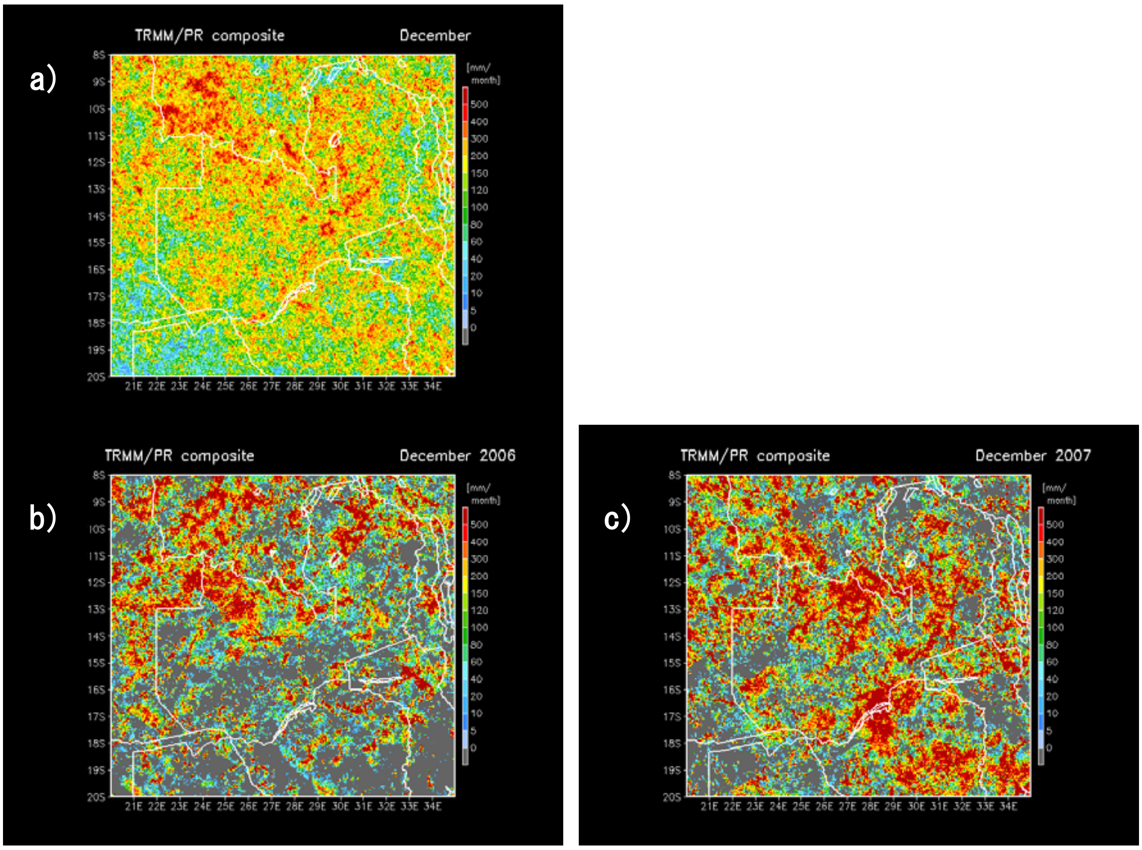

Figure 5. December rainfall climatology data from (a) TRMM/PR (same as that in Fig. 2c) and composite data for rainfall in (b) December 2006 and (c) December 2007.

4. Summary of rainfall patterns in Zambia

- Seasonal precipitation at Lusaka is decreasing, at least from the 1970s to 1990s.
- Seasonal precipitation at Chipato and Livingstone decreased from 1961 to 2003.
- Seasonal precipitation began to increase after 2003.
- Choma, Lusaka, and Livingstone receive less rainfall in El Nino years and more rainfall in La Nina years.
- Rainfall maxima around Lake Kariba were observed by TRMM/PR in December 2007.
- It is likely that ENSO (El Nino Southern Oscillation) is one of the most important factors regulating rainfall in South Zambia. However, other factors also should be investigated.

Acknowledgement

We would like to thank Mr. O. A. Mwangase of Zambia Meteorological Department.

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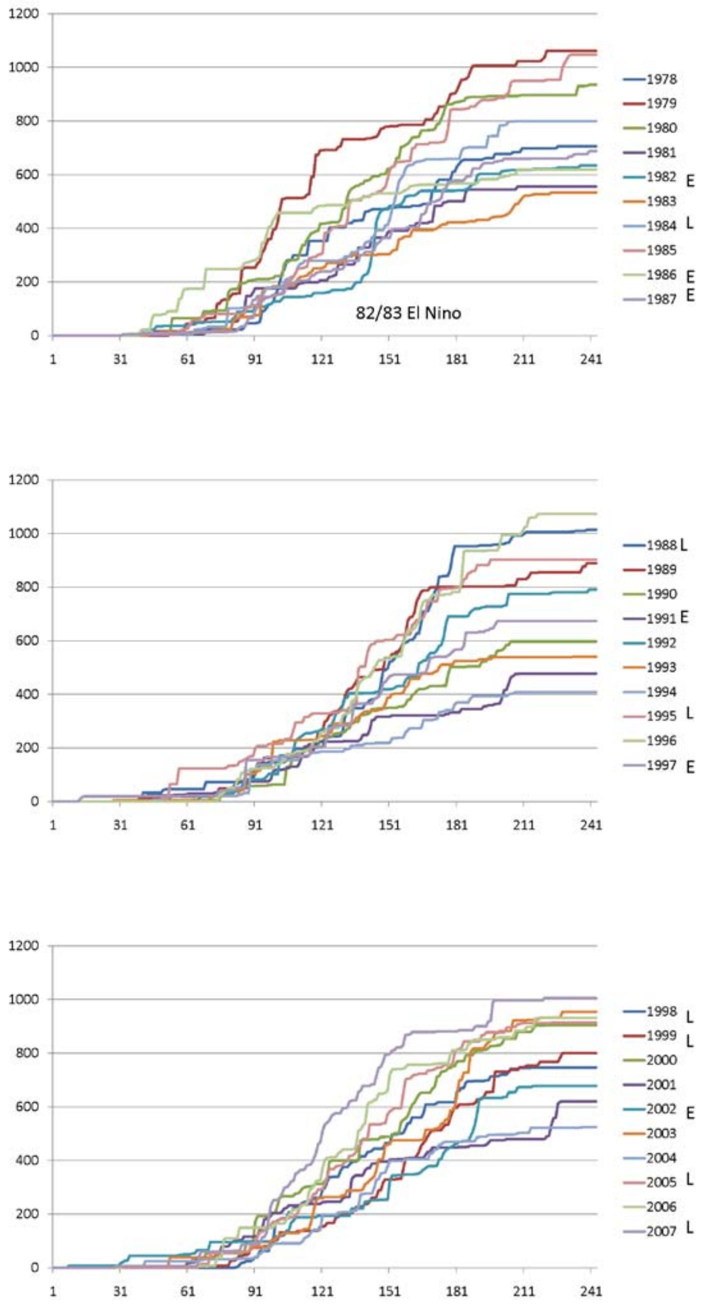

Figure 6. Daily accumulated rainfall from September to April each year at Choma. Upper, 1980s; middle, 1990s; lower, 2000s. Color indicates year; E, El Nino; L, La Nina.

Resilience of farming households to the Indian Ocean's Tsunami Disaster in Tamil Nadu of India

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Abstract

This paper investigates the magnitude of income shocks and their recovery of tsunami affected households during the post-tsunami period 2005-2008 in Nagapattinam District, Tamil Nadu, India. Most farmers suffered from decline of income and assets immediately after tsunami. During the 2005/06 planting season, our estimate indicates that farming households saw their farm income drop by as much as 60 percent. By 2007/08 agricultural season, households showed a near complete recovery of their incomes. After tsunami, there is a major transformation of the livelihood from agricultural production to wage labor. The major coping strategies dominated by receiving aid, borrowing money for most households. Other coping strategies included consumption reduction followed by removing children from school. The empirical results showed strong growth convergence during post-tsunami period. During the post-tsunami period, in nearly all categories of nominal incomes, the recovery was observed. However, when the price increase is taken into account, the effect of the recovery become less obvious. Shock sensitivity analysis indicated that the access to factor markets such as aid received, access to credit market and access to labor market, are important household resilience enhancing factors in terms of income shock recovery. As the results, the speed of the recovery was different in biophysical environment and in social environment in tsunami affected area. Government needs to carefully monitor soil and water to suggest recovery of agricultural production and support disaster affected people by providing access to factor market so that they can recover from income loss quickly.

1. Introduction

In the morning of 26th December 2004, a large scale earthquake that occurred in Indian Ocean and caused tremendous damage to the eastern coastal area of India. In India alone, the earthquake casualties reported were more than 16,000 (Miller, 2005). Most affected coastal areas were Tamil Nadu, Kerala, Andra Pradesh, and Andaman and Nicobal Islands. In Tamil Nadu state, three districts were mostly affected, namely Nagapattinam, Cuddalore, Kanniyakumari. Among three districts, the damage by tsunami in Nagapattinam was largest with more than 7,000 casualties and 5,000 hectares of agricultural lands. Tsunami also left people with psychological shocks since they never experienced such an incident for a century

(Miller, Rajikumar, Shanthasheela). It is of primary importance for government and communities to consider how and in what way the affected people and communities in coastal ecosystems recover from a huge disaster such as tsunami. There is an effort to promote integrated coastal management (ICM) to solve for resource use conflict and build more resilient coastal communities and environment (Wong 2009).

The concept of ecological resilience has been a focus of ecological research since defined in the seminal paper "Resilience and Stability of Ecological Systems" by C. S. Holling (1973). The earlier concept of resilience is called *engineering resilience* where resilience is defined as the recovery time for an ecological system to return to the initial equilibrium condition present before disturbance. Systems that return to initial equilibrium conditions more quickly are considered to be more resilient that systems that take a long period to recover after disturbances. The equilibrium concept was expanded to the concept of *ecological resilience*, which emphasizes capacity to endure disturbance, incorporating non-linearity, multiple equilibria and regime shifts. After the 1990s, the resilience concept focuses more on the properties of self-organization after disturbance. Recently researchers applied these resilience concepts used in ecology and engineering to complex social-ecological systems (Levin et al., 1998; Levin, 1999; Berkes, Fikret & Folke eds., 1998; Berkes, Colding & Folke eds., 2003, Umetsu 2010). Resilience is a particularly relevant concept for considering the recovery of communities affected by disasters and the development of rural societies whose livelihoods are highly dependent on natural resource base. Not only the fast recovery of social-ecological system, but the capacity to cope with uncertainty and surprise is required (Adger et al., 2005).

In the economic literature, there is a debate over what should be recovered for marginal agricultural households after environmental shocks like tsunami, hurricane, drought and earthquake. Asset smoothing circle asserts the existence of poverty trap, a critical minimum asset threshold, below which households are difficult to build up their productive assets and move up economically from poverty line (Carter and Barrett 2006; Little et al. 2006; Carter et al. 2007). On the other hand, income smoothing circles consider poverty in terms of income level and poverty is defined by the level of income where environmental shocks may push some marginal households to below poverty line (Dercon 2004). This debate has significant impacts since it immediately influences policy makers to consider what really should be restored after such a shock in the short-run and in the long-run.

The purpose of the paper is to consider how income of tsunami affected households recovered from a shock and to reveal the path and factors affecting recovery. We focus more on mid-term recovery and changes rather than short-run recovery immediately after tsunami. Particular emphasis is placed on income shocks and their recovery. The organization of the paper is as follows. First section reviews current literature of income shock and coping. Secondly we build a model for analyzing recovery and resilience to a major natural disaster. Thirdly we apply this method to tsunami affected agricultural households in Tamil Nadu, India. Last section concludes the paper and to provide policy recommendations for building resilience for rural communities during the post-disaster period.

2. Method

2.1 Empirical strategies

Our empirical approach is inspired by Carter, Little, Mogues and Negatu's (2007) asset growth model that allows transitional dynamics and shocks to play explicit roles in determining the growth of household wealth (e.g. asset or income). In this model, growth rate is related to an initial level of income, shocks and a host of factors determining efficiency and steady state. The model is applied to examine resilience to shock as defined by a capacity to recover asset or income to a pre-shock level by using data from pre- and post-shock periods. In the context of panel study of household incomes of *N* households (*N*= *1, 2,…, i*) over *t* periods, the model can be specified as:

$$\ln y_{it}\text{-}\ln y_{it-1} = \alpha + \beta \ln y_{it-1} + \gamma \ln S_{it} + \delta Z_{it} + \eta X_i + \varepsilon_{it} \quad (1)$$

Here, S_{it} denotes shocks (e.g. income shock, asset shock) and Z_{it} and X_i represent, respectively, time-varying and fixed characteristics of the households determining, for example, saving or investment in human capital. The constant term, α, is a common source of growth to all households; and the ε_{it} is an error term with mean of zero. In the context of pre- and post-shock situation, one may substitute $\ln y_{it-1}$ with the pre-shock income denoted by $\ln y_{ib}$ and the $\ln y_{it}$ is the post-shock recovery income stretching several periods as follow:

$$\ln y_{it}\text{-}\ln y_{ib} = \alpha + \beta \ln y_{ib} + \gamma \ln S_{it} + \delta Z_{it} + \eta X_i + \varepsilon_{it} \quad (2)$$

A standard use of this model is to determine whether the conditional convergence exist in the household data. The $\beta < 0$ would signal the existence of conditional convergence which is an equilibrium income that all household incomes in the data grow toward. The income convergence condition implies that the lower income group would have a growth accumulation process that is faster than that of the higher income group. The model can be adapted to examine whether a shock has persistent effects on income growth by augmenting a distributed lag terms as follow:

$$\ln y_{it}\text{-}\ln y_{ib} = \alpha + \beta \ln y_{ib} + \gamma_1(\ln S_{it} - \ln S_{it-1}) + \gamma_2(\ln S_{it-1} - \ln S_{it-2}) + \delta Z_{it} + \eta X_i + \varepsilon_{it} \quad (3)$$

The shock persistence is identified when γ_2 that is significantly less (greater) than zero for negative (positive) persistent effects on growth.

To identify income recovery, we follow Carter et al.'s approach by incorporating income loss term, ω_{it}, normalized by the pre-shock income. The simple growth model is modified as follow:

$$\ln y_{it}\text{-}\ln y_{ib} = \alpha + \beta \ln y_{ib} + \theta(y_{ib}, K_i, L_i)\ \omega_{it} + \gamma_1(\ln S_{it} - \ln S_{it-1}) + \gamma_2(\ln S_{it-1} - \ln S_{it-2}) + \delta Z_{it} + \eta X_i + \varepsilon_{it} \quad (4)$$

The $\theta(y_{ib}, K_i, L_i)$ is a parameter to be estimated conditional on pre-shock income level, access to capital market, K_i, and access to labor market, L_i. The household incomes have not yet recovered if the θ = -1 which means that a 10 percent income loss results in a 10 percent growth reduction. The θ < -1 signals that the households have further lost their capacity to generate income, for example, by not being able to afford necessary inputs such as fertilizers or labor employments. Household income recovery is identified if θ > -1. We use a general model in (4) to investigate determinants of income growth in a reduced form regression.

2.2 Data

The study site is located in Nagapattinam District of Tamil Nadu State, India where the damage was highest among districts affected by 2004 tsunami (Figure 1). Twenty four sample villages in coastal area were selected (Table 1), and about ten households in each village were selected for the long term tsunami-impact household survey. The total sample size is 240 households. All sample households are residents of tsunami affected area.

We conducted household survey in 2006, 2007 and 2008 and interviewed for consecutive four cropping seasons after tsunami disaster, i.e., 2004/2005, 2005/2006, 2006/2007, 2007/2008. Cropping season starts from summer season (February to May), Karif/Kuruvai season (June to September), and Rabi/Samba/Thaladi season (October to January). Karif season, which is the major paddy season that generates farm income in this area, is during North-east Monsoon season (Figure 3). The normal annual precipitation in Nagapattinam is 1341.7mm and that for North-east Monsoon is usually 886.4 mm. North-east Monsoon and South-west Monsoon are the two major rainy seasons in Nagapattinam. In 2004 and 2005, the North-east Monsoon season caused heavy rain and floods in Nagapattinam District. The 2004/2005 cropping season was directly hit by tsunami just before the harvest in January. And the subsequent three cropping seasons, 2005/2006, 2006/2007, 2007/2008 indicates post-tsunami period of recovery.

During the study period, we interviewed the same farmers to assess the impact of tsunami on agricultural production, household income including farm income, non-agricultural income including allied activities and wage income. In the study area, the dominant production system is rainfed agriculture and farmers produce paddy, pulses, gingerly, groundnuts, cashew nuts, coconuts, mango and others. Most farmers are marginal and about 74 percent of farmers own less than one hectare of land (Palanisami et al., 2010).

When tsunami hit the study area, sea water intrusion caused salinity level to rise in agricultural land and groundwater. In addition, ten observation wells were constructed to monitor changes in groundwater quality every month from June 2006 to March 2008. Also soil samples were analyzed for electric conductivity and pH values (Kume et al. 2009).

Data used in this analysis are a panel of 240 households over a four-year period starting from 2004/05 to 2007/08 agricultural season and covering 24 tsunami affected villages of the Nagapattinam District, Tamil Nadu State. We supplement our social household survey with ecological examinations of soil's and water's chemistry in our study villages to determine the extent to which the tsunami has altered their physical properties and their subsequent effects on households' income generating capacity.

The livelihood of more than three out of four households in our study areas directly and indirectly depends on agriculture, both as farmers and as farm labors (see Table 2).

Table 3 shows that merely 2.5 percent of the sampled households suffer physical injury. The majority of the households experience losses directly to their income or to their income generating capacity (e.g. job losses and productive asset losses). During the 2005/2006 cropping season, one year after tsunami, farmers replied declined income (73.5%), production asset loss (52%), and unemployment (50%). These incidents were reduced in 2006/2007 season, two years after tsunami, and became marginal during 2007/2008 season, three years after tsunami.

Table 2: Self-Report of Household Main Occupations, India

Main HH Occupation	2004/05 (Pre-Tsunami)		2005/06		2006/07		2007/08	
	No.	%	No.	%	No.	%	No.	%
Agriculture	176	73.3	59	24.6	60	25.0	92	38.3
Farm and Non-farm labor	48	20.0	164	68.3	165	68.8	136	56.7
Business	14	5.9	15	6.3	13	5.4	10	4.2
Missing	2	0.8	2	0.8	2	0.8	2	0.8
Total	240	100	240	100	240	100	240	100

Source: RIHN, TNAU, Tsunami Survey 2006, 2007 and 2008.

Table 3: Effects of Tsunami on Household Welfare, India

Category	2005/06		2006/07		2007/08	
	No.	%	No.	%	No.	%
Declining income	175	73.5	113	47.5	6	2.5
Physical injuries due to Tsunami	6	2.5	0	0	1	0.4
Production asset loss	124	52.1	60	25.2	8	3.3
Unemployment	119	50.0	54	22.7	8	3.3
House damaged	0	0	0	0	0	0
Household durable loss	0	0	0	0	0	0
Cash and jewels loss	0	0	0	0	0	0

Source: RIHN, TNAU, Tsunami Survey 2006, 2007 and 2008.

The households cope with the impact of tsunami in a variety of ways. Receiving aid (97.5%) and borrowing money (98.3 %) are their main coping strategies. Nearly every household reports to engage in both activities. The second most popular coping behavior is consumption reduction (49.6%), following by removing children from school (26.7%) perhaps to smooth income. One-tenth of the households attempted to smooth income by engaging in government employment scheme (10.8%). Interestingly, a 20 percent of households indicate no change in their behaviors.

The extent of expected income losses is reported in Table 4. On average, income losses linearly increase by household income level. Transfer and relief are generally small in size and able to offset only half of the income losses from crop failure. The lowest income quartile appears to be the only group to receive aid more than offset their income losses.

Table 4: Average Income Losses and Relief Received by Pre-Shock Income Quartile (Rs./household)

Category	Income Quartile			
	I	II	III	IV
Income loss	2,349	5,201	6,320	8,980
Transfer and aid	2,771	2,884	3,294	4,705
Aid as percentage of income loss	117.9	55.4	52.1	52.4

Source: RIHN, TNAU, Tsunami Survey 2006, 2007 and 2008.

Table 5: Share of Aggregate Income by Income Sources (Rs./household)

Income Share	2004/05	2005/06	2006/07	2007/08
Farm income	26.5	10.3	15.0	29.8
Livestock income	7.2	8.5	4.4	7.2
Non-farm income	9.7	9.2	6.2	4.2
Employment income	56.6	72.0	74.4	58.8
Total	100	100	100	100

Source: RIHN, TNAU, Tsunami Survey 2006, 2007 and 2008.

Note: Households' farm incomes of the 2004/05 are estimated.

Table 5 displays structure of aggregate income of data households. Although the majority of the respondents indicate agriculture as their main occupations, the largest share of household pre-shock earned incomes is from employment (56.6%). Agriculture accounts for only one-fourth of the total earned income. The share of labor income increased to 72 and 74.4 percent at the expense of reduction in the share of farm income in 2005/06 and 2006/07 respectively. The increase is pushed in part by crop failure and pull by the attractiveness of wage income, made available by various government employment schemes. For there are various restrictions on government employment schemes, farmers quickly returned to agriculture as the soil productivity is restored.

It is worth noting that the household farm income of 2004/05 is estimated based on peer's production efficiency. Since the tsunami occurred at the very end of the cropping season of 2004/05, farmers were able to provide us with near complete details of their income and input utilizations for the entire 2004/05 agricultural season. The input usage, productivity and crop sales of unaffected agricultural households in our sample and the pre-tsunami farm production of villages in Nagapattinam District in the 2003/04 season are used to estimate expected farm incomes for our data households in the 2004/05 season. This expected farm income is subsequently used to estimate crop income loss from tsunami both for the 2004/05 and the following seasons.

Table 6: Average Nominal and Real Income by Income Sources, India (2004=100) (Rs./year/household)

Income	**N**	**2004/05**	**2005/06**	**2006/07**	**2007/08**
Nominal					
Farm income	240	7,299	2,395	4,137	7,869
Allied activity income	240	1,971	1,977	1,200	1,908
Non-farm income	240	2,679	2,156	1,721	1,113
Employment income	240	15,603	16,840	20,561	15,555
Total earned income	240	27,552	23,368	27,619	26,445
Transfer & relief	240	0	9,444	555	67
Total income from all sources	240	27,552	32,812	28,174	26,511
Per capita earned income	238	8,772	7,423	8,693	8,631
Per capita total income	238	8,772	10,466	8,871	8,650
Real					
Farm income	240	7,299	2,303	3,761	6,842
Allied activity income	240	1,971	1,901	1,091	1,659
Non-farm income	240	2,679	2,073	1,564	967
Employment income	240	15,603	16,192	18,692	13,526
Total earned income	240	27,552	22,470	25,108	22,995
Transfer & relief	240	0	9,080	505	58
Total income from all sources	240	27,552	31,550	25,613	23,053
Per capita earned income	238	8,772	7,138	7,903	7,505
Per capita total income	238	8,772	10,064	8,065	7,522

Source: RIHN, TNAU, Tsunami Survey 2006, 2007 and 2008. The 2004/2005 income is estimated.

Table 6 shows trends of nominal and real average income per household and per capita over time. Full income recovery seems to be indicated by nearly every category of nominal incomes. For example, the post-shock farm income dropped from the pre-shock level of Rs 7,299 in 2004/05 to Rs 2,395 in 2005/06; by 2007/08 the average farm income has recovered to slightly above the pre-shock level at Rs. 7,869. However, when inflation is factored in, it is less evident whether or not income recovery is reached. We now turn to empirical analyses to determine the status of household income recovery or resilience to shock.

3. Results

We examine the process of income recovery based on the simple growth model given in (4) above. The results of parameter estimates are reported in Table 7 and 8. Table 7 and 8 differs in that the distributed lag of the percentage change in soil EC value is specified in the Table 7 to test for persistency of tsunami impact. As such, the panel of our data is reduced to a single cross-section and the period of our data analysis is reduced from 2004/05-2007/08 to 2004/05-2006/07 due to the unavailability of the EC measurements in the 2007/08 season; OLS estimator is used. In Table 8, the model specify only a lag percentage change of the soil EC values and that allow us to take advantage of the panel nature of our household data. In each table, two alternative specifications of (4) are displayed. The first is a restricted model that specify income growth rate as a function of initial or pre-shock income level, the shock variables and demographic factors. The second is the full model that adds shock mitigating factors such as aid received, access to labor market and credit market into the specification. Wald tests clearly reject the null hypothesis of no mitigating factors. Overall, the restricted and the full model and the OLS and the panel estimator produce qualitatively similar results.

A strong pattern that emerges out of all equations is a clear growth convergence. The convergence appears to be at a faster speed for the OLS estimates (ranging from -0.56 to -0.68) than for the maximum likelihood estimator (MLE) which varies in range from -0.35 to -0.49. The faster speed of convergence is probably a result of government and NGO's interventions which were pro-poor. In addition, the relief efforts were discontinued before the 2007/08 season in which the MLE covers.

A second important pattern these equations signals is income recovery. The coefficients of the income losses normalized by pre-shock income are negative and lying between 0 and -1. Wald tests clearly reject the null hypotheses of negative unitary of the income shock coefficients in all equations. The parameters of the income shock variable vary in range from -0.14 to –0.40 which means that a 10 percent income shock is related to a reduction of income growth by 1 to 4 percent. It is worth noting that the income shock coefficients in the full model of Table 7 are negative and not significantly different from zero after controlling for mitigating factors. One should be cautious not to prematurely interpret this as an evidence of full income recovery. Households losing productive asset, which is a dummy variable, are likely to see further reduction in their income growth. However, the variable does not carry much weight because the coefficients are not statistically different from zero.

To examine whether tsunami has persistent effects on income growth, we use the distributed lags of the percentage change of the soil EC to proxy physical effects of the tsunami. We expect the coefficients of the tsunami surrogate to have either negative or no effects on income growth because the soil EC quickly returns to the pre-shock level a year after the tsunami. Contrary to our expectations, nearly all equations appear to indicate that tsunami has persistent and positive effects on income growth. The coefficients of the lag soil EC growth are all positive and significantly different from zero in all but the restricted panel equations. Two possible explanations are in order. First, what comes with tsunami is not only salinity but also a variety of sediment deposits. As rain and flood helps the salinity level to quickly return to its pre-shock level, certain types of sediment deposits have high organic materials which help to increase soil minerals and improve soil fertility. This can lead to an increase in farm income and the overall earned income. Secondly, the lag of the soil EC growth rate indicates quicker recovery of soil salinity to its pre-shock level. A quicker is the recovery of soil salinity, the higher is the farm productivity and the household income.

Table 7: OLS Estimates of Income Growth Model, 2004/05-2006/07

Explanatory Variables	Earned Income		All Income		Earned Income		All Income	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Preshock income	-0.5633 ***	0.1486	-0.6128 ***	0.1462	-0.6788 ***	0.1765	-0.6873 ***	0.1763
Land per adult (A)	-1.7797 ***	0.6881	-1.9608 ***	0.7007	-2.8361 ***	1.0906	-2.8304 ***	1.0924
A^2	0.9750	0.8776	1.0505	0.9037	2.3644 *	1.3261	2.3398 *	1.3322
Income shock (ω)	-0.2929 ***	0.1074	-0.3102 ***	0.1072	-0.1405	0.1240	-0.1411	0.1246
Asset shock	-0.2758	0.3292	-0.1938	0.3031	-0.0539	0.3699	-0.0840	0.3686
Soil EC_t	0.1066 **	0.0433	0.0868 **	0.0429	0.0529	0.0419	0.0501	0.0420
Soil EC_{t-1}	0.1175 **	0.0472	0.1053 **	0.0469	0.1146 **	0.0489	0.1142 **	0.0491
Aid received					-0.2384 **	0.1047	0.1227	0.1032
Access to credit					0.5391	1.1681	0.3215	1.0486
Access to credit*ω					-0.0967	0.0780	-0.0822	0.0724
Access to labor market					2.4144 *	1.3283	2.4564 *	1.3221
Access to labor market*ω					-0.0609	0.0530	-0.0630	0.0529
Education of HH head	0.1120	0.1788	0.1315	0.1764	0.0585	0.1499	0.0679	0.1497
Age of HH head	0.2773	0.3286	0.2478	0.3237	0.2111	0.3224	0.2098	0.3224
Average adult's education	-0.0408	0.2850	-0.0643	0.2807	0.0092	0.2443	0.0009	0.2432
Farmer	0.1764	0.1915	0.1791	0.1889	0.2163	0.2941	0.2228	0.2947
Labor	-0.0134	0.2199	-0.0976	0.2118	-0.3625	0.3027	-0.3778	0.3021
Constant	4.9003 ***	1.7147	5.5764 ***	1.6708	6.0782 ***	1.9392	6.1783 ***	1.9384
R^2	0.1781		0.2075		0.2676		0.2676	
N	225		225		225		225	
F Statistics	7.95 ***		9.21 ***		8.26 ***		9.41 ***	

Note: ***, ** and * denote significant at 0.01, 0.05 and 0.10 level respectively.
Soil $EC_t = \ln EC_t - \ln EC_{t-1}$ and Soil $EC_{t-1} = \ln EC_{t-1} - \ln EC_{t-2}$.

Table 8: Maximum Likelihood Estimates of Random Effect Model, 2004/05-2007/08

Explanatory Variables	Earned Income		All Income		Earned Income		All Income	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Preshock income	-0.3518 ***	0.0664	-0.3872 ***	0.0653	-0.4772 ***	0.0668	-0.4942 ***	0.0661
Land per adult (A)	-1.8588 ***	0.3608	-2.1004 ***	0.3550	-1.6174 ***	0.3614	-1.7031 ***	0.3578
A^2	1.1505 ***	0.3343	1.2968 ***	0.3289	1.1030 ***	0.3257	1.1571 ***	0.3225
Income shock (ω)	-0.3753 ***	0.0890	-0.4016 ***	0.0876	-0.2536 **	0.1008	-0.2599 ***	0.0998
Asset shock	-0.2004	0.3252	-0.1184	0.3199	-0.0795	0.3117	-0.1100	0.3086
Soil EC_{t-1}	0.0222	0.0222	0.0187	0.0218	0.0522 **	0.0218	0.0534 **	0.0216
Aid received					-0.1304	0.1298	0.2211 *	0.1285
Access to credit					-0.5192	0.4290	-0.5007	0.4247
Access to credit*ω					-0.0184	0.0266	-0.0177	0.0264
Access to labor market					2.3881 ***	0.4225	2.5080 ***	0.4184
Access to labor market*ω					-0.0234	0.0187	-0.0254	0.0185
Education of HH head	0.0602	0.0879	0.0668	0.0864	0.0451	0.0834	0.0451	0.0826
Age of HH head	0.0917	0.1750	0.0994	0.1722	0.0983	0.1661	0.1230	0.1645
Average adult's education	-0.0411	0.1085	-0.0463	0.1067	-0.0097	0.1032	0.0012	0.1022
Farmer	0.2571	0.2115	0.2441	0.2081	0.1328	0.2211	0.0979	0.2189
Labor	0.1132	0.2177	0.0595	0.2142	-0.1238	0.2096	-0.1551	0.2075
Constant	3.2561 ***	0.9907	3.6595 ***	0.9746	4.2200 ***	0.9587	4.3050 ***	0.9492
σ_u	0.0000	0.1279	0.0000	0.1178	0.0000	0.2050	0.0000	0.1730
σ_e	0.9025	0.0302	0.8879	0.0297	0.8553	0.0286	0.8468	0.0283
ρ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N	448		448		448		448	
Log likelihood	-589.731		-582.421		-565.651		-561.187	
LR χ^2(11)/(16)	76.00		92.28		124.16		134.74	

Note: ***, ** and * denote significant at 0.01, 0.05 and 0.10 level respectively.
Soil $EC_{t-1} = \ln EC_{t-1} - \ln EC_{t-2}$.

Another important policy question is how successful and by how much is the access to factor market mitigate the tsunami impact. We specify aid received, access to credit market and access to labor market as key mitigating factors. The aid received is defined as a summation of transfer from friends and relatives and relief normalized by the pre-shock income. The indicator for access to credit market is a dummy variable equal to one if the households have no excess demand for credit and zero otherwise. The labor market access indicator is defined as average labor income per village and scaled to lie within zero and one. The use of the average community's instead of the households' employment income is to avoid endogeneity bias resulting from household labor supply decision.

It is found that the aid received has positive effect on income growth in the all income equations but counter-intuitively negative in the total earned income equation. It is possible that the significant amount of aid received may have disincentive effects to engage in livelihood activities. In 2005/06 when the amount of aid is at its peak, 6 percent of the data households reported no earned income and probably survive solely on relief funds.

Access to credit appears to be positive in some equations and negative in another. In all equations, the coefficients are not significantly different from zero. However, the interaction term of the credit market access indicator and the income loss variable shows consistent negative effects on income growth but not significantly different from zero. This probably means that credit market plays only minor role in mitigating the impact of shock since the majority of households have no full access to credit.

The access to labor market plays very important roles as a shock mitigator. The coefficients of the labor market access indicator are consistently positive and relatively large in all equations.

Table 9: Shock Sensitivity and Resilience

	No shock (ω=0)	20% Income Shock (ω=0.2)		
		Unaided & Poor Market Access	Aided & Poor Market Access	Aided & Good Market Access
Pre-shock income (Rs)	19,592	19,592	19,592	19,592
Post-shock income (Rs)	24,040	12,382	14,185	20,764
Post-shock income/No Shock Income (%)	100	49.7	57.2	84.3
Growth in three years (%)	22.7	-36.8	-27.6	6.0
Average growth rate/year (%)	7.6	-12.3	-9.2	2.0

To highlight the significance of the shock mitigating variables, we calculate post shock income from the full model of the all income equation of the panel estimator using different market access scenarios. Table 9 displays our findings. Under the counter-factual no shock scenario, real household income is expected to grow by 7 percent per annum and the expected income is expected to be Rs. 24,040 by the 2007/08 season. For a 20 percent income shock which is an average income loss over a three year period, the post-shock income will fall further by 36.8 percent over our study period or an average of -12.3 percent/year under an unaided and poor factor market access condition. However, aid provision alone without improving market access will slightly improve income from unaided scenario by 14.5 percent but still fall below the pre-shock level with a negative growth of 27.6 percent for a period of three years or -9.2 percent/year. With aid and good access to factor markets, the income improves over the aid and poor market access by 46 percent and put the household on to positive growth trajectory within three years with an average annual income growth rate of 2 percent. Access to factor markets is an important household resilience enhancing factor.

Demographic/human capital factors appear to show no significant explanatory power. This does not mean that human capital and demographic factors have no effect on income growth. The lack of statistical power is probably a result of low variations in these factors.

We also examine whether the household pre-shock occupation matters in their recovery. It is found that initial occupation has no effect on income growth which means that they all have equal growth.

4. Discussion and Conclusion

This paper investigates the magnitude of income shocks and their recovery of tsunami affected households during the post-tsunami period 2005-2008. The important findings are as follows:

Most farmers suffered from decline of income and assets immediately after tsunami. During the 2005/06 planting season, our estimate indicates that farming households saw their farm income drop by as much as 60 percent. By 2007/08 agricultural season, however, households have showed signs of re-accumulation of their productive assets to their previous growth trajectory and a near complete recovery of their incomes.

After tsunami, there is a major transformation of the livelihood of agricultural households in the sample area. Households whose main occupation is agriculture reduced from 73.3% in pre-tsunami reduced to 38.3 %. On the other hand, farm and non-farm labor increased from 20% to 68 % immediately after tsunami and 56.7% three years after tsunami.

The major coping strategies dominated by receiving aid, borrowing money for most households. Other coping strategies included consumption reduction followed by removing children from school.

The empirical results showed strong growth convergence to its pre-shock income level. The implication of the growth convergence is that the lower income group has more rapid income growth than its higher income counterpart.

During the post-tsunami period, in nearly all categories of nominal incomes, the recovery was observed. However, when the price increase is taken into account, the effect of the recovery becomes less obvious. Evidences from our empirical analyses indicate the income recovery of the sampled household has probably attained.

Shock sensitivity analysis indicated that the access to factor markets such as aid received, access to credit market and access to labor market, are an important household resilience enhancing factors in terms of income shock recovery.

In the tsunami affected agricultural area in Nagapattinam, the recovery of social system and natural system indicated different recovery paths. It is shown in the previous studies (Chandrasekharan et al. 2008; Kume et al. 2009) that the biophysical environment for agricultural production in this area largely recovered from tsunami by the following cropping season due to heavy rainfall. Although the physical environment recovered rather quickly, the farm production and household income did not immediately recover from tsunami that many farmers reported that they could come back to the normal agricultural production during the agricultural season 2007/2008 as indicated in Palanisami et al. (2010). It took them almost three years until agricultural production recover fully to pre-tsunami level. In addition, the structure of livelihood has shifted from agricultural production to wage labor.

For the recovery of huge disaster like 2004 tsunami, it is important not only the fast recovery of social-ecological system, but the building the capacity to cope with uncertainty and surprise (Adger et al., 2005). As the results of the study suggests, the speed of the recovery may be different in biophysical environment and social environment. Government needs to carefully monitor soil and water to suggest recovery of agricultural production and support disaster affected people by providing access to factor market so that they can recover from income loss quickly.

Acknowledgement

This is a partial contribution of “Vulnerability and Resilience of Social-Ecological Systems” Project, Research Institute for Humanity and Nature, Kyoto Japan. Also, earlier research was supported by "Distribution and Sharing of Resources in Symbolic and Ecological Systems: Integrative Model-building in Anthropology", Grant-in-Aid for Scientific Research of Priority Areas, Ministry of Education, Culture, Sports, Science, and Technology, Program No. 14083208.

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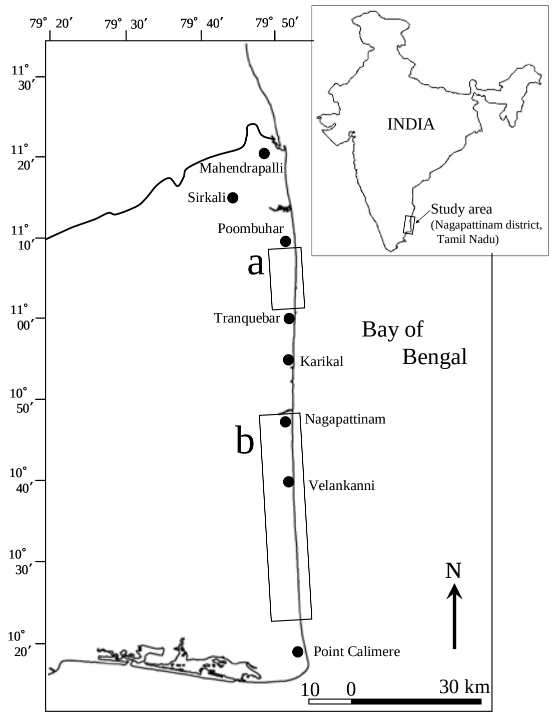


Fig.1 Map of study area (Nagapattinam District, Tamil Nadu, India)

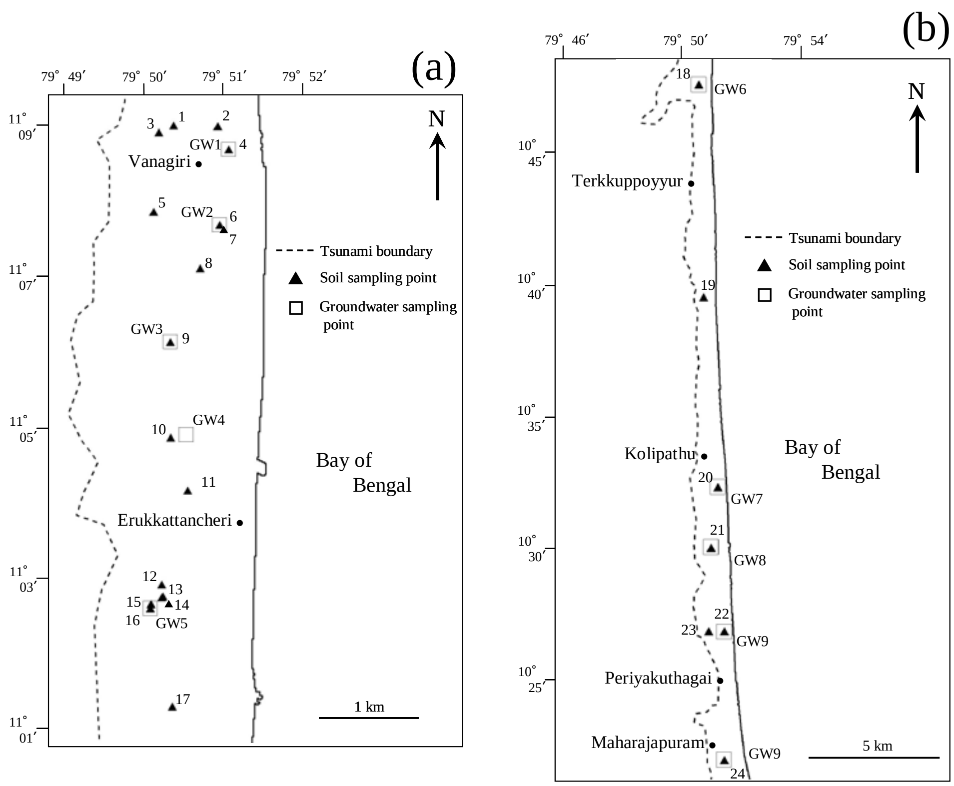


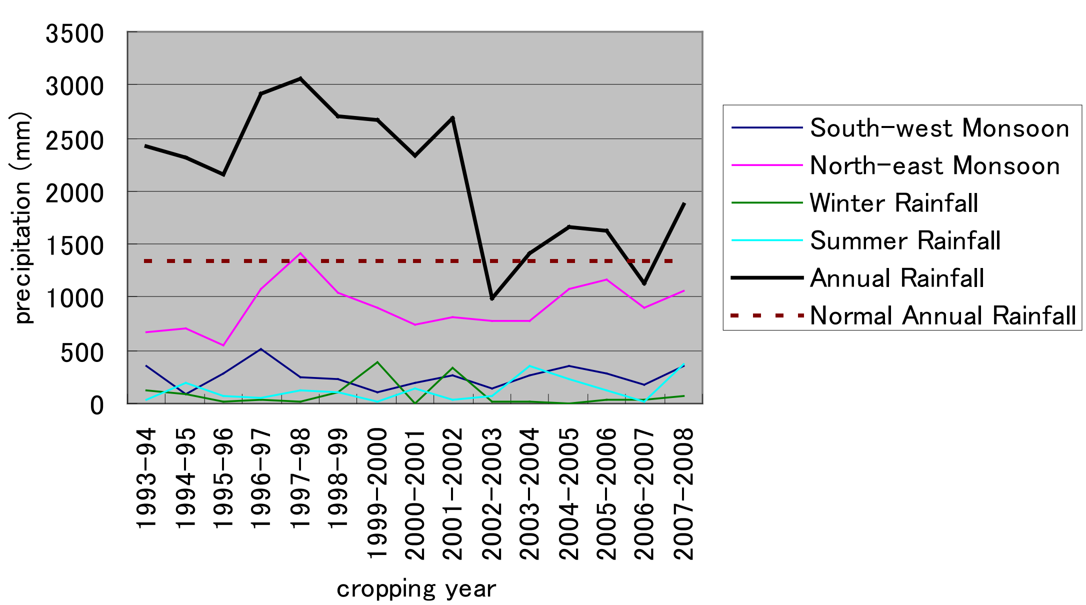
Fig. 2 Location of sample villages (These map locations correspond with areas 'a' and 'b' shown in Fig. 1)

Table 1. Names of Sample Villages

S.No	Village name	Block Name	Taluk Name	Altitude (meter)*
1	Tirumullaivasal	Kollidam	Sirgali	9
2	Puthuthurai	Sirgali	Sirgali	13
3	Vettangudi	Kollidam	Sirgali	10
4	Keelaiyur	Sirgali	Sirgali	5
5	Tennampattinam	Sirgali	Sirgali	10
6	Vanagiri	Sirgali	Sirgali	1
7	Melaiyur	Sirgali	Sirgali	8
8	Nepathur	Sirgali	Sirgali	10
9	Maruthampallam	Tarangampadi	Tarangampadi	1
10	Neithavasal (Veppangudi)	Sirgali	Sirgali	5
11	Vilunthammavadi	Kilvelur	Kilvelur	11
12	Prathamaramapuram	Kilvelur	Kilvelur	10
13	Vettaikaranirruppu	Kilvelur	Kilvelur	13
14	Poigainallur (North+South)	Nagapattinam	Nagapattinam	6
15	Vadakku palpannaicheri	Nagapattinam	Nagapattinam	8
16	Terkku palpannaicheri	Nagapattinam	Nagapattinam	8
17	Manigapangu	Tarangampadi	Tarangampadi	4
18	Satangudi (Erukattacheri)	Tarangampadi	Tarangampadi	4
19	Kovilpathu	Talainayiru	Vedaranyam	10
20	Periyakuthagai	Vedaranyam	Vedaranyam	13
21	Pushpavanam	Vedaranyam	Vedaranyam	10
22	Agasthiyampalli (Maniyanthevu)	Vedaranyam	Vedaranyam	5
23	Vellapallam	Talainayiru	Vedaranyam	13
24	Naluvedapathi	Talainayiru	Vedaranyam	10

* Avove mean sea level

Fig. 3. Seasonwise Rainfall Distribution in Nagapatttinam District, Tamilnadu, India (mm)



Recovery of agricultural livelihoods after the 2004 tsunami in the Andaman Islands, India by interventions by agricultural technologies

Takashi Kume
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Abstract

The Andaman Islands, as well as the neighboring Nicobar Islands in India were among the areas worst affected by the 2004 tsunami. Before the tsunami, the islands' hydrological schemes were suitable for agriculture because of the abundant rainfall. However, because of heavy tsunami damage to the agricultural environment, farmers have had to apply new agricultural technologies to restore their livelihoods. In natural disasters, peoples' livelihoods and the natural condition of the land need to be rapidly recovered. This paper reports how livelihoods are being recovered by intervention with agricultural technologies in the Andaman Islands, and an assessment of the recovery from tsunami damage such as the salinization of soil, and to water resources and rice fields. In the pilot study areas, the interventions have successfully recovered farmers' agriculture livelihood using newly developed technologies such as the raised crop beds with a coconut husk system or the broad bed and furrows system. Soil salinity and water resources recovered to pre-tsunami levels after two rainy seasons. A main reason for this rapid recovery was the high rainfall—more than 3,000 mm per year. However, in the case of the Andaman Islands, a successful recovery was also to the result of interventions by agricultural technologies. Farmers' livelihoods were seen to have been successfully restored through the synergy of human activities and natural hydrological schemes.

1. Introduction

In December 2004, countries bordering the Indian Ocean were hit by a tsunami that damaged ecosystems, peoples' livelihoods and hindered biodiversity. This natural disaster caused a huge loss of human and animal life, and damaged residences, fisheries and agricultural fields. The Andaman Islands, as well as the neighboring Nicobar Islands in India were among the worst-affected areas (Velmurugan et al., 2006). The islands have not experienced another such disaster in recent history. The islands lie just north of the earthquake epicenter, and the consequent tsunami was up to 15 m in the southern Nicobar Islands. The official death toll reached 1,310, and approximately 5,600 people are still missing.

Before the tsunami, the islands' hydrological scheme was suitable for agriculture because of its abundant rainfall. The main crops of the islands are rice, coconuts, spices, fruits and vegetables. After the tsunami, South Andaman Island sank slightly and North Andaman Island was lifted up several meters by the earthquake. Because of this, some paddy fields on the South Island are now below sea level and have been abandoned. On the North Island, mangrove forests dried up because of natural vegetation pattern changes due to the elevation and geomorphologic shifts. As a result of these drastic changes to the agricultural environment, farmers have had to apply new agricultural technologies to restore their livelihoods.

The tsunami devastated the livelihoods of the residents of the island with losses of natural resources, disjuncture of communities and the disturbance of industrial activities. The income of those affected is still partly dependent on tsunami relief funds from the government. In disaster situations, peoples' livelihoods and the natural condition of the land need to be rapidly recovered. This paper reports how livelihoods are being recovered by interventions of agricultural technologies in Andaman Islands.

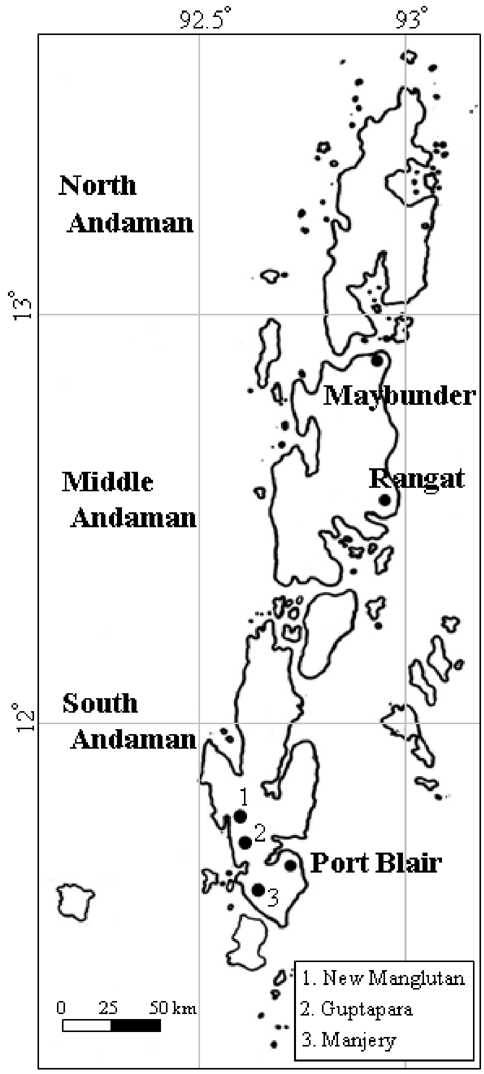

Fig.1 Study sites on the Andaman Islands.

2. Study area

The Andaman Islands (Fig.1) are located in Indian Ocean, and lie between latitude 11 and 14° North and between longitude 92° and 94° East. There are 572 islands in the territory, of which only approximately 38 are permanently inhabited. Most of the islands (about 550) are in the Andaman group, 26 of which are inhabited. The highest point is located in North Andaman Island (Saddle Peak at 732 meters). The total area of the Andaman Islands is approximately 408 km^2. Average annual rainfall of Port Blair is 3180 mm, and there were 149 days of rain at Port Blair were in 2003. Mean minimum temperature was 23.9° C and mean maximum temperature was 30.2° C. The total population of the islands is approximately 356 thousand.

The total agricultural area in the Andaman and Nicobar Island groups is 48,675 ha. In the Andaman Islands, the main crop is rice, whereas coconut and areca nut are the biggest cash crops on the Nicobar Islands. Pulses, oilseeds and vegetables are also grown, with by rice grown during the Rabi season. Many kind of fruit such as mango, sapota, orange, banana, papaya, pineapple and root crops are grown in hilly regions. Spices such as pepper, clove, nutmeg, and cinnamon are grown in a multitier cropping system. Rubber, red oil, palm and cashew are also grown on a limited scale on these islands.

3. Interventions of agricultural technologies and impact assessment of the tsunami on the ecosystem

Four villages (Fig.1)—New Manglutan, Guptapara, Manjery and Indiranagar (not shown in Fig.1)—in South Andaman were selected for the pilot study. Agricultural intervention

Table 1. Technological interventions made in various situations

No.	Situation	Technological interventions
1	Low-lying coastal areas where there is permanent groundwater infiltration by sea water and the depth of sea water increases with high tide	· Family poultry production for immediate livelihood and nutritional stability ·Goat farming ·Detection of reproductive disorders and the implementation of therapeutic measures in cattle ·Use of azolla as a feed supplement for backyard poultry
2	Low-lying coastal areas into which sea water advances with high tide and recedes with low tide	·Assessment of spatial and temporal variability in soil · Technological interventions for managing degraded natural resources · Raising crop beds with coconut husk applied for salinity management ·Broad bed and furrow system for soil and water management ·Brackish water-based Integrated Farming System (IFS)
3	Low lying coastal areas where sea water has intruded, only during the Tsunami—receding permanently afterwards	·Assessment of temporal and spatial status of soil and water ·Mat nursery and system of rice intensification method of paddy cultivation ·Crop diversification through the introduction of vegetables · Freshwater pond based IFS · Participatory water resource development and management through Water User Association

technologies were applied to different areas dependent on the level of tsunami damage and the site location. In addition, impact assessment was conducted on the soil, water, and crop yield. Table 1 summarized the details of interventions made in each situation (Srivastava et al., 2009a, 2009b).

Interventions such as the application of raised crop beds with coconut husks (RCBCH) for salinity management, and broad bed and furrow (BBF) system for soil and water management, which were applied in low lying coastal areas where sea water advances with high tide and recedes with low tide, are shown in this paper. The results of impact assessment are also reported.

4. Recovery of livelihood after the interventions

4.1 RCBCH application for salinity management

A mound sized 1 m wide and 0.3 m high is prepared, and compost is mixed with soil for fertilization. Coconut husks cover the ridge to guard vegetables against continuous and heavy rains (Fig.2). The advantages of the RCBCH method are increasing microbial content in the soil and the improvement of acidic soil by increasing soil pH. The coconut husks also serve as a rich source of potash. Of seven pilot fields were selected, and the net profit from the fields was from 50,000 to 75,000 Rs. per ha.

Fig.2 Raised beds with coconut husk application (photo from Srivastava, 2009)

4.2 BBF system for soil and water management

The Inhibited growth of vegetables and the dilution of fodder is caused by excess rainfall during the rainy season (June–December). In contrast, during the dry season vegetable production is significantly damaged by snails, bacterial wilt and a shortage of water. The BBF system for soil and water management is a kind of integrated farming system to grow vegetables, enhance fodder and to rear fish (glass carp) in rice fields using water harvested in furrows throughout the dry season.

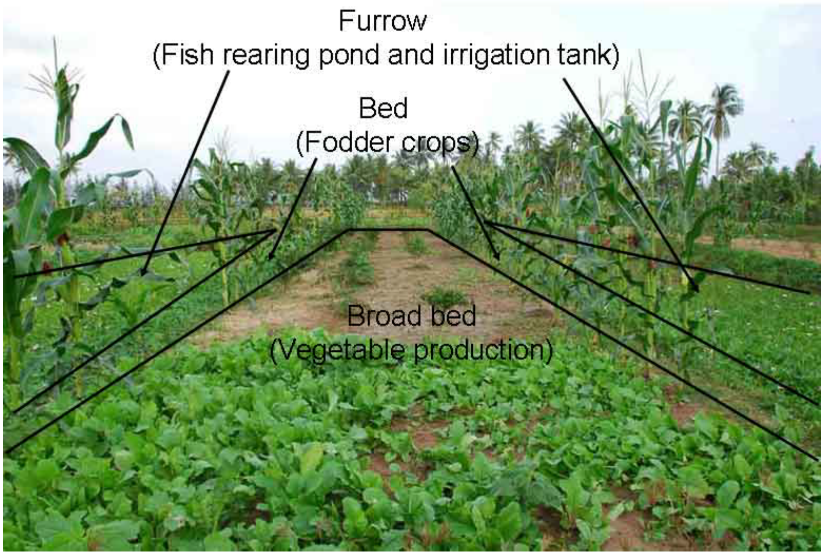

Fig.3 Broad Bed and Furrow (BBF) system in the pilot study area

As shown in Fig.3, the BBF system has a central broad bed (4 m wide and 1 m in height) and narrow beds and furrows (6 m wide and 1 m deep). Vegetables and fodder crops are planted in the broad bed and narrow beds, respectively. Glass carps are rearing in the furrows and harvested water are used for irrigation. The resulting net returns for the first year were 62,000 Rs. per ha, from the combined sales of the vegetables, rice and fish. In the second year, income nearly doubled (117,000 Rs. per ha). The small return in the first year was due to the construct costs associated with the BBF system.

5. Results of impact assessment on soil, water, and vegetation

Changes in salinity status of soil and water have already been reported (Nayak et al., 2009, Raja et al., 2009). Low-lying coastal areas were affected by the tsunami and some areas remain salinized because of drainage problems. Therefore, ponds and dug wells in some areas are still affected by salinization.

Before the tsunami, electrical conductivity (EC) of soil saturated paste was found to be 0.32 dS/m and 0.04 dS/m at 0–0.15 m and 0.15–0.3 m soil depth, respectively. Immediately after the tsunami, it increased sharply and ranged from 7.6 to 34.4 dS/m at 0–0.15m soil depth. However, after one rainy season, the levels decreased to 6.8 to 11.2 dS/m. After the second rainy season, significant decreases in ECe were found that ranged from 3.7 to 7.6 dS/m. In addition, soil pH was also close to pre-tsunami levels in most cases after both rainy seasons.

EC of wells and pond water ranged from 2.3 to 11.8 dS/m after the tsunami, and decreased to below 2.0 dS/m in most areas after two rainy seasons. In the case of the islands, gypsum application was not needed for the rehabilitation of salinized soil because rainfall had leached enough salt from the soil and drained salt from aquifers.

Impact assessment of the effects of the tsunami on vegetation was reported by Venkatesh et al. (2006). After one rainy season, rice yield in areas where the tsunami damage was estimated to be severe was reduced by 59% of that in non-affected areas, and to 37% of pre-tsunami yields in moderately affected areas.

6. Summary

Interventions successfully recovered farmers' agriculture livelihood through the application of newly developed technologies such as the RCBCH and BBF systems in the pilot study areas. The tsunami-affected saline soils were recovered to pre-tsunami levels after two rainy seasons. The ECs of pond water and dug well water were low enough (less than 4 dS/m) for agricultural production. There are no data about rice yields after recovery. However, rice yields may have fully recovered after two rainy seasons, considering the decrease in soil, pond, and dug well water ECs. The main reason for the rapid recovery in the affected areas was heavy rainfall. In the case of the Andaman Islands, the success in recovery of livelihoods was also due to agricultural interventions. The successful recovery of livelihoods in the Andaman Islands shows the effectiveness of the synergy of human activities and natural hydrological schemes.

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Abstracts of Resilience Seminar in FY2010

The 30th Resilience Seminar

Date & time: April. 10th, 2010, 16:00-17:30

Place: RIHN Lecture Hall

Title: Resilience of Ecological Resource and Livelihood: A case of the Sereer in Senegal

Speaker: Masaaki Hirai (Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, JAPAN)

Language: Japanese

[Abstract]

Resilience of Ecological Resource and Livelihood: A case of the Sereer in Senegal

In Sudanian Savanna of West Africa, we can find numerous densely populated areas and these areas have common features in their livelihood systems: "intensive agriculture" and "refined resource use and management" . In this presentation, I will discuss technical and institutional factors which had formed these features, and also its recent reform under socio-economical environmental changes, from case of the Sereer living in Senegal.

The 44th RIHN Seminar and the 31st Resilience Seminar

Date & time: June 17th, 2010, 13:30-15:00

Place: RIHN Lecture Hall

Title: Food Security, Climate Variability and Land Use in Zambia : Methods for Spatial Analysis and Modeling Vulnerability and Resilience of Smallholder Systems

Speaker: Tom Evans (RHIN Visiting Research Fellow Department of Geography, Indiana University, Indiana, USA)

Language: English

[Abstract]

Smallholders in rural Zambia are exposed to a number of shocks that threaten their livelihoods. With the majority of smallholders directly or indirectly dependent on local-level crop production, climate variability presents a particular threat to human-well being and food security. There are scale-dependent relationships that must be considered in assessing the vulnerability of smallholders to climate variability. This presentation will present methods for analyzing food security and smallholder resilience at multiple spatial scales of analysis. In particular, conceptual approaches are discussed to articulate the resilience of smallholders at household, community and regional levels of analysis. Results from a rich household survey data conducted in 2007 are integrated with land use data derived from satellite imagery to assess the vulnerability of smallholders at these diverse spatial scales. An agent-based modeling approach is presented as a mechanism to investigate the future potential vulnerability of smallholders to climate variability. These tools are discussed as components

of an integrated multi-method approach for characterizing the spatial dimensions of resilience in smallholder systems.

The 32nd Resilience Seminar

Date & time: Oct. 22nd, 16:00-17:30

Place: RIHN Lecture Hall

Title: Vulnerability and Resilience of Canal-Irrigated Agriculture against Floods: The Case of Pakistan

Speaker: Takashi Kurosaki (Professor, Institute of Economic Research, Hitotsubashi University, Tokyo, JAPAN)

Language: Japanese

[Abstract]

How rural households in canal-irrigated areas in Pakistan cope with flood risk? To address this question, using panel data of household economies surveyed in 2001 and 2004, we first associate household-level welfare fluctuations with covariate shocks like floods, droughts, and pest-attacks. We then extrapolate its implications to the current floods, which are indeed disastrous and unprecedented. Research proposal concludes the presentation.

List of Working Paper on Social-Ecological Resilience Series

No. 2008-001	Moses Mwale, *Synthesis of Soil Management Options for Better Targeting of Technologies and Ecological Resilience under Variable Environmental Conditions*
No. 2008-002	Thamana Lekprichakul, *Impact of 2004/2005 Drought on Zambia's Agricultural Production and Economy: Preliminary Results*
No. 2008-003	Gear M. Kajoba, *Vulnerability and Resilience of Rural Society in Zambia: From the View Point of Land Tenure and Food Security*
No. 2008-004	Lawrence S Flint, *Socio-Ecological Vulnerability and Resilience in an Arena of Rapid Environmental Change: Community Adaptation to Climate Variability in the Upper Zambezi Floodplain*
No. 2008-005	Tetsuya Nakamura, *The Livelihood of 'Escarpment Tonga': A Case Study of One Village, Southern Zambia*
No. 2008-006	Chihiro Ito, *Re-thinking Labour Migration in Relation to Livelihood Diversity in African Rural Area: A Case Study in Southern Province, Zambia*
No. 2009-007	Matheaus Kioko Kauti, *Rural Livelihood Security Assessment for Smallholders Undergoing Economic Changes and Agro-ClimaticEvents in Central Kenya*
No. 2009-009	Gear M.Kajoba, *Vulnerability of Food Production Systems of Small-Scale Farmers to Climate Change in Southern Zambia: A Search for Adaptive Strategies*
No. 2009-010	Chileshe L. Mulenga, *Resilience of Rural Households and Communities to Economic Shocks, HIV/AIDS and Recurrent Droughts: The Case of Households and Communities in the Mwami Area, Chipata, Zambia*
No. 2009-011	Bennett Siamwiinde Siamwiza, *An Historical Analysis of Vulnerability and Resilience in a Semi-Arid Region of Zambia*
No. 2009-012	Chewe M. Chabatama**,** *Ecological Adversity and Food Supply in Northwest Zambia*

FY2010 E-04 (FR4) Project Research Activity Overview												2011.1.18
2010	4	5	6	7	8	9	10	11	12	1	2	3
Resilience Seminar	16:00-17:30		13:30-15:00				16:00-17:30					
	10-Apr		17-Jun				22-Oct					
	(30th)		(31st)				(32nd)			(33rd)	(34th)	
Core-mamber Meeting	＊4/10		＊6/19	＊7/29			＊10/2	＊11/5		＊1/14	＊2/3	
Workshop			WS 6/19				WS 10/1-2					Resilience2011
			RIHN 10:00-17:00				RIHN 10:00-17:00					3/11-3/16
Study Meeting			12thWS				13thWS					Arizona State U
FR2 Project Report							Abstract 10/15	R2 Project Report due 13 Dec		Printing	HP upload	
		H22 FR4 budge	budget survey		(budget request				2011 budget		011 FR5 budge	
		hearing 5/28	11-Jun		6-Aug				10-Dec		hearing 2/21	
FR Related Meetings		JpGU					GLP Open Mee					
		5/23-28 Makuhari					10/17-19		JASID 2010			(FS hearing)
	(IS application 4/6)					(IS hearing 9/4)	Arizona State U.		12/4-5			5-Mar
	IS hearing 4/15								Waseda Univ.			
RIHN Events				RIHN Forum			RIHN Int'l Symposium		RIHN Project		PEC	
				10-Jul			13-15 October		Meeting		2/16-17	
			World Cup	KICC			RIHN		8-10 December			
Field Trip Schedule			6/11-7/11						Coop In Kyoto			
Shinjo	4/24 - 5/27						10/12 - 11/2	(-11/24)				3/25-4/27
Tanaka												Tempe/U.S.A.
Miyazaki		4/27 - 6/3			8/17-8/30	GLP/U.S.A.	10/15 - 10/24		11/22 - 12/20		3/29-4/25	Resilience2011
Miura												
Shibata												
Takenaka (D1)												
Ando (D1)	4/24 - 5/27						10/12 - 2011/4/16		end of cropping season			
Kuramitsu (M1)	4/24 - 5/27						10/12 - 2011/6/2		end of cropping season			
Sakurai						8/29 - 9/8						Resilience2011
Kanno												
Shimono												
Yamauchi					8/3-8/12							Resilience2011
Kitsuki (D1)						8/29 - 9/29					2/1 - 3/15	
Miura (M2)						8/29 - 9/29						3/6 - 3/20
Kon (M2)					8/3-9/29							
Kubo (M1)					8/3-8/30							
Shimada		(5/9-6/9 Sweden)		(Nigeria)				11/4 - 11/22				
Hanzawa					(8/19-9/8)				12/18 - 1/3			
Kodamaya									(12/18 - 1/3)			
Ishimoto		5/17 - 6/14									2/9 - 2/25	
Narisawa (D2)												
Itoh (D1)												
Kyo (M2)												
Yoshimura												
Saeki												
Yamashita												
Matsumura								AIWEST/Aceh	Hyderabad			
Umestu								11/21 - 11/27	12/15-12/20		2W	Resilience2011
Lekprichakul			6/28 - 7/3	ASDP/U.S.A	8/3-8/28	GLP/U.S.A.	10/16 - 10/21					Resilience2011
Kume						GLP/U.S.A.	10/15 - 10/24	11/21 - 11/27		1/8-1/14		Resilience2011
Yatagai								AIWEST/Aceh		Sri Lanka		
Palanisami										1/24-1/30	RIHN	
Kajoba												
Mulenga												
Evans (Visiting Fellow	1/18 - 6/30	RIHN								1/8-1/15	RIHN	Resilience2011

はじめに

地球研平成 22 年度フルリサーチ (FR4) 研究「社会・生態システムの脆弱性とレジリアンス」は本プロジェクトとしての 4 年目を無事終了した。本プロジェクトは地球研の 5 つの領域プログラム（循環、多様性、資源、文明環境史、地球地域学）の中で「地球地域学プログラム」に所属している。今年からは、地球研の第２期中期計画として未来設計イニシアティブがスタートし、プログラムからイニシアティブへの橋渡しが期待されている。

2010 年度はプロジェクトの調査を開始してから３度目の雨期の調査を終了した。過去３年間の降水量は平均以上であった。圃場試験の結果からは、雨量の変動によるショックは畑の位置を分散させることによってある程度回避できることが明らかになった。加えて、長期的な世帯調査から、2007 年 12 月の大雨が世帯の食料消費の変動に与えた影響を明らかにしつつある。また、４度目の雨期である 2010/2011 年農作期も始まったが、今回も平均降水量を上回ることが予測されている。

今年度はプロジェクト成果の国際的な発信にも力を入れた。10 月には GLP Open Meeting 2010 へプロジェクトから４名が発表､11 月には 2004 年インド洋津波の被害が最も大きかったインドネシアのアチェで開催された AIWEST-DR 2010 において２名が発表した。大会のメインテーマはコミュニティのレジリアンスを醸成することであった。さらに 3 月には Resilience2011 および EnvironmentAsia への参加も予定されている。国内では 12 月に国際開発学会において企画セッションを開催し、プロジェクト外でのレジリアンスの議論を共有することができた。

プロジェクトメンバーの方々にはプロジェクトの順調な発展のためにご尽力をいただき感謝したい。また地球研のプロジェクト評価委員会 (PEC)、所長、プログラム主幹、管理部および研究部スタッフの方々にこの様な統合プロジェクトを実施するためにご支援いただいたことに感謝申しあげる。プロジェクト終了までの間にレジリアンス研究をさらに発展させる基盤をつくるように尽力したいと考える。

平成 23 年 1 月

総合地球環境学研究所
E-04(FR4) プロジェクト・リーダー
梅津　千恵子

プロジェクトタイトル	**社会・生態システムの脆弱性とレジリアンス**
プロジェクト No.・略称	E-04 （レジリアンス・プロジェクト）
領域プログラム	「地球地域学」プログラム
プロジェクトリーダー	梅津　千恵子

ホームページ： http://www.chikyu.ac.jp/resilience/
キーワード：レジリアンス，貧困，　社会・生態システム，資源管理，環境変動，脆弱性，人間の安全保障，半乾燥熱帯，適応力

1. 研究プロジェクトの全体像

1）目的と背景

研究目的：本プロジェクトでは，途上国の農村地域において，旱ばつや洪水などの環境変動に対する社会・生態システム、特に世帯の食料生産と食料消費水準のレジリアンス（回復力）を高める方策を考えることを主目的とする。そのため，まず，環境変動に対する人間活動を社会・生態システムの脆弱性とレジリアンスという観点からとらえ，環境変動が社会・生態システムに及ぼす影響とそのショックから回復するメカニズムと対処戦略を明らかにする。また、具体的な事例から社会・生態レジリアンスの要因を特定するために，家計やコミュニティ，そして社会制度が果たしている役割を分析する。これらレジリアンスの要因の特定とショックからの回復メカニズムの解明を通じて，社会・生態レジリアンスの本質を明らかにする。そして，レジリアンスを高めるための方策を議論し，途上国地域において人間の安全保障を醸成するための示唆を与える。調査対象地域は、ザンビア（南部州、東部州）を中心とした半乾燥熱帯の旱ばつ常襲地帯である（図１）。

研究の背景：貧困と環境破壊は密接に関係しており，貧困が環境破壊を生み，環境破壊が貧困を生むという悪循環を生み出している。この悪循環は森林破壊や砂漠化などの「地球環境問題」の主原因の一つであると考えられている。世界の貧困人口の大部分は集中するサブサハラ・アフリカや南アジアの半乾燥熱帯に集中し、伝統的なコミュニティ（社会）や環境資源（生態）に強く依存して生業を営んでいる。これらの地域において天水農業に依存する人々の生活は環境変動に対して脆弱であり、植生や土壌などの環境資源は人間活動に対して脆弱である。ゆえに，さまざまな環境変動に対する社会・生態システムのレジリアンスの低下は深刻な問題となり、システムの保全と強化は重要な課題となっている。よって，この「地球環境問題」の解決のためには，人間社会および生態系が環境変動の影響（ショック）から速やかに回復することが鍵となる。近年の国際的な持続可能性や国際開発の議論の中でもレジリアンスは重要な要素として位置づけられており、その実証と実践が急務となっている。(UNDP, UNEP, WB, WRI, 2008; ICSU, 2010)。

2）地球環境問題の解決にどう資する研究なのか？

環境変動の被害は社会経済的に脆弱なグループがまず被害を受ける。本プロジェクトでは，社会・生態システムの脆弱性を「地球環境問題」として捉え，脆弱性を規定する要因を解明し，途上国農村で地域社会のレジリアンスを高める方策を提案することが「地球環境問題」の解決につながると考える。現地での実験、測定，インタビュー、観察，分析を通してレジリアンスの鍵となる要素を検討し，その要素を用いて地域の生態系と資源管理へのオプションを提示する。

3）領域プログラム・未来設計イニシアティブにおける位置付け

本プロジェクトは「地球地域学」プログラム及び「未来設計イニシアティブ」の中で、概念、方法、地域を主体にした学際的統合研究の開発・実施へ貢献している。レジリアンス研究は「地球地域学」プログラムが掲げる「地域の知」のみならず、地球研がキーワードとして掲げる「人間と自然の相互作用環」の解明および「未来可能性」の実現に半乾燥熱帯地域の農村世帯のレジリアンスという具体的な事例で貢献するものである。

2. 全研究プロセスにおける本年度の課題と成果

１）本年度の研究課題
平成 22 年度は調査・観測を継続しながら、3 年目 2009/2010 年農作期の観測データの収集・整理・分析を行う。 ―レジリアンスの概念とその解明に向けた作業仮説の整理を行い、その実証に向けた定性的・定量的分析を進める（図 2）。 ―ザンビア東部・南部州でそれぞれ実施している圃場試験において、メイズ収量の規定要因を明らかにする。さらに、南部州では収量規定要因の図化を試みる。 ―2007 年 11 月（2007/08 年雨期の開始）より南部州のプロジェクトサイトで始めた家計調査，身体計測，降水量測定を 2010 年 11 月まで継続する。降水量変動が家計の食料消費や栄養状況に及ぼす影響の分析を 2007/08 年と 2008/09 年の 2 作期を含むものに拡大し、家計レベルの食料消費水準のレジリアンスを定量化する。 ―南部州サイトにおいて 2007 年から 2009 年にかけて起こった環境変動（多雨被害）に対する農民の対処戦略を明らかにするため、生業活動の変化の時空間把握と、同地域・同期間における食糧援助活動の把握、さらにそれらの相互作用の検討を実施する。 ―ザンビア中央州の一農村における過去 20 年間のフィールドデータを分析し、農民、農家世帯の脆弱性増大プロセスとその要因を考察する。農村部の脆弱性増大に関わる農村地域内生業(農業、林業、牧畜業)および村外経済活動(出稼ぎ、ネットワーク作り)に関する現地調査を継続する。
２）本年度に挙げ得た成果
―農村世帯の食料消費と生計が旱ばつや洪水等のショックから回復するメカニズムや速度を中心としてレジリアンスの実証研究を集約させることとし、レジリアンスの実証アプローチとして定量的な研究と定性的な研究を補完的に実施した。 ―集中世帯調査のデータ整備により、特に定量的な分析に進展がみられた。 ―東部州の試験では、開墾に伴う火入れが土壌養分やメイズ収量に与える影響は、焼却される木材バイオマス量によって異なることが示された。南部州の試験からは、圃場の地形上の位置や気温によって、メイズ収量が大きく規定されていることが示された。 ―2007/08 年と 2008/09 年の 2 作期を含むデータセットを分析向けに整備し、家計レベルのレジリアンスを定量的に計測し、レジリアンスに影響を与える要因を明らかにした。摂取カロリーでみた収穫期前（2 月頃）の食料消費の落ち込みは、2007/08 年と 2008/09 年のどちらも同様に観察された。2008 年 3 月以降、食料消費はゆるやかに回復したがそのペースは遅かった。2007 年 12 月の大雨による農作物の影響は次の収穫期前の食料価格の高騰として現れた。2007 年 12 月の大雨からの最終的な回復は 2008/09 年収穫後であり、摂取カロリーの回復には 1 年以上を要していた。 ―多雨被害後の農民の対応は多様であり、作付けの転換などの農業生産での対処の外、多雨被害によりトウモロコシを販売できなかった世帯では農産加工物の販売、家畜・家禽の販売、その他農外就業により新規の現金獲得の手段を開拓していた。 ―市場自由化や政治的民主化が、農民個人や農家世帯の資源アクセスに変化をもたらし、商品作物栽培の拡大、共同労働システムの弱体化、森林保護区の破壊等が進展した。この過程を通し一部の農民や農家世帯の脆弱性が増大してきたことを明らかにした。 ―農村世帯の困窮時の対処行動として社会ネットワークを介した支援の獲得が行われること、その現代的方法として携帯電話が活用されているケースもあった。 ―研究成果を国際的に発信することに重点を置き、GLP Open Meeting (USA), AIWEST-DR2010 (Indonesia),国際写真測量学会（京都）などで発表し，Resilinece2011 (USA), EnvironmentAsia (Thailand)へも参加予定。また、国内の様々な学会や研究会で報告し、国際開発学会では企画セッション「社会生態システムのレジリアンスと貧困削減」を開催した。レジリアンス研究会を 3 回、ワークショップを今年度 2 回開催した。 ―プロジェクト報告書(FS,PR,FR1,FR2,FR3,FR4)，レジリアンス・ワーキングペーパー(001-012)を刊行し、プロジェクトウェブサイトに掲載し公開している。http://www.chikyu.ac.jp/resilience/ ―日本学術会議･IHDP 分科会へプロジェクトメンバーが参加することで国際的な研究コミュニティへ参画する基盤を形成した。

3.本年度の研究体制

１）研究体制

―４つのテーマについて研究を実施し，世帯，地域レベルから歴史的，空間的分析などを相互にリンクさせる。特に自然科学分野の研究者との学際的研究により，科学的情報を社会科学の研究に応用できる研究者の参加を得ている。特に今年度は「概念、方法、地域」を主体にした統合に重点を置き、その方法等を検討し、会合も多く持った。基本的に長期滞在を重点としてきたが、現地カウンターパートとアシスタントの教育によりフィールド滞在期間を前年度より短縮することができた。また調査地での住環境を整備することにより観測・研究体制の強化を行なった。

4.本年度の研究成果についての自己診断

１）目標以上の成果を挙げたと評価出来る点

―長期的な聞き取り調査により、多雨被害という環境変動後の農村世帯構成員のカロリー摂取量・健康指標の変動と対処行動の幅を追跡することが出来、世帯構成員の食料消費水準や健康指標のレジリアンスのプロセスについての貴重な情報を得た。
―脆弱性の増大の理由とプロセスが、主体(農民、農家世帯、農村社会等)の違いにより異なること、さらに脆弱性増大が、様々な理由から起きており、対象地域の中で、経済的、社会・政治的、文化的という領域の異なる間でも伝播することを明らかにすることができた。

２）目標に達しなかったと評価すべき点

―世帯調査データを精査した結果、多くの入力ミスを発見したが、現時点までに修正が完了していない。今年度内には残りのデータ整備を終える予定である。
―レジリエンスと関係がある、脆弱性緩和の条件やそのプロセスを明らかにすることができなかった。

３）領域プログラムの研究戦略で得られた成果・課題

―本プロジェクトは「地球地域学」プログラムの構成員として、概念、方法、地域を主体にした学際的な統合研究の開発・実施へ貢献している。本研究の中心概念であるレジリアンスは、環境の変動による人間社会の影響をインフラ整備や技術によって阻止するという対応ではなく、環境変動を社会生態システムがしなやかに受け入れ、許容しながら回復・発展するという環境問題に対する新たな視点を提供するという点に大きな意義がある。旱ばつ等の一時的なショックへの対応のみならず、予測できない変動への社会の対応能力を高めるという考え方は、気候変動に対する社会の対応について新たな視点を提供し、未来可能性に向けてレジリアントな社会を構築するための示唆を与えるものである。

5.昨年度発表会における質疑及び評価委員会コメントへの対応

―レジリアンスの定量化については半乾燥熱帯地域(SAT)の農村社会での人間の安全保障を考える上で重要となる農業生産、食料消費水準、健康指標の変動の長期的な測定・観察を通じて、それらの要因を定量的・定性的に分析している。レジリアンスの考察には短期的な環境変動への対処のみではなく、中期的・長期的な視点も重要であると考える。但し、５年間という限定されたプロジェクト期間では、観察は短期的・中期的なものに限られる。
―社会的・経済的・文化的・自然的・歴史的に異なる地域社会でのレジリエンスについて考えてゆくことで補完し、概念のもつ潜在性を開発するべきとのコメントをいただいたが、今年度は十分実施することが出来なかったが、最終年に開催予定のさまざまな研究会、国際シンポジウムなどの場を通じて実現していきたい。
―Stockholm Resilience Center との連携は 2010 年 3 月に地球研の研究動向調査により実現し、Stockholm Resilience Center の Scientific Director である Dr. Carl Folke と会い、今後の協力をお願いすることが出来た。

6. 来年度以降への課題

―環境変動に対する半乾燥熱帯農村地域における社会生態システムのレジリアンスを向上させるための示唆を与える。
―4期にわたる圃場試験の結果をとりまとめ、年次変動も考慮したメイズ収量規定要因を明らかにする。
―2007/08 年、2008/09 年、2009/10 年の 3 年にわたる世帯調査のデータセットを完成させ、それを用いて家計レベルのレジリアンスの計測およびそのレジリアンスに影響を与える要因の解明を実施する。農村世帯の回復の要因、世帯が持つ対処能力については資産の大きさが重要と考えられるが、今後のデータ整備によってさらに要因の分析を行う。
―脆弱性緩和とレジリエンスの関係を考察する。土地などの資産、制度、ネットワークなどが世帯やコミュニティのレジリアンスに果たす役割を社会関係資本との関連から考える。
―ショックを緩和する自然資源（生態システム）の役割については今後さらに検討する。
―プロジェクトの成果をさらに統合し、異なるスケールでの比較を行う。
―研究成果を学術論文、書籍として出版し、国際シンポジウムを開催して国内のみならず国際的研究コミュニティにプロジェクトの成果を発信する。
―環境変動の影響を受けやすい半乾燥熱帯地域での適応策を考え、貧困削減に資することによって地球環境問題の解決に貢献したい。

―レジリアンスは、持続可能性の議論の中でも重要な役割を担っている広範な概念であり、地球環境問題に関する多くの研究課題、気候変動を含むさまざまな環境変動、災害のリスク削減 (Disaster Risk Reduction)等へのフレームワークを提供し、近年その実践的な分野が急速に発展している。第 2 期中期計画の基幹ハブ・イニシアティブの展開にとっても重要なキーワードならびに研究対象となる。今後は 2011 年 6 月に開催される国際シンポジウムや 11 月に開催される地球研国際シンポ及びさまざまな研究会を通じて他のプロジェクトとの連携を強め、レジリアンス概念の可能性と実践化について所内外との議論を深めて行き、新たな基幹プロジェクトの創出に貢献したい。

7. 年次進行表

	H17 FS	H18 PR	H19 FR1	H20 FR2	H21 FR3	H22 FR4	H23 FR5
分析手法の確立	xxx	xx	xx	x			
ザンビア							
I. 生態レジリアンス	x	xx	xxx	xxx	xxx	xxx	x
II. 環境変動と農家世帯	x	xxx	xxx	xxx	xxx	xxx	x
III. 脆弱性と制度・歴史	xx	xx	xxx	xxx	xxx	xxx	xxx
IV. 広域と統合解析	x	xx	xxx	xxx	xxx	xxx	xxx
インド		x	x	x	x		
ブルキナファソ			x	x	x		
国際ワークショップ			x		x		x
報 告 書	FS 報告	PR 報告	年度報告	中間報告	年度報告	年度報告	最終報告

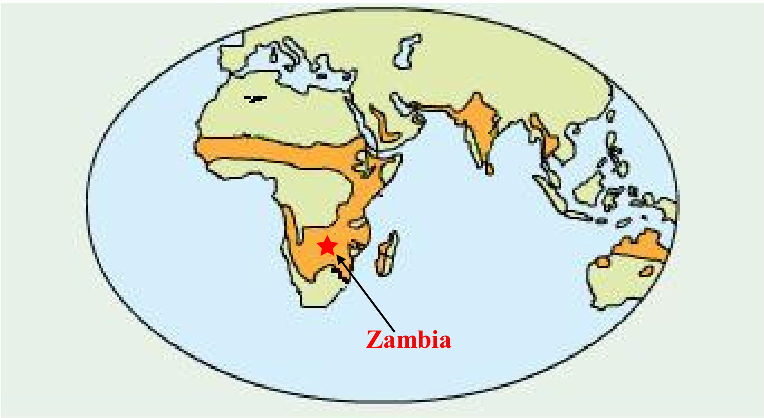

図１．半乾燥熱帯と調査対象地域

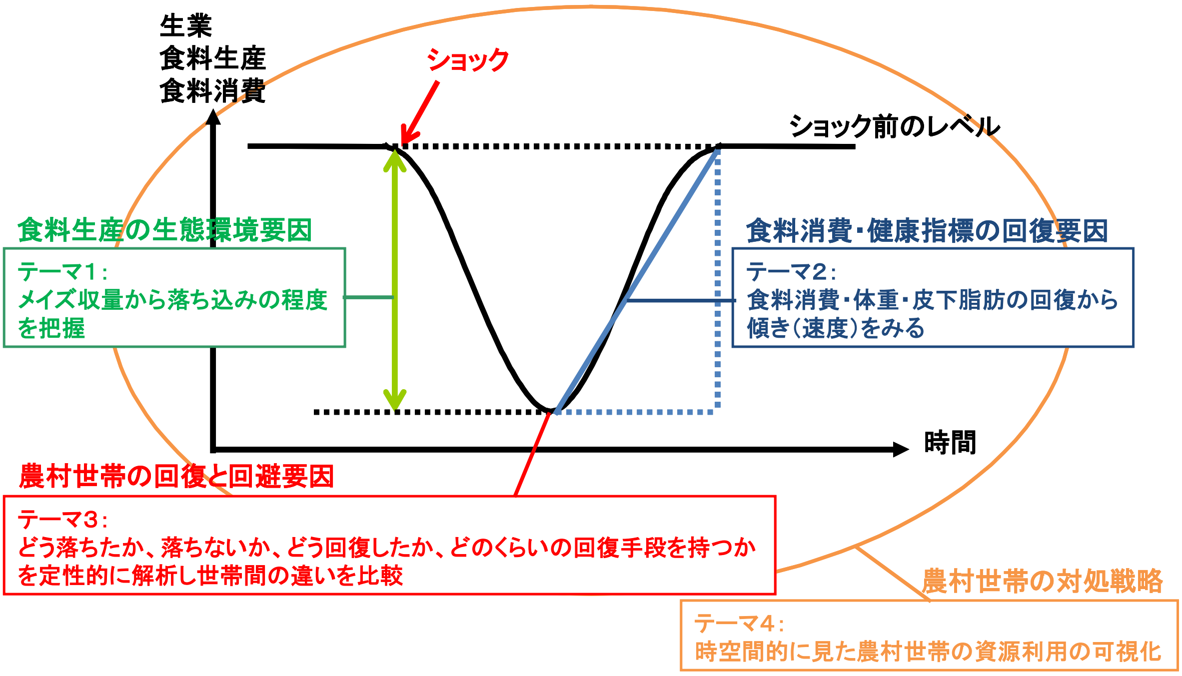

図２．レジリアンスへのアプローチ

E-04 (FR4) プロジェクトメンバー表 （平成22年度） 2010.12

	氏名	フリガナ	所属	サブ所属	職名	専門分野	役割分担
ﾘｰﾀﾞｰ	梅津　千恵子	ウメツ　チエコ	総合地球環境学研究所	研究部	准教授	環境資源経済学	地域経済分析・農村調査
A	谷内　茂雄	ヤチ　シゲオ	京都大学生態学研究センター		准教授	数理生態学	アドバイザー
	Theme I						
○	真常　仁志	ｼﾝｼﾞｮｳ　ﾋﾄｼ	京都大学大学院農学研究科	地域環境科学専攻土壌学分野	助教	土壌資源学	土壌有機物の分解・肥沃度測定
	安藤　薫	ｱﾝﾄﾞｳ　ｶｵﾘ	京都大学農学研究科	地域環境科学専攻土壌学分野	大学院生	土壌資源学	土壌有機物の分解・肥沃度測定
	倉光 源	クラミツ ハジメ	京都大学大学院農学研究科	農学専攻雑草学分野	大学院生	雑草学	草本群落構成種調査
	柴田昌三	ｼﾊﾞﾀ　ｼｮｳｿﾞｳ	京都大学フィールド科学教育研究センター	上賀茂試験地	教授	森林生態	樹木構成種調査
○	田中　樹	タナカ　ウエル	京都大学大学院地球環境学堂	陸域生態系管理論分野	准教授	境界農学	土地利用とリスク管理の仕組み
	三浦励一	ミウラ レイイチ	京都大学大学院農学研究科	農学専攻雑草学分野	講師	雑草学	草本群落構成種調査
○	宮嵜英寿	ﾐﾔｻﾞｷ ﾋﾃﾞﾄｼ	総合地球環境学研究所	研究部	プロジェクト研究員	土壌資源学	土地利用・履歴調査
○	Moses Mwale		Mt. Makulu Central Research Station, Zambia Agriculural Research Station	Ministry of Agriculture and Cooperatives	Vice Director	土壌学	土壌分析
	Theme II						
○	櫻井　武司	サクライ　タケシ	一橋大学経済研究所	日本・アジア経済研究部門	教授	開発経済学	農村世帯調査
	菅野洋光	カンノヒロミツ	(独)農業・食品産業技術総合研究機構　東北農業研究センター	やませ気象変動研究チーム	チーム長	気候学・農業気象学	気象観測
	木附晃実	キツキ　アキノリ	一橋大学大学院経済学研究科		大学院生	開発経済学	農村世帯調査
	三浦　憲	ミウラ　ケン	一橋大学大学院経済学研究科		大学院生	開発経済学	農村世帯調査
	久保晴敬	クボ　ハルタカ	北海道大学大学院保健科学研究院	保健科学専攻	大学院生	人類生態学	成長、栄養状態と健康の評価
	下野　裕之	ｼﾓﾉ　ﾋﾛﾕｷ	岩手大学農学部	農学生命課程	准教授	作物学	作物モデル化
	山内太郎	ヤマウチ タロウ	北海道大学大学院保健科学研究院	保健科学専攻	准教授	人類生態学	成長、栄養状態と健康の評価
	今　小百合	コン　サユリ	北海道大学大学院保健科学研究院	保健科学専攻	大学院生	人類生態学	成長、栄養状態と健康の評価
	Theme III						
○	島田　周平	ｼﾏﾀﾞ　ｼｭｳﾍｲ	京都大学大学院アジア・アフリカ地域研究研究科	アフリカ地域研究専攻	教授	環境地理学	農村社会・制度調査
○	石本　雄大	ｲｼﾓﾄ　ﾕｳﾀﾞｲ	総合地球環境学研究所	研究部	プロジェクト研究員	生態人類学	救荒作物と農村世帯
	伊藤千尋	イトウ チヒロ	京都大学大学院アジア・アフリカ地域研究研究科	アフリカ地域研究専攻	博士課程	人文地理	農村の出稼ぎ労働
	姜　　明江	ｷｮｳ　ｱｷｴ	京都大学大学院アジアアフリカ地域研究研究科	アフリカ地域研究専攻	博士課程	緩和医療学	やまいの共生とケア
	児玉谷史朗	コダマヤ シロウ	一橋大学大学院社会学研究科	総合社会科学専攻	教授	アフリカ社会学	農業生産と社会変容
	成澤　徳子	ﾅﾘｻﾜ　ﾉﾘｺ	京都大学大学院アジアアフリカ地域研究研究科	アフリカ地域研究専攻	博士課程	ジェンダー人類学	農村女性の現金稼得
	半澤和夫	ハンザワ カズオ	日本大学生物資源科学部	国際地域開発学科	教授	農業経済	農村世帯調査
	Gear M. Kajoba		University of Zambia	Department of Geography	Senior Lecturer	地理学	土地制度と食料安全保障
	Chileshe Mulenga		University of Zambia	Institute of Economic and Social Research (INESOR)	Senior Lecturer	経済地理学	社会行動分析
	Theme IV						
○	吉村　充則	ﾖｼﾑﾗ　ﾐﾂﾉﾘ	株式会社　パスコ	研究開発センター	主任研究員	リモートセンシング	生態変移モニタリング
	梅津　千恵子	ウメツ　チエコ	総合地球環境学研究所	研究部	准教授	環境資源経済学	地域経済分析・農村調査
	佐伯　田鶴	サエキ　タヅ	国立環境研究所	地球環境研究センター	NIESアシスタントフェロ	大気物理学	気候モニタリング
	松村圭一郎	ﾏﾂﾑﾗ　ｹｲｲﾁﾛｳ	立教大学社会学部	現代文化学科	准教授	文化人類学	農村社会と土地所有
○	山下　恵	ヤマシタ　メグミ	学校法人　近畿測量専門学校		講師	地理情報学	植生モニタリング
○	Thamana Lekprichakul		総合地球環境学研究所	研究部	プロジェクト上級研究員	医療経済学	農村世帯調査・分析
	India						
○	K. Palanisami		International Water Management Institute	IWMI-TaTa Program	Program Coordinator	農業経済学	農村世帯調査・分析
○	久米　崇	ｸﾒ　ﾀｶｼ	総合地球環境学研究所	研究推進戦略センター	特任准教授	土壌水文学	津波被害調査
	谷田貝亜紀代	ヤタガイ　アキヨ	総合地球環境学研究所	研究部	助教	気象・気候学	モンスーン降雨分析
	C.R Ranganathan		Tamilnadu Agricultural University	Department of Mathematics	Professor	数理モデル	社会経済モデル分析
	V. Geethalakshmi		Tamilnadu Agricultural University	Department of Agricultural Meteorology	Professor	農業気象学	モンスーン降雨分析
	Burkina Faso						
○	Tom Evans		Indiana University	Department of Geography	Associate Professor	geography	agent-based modelling

○＝コアメンバー; A = アドバイザー

半乾燥熱帯地域の農村世帯のレジリアンス―社会生態システムの連関

梅津千恵子
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はじめに

レジリアンスとはあるシステムがショックを受けた際に、同じ機能、構造、フィードバック、及び同一性を保持できるシステムの能力として定義される(Walker 2004)。レジリアンスは生態学的、社会経済的な意味で定義されてきたが、その実践的な評価はこれからの課題である。近年、国際開発分野での新たな展開として注目されるのは、レジリアンスの概念を生態資源に生活を依存する途上国地域の開発問題へ応用する取り組みが始まったことである(Perrings, 2006; Mäler, 2008; UNDP, UNEP, WB, WRI, 2008; ICRISAT, 2010)。またアカデミックコミュニティにおいてもレジリアンスは持続可能性を達成するための重要な要素のひとつとして考えられている(ICSU, 2010)。

特にサブサハラ・アフリカの半乾燥熱帯地域では、伝統的な農村コミュニティは生態資源に強く依存して生業を営んでおり、貧困と資源荒廃が問題となっている。植生や土壌などの生態資源は人間活動に対して脆弱であるため、天水農業に依存する人々の生活は環境変動に対して脆弱であり、人間社会および生態系が環境変動の影響から速やかに回復すること（レジリアンス）が発展の鍵となる。レジリアンスの概念に関する議論は過去 10 年間に盛んに行われたものの、途上国の農村世帯のレジリアンスに関する実証研究は非常に少なかった。

「社会生態システムの脆弱性とレジリアンス」（レジリアンスプロジェクト）ではザンビアの農村地域における定性的・定量的レジリアンス実証研究のアプローチを提案した（梅津他、2010）。レジリアンスの構築を実践的にするために、半乾燥熱帯地域の農村世帯の人間の安全保障という文脈でレジリアンスを考えることが、重要と考える。本プロジェクトでは、旱ばつ、洪水、そして社会変動などの<u>環境変動に対する</u>レジリアンスを考える。また<u>食料供給、食料消費、健康状態、農業生産、生業の</u>レジリアンスを考える。最後に、<u>人間の安全保障―すなわち生存、生業、尊厳（人間の安全保障委員会事務局 2003）のための</u>レジリアンスを考える。

本稿の目的はプロジェクトで実践するレジリアンス実証研究のアプローチを概観し、社会生態システムの連関に注目して研究の成果を要約するものである。

レジリアンス実証へのアプローチ

旱ばつや洪水が起こった緊急時には、生存を維持するための食料確保が世帯とコミュニティにとっての最重要課題となることから、半乾燥熱帯地域の自給的農村世帯にとっての社会・生態システムのレジリアンスとは、環境変動に対する、農村世帯の生存を維持する食料消費と、食料生産と生業のレジリアンスを考えることに他ならない。研究対象とする環境変動は主に旱ばつ・洪水などの災害などによって地域やコミュニティが一様に被る共通のショック(covariate shock)である。

レジリアンスプロジェクトでは、4 つのテーマが相互に協力しながら、さまざまなアプローチでレジリアンスを研究している。レジリアンス解明への実証的なアプローチとしては、農村世帯の食料消費と生業が旱ばつや洪水等のショックから回復するメカニズムや速度を中心としてレジリアンスを研究する（図 1）。具体的にはテーマ 1 ではメイズ収量から落ち込みの程度を把握する。テーマ 2 では食料消費・体重・皮下脂肪の回復からその速度を見る。テーマ 3 ではどう落ちたか、落ちないか、またどう回復したか、どのくらいの回復手段を持つかを定性的に解析し世帯間の違いを比較する。テーマ 4 では時空間的に見た農村世帯の土地などの資源利用や土地被覆の可視化を行なう。加えて、レジリアンスの時空間的相違と、歴史的な変動に注目した調査も行われている（Evans et al., 2010）。また、インド洋津波などの大規模な災害においては、社会生態システム(Social-Ecological System: SES)は別の状態へ移行する可能性もあり得る。

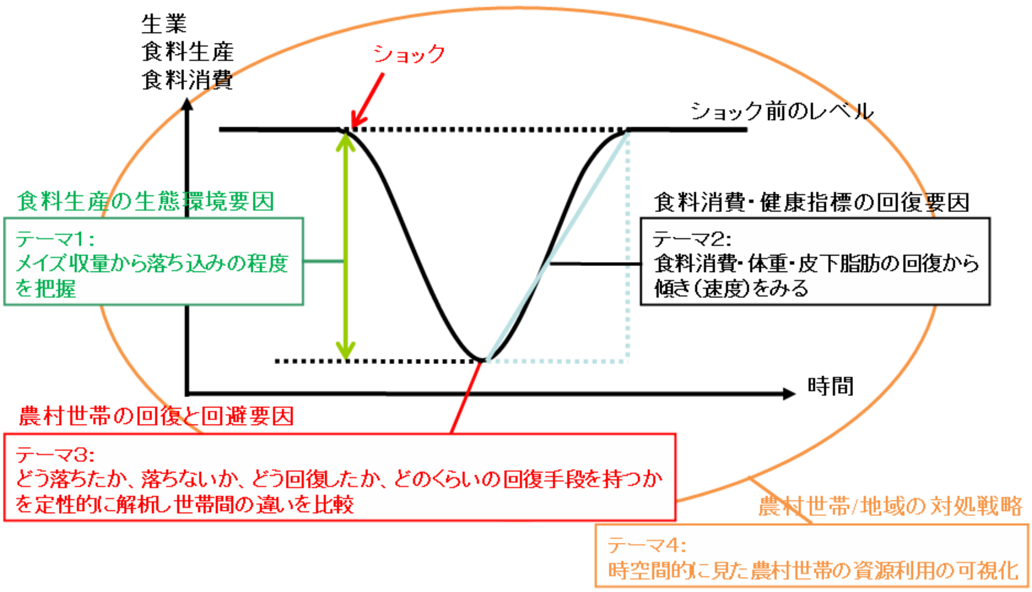

図１．レジリアンス実証へのアプローチ

社会生態システムの連関とレジリアンス

図 2 はレジリアンスプロジェクトの調査項目とレジリアンスのインディケーターと要素を示している。またこの図は旱ばつや洪水の常襲地帯での降雨、食料供給、食料消費、健康、生態系サービスの連関を示している。ここで考える社会生態システムとは、人間活動と密着した農業生態システムである。雨量や社会変動などの環境変動（何に対するレジリアンスかを示す）は青で示されている。レジリアンスのインディケーターである食料供給、食料消費、食料生産、健康状態（何のレジリアンスかを示す）はオレンジで示されている。要素をつなぐ矢印はプロジェクトの作業仮説を示している。プロジェクトの目的は、レジリアンスのインディケーターを検証することのみならず、この矢印の有無や強弱を明らかにすること、そして何がレジリアンスの要素や条件になっているのかを解明することにある。

調査地はザンビア南部州・シナゾングェ県とチョマ県の 3 サイトである。調査地の住民である低地トンガ(Valley Tonga)人は 1959 年のカリバダムの建設に伴う強制移住という大きな社会的政治的変動にさらされた(Colson, 1960; Scudder, 1962, 2010)。サイト A はカリバ湖岸で平地

であり、カリバダム建設以前からの旧村と移住村が隣接する。サイトＢは斜面が多い丘陵地であり、1980 年代以降の移住村である。サイトＣは３地区の中でも最も標高が高い高地平原の端に位置し、旧村である。

雨量変動から穀物生産へ

雨量の変動などによる環境変動によって、農地からの収穫量が変動し、直接的に農民世帯の食料供給可能性と消費（生存）に影響を与える（図２）。ザンビア南部州における過去の降雨量データによれば、1991/1992, 1994/1995, 2001/2002, 2004/2005 年農作期に大きな旱ばつが発生している(Zambia Meteorological Department)。少雨の年はエルニーニョ年と、多雨の年はラニーニャ年と重なる傾向にある（Yatagai 本報告書）。降雨量はザンビアの主な主食であるトウモロコシ生産高と農村世帯へ、直接的に影響を与えてきており、南部州の貧困層の割合は、1991/1992 年雨期の厳しい旱ばつ直後に 1991 年の 79%から 1993 年の 86%にまで上昇した。その後、貧困層の絶対数は 2002 年までは減少したものの、近年の旱ばつにより増加傾向が見られる(Thamana 本報告書)。この地域では旱ばつが主な気候ショックであるものの、過去 3 度の農作期 2007/2008, 2008/2009, 2009/2010 は調査地で年平均よりも多い降雨量を記録した。降雨量の季節変動は 3 雨期とも異なっていた (Kanno et al. 本報告書)。トウモロコシの播種時期を人為的に遅くする実験では、収量の低下が認められ、世帯は最適な播種の時期を選択していることが分かった(Shimono et al., 本報告書)。トウモロコシ収量は南部州では地形や温度によって影響を受け(Miyazaki et al., 2010)、東部州では火入れによるバイオマス量によって影響を受けていた(Shinjo et al., Miura et al., Sokotela et al., 本報告書)。

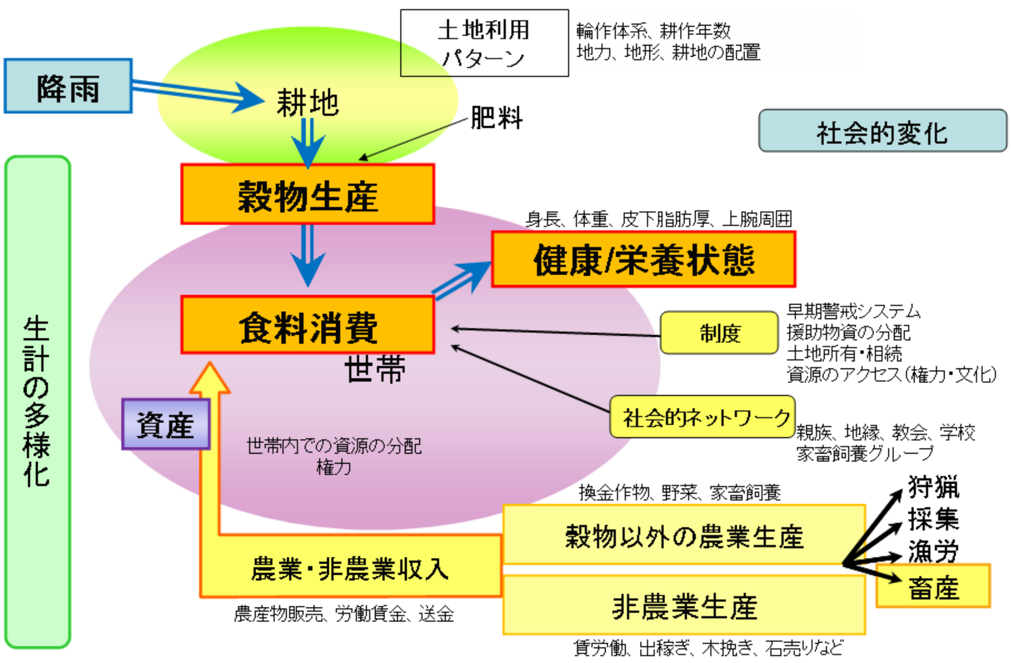

図2. ザンビア農村世帯の食料消費水準の回復に影響を与える要因（仮説）

記録的豪雨による世帯の農業生産・食料消費・健康指標への影響

2007 年 12 月 29 日に激しい雨が南部州シナゾングェ郡を襲った。シナゾングェ郡の平均降雨量は 694.9mm (Saeki et al., 2008)であるが、サイトＡ，Ｂ，Ｃの中でサイトＡの週降雨量は雨量計平均で 473 mm を記録し、この地域のトウモロコシ畑に大きな被害を与えた。被害は 3 ヶ所の調査地の中ではサイトＡで最も大きく、この豪雨のあと、被害を受けた畑のうち 30%の畑は放棄され、54%の畑ではトウモロコシの再播種が行われた。サイトＣではトウモロコシからサツマイモへの作付け転換が行われた。起伏の大きいサイトＣでは農地の位置が雨量の変動をある程度緩和していることが示された(Miyazaki; Yamashita; 本報告書)。豪雨は結果として 2008 年の収量低下となって、農家世帯構成員の食料消費、健康指標の低下をもたらした。調査地住民のエネルギー摂取量の 8 割は主にトウモロコシなどの穀物に依存していることが食料調査の結果明らかとなった（Kon et al., 本報告書)。調査世帯の児童は、年齢に対して低身長ではあるが、栄養状態はアメリカ標準値と比較すると良好であった（Yamauchi et al. 本報告書)。週単位の長期聞き取り調査によって、カロリー摂取量が豪雨の直後に減少し、その後ゆっくり回復していたことが示された。体重も食料消費の低下とともに低下した。この軌跡が食料消費の回復速度によるレジリアンスの定量分析の基となった。ほとんどの世帯は雨量ショック後の食料消費の回復に 1 年以上を要しており、特に貧困層の消費は雨量のショックに影響を受けやすいことが示された。2008 年のトウモロコシの収量低下は翌年収穫期直前の食料価格の高騰として現れ、貧困層を直撃した (Sakurai et al. 本報告書)。

豪雨ショック後の食料消費と生業回復のための対処行動

世帯の農地からの食料供給が減少すると、世帯主はあらゆる手段を駆使して世帯の食料を確保しようとする。この場合、所有する現金が特に主食の消費平準化にとって非常に重要な役割を果たしていた(Kitsuki and Sakurai 本報告書)。豪雨のあとにいくつかの世帯が野菜、家畜、家禽の販売等全く新規の現金獲得活動に着手していたことからも現金の重要性は示される(Miyazaki 本報告書)。資産としての農家世帯の牛保有数の分析から、貧困農民は牛を売らずに消費を低下させる傾向にある一方、富裕農民は牛を売って消費を平準化していることが分かった (Miura et al. 本報告書)。サイトＡとＢにおいて豪雨の後、消費を低下させるのみならず、再播種などのために農業労働が長時間に及んでいることも確認された。またこの時期には児童の労働時間も多くなっており、教育への影響が懸念される(Nasuda et al., 本報告書)。農業生産が世帯の食料供給に不足する場合は、世帯構成員は賃労働などの非農業活動に従事して食料を世帯に供給し生活を維持する。旱ばつや洪水による被害が生じた場合、援助機関による食料配給システムや資源へのアクセスを確保する地域の組織や制度は世帯の生存と維持にとって重要である。しかし、援助機関による食料配布の時期は必ずしも必要性に合っていない場合も見うけられた(Matsumura 本報告)。食料援助のような組織化されたシステムに加え、親戚や友人等の社会ネットワークが重要な役割を果たしている。近年、現金や物品などを親元や親戚へリクエストする際に携帯電話が活用されるケースが観察されている (Ishimoto 本報告書)。

旱ばつ年に食料生産が低下したとしても、農村世帯はさまざまな対処戦略や代替の経済活動を駆使してショックから回復しようとする。加えて、地域レベルでの資源や生業の動態が生存と生業を維持するためにレジリアンスの源となる。生態系サービスはさまざまな資源を地域のコミュニティに供給する。例えば、農業生態システムは食料を供給し、湖沼生態システムは

漁業資源を供給し、森林生態システムは救荒作物、エネルギーとしての薪、生活用水、建設資材などを供給する。

事前および事後のリスク対処戦略として、資源アクセスへの選択肢が多様であることがレジリアンスの重要な要素のひとつとなっている (島田, 2009; Thamana 2007)。本報告書の中で石本は、レジリアンスを能力、資産、外的ショックの３要素で説明し、さらに能力を事前的適応能力と事後的対処能力に分けている。資源へのアクセスは農業から牧畜、農業から非農業などさまざまな生業形態間の生業の代替を通して行われる。また市場、社会的組織・制度などを介したり、社会的ネットワークも資源のアクセスには重要である。アフリカの農村世帯は、自然災害のリスクのみならず、社会経済リスクにもさらされている。グローバライゼーションによる換金作物の国際価格の変動、政治的な変遷、補助金や税金、土地所有制度や農業政策の変化など社会経済リスクへも対処しなければならない。伝統的資源アクセスのシステムから新しいシステムへの移行にはいくつかのチャンネルの衰退と簇生（そうせい）が見られた（島田, 本報告書)。

地域を一様に襲うショックとしてのインド洋津波

インド洋津波などの災害は、地域やコミュニティが一様に被る共通のショックである。2004 年 12 月 26 日に発生した津波はインド洋沿岸に多大な被害をもたらした。津波という激しい自然災害（ショック）に対して社会生態システムはどのように回復したのであろうか。インド洋沿岸で最も被害が大きかったインド・タミルナド州・ナガパッティナム郡では、津波の翌年のモンスーンによる降雨によって津波によってもたらされた塩類が農地から流されたため、農地の回復は１年から１年半程度であったが、人間活動としての農業システムへの介入も重要であった(Kume et al., 2009; Kume 本報告書)。農地の回復は迅速であったものの、社会システムの回復には３年を要したことが長期の世帯調査から明らかになっている。その回復には労働市場の存在が重要な役割を果たしていた（Umetsu et al., 本報告書）。

レジリアンスを包括的に考える

本報告では、プロジェクトにおけるレジリアンス解明への実証的アプローチの研究成果を概観した。半乾燥熱帯域の農村世帯の生業という文脈でレジリアンスを考える。対象となるのはザンビア南部の旱ばつ常襲地帯の農村世帯であり、彼らの生存と生業である。特に注目するのは、旱ばつや洪水など環境のショックを受けた後の食料消費、食料供給、そして生業の回復である。その時に明らかなことは、人々の生活の営みの中で社会生態システムのレジリアンスを包括的に捉えることの重要性である。すなわち、レジリアンスは回復すること（速度・レベル）であり、回復の軌跡（どのように戻るのか）であり、回復するメカニズム（何がドライバーなのか）であり、その他にも回復するための能力・学習による自己組織力やそれらを発揮することの出来る組織・制度などの総体として考えるべきである。

レジリアンスは自然資源管理に対する異なるアプローチへの扉を開く可能性を持つ概念である(Resilience Alliance 2007)。農村社会の持続性を考える際には、個々の世帯のレジリアンスはその地域コミュニティ全体のレジリアンスの基盤となる。レジリアンスとはさまざまなレベルでの持続的な社会を構築するために社会が獲得すべき基本的な能力の一つであろう。

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ザンビア東部の半乾燥疎開林における開墾・火入れに伴う土壌養分・トウモロコシ生育の変化

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要旨（なお、本文中に引用している図表については、英文を参照されたい）

ザンビアでは昨今森林から農耕地への転換が増加しており、その土壌や作物への影響を評価することは持続的な農業生産を考える上で重要である。ザンビア東部州では開墾の際火入れを行うが、木本バイオマスが少ないため高木に低木を積み上げた箇所にのみ火が入る。従って当地域で森林開墾後の耕作による土壌養分や作物生育の変化を知るためには、火入れの有無を考慮した耕地全体の評価が必要である。また高木と低木を積み上げず、分けて火入れをすることで、その面積を拡大させれば収量が増加する可能性がある。そこで本研究では森林開墾後の耕作が土壌養分・作物生育に与える影響を燃やすバイオマス量、火入れの有無と耕作年数の違いの 2 点に着目し評価した。

調査地はザンビア東部州ムウェルワ村で、年平均降水量 792 mm、年平均気温 24℃であり明瞭な乾季と雨季がある。試験区は土壌中の全窒素含量が均一な土地を選び、48 m×31 m を 1 区とし耕作 1 年目・耕作 2 年目を各 3 連設置した。火入れは各区内でパッチ状に行った（Fig. 2）。耕作 2 年目の区では 2007 年に木本を分けず、耕作 1 年目の区では 2008 年に高木・低木に分けて火入れを行った（Table 1）。土壌は 2008 年の雨季前に 0-15 cm 深で採取したが、不耕起で行われる耕作 1 年目の火入れ区のみ 0-5, 5-10, 10-15 cm 深で採取した。測定項目は土壌中の易分解性有機物量・窒素無機化量・可給態リン量とトウモロコシ・雑草の乾物重である。

耕作 1 年目の火入れ区で、土壌は燃やすバイオマス量による影響を受け、高木下の土壌は低木下の土壌より温度が下層まで上昇し、それに伴い無機態窒素量・可給態リンの増加が見られた。また燃やすバイオマス量で収量に変化はなく、高木・低木を分けることで火入れ面積が拡大したことから畑地全体では収量は増加した。

耕作 2 年目の火入れ区で土壌中の無機態窒素量は 1 年目より減少したが、耕作 2 年目の火入れなし区よりも高かった。可給態リンは火入れ区の耕作 1 年目・2 年目で変化せず、依然高い値を示した。収量はこれを反映し（Fig. 3）、2 年目の耕作で収量は 1 年目より減少するものの火入れなし区より依然高く、火入れによって少なくとも 2 年間増収することがわかった。火入れなし区では土壌の中の窒素無機化量・可給態リン量が 2 年目に増加したにもかかわらず収量は増加しなかった（Fig. 3）。2 年目で雑草量がトウモロコシ生育後期に増加したため、本研究では収量増加がみられなかったと考えられる。

ペタウケ地方の植物写真ガイドの作製

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要旨

真常仁志氏を中心として運営されているザンビア東部州の野外試験地では，トウモロコシの連年作付けや休閑のさまざまな組み合わせが土壌と植生に及ぼす影響について継続調査を行なっている。現場での植生調査においてはしばしば植物同定上の困難にぶつかることになった。既存のフロラや図鑑類の解説は同定にあたって花や果実が手元にあることを前提としているのに対し，人為的撹乱を受ける調査地に現れる幼樹や草本の実生は，多くの場合それらを欠いていることなどが理由である。そこで，現地における調査の便宜をはかるため，筆者らは出現頻度の高い 80 種をとりあげた簡易なフィールドガイドを作製し，利用している。本報告書中ではその一部を英訳して示す。最終的には 100 種程度を目標に，生態写真に英文テキストを付した同定ガイドを作製し，プロジェクトのウェブサイト内で公開することを予定している。

本報告書では，調査地内においてもっとも出現頻度の高い，以下の 25 種をとりあげた。

マメ科木本
- *Brachystegia manga*
- *Brachystegia allenii*
- *Brachystegia stipulata*
- *Julbernardia globiflora*
- *Dalbergiella nyasae*
- *Burkea africana*
- *Dichrostachys cinerea*

マメ科以外の木本
- *Diplorhynchus condylocarpon*
- *Bridelia cathartica*
- *Pseudolachnostylis maprouneifolia*
- *Lannea discolor*
- *Flacourtia indica*

イネ科草本
- *Melinis repens*
- *Heteropogon contortus*
- *Rottboellia exaltata*
- *Hyparrhenia filipendula*
- *Hyparrhenia variabilis*
- *Hyparrhenia dichroa*

イネ科以外の草本
- *Bidens schimperi*
- *Vernonia petersii*
- *Vernonia poskeana*
- *Trichodesma zeylanicum*
- *Amaranthus hybridus*

ザンビア東部州における土壌肥沃度回復と持続的農業推進のためのアグロフォレストリーの評価

－2009/10 年作季の進捗報告－

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要旨

ザンビア東部州で真常らが設置している野外試験地に隣接する圃場において、土壌肥沃度の回復のためのアグロフォレストリー種の展示と評価を実施している。候補となる種として *Grilicidia sepium*、 *Mucuna repensis*（ハッショウマメ）、*Cajanus cajan*（キマメ）を 2007 年より栽培している。いずれもマメ科であり、窒素固定による土壌肥沃度の向上が期待される。高さや基部直径の測定のほか、生育状態を目視により観察したが、特に目立った生育の遅滞は認められなかった。2009/10 年の雨季で G. sepium とキマメの栽培は終了した。次作季には、これらを刈り倒した後を耕地にしてメイズを栽培し、アグロフォレストリーによるメイズ生産性向上、土壌肥沃度向上の可能性について明らかにする。

家計消費の脆弱性と回復力およびそれらの決定因
-ザンビア南部州の事例-

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要旨

発展途上国の農村部では人々の生計は様々なリスクに曝されているが，そうしたリスクへの対処行動やリスク存在下での消費平準化については，すでに多くの経済学的な研究が行われてきた。しかし，家計や個人が消費水準を回復するのに要する時間についてはまだ十分な検討が行われていない。その学術上の欠落を埋めるために，本稿は生態学からレジリアンスという概念を借用し，レジリアンスを消費平準化という文脈で定義することで，回復過程に時間の次元を明示的に取り入れた。さらに，このようにして定義したレジリアンスを実証するために，消費平準化に関する多くの既存研究とは異なり，集計的ショックの前後に集めた家計の週次データを用いた。

本稿で採用した実証可能なレジリアンスの定義によれば，レジリアンスは家計の 1 人当たりの食料消費がショック後に回復する速度として計測できる。この定義にしたがい，本稿はザンビアの農村部で集めたデータを使ってレジリアンスを推計する。ザンビア農村部に位置する調査地では，降水量の変動に大きく影響を受ける天水農業が営まれているが，家計調査を開始した直後の 2007 年 12 月に予期せぬ豪雨が発生した。そこで，本稿では，その豪雨ショック後の農家家計の消費の回復速度を測定することでレジリアンスを評価した。

家計レベルのパネルデータを使った分析から，件の豪雨は家計にショック，すなわち食料消費の減少をもたらしたこと，ショックからの回復にほぼ 1 年を要したことが明らかとなった。さらに，分析の結果は，土地や家畜等の資産保有が家計のレジリアンスを高めていることも示している。そこで，調査対象家計を牛資産保有額に基づき富裕層と貧困層に 2 分し，同様の分析を各層ごとに行ったところ，富裕層の方が貧困層よりもレジリアンスの水準が高い（つまり消費の回復速度が速い）ことがわかった。以上の結果は，貧困層に属する一部の家計は資産保有が十分でなく，ショック後に消費を回復することができなかったことを示唆している。他方，豪雨ショックに対する感受性に関しては，貧困層の方が富裕層よりもショック後直ちに消費を減少させており，貧困層の方が豪雨ショックに対する感受性が強いことも明らかとなった。

本稿では，調査対象家計がショック後にどのようにして消費を回復したのか，例えば労働供給の増加や家畜の売却などについては論じていない。しかし，本稿で用いた家計調査には，そうした家計の対処行動に関して豊富な情報が含まれているため，対処行動をレジリアンスの分析に取り入れることが次の研究課題である。

ザンビア農村部における豪雨ショックの資産動学への影響
-飼育牛の頭数変化に関する検証-

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要旨

アフリカ農村部において、牛に代表される生産資本の蓄積と取り崩しは、変動する所得に対して消費を平準化するための生存戦略の中心であると考えられてきた（バッファーストック仮説）。しかしながら、この仮説を検証した先行研究は一貫した結果を提示していない。これに対する説明として、近年の資産動学に関する既存研究は、相対的に貧しい家計は消費を平準化するよりもむしろ､生産資産を平準化する可能性を示唆してきた。しかし、これに関する実証的証拠も非常に限られている。

本稿は、期初の資産水準によって平準化行動が異なるという既存研究からの示唆を考慮に入れ、牛に関するバッファーストック仮説を再検討する。そのために、まず資産変動に関する感応性、ならびに復元力に対して計測可能な定義を与える。ここでは、感応性をショックの家計資産への影響の深さと定義し、一方、復元力をショックからの回復速度として定義した。

次に、本稿は最も旱魃の被害を受けやすい地域の一つであるザンビア南部州の農家家計から成る高頻度パネルデータを用いた。このデータは、2007 年から 2009 年の間に集められているが、調査地においては稀な豪雨の年を含んでいる。分析では、牛の頭数変化に着目してパネル推定を行うことで、資産平準化と消費平準化を分ける資産保有水準が存在するか否かを検討し、さらに、それぞれのレジーム毎に豪雨ショックに対する資産の感応性の決定要因を推計した。

結果は、家計の感応性はショック以前の牛保有頭数に依存していることを明らかにし、このことは資産における動学的な複数均衡の存在を示唆している。しかし一方で、洪水が起きた年に牛を保持した家計は、次の年に遅れる形で豪雨の影響を受けている可能性も明らかとなり、資産動学と経済階層移動の長期的な関係性への示唆を与えた。加えて、本稿はレジームにより、感応性の決定要因が異なっていることを示した。

ザンビア農村における季節消費の平準化

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要旨

本研究の目的は、所得の変動に対する消費構成と獲得源の変化の様相を明らかにすることである。

調査地域はザンビア南部州のシナゾンゲ地域の低部平原に位置するサイト A、中部傾斜地に位置するサイト B、高部平原に位置するサイト C の 3 地域である。各地域より 16 家計ずつ選ばれた合計 48 家計が家計調査の対象であり、2007 年 11 月より毎週実施されている。本研究では 2007 年 11 月から 2009 年 10 月までの家計調査のデータを集計し、月別の成人換算一人当たりの一週間の消費額の平均値を地域毎に算出した上で記述統計分析を行った。

分析では消費財を主食、野菜・果物、畜産物、非食料財の 4 つのカテゴリーに分類し、個別の消費変動に着目した。消費構成の概要は、分析期間における成人換算一人当たりの消費額のうち、食料消費が 83.7%-88.5%、非食料消費は全体の 11.5%-16.3%であった。また、全体の消費額のうち 50.5%-52.6%が主食、12.8%-20.1%が野菜・果物、8.2%-9.6%が畜産物であった。

非食料消費と総消費に関して、各地域、各月毎に平均的な消費水準からの乖離度合を比較した。その結果、非食料消費と総消費の平均値からの乖離度合には正の相関が見られ、さらに非食料消費の月毎の乖離度合は総消費の乖離度合よりはるかに大きいものであった。この結果は、非食料消費が食料消費の変動を抑えるための緩衝剤となっていることを示唆する。

主食に関しては、サイト B、C では自給による消費が主だが、サイト A では現金による購入が主であった。このことは、サイト A において現金収入が主食獲得手段として重要であることを意味する。また、主食の消費は概ね平準化されており、そのためには現金の役割が大きいことが明らかになった。

野菜・果物の消費変動に関しても、収穫期に消費量が大幅に伸びる時期を除いて概ね平準化がなされていた。消費平準化のためには現金による購入とともに野生植物の採集が大きな役割を果たしている。

畜産物に関しては、他の食糧とは異なりあまり消費が平準化されていない。畜産物消費と総消費に関して、各地域、各月毎に平均的な消費水準からの乖離度合いを比較した結果、畜産物消費と総消費の平均値からの乖離度合いには正の相関が見られ、さらに畜産物消費の月毎の乖離度合いは総消費の乖離度合よりはるかに大きいものであった。この結果は、畜産物消費は非食料消費同様、食料消費の変動を抑えるための緩衝剤となっていることを示唆する。

豪雨被害が家計および個人の時間配分に与える影響分析

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要旨

農業家計において、災害ショックは農業生産物に打撃を与えることで家計所得に深刻な影響を与える。この災害ショックを受けた後の家計の対処方法の一つに、労働供給を変化させることが考えられる。災害ショックが時間配分に与える影響を分析した研究はいくつかあるが、多くはショック前後の時間使用データの比較を行うことで、そのインパクトを計測している。災害ショックへの家計の対処方法は複雑で、時間経過とともに変化することが予想されるが、先行研究ではデータの制約上、これらの分析は行われてこなかった。

本稿では、ザンビアの南部州の家計調査より得た長期的かつ調査頻度が高い時間使用に関するパネルデータを使用することで、ショック後の時間経過を考慮した分析を行うことが可能となった。調査期間は 2007 年 10 月～2009 年 10 月までの 2 作期であるが、初年度の雨期の初めの 2007 年 12 月に豪雨が発生し、農産物に深刻な影響を与えた。また調査対象地域のサイト A（カリバ湖岸の低地）と、サイト B（カリバ湖岸低地と中央高地の中間斜面）では、降雨量が異なり豪雨被害の深刻度が異なっていた。そこで本稿では、長期的な時間使用のパネルデータとサイトごとに計測した降雨量のデータを用いて、災害ショックが時間配分に与える影響を、時間経過と地域的な災害被害の差異を用いて分析した。

まず調査地域サイト A とサイト B における個人特性の違いを、カテゴリー別に分類することで分析を行った。就学率は 2 つの地域で差異がなかったが、大人の教育水準に関してはサイト A の方が高かった。しかしどちらにおいても性差の違いは観察されなかった。18 歳以上が従事している職業に関しては、どちらのサイトにおいても主に農業に従事しており、標本の 3 分の 2 は農業以外に第 2 の職業を持っていない。時間使用に関しては、豪雨の被害を受けた 2007 年の雨季のショック直後に､両サイトとも農業労働の時間が増えていた。被害が深刻であったサイト A ではその増加量がサイト B よりも顕著に大きかった。また翌年度の雨季では、両サイトとも 2007 年の雨季のように農業労働を増やしておらず、初年度の農業労働時間の増加が豪雨の影響であることが示唆される。次に家事労働時間に関しては、サイト A の方がサイト B よりも年間の労働時間の変動が激しい。被害が深刻であったサイト A では、災害が起きた初年度には家事労働時間は農業労働時間と対称的な変動を観察するが、この動きは次年度には観察されなかった。他方、サイト B にでは降水量と家事労働時間の関係は観察できない。6 歳から 18 歳の子供についても、成人の農業労働時間の増加に合わせて農業労働時間の増加が観察されたが、子供達の多くが通学しているにもかかわらず、豪雨が教育時間の減少をもたらした証拠は得られなかった。

以上より、調査対象の農家家計は、豪雨による農業への被害に対して、農業への労働供給の増加により対処していることが明らかとなった。

ザンビア共和国農村部に居住するトンガの子どもの成長と栄養状態
―26ヶ月間の成長モニタリング―

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要旨

目的

2007年11月から2009年12月までの26ヶ月間にわたる成長モニタリングデータ（月ごとに測定された身長および週ごとに測定された体重）を解析し、ザンビア共和国南部州シナゾングウェ地区に居住する子どもの成長と栄養状態を評価した。

対象と方法

調査対象48世帯から218名の子ども（男子106名、女子112名）について、身長（月ごとに測定）と体重（週ごとに測定）が得られた。体重は月ごとに平均して解析に用いた。身長と体重からBMI（体重[kg]÷身長[m]^2）を算出した。26ヶ月間に測定された全データを用いて、男女別に身長と体重の成長曲線を作成し、国際的に広く用いられている米国白人集団のリファレンス（National Center for Health Statistics [NCHS]）のパーセンタイル曲線を用いて成長状況を評価した。

対象者の栄養状態については、Zスコア（リファレンスの中央値と測定値との差異を標準偏差の倍数で表し、標準化した指標）を算出して評価した。Zスコアは年齢に対する身長（HAZ）、年齢に対する体重（WAZ）、身長に対する体重（WHZ）、年齢に対するBMI（BMIAZ）　の4種類であり、それぞれstunting（年齢に対して低身長：HAZ < -2）、underweight（年齢に対して低体重：WAZ < -2）、wasting（身長に対して低体重：WHZ < -2）、thinness（年齢に対して低BMI：BMIAZ < -2）と栄養不良状態が定義されている。これらの栄養不良の子どもの割合を算出した。

結果と考察

以前の報告と同様、ザンビアの子どものstuntingの割合は高かった。しかし、身長や体重のみではなく、その両方を考慮した指標（WHZおよびBMIAZ）では栄養不良の割合は低く、対象者の栄養状態は良好であると考えられる。

HAZとWAZが思春期開始期である11歳前後で低下し、その後再び上昇し、思春期終了期の16歳前後で思春期開始前の水準に戻るという栄養状態（Zスコア）の特徴的な年齢による変動が確認された。考えられる理由として、リファレンス（米国集団）に比べて本研究対象集団の第二次性徴が2年ほど遅れていることが挙げられる。

対象者の成長と栄養状態を適正に評価するために、ローカルなリファレンスデータ（成長曲線）を開発することが急務である。

ザンビア共和国南部州の異なる生態学的環境に暮らす成人男女における地域ごとのライフスタイルの特徴
-食事・身体活動・行動パターンの分析-

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要旨

昨年度のプロジェクト報告書において、ザンビア共和国南部州の生態学的に異なる３地域に暮らす成人男女は、地理的に隣接しているにも関わらず各地域で栄養状態（体格）が異なっていること、さらに体重の季節による変動パターンが地域で異なっていることを示した。これらの結果から、地域ごとに特徴的なライフスタイル（食生活、行動パターン）が存在し、住民の栄養状態および体重の季節変動に影響を及ぼしていることが示唆された。

上記の知見を踏まえ、2010 年８～９月に、身体計測の対象者の中から 56 人の対象者を選定して食事・身体活動・行動範囲に関する詳細な調査を行った。本稿は、これらの結果について地域間および同地域の男女間のライフスタイルの違いに焦点を当てて報告する。

エネルギー摂取量、消費量およびエネルギーバランス（摂取量－消費量）においては有意な地域間差はみとめられなかった。しかし、栄養素摂取量、主要栄養素におけるエネルギー比率、エネルギー・主要栄養素摂取量に占める食品群別摂取割合をみると、食生活の地域差が確認された。また、身体活動レベルや行動半径の結果から、身体活動・行動パターンの地域差が明らかになった。

各地域について簡単にまとめると、まず下部平原地（Lowland）では、他の２地域と比べて、食事および身体活動において性差が大きいことが示された。これは調査を実施した乾季に、男性が副業のため家庭をあけることが多いという理由によると考えられる。また、湖に近いという地理的特性から魚類の摂取割合が高く、男性では自家製の発酵酒を飲む者が多かった。次に中間傾斜地（Hillside）では、男女ともに３地域で最も行動範囲が広く、とくに女性では 3 地域で最も身体活動が高いことがわかった。最後に上部平原地（Upland）では、３地域で唯一サツマイモが食べられていることが特徴的であった。さらに、乾季でも夫婦揃って農業に従事する世帯が多いことから、空間利用・身体活動パターンが男女で類似していることがわかった。

ザンビア、シナゾンウェにおける 3 雨季の気象観測解析

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要旨

2007 年 9 月から、ザンビアのシナゾンウェ州にて気象観測を開始し、今年度は 3 シーズン目の雨季データを取得することが出来た。2009/10 年雨季を中心に、3 雨季(2007/08,2008/09,2009/10 年)の比較・解析を行った。

1)3 雨季の降水量時間変化をみたところ、2007/08 年は雨季の前半で降水量が多く、2009/10 年は後半で多く、2008/09 年はほぼ一定の降水量が観測された。2007/08 年はエルニーニョ年であり、2009/10 年はラニーニャ年で、2008/09 年の通常年と合わせて特徴的な 3 事例が得られたことになる。

2）時間単位での降水量変動をみたところ、3 雨季・3 サイトを通して 17 時～午前 2 時の明瞭な降水が認められた。2009/10 年雨季では、朝雨のピークが低地（サイト A）から高地（サイト C）へと移動する現象が認められた。日中は雨があまり降らないが、2007/08 年のみ日中も明瞭に降水が観測され、エルニーニョ現象による影響が考えられる。

3) 気温の時間変化は年々の差が小さいが、相対湿度はエルニーニョ年とラニーニャ年の差が顕著に見られた。すなわち、2009/10 年雨季の 12 月から 1 月にかけて相対湿度が他の 2 雨季に比べて顕著に低く、また 3 月後半から 4 月にかけて高湿度が観測された（ラニーニャ年)。一方、2008 年の 2 月～4 月は全般的に値が低く、他の 2 雨季と異なっている（エルニーニョ年)。

4）相当温位、混合比、日射量についても、各年特徴的な季節内変動が認められた。原因については、エルニーニョ、ラニーニャ現象に起因する大規模場の変動が局地的な気象要素の変動にも影響していることが考えられる。

5）2009/10 年雨季には、2 月中旬に、10 日以上無降水の中休み(break)が認められる。これを事例として、ローカルな雨量変動が大規模場とどのように関係しているのか、可降水量を用いて検討した。その結果、中休みの前後は熱帯収束帯(ITCZ)がザンビアの観測サイトにかかっていたのに対して、中休み期間はベルト上の ITCZ が内陸部で途切れる形になっており、観測サイト周辺の値も低かった。従って、ローカルな降水量変動は ITCZ 等の大規模場と密接に関連していることが分かった。

6) 気象モデルを用いた数値シミュレーションで、これまで述べてきた 3 雨季の違いの再現を試みた。12 月と 2 月の降水量分布を事例として比較したところ、12 月のエルニーニョ年の多降水、2 月のラニーニャ年の多降水が再現出来た。今後はさらに多くの気象要素・期間でシミュレーションを行い、ザンビアの降水量変動の特性を明らかにする予定である。

ザンビア南部州のトウモロコシの生産性に作期移動が及ぼす影響

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要旨
ザンビア南部州のトウモロコシの生産性に作期移動が及ぼす影響を 2008/09 年，2009/10 年に評価した。いずれの地点でも作期を遅くすることで収量の低下が年次を超え認められ，平均で 19%低下し，その低下程度と播種直後 30 日間の気温また風速の間で密接な関係があった。農家が選択する植付時期が最適であることが示された。

1. はじめに

地球温暖化に伴う気候変動，特に降水パターンの変化がザンビアの主食であるトウモロコシの生産に及ぼす影響が懸念されている。本研究では，雨季の開始時期の判断がトウモロコシの生産性に及ぼす影響を評価するため，降水パターンに変異のある高度の異なる３地域においてトウモロコシを栽培し生産性への影響を評価した。

2. 材料と方法

トウモロコシのザンビア在来品種 Jileile を高度の異なる３つの地域（標高の低い順からA，B，C，A 地点 = Sianemba 村 と Siameja 村，B 地点 = Chanzika 村，C 地点 = Siachaya 村における計６つの異なる圃場）の 2008/09 年のシーズンに２～３作期で栽培した（栽植密度 3.3 本/m^2）。対照区（11 月下旬～12 月上旬，第 1 表）を基準に 10 日，20 日作期を遅らせる試験区を設置した。栽培は施肥，薬散等は行わない現地の慣行法に沿った。除草は適宜，実施した。各試験区のサイズは対照区が 20m×20m，作期移動区が 10m×20m とした。出芽日，開花日を調査するとともに，収穫期（3 月下旬から 4 月上旬）に子実収量（70℃乾燥）を調査した。A 地点と C 地点では降水量，日射量，気温，風速を計測し，B 地点については気温のみを計測した。

3. 結果と考察

１） 子実収量は，いずれの年次，地点においても，遅植えすることにより，平均で 19%低下した。その低下には全バイオマスならびに収穫指数が関係していた。

２） 相対収量（遅植え/対照）について，播種後 30 日間平均の気温，風速，日射量，降水量との関係をとると，日射量と降水量との間では明瞭な関係が認めれず，気温と風速との間で密接な関係が認められた。すなわち，気温が低く，風速が強い条件では，遅植えによる収量低下が大きくなることを示した。

３） 以上，２シーズンの気象条件かつ作期の範囲では，いずれの地点においても通常の植え付け時期が最も高い収量性を示し，その妥当性が明らかとなった。

ザンビアの1農村における最近の脆弱性の変化

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1. はじめに

個人や世帯の脆弱性とは、広義の財産へのアクセス権の様態とその確かさによって判断することができる(拙著 1999)。つまり、投資も貯蔵も含め、社会関係を利用していかに人々が自然資源を自らの意図、目的のために使うことができるかという、資源へのアクセスの確かさが個人や世帯の脆弱性を左右している、ということを以前述べたことがある(拙著 2009)。

資源へのアクセスの確かさが脆弱性の増大に密接な関係を持っているとすると、アフリカの農民にとっての脆弱性は、資源へのアクセスのあり方がまずもってクリティカルな意味を持っていることになる。農民が資源にアクセスする方法は、大きく分けて2つある。1つは自然的生産資源に対する労働による直接的働きかけであり、今1つはすでに他人がそのような直接的アクセスで手に入れた資源に、間接的にアクセスする方法である。直接的アクセスの豊かさを規定するものは、土地所有、生産資本、そして労働力であり、それらの概念は社会諸科学の根幹をなしてきた。これに対し間接的アクセスの豊かさを規定するものは、血縁関係や友人関係、地縁関係、宗教仲間などを含む人的ネットワークや、公的であるかどうかを問わず社会的に認知されている制度などである。

資源への直接的アクセスが疎外されていることからくる脆弱性については構造的脆弱性としてウォルデ・マリアム[1]等がすでに述べたところであるが、間接的アクセスが弱体化することによる脆弱性増大に関する研究はいまだ多くはない。本論では、人的ネットワークや制度が、脆弱性増大や緩和にどのような役割を担っているのかといった点について検討してみたい。

ところで人的ネットワークや制度が、個人や社会の脆弱性に対してどのような影響を与えているかという問題意識は、経済学におけるソーシャル・キャピタルに関する問題意識と密接に重なるところがある。経済学のソーシャル・キャピタル論において注目されるのが、人的ネットワークや制度の発達状況と経済発展との相関関係であるので、脆弱性論における人的ネットワークと制度に対する関心とは当然異なる。しかしながら、人的ネットワークや制度を機能的に分析するという点で類似点があり、また経済発展と脆弱性がどの様な関係にあるのかといった課題に切り込むためにも、ここで経済学におけるソーシャル・キャピタル概念と脆弱性論における人的ネットワークのとらえ方の違いについて、少し検討しておきたい。

2. 経済学におけるソーシャル・キャピタル

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1 エチオピアの小農の脆弱性は、社会的システムによって生み出されるものであると言う。その社会的システムとは、遊牧民(nomadic pastoralists)を含んだ小農(peasant)世界、自然の力(natural forces)、社会経済的・政治的力(socio-economic and political forces)の3つの構成要素から成っているという。小農たちは、一方で自然の力に依存し他方で社会的・政治的な力に抑圧され搾取されているというのである(Wolde Mariam1986: 11)

経済学でソーシャル・キャピタルが取りあげられるのは、ソーシャル・キャピタルの発達と経済発展との間に何らかの関係性が存在するのではないかという問題意識からである。ソーシャル・キャピタルの定義についてはこれまでもいろいろ議論されてきており、一つに収斂しているわけではないが、「人々の水平的なつながりである社会的ネットワークとそれに結びついた規範の集まり」というパットナムの定義が最もよく知られている。これをもとに、1996 年に世界銀行内で組織された研究推進イニシアティブ、「ソーシャル・キャピタル・イニシアティブ」(SCI) では、ソーシャル・キャピタルの定義として「社会の内部的および文化的結束性、人々の間の相互作用を左右する規範および価値、そして人々が組み込まれている諸制度を」含むものと広義に捉えられている (宮川 2004: p.34)。

いずれにしろ、経済学のソーシャル・キャピタル論における人的ネットワークや制度に対する関心事は、それらの発達と経済発展の相関関係にある。したがってソーシャル・キャピタル論の主たる関心は、①ソーシャル・キャピタルの定量的把握に重きが置かれ、②ソーシャル・キャピタルの発達と経済発展や成長との関連性が追究され、その上で、③経済発展や成長にプラスの効果を与える人的ネットワークや制度とは何かを明らかにする点に向けられる。

これまでの研究で、①に関しては、理論の厳密性と現実説明力との間のトレードオフ関係が指摘され、定量化できる範囲の限界性から、ソーシャル・キャピタル概念の有効性に対する疑義も出されている。しかしながら、人間をホモ・エコノミクスととらえる仮定を一時的にではあれ離れ、経済的・社会的・技術的な要因を総合的に評価することの重要性を訴える意見も一部の経済学者から出ている(大守 : p.110)。

②に関しては、定量化の困難さが問題とされつつも幾つかの「実証的」研究がなされてきた。それらの多くは、経済成長や発展が、(プラスの効果を持つ) ソーシャル・キャピタルの発達状況と何らかの関係があることを示している。中には経済発展とソーシャル・キャピタルの発達の因果関係を逆転させ、工業発展などの地域経済の発展が、その地域におけるソーシャル・キャピタルの発達を促進しているという研究報告もなされている。残念ながら、経済発展とソーシャル・キャピタルの発達との関係を解明するための定量的分析の多くは未だに反論の余地が多いのが現状である。しかしながら、人間をホモ・エコノミクスと捉えることで見失う残差－それは残差というにはあまりに大きすぎるのだが－の分析に少しでも踏み込もうとする試みとしては評価できるものと考える。

最後の③に関しては、経済学が分析方法として方法論的個人主義を取ってきたこと、およびソーシャル・キャピタルの実証研究が主として先進工業国で発展してきたことが反映している面はあるが、幾つかの興味深い点を指摘してきた。すなわち、集団内におけるメンバーの自主性や平等性が保障されている人的ネットワークの発達が経済発展と相関しているという指摘である。

パットナムはイタリアの研究事例から、水平的結合で特徴づけられるネットワークの方が垂直的結合のそれよりもより生産的なソーシャル・キャピタルであると述べた。それは別の言い方で表現されることもある。つまり、「非排除的・浸透的で、異質的集団の結びつきの橋渡しをする」ような接合型[2](bridging)と、「同質的なメンバーの集まりで、外部者を排除するよう

[2] 橋渡し型と訳される場合もある(パットナム 2006: 19)。

な性格」をもつ結束型(bonding)とに大別した場合、前者が積極的に前へと進む、社会全体にプラスの効果をもたらすソーシャル・キャピタルであるのに対し、後者は社会全体にとって好ましくないものであるといった言い方である(宮川 2004:p.43)。

経済学におけるソーシャル・キャピタル論はこのような成果を挙げ発展してきているのであるが、幾つかの問題点も見えてきている。たとえば、定量化への過度のこだわりから来る限界と、それとも関連することであるが、統計資料のある先進工業国研究の分析に偏りすぎている点である。後者の点は、経済学で取り上げるソーシャル・キャピタルの定義にも反映している。つまり経済学におけるソーシャル・キャピタルの定義が、ネットワークを形成する集団の開放性と集団内部でのメンバーの対等性を過度に重視している可能性があるのである。個人的自由や平等性は、成熟した市民が存在する（先進工業国の）社会でよく実現されているといった実証研究の成果も、結局はこのような限界性を反映した分析結果であるといえるかもしれない。

すでに拙稿(2009)でも述べたように、アフリカを含むいわゆる発展途上国では、人的ネットワークはそれがいかなるものであれ、既存の政治体制や権力構造から独立して存在するものは少なく、垂直的結合の性格を持つものや「同質的なメンバーの集まりで、外部者を排除するような性格」をもつ結束型(bonding)のものが多い。上記のような経済学におけるソーシャル・キャピタルを念頭におくと、アフリカの社会とりわけ農村社会においては、経済発展にプラスの効果を持つと思われる人的ネットワークとしてのソーシャル・キャピタルは存在しないということになる。

ここが、経済学が対象とする人的ネットワークと制度と、脆弱性論が対象とすべきそれとの相違点であるといえる。脆弱性論における人的ネットワークや制度の分析においては、この先進工業国における分析の限界を超える必要がある。以下では、脆弱性論が対象とすべき人的ネットワークや制度、そしてその分析方法について検討を加えてみたい。

3. 脆弱性論における人的ネットワークと制度

脆弱性論における主たる関心事は、人的ネットワークや制度と資源アクセスとの関係である。人的ネットワークや制度が、資源アクセスにとってプラスの効果を持つかどうかといった問いかけをする点では、経済発展への影響を問題とするソーシャル・キャピタル概念と関連する。しかし、先に示唆したように、脆弱性論で議論する人的ネットワークや制度は、経済学でいうソーシャル・キャピタルに含まれないものも対象とする。

経済学では、結束型のネットワークの事例として、血の結束を誓う暴力団やマフィア、麻薬密輸ネットワーク、排他的人種差別主義者等をあげることが多い。しかし、アフリカなどの発展途上国では、結束型ネットワークが多種かつ多数存在しており、それらは必ずしも社会全体にとって好ましからざるものと断定できるものではない。例えば、アフリカにおいては、民族的組織を一律に垂直型・結束型と見なして、分析の対象から外すということになると、人的ネットワークが資源アクセスにとって果たしている重要な役割を見逃してしまうことになる。それは、脆弱性論においては致命的なことになる[3]。

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[3] もっとも最近は、経済学のソーシャル・キャピタル論においても、「経路依存性」の重要性が指摘されてきていて、垂直型・結束型のネットワークを、一律に排除するということは少なくなるかもしれない（大守 2004:118)。

パットナムは「一人でボウリングをする」(パットナム 2004: pp. 55-76) で、アメリカにおけるソーシャル・キャピタルは 1970 年代前半を「分水嶺」のように減退してきたと述べた[4]。そのときに彼が考えたのが、「一般化された互酬関係」の規範の後退であり、互酬関係の中で醸成される信頼感の低下という点であった。互酬関係の中で醸成される信頼感の低下は、間接的資源アクセスの低下を意味するので、それは脆弱性増大をもたらす変化でもある。しかし、パットナムが議論の対象としているソーシャル・キャピタルは、アフリカにあってはもともと発達の厚みがない「一般化された互酬関係」であり、その規範の後退をもって脆弱性増大を議論することは、生産的な議論とはなりえない。

現代アフリカ社会の脆弱性をみるときの文脈で検討されるべきことは、「一般化された互酬関係」の存在の有無やその後退の如何ではないとしたら、何を見ればいいのであろうか。私は、①「一般化された互酬関係」であるかどうかを問わず、人的ネットワークの総体的変化を見ること、②その中で「一般化された互酬関係」に近いものと総体的に遠いものとを区分けし、その比率の変化をみる、この 2 点が主要な観点になると考える。そうすると、垂直型・結束型ネットワーク内での互酬関係から「一般化された互酬関係」へのシフトが起きているのかどうか、またシフトが起きているとして、その過程で互酬関係の弱体化が見られるかどうか、という点から脆弱性の変化を分析できると考える。

激しい社会経済変化を遂げている現代アフリカにおいて、互酬関係が変化している可能性は充分に考えられ、それを示す研究成果は非常に多い。さらに、その変化の過程で垂直型・結束型ネットワークの互酬関係が弱体した後に、一般化された互酬関係がそれに取って代わる役割を果たすに至っていない状態が起きている可能性も考えられる。脆弱性の観点からいえば極めて危険な状態である。一時的ではあれ、間接的な資源アクセスのネットワークが機能低下を起こすことは、脆弱性論でいうところの危機に「晒された」状態であるといえる。この点に関する研究報告はまだ無いが、このような観点に関する調査研究こそが現在切実に求められているところではなかろうか。

かつてアフリカの農民のブリコラージュ性について述べたことがある(島田 2007)。そこでは、農民の制度や組織の組み替えの巧みさや人々の流動性の高さを指摘した。それは組み替えによる制度や組織の緻密化や高度化を意味するのではなく、既存の制度や組織を使った資源アクセスのチャンネルを捨てないで、新しいチャンネルを追加することを意味することであるとした。このチャンネルの増大は、互酬関係の変容過程で起きる「晒される危険性」を回避するための経験的知恵かもしれない。

また、Berry(1993)は、ネットワークに対する投資が時に異常なインフレを起こすことを、ナイジェリアの事例から明らかにした。生産財投資と比較して必ずしも確実な効果が期待できないネットワークに、何故人々は過剰な投資をするのであろうか。この疑問に対しては、資金に余裕があるときにネットワークに資金を投入する行為は、不確かとはいえ長期的に利己的利益を実現する 1 つの戦略的行動であるとするゲーム理論的解釈も可能である。あるいは、人間の行動のなかには本能的に協調的行動や利他的行動が備わっているのであり、各個人レベルで

[4] パットナムは、20 世紀の後半 3 分の 1 とか、過去 2 世代にわたりとかいろいろな言い方をしているが、1970 年代以降にソーシャル・キャピタルの減退があったと述べている(パットナム 2006)。

最適性を狙ったものとは言えないという解釈も可能である(大守 2004: pp. 113-114)。しかし、脆弱性の観点からみると、この行動も互酬関係の変化の過程で起きるかもしれない、「晒される危険性」に対する防衛的措置といえるかもしれない。

いずれにしろ、このような人間の行動の動機とその背後に横たわる一般的理由を検討するためには、事例研究を積み重ね、資源へのアクセス・チャンネルの変化過程と、その過程で起きる脆弱性増大をつぶさに観察することが必要である。以下では、2010 年 11 月の現地調査で明らかになった、ザンビアの C 村における最近の人的ネットワークの変化に焦点を合わせ、それらの変化と脆弱性との関係について検討してみたい。

4. C 村で見た人的ネットワークの変化と脆弱性

筆者はザンビア中央州にある C 村において 1990 年代から継続的な調査を行ってきた。(図 1) そして、今回約 6 年ぶりに現地調査を実施することができ、社会組織に幾つかの変化が起きていることをみてきた。今回は、その中から人的ネットワークの変化に焦点を当て、そのことがもたらしている脆弱性の変化について考察してみたい。

今回観察された変化は大きく分けて 2 つある。1 つは全く新しい組織の発展であり、今 1 つは、以前から存在した制度・組織であるものの、その制度・組織の中で新しく展開してきている変化である。

4.1. 新しい組織の簇生：小規模金融

正確に言えば、この村で小規模金融が正式に始まったのは 2003 年であった。2000 年に貧困削減計画の一環で、この村に灌漑農業とアグロフォレストリーの推進（Vifor 計画）を図る国際的 NGO が進出してきた。このときに、この事業を推進するために、小規模貸し付けの制度が導入された。それはマイクロ・プロジェクト・ユニット（MPU）と呼ばれ、初期資金として NGO から 7 百万 K(クワッチャ)の援助が行われた。

この MPU は、灌漑農業に必要な足踏みポンプの購入に向けた計画としてスタートした。灌漑農業計画に参加しようという農民は、52 万 K をあらかじめ MPU に支払い、足踏みポンプの提供を受けるものとされた。このポンプの購入資金は、利子率 2.5%／月の条件で 6 ヶ月後に返済するというものであった。その後にこの MPU は、肥料の購入に充てるためにも融資を行うようになった。

しかしながら、最初の足踏みポンプの購入に際し、一部の購入希望メンバーに足踏みポンプが届かず、逆に執行部メンバーの中には夫妻で 2 台のポンプを入手した世帯もあるという不公正な運営が見られ、そのような運営に不満を持つ人たちはこの MPU から離脱した。さらに不運なことに、この Vifor 計画の中心メンバー、すなわちそれは MPU の執行部でもあるのであるが、そのメンバーのうち複数の人が相次いで亡くなるという事態が起きた。その死亡者の中には MPU に負債を負う人もいて、その負債を引き継ぐ人がいないケースが生じた。このため、MPU は 2007 年には新たな貸し付け業務が行えない状態に陥った。この状態は 2010 年の現在も続いており、この貸付制度は多くの村人が「失敗した」と考えている。

それに代わって活動を活発化させているのが今年(2010 年)の現地調査で明らかになった OSAWE(財産・富の自己蓄積)と呼ばれる小規模金融組織である。その多くは 2009 年以降にはじ

まったばかりのものであるが、現在活動しているグループは10以上ある。

現在運営されているOSAWEは、その起源から大きく3つのグループに分けられる。最初のグループは、かつてのViforのメンバーによって結成されたOSAWEである。2つ目のグループが、2008年から開始されたグループで、参加型農業開発組織（OPAD）のメンバーによって結成されたグループである。このOPADは、農民は最初に作物の種子やニワトリの供与を受け、収穫（再生産）後に決められた量や数の返却を行い、それを次の農民に供与するという開発事業組織であったが、その事業の中の1つとして自助事業も開始され、そこで小規模金融の組織化が行われた。そして最後のグループが、このどちらにも属さず、自分たちのイニシアティブで組織化されたOSAWEである。もちろん、そのやり方はViforやOPADのメンバーたちがやっている方法と全く同じであるが、ViforやOPADでの月極貯蓄額が50,000Kであったが、その額が高すぎると感じる人たちも参加できるように、15,000Kにしているところもある。

このように、貯蓄・貸し付け事業はこの村の人にとって新しいものであった。それにもかかわらず、近年急速に拡大しつつある。もちろん、ViforやOPADといった外部からの働きかけがあり、一部のファシリテイターはこれらのNGOの教育プログラムで具体的な運営方法を学んだといえる。しかし、現在簇生しつつあるOSAWEの中は、そのようなファシリテイター以外の人たちが組織してできたものもあり、村人の間で自主的に組織されているものもある。ある教会では、信徒仲間でOSAWEに似た貯蓄・貸し付けグループが作られていた。毎月10,000Kを徴収し、その資金を貸し付けに回すという点では通常のOSAWEと同じであるが、利子運用で生まれた利益金は教会のクリスマス関連事業に寄付するという。

もちろん村人の中には、この新しい貯蓄・貸付制度に対して懐疑的な人も多い。Viforで行われたような不正が起きることを心配する人や、返済に失敗するとすぐに訴えられるといった新制度の厳格性を恐れる人など様々である。しかし、そのような人たちの中にも、様子見をしているといった感じの人もあり、この新しい貯蓄・貸付いけ制度は着実に農民の日常生活の中に入り込みつつあるといえる。

4.2. 家畜・農具の賃貸し

雨季が始まり開始されるアップランドの耕作は、通常牛耕で行う。牛耕のためには最小２頭の牛と犁が必要である。すべての世帯が牛と犁を所有する訳ではない。牛2頭と犁の組み合わせ、つまり「セット」を持たない世帯では、拡大家族で行う共同耕作で耕起作業を行っている。しかし、近くに助け合える拡大家族がなく「セット」が確保できない場合、「酒の仕事」や、現金や現物による支払いを条件に、隣人に牛や犁を借りて耕起や播種を行う。

伝統的には、拡大家族内での共同耕作が一番盛んで、現金や現物支払いによる賃耕は少数であった。現在も親族内での共同耕作が多数を占める。しかし今回の調査で判明したことは、有償による犁や牛の貸し借りが、拡大家族内の共同耕作の枠組みの中で拡大してきているという点である。

拡大家族内での耕作ローテーションは、メンバー1人あたりの「セット」利用日数を2日から5日間に設定し、年長者順に回すのが一般的である。今回多く観察されたことは、自分の「セット」利用日に、それを他の人に賃貸しするやり方である。それは、ローテーションの枠組みに手を加えるものではないが、そのシステムの中で賃耕が増えつつあることを意味している。

これは、伝統的共同耕作のグループが縮小化していることと無関係ではない。共同耕作の単位の縮小化は、ローテーション内での農民個々人の「セット」利用日数の延長を可能にする。例えば 6 人以上のグループによる共同耕作では、1 人あたりの耕作日は 2 日か 3 日が普通である。しかし、共同耕作グループの人数が 2 人か 3 人と少数になれば、1 人あたり耕作期間を 4 日か 5 日に延ばすことができる。これが、牛と犁の「セット」を他人に貸す余裕を生んでいる。

このような賃耕は、拡大家族内の共同耕作の外でも増えてきている。牛か犁を所有しているものの一人では犁耕ができない人たちが、牛や犁を持ち寄り「セット」を作って協同で耕起作業をする場合がある。Twakanjilana chipani と呼ばれる協同作業である。その協同作業用の「セット」を他の人の畑の賃耕に使う方法が増えているのである。

共同耕作グループのメンバーが 2 名で、4 日おきに耕作期間を交代する場合、自分の畑の耕起作業が終わるのも早くなる。そこで、自分の耕作期間を利用して、犁耕を希望している人の畑に出かけて耕起することが可能となるのである。そのようなやり方している人が増えているのである。

5. 脆弱性の変化

共同耕作グループの縮小化は、耕起作業の重要な手段である牛と犁を持たない寡婦世帯や、若者世帯にとって資源アクセスの弱体化を意味する。また、外部からの援助で始められた Vifor などのプロジェクトが、5 年を持たずに「失敗」し、活動が停滞してしまったことも、農民間で疑心暗鬼の気持ちを持たせ、村内の団結を弱めることになった。この論文では述べなかったが、このプロジェクトが、村長を避けるように組織化が進められたために、村長が反発し、このプロジェクトで重要な役割を担っている農民たちに「村落追放」令を出すという事件に発展した。村長からみれば「村人が利己的になってきた」という状況、村人からみれば「村長の意向 1 つで追放令を受ける」という危うい状況になってきたということである。

資源へのアクセスが弱められる状況を脆弱性増大と捉えれば、これらの変化はこの村の農民や世帯の脆弱性が増大していることを示している。しかしながら、3. で述べたように、これらの共同耕作グループの縮小化や Vifor のプロジェクトの失敗は、小規模金融の拡大や共同耕作システム内での賃耕の増大など、新しい動きを惹き起こしている。それらは、既存システムの弱体化の後に発生してきた新しい資源アクセスの方法であり、脆弱性の視点からいえば、それは脆弱性緩和の効果を持っているということができる。

もし、脆弱性増大を資源アクセスの確かさに求めるとすれば、今回の村落調査で明らかになったことは、資源アクセスを巡る変化は、この村の農民や世帯の脆弱性を増大させる側面とそれを緩和させる側面の両面を持っていることが明らかとなった。そして今回観察されたケースでは、脆弱性増大の過程の後に、それを補うかのように緩和の過程が継起的に起きてきているらしいことも明らかとなった。以上の脆弱性の変化を模式的に示したのが図 2 である。

6. おわりにかえて

本論では、資源アクセスの確かさの変化を基準に、最近の C 村における脆弱性の変化について試論的分析を行った。本論では必ずしも厳密に議論をしていないが、資源アクセスの方法には様々なチャンネルがあり、それらのチャンネルの総体をもって脆弱性を規定するのが本来あ

るべき方法であろう。そのためには、個々のチャンネルが持っている資源アクセスの確かさを測ったうえで、他の様々なチャンネルとの相互関係や、チャンネル相互間の審級関係を明らかにする必要がある。それは今後の課題として残さざるを得なかった。

本論では、C 村で進展している、伝統的資源アクセスのシステムから新しいシステムへの変化が、幾つかのチャンネルの弱体化を招きつつもそれに代わる他のチャンネルの創造を惹起しており、そのことがシステムの変化の過程で直面するかもしれない個人や世帯の「晒される危険性」を緩和していることを示唆した。

また、ソーシャル・キャピタル論との関連でいえば、今 C 村で新しく生まれてきている貯蓄・貸し付け組織や賃耕の制度は、それ以前のものに比べ余程「一般化された互酬関係」に近い接合型の組織・制度であるといえる。だとすると、この村でここ 10 年の間に起きた人的ネットワークや制度の変化は、ソーシャル・キャピタルの萌芽と捉えられるかもしれない。しかし、この点に関してはまだ検討すべき点が残っている。賃耕の制度でも述べたとおりに、現在のところ新しいシステムは共同耕作システムのローテーションの内部で一部ループ上に突出した賃耕システムであり、ソーシャル・キャピタル論の議論でいえば、結束型のシステムに一部接合型のシステムが部分的に接合されているだけの可能性もあるからである。

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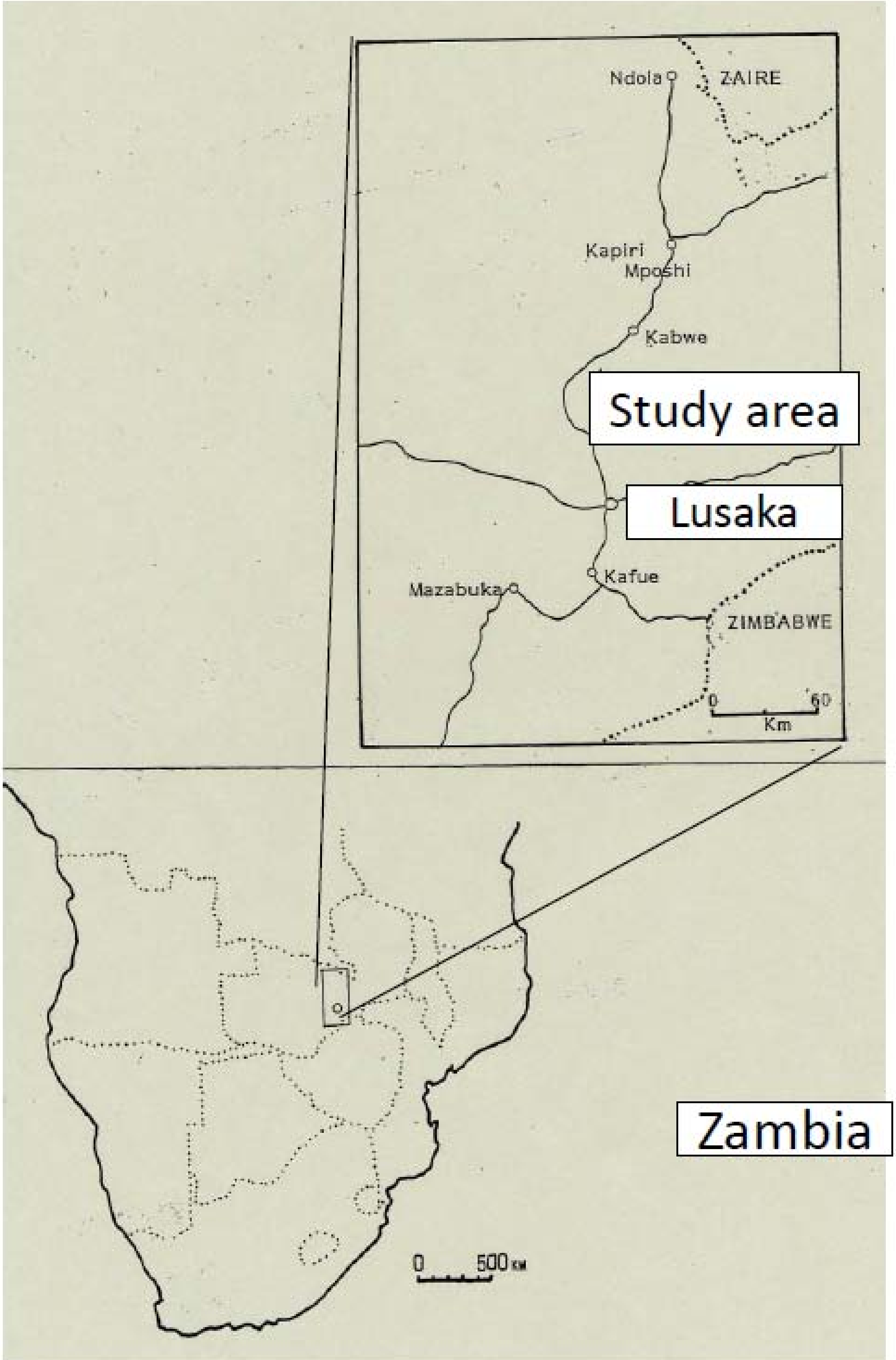
Ndola
ZAIRE
Kapiri
Mposhi
Kabwe
Study area
Lusaka
Kafue
Mazabuka
ZIMBABWE
0
60
Km
Zambia
0
500KM

図１　調査地

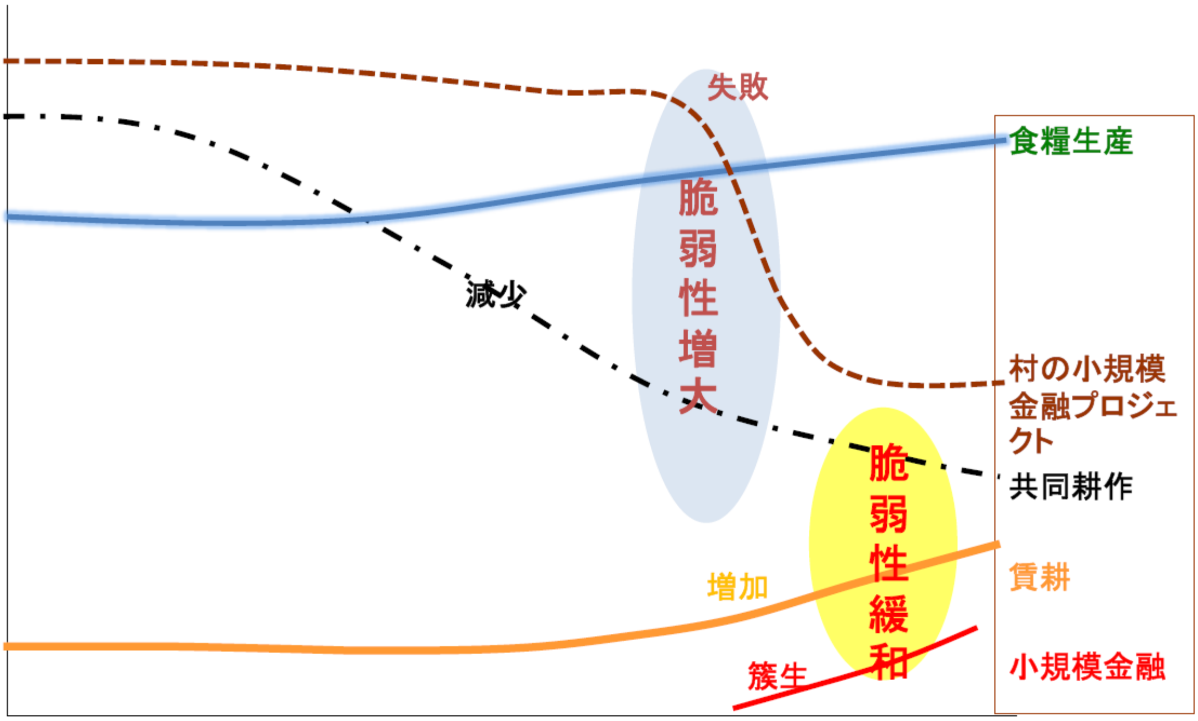

図 2　脆弱性の変化

ザンビア南部州における農業的脆弱性とリスクに対する
対処行動・援助の相互関係について
- 農村社会のレジアンスを考える-

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ザンビア南部州に暮らす人々は、天水農業に生活を依存している。また、ザンビア南部州を含むサハラアフリカは、毎年のように干ばつなどの気候変動の影響による自然環境変化の影響を受ける地域として知られている。筆者らは、このザンビア南部州のもっとも標高が低いカリバ湖岸から北に位置する台地までの地形変化を利用した調査地(サイトA・B・C)を設定し、農業的脆弱性とリスクに対する対処行動や援助について世帯の生計レベルで調査を行ってきた。さらに、衛星データや航空写真を利用した土地利用に関する解析も行ってきた。本年度は、これまでに収集し蓄積してきたデータを時系列で理解し、農村社会のレジリアンスについて考察を行った。以下にその概要を示す。

最初に、さまざまな情報を統合し、理解を進める上でのキーとなるコンセプトについて議論した。議論のキーは、農村社会におけるレジリアンスを「被害の受けにくさ」と「被害からの回復」とした。「被害の受けにくさ」とは、ショックへの頑強さと柔軟さの 2 つの側面がある。本研究では、レジリアンスと諸概念との関係を明確にした。農村社会におけるレジリアンスを考える上で、対応能力の解明へのアプローチを挙げ、対応能力の発露としての対処行動について、特定のショック(今回においては突発的多雨)に関して時系列順に考察した。次に、調査世帯の農民が耕作をおこなっている畑について、GPS 等を用いて分布位置を把握するとともに、大雨被害前後における耕作パタンや現金獲得法の変化について時系列把握した。さらに、衛星画像の時系列解析や航空写真の時系列解析とを GIS の下に重ね合わせ、農村世帯の生活について調査した。くわえて、調査地において近年急速に普及してきている携帯電話についても、コミュニケーションツールとして位置付け、この携帯電話が相互扶助における役割について調査し、贈与・援助の実態を明らかにした。さらに、同地域では、ザンビア政府や NGO が食糧援助プログラムを実施してきている．ここでは実際の食糧援助が農民の食糧不足リスクにどのように対処してきたのかを、 2005 年から 2008 年までのシナゾングウェ地区の事例をもとにそのプロセスを分析した.

その結果、調査村に暮らす農民は、多岐にわたる気候変動に対する事前的対策を取っていることがわかった。さらに実際の気候変動の影響が多雨によって顕在化した後にも、耕作パタンだけでなく、それまでに蓄えてきた資材の売買などの多岐にわたる対処行動をとることがわかった。これらの成果から、アフリカ農村社会のレジリアンスにおいては, 農村内部の農民世帯だけでなく, より広いコンテクストを視野に入れ、自然環境から社会制度に至る生活にかかわるさまざまな状況の時系列かつ詳細解析が重要であることわかった。

ザンビアの貧困と食料安全保障—貧困の計測、傾向とその要因
Zambia's Poverty and Food Security: Measurements, Trends and Decomposition

Thamana Lekprichakul
Research Institute for Humanity and Nature

要旨

本稿は調査地であるザンビア南部州・東部州における貧困の計測手法と貧困状況をそのレベルと傾向に焦点を当てて検討したものである。ザンビアの貧困は絶対貧困アプローチによって計測され、世帯は月間食料消費支出が最低必須カロリー（最低フードバスケット）の費用に満たない場合に貧困とされる。この食料消費に基づく貧困指標は世帯の食料安全保障へ直接つながっている。1990 年の構造調整プログラムの実施と 1991/92 年農作期に発生した旱ばつは、1993 年に農村部と都市部の両地域で貧困層を急増させた。貧困が急増したのは都市部、特にルサカとコッパーベルトであった。ザンビア全体の貧困層は 1998 年以降の経済成長期には改善の兆しが見えた。この期間の経済成長は都市住民に対して特に便益を及ぼし、ルサカでは貧困層に含まれる人口の減少となった。これに対して、南部州と東部州の貧困は増加の傾向とともに貧富の差が拡大する結果となった。その転換点は 2002 年であり、南部州と東部州の貧困の傾向は何度かの旱ばつの発生により 2000 年代初頭に農業生産が影響を受けたためであった。

ザンビア南部の季節降水量の経年変動

谷田貝亜紀代
総合地球環境学研究所

要旨

ザンビアの農業は天水に依存し、季節降水量とその降り方はその経済にとり重要である。播種のタイミングや作付種の決定などの農業活動には、過去の雨量や降り方が農夫や共同体の経験や意識に影響を与えているはずであり、旱魃のショックに対するレジリアンスを議論する上でも、基本情報として過去数十年間の降水変動傾向の実態を把握しておくことは重要である。本稿では、ザンビア全域の降水量分布の気候学的特徴を述べ、プロジェクトの主対象地域である南部の過去数十年間の降水量変動傾向の初期結果を示す。

- ザンビア南部の年間降水量は平均 500~900 ミリでは半乾燥地域に属する。雨季は 11 月から 3 月で、5 月から 9 月はほとんど降水が観測されない。
- 東部の Chipata、南部の Livingstone の 1961 年—2003 年の季節降水量はいずれも減少傾向を示す。ルサカは 1970 年代と 1990 年代は減少傾向を示す。.
- Chipata, Lusaka, Livingstone およびプロジェクトサイト近接の Choma の季節降水量変動（1978/79—2007/08）は、2003 年以降増加傾向を示す。またエルニーニョ発生時期には降水量が少なく、ラニーニャ発生時期には降水量は多い傾向にある。
- プロジェクトが雨量計観測を開始した 2007/2008 は異常な多雨であったことが報告されている。熱帯降雨観測衛星降雨レーダ（TRMM/PR）は、2007 年 12 月にカリバ湖周辺の強雨を示し、2006 年 12 月や 10 年平均値と比較しても極端な現象であったことをとらえた。
- プロジェクトサイトの最近接地点（ザンビア気象庁観測）Choma について、農業活動にとって重要な指標である積算日降水量の変化傾向を 1978/79-2007/08 について示した。Lekprichakul (2006)が作物生産量から定義した旱魃は 1990 年-2007 年のうち 6 シーズン(91/92, 94/95, 97/98, 00/01, 01/02, 04/05)である。このうち 00/01 シーズンは多雨でラニーニャであった。残る 5 シーズンは少雨傾向であるがエルニーニョが発生したのは 91/92, 97/98,02/03 シーズンのみである。この結果は、降雨量やその支配要因さらに降り方（日降水量変化傾向）と作物生産の間には、複雑な要因があることを示唆している。

インド・タミルナドゥ州インド洋津波災害への農村世帯のレジリアンス *

Resilience of farming households to the Indian Ocean's Tsunami Disaster in Tamil Nadu of India

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本稿はインド・タミルナドゥ州・ナガパッティナム郡において津波被災後の 2005 年から 2008 年までの期間に農村世帯が受けた所得へのショックの程度とその回復を調査したものである。津波直後ほとんどの農民は所得と資産の低下を余儀なくされた。2005/2006 年農作期には、60 パーセントの農業所得低下があったが、2007/2008 年農作期には、ほぼ完全に津波前の所得に回復した。津波直後は、農業生産から賃労働への生業の転換が見られた。主な対処戦略として、援助の授受と借金が殆どの世帯で見られた。その他の対処戦略は、消費の削減、児童の就学延期などであった。実証分析の結果から、津波後の期間に所得成長率の収束が見られた。この期間には、全てのカテゴリーにおいて実質所得の回復が観察されたが、価格上昇を考慮に入れると回復の効果はそれほど明らかではなかった。所得へのショックからの回復に対する感度分析では、要素市場へのアクセス、金融市場へのアクセス、労働市場へのアクセスなどがレジリアンスを向上させる重要な要因となっていた。結果として、津波被害を受けた地域の回復のスピードは生態環境と社会環境とでは差があった。土壌と水資源をモニターして農業生産環境の回復状況に関する情報や、生産要素市場へのアクセスを提供することによって、被災した農民が所得の低下からすみやかに回復するための支援を供与することが求められる。

* 本論文は総合地球環境学研究所とタミルナドゥ農業大学によって 2005 年から 2009 年に実施された共同研究の成果の一部である。津波発生 1 年後の調査は平成 14-18 年度文部科学省特定領域研究「資源の分配と共有に関する人類学的統合領域の構築—象徴系と生態系の連関をとおして」研究代表・内堀基光、「資源と生態史—空間領域の占有と共有」生態史班代表・秋道智彌 (課題番号 14083208）から研究費の支援を受けた。ここに深く感謝する。

農業技術の介入によるインドアンダマン諸島における 2004 年津波からの農業家計の回復

久米崇
総合地球環境学研究

要旨

アンダマン諸島は，近隣のニコバル諸島とともに，2004 年 12 月の津波によって最も大きな被害を受けた地域の一つである．津波前，アンダマン諸島は十分な降水により，農業生産に適した環境であった．しかし，津波による農業環境の破壊が大きく，農家は家計を迅速に元の状態に戻すため，新しい農業技術を導入する必要が生じた．自然災害の被災地では，住民の家計と自然環境は速やかに回復されるべきである．本稿では，アンダマン諸島において農業技術の介入によってどのように農家の家計が回復したかを報告する．同時に自然環境，すなわち土壌，水資源，稲作生産に関する津波被害（特に塩性化被害）の程度とその回復についても報告する．試験圃場では，圃場面を盛り土によって高くしココナツの外皮で作物を覆う方法と，幅広の圃場面と畝を設ける方法によって，農家家計を回復させることに成功した．2 度の雨期後には，土壌および水資源の塩性化は津波前の状態に回復した．その主な回復要因は，年間 3,000 mm を越える降水が塩分を洗脱したことによる．アンダマン諸島における家計の回復は，農業技術の介入によるものでもある．本調査地における農家家計の回復は，人間活動（新しい農業技術の介入）と自然水循環（豊富な降水）の相乗効果によるものであるといえよう．

レジリアンスプロジェクト第 13 回ワークショップ

日時：　平成 22 年 10 月 1 日（金）　10:00-17:00,　2 日（土）　10:00-17:00
場所：　総合地球環境学研究所　セミナー室 3&4

10 月 1 日（金）　10:00-17:00

10:00-10:05	開会の挨拶・プロジェクト最終年度に向けて	
	阿部健一	（総合地球環境学研究所）
10:05-10:10	年末発表会に向けて	
	梅津千恵子	（総合地球環境学研究所）
10:10-10:40	テーマⅠ総括発表（代理発表）	
	宮嵜英寿	（総合地球環境学研究所）
10:40-11:10	テーマⅢ総括発表	
	島田周平	（京都大学大学院ｱｼﾞｱ･ｱﾌﾘｶ地域研究研究科）
11:10-11:40	テーマⅣ総括発表（代理発表）	
	山下恵	（近畿測量学校）
11:40-12:10	テーマⅣ（広域）総括発表	
	梅津千恵子	（総合地球環境学研究所）
12:10-13:15	昼食	
13:15-13:45	テーマⅡ総括発表	
	櫻井武司	（一橋大学経済研究所）
13:45-14:15	12 月発表会に向けた内容説明および発表スライド案の提案	
	梅津千恵子	（総合地球環境学研究所）
14:15-14:30	休憩	
14:30-17:00	総合討論	
	司会：　久米崇	（総合地球環境学研究所）

10 月 2 日（土）　10:00-17:00

10:00-12:15	全体会議	
	司会：　梅津　千恵子	（総合地球環境学研究所）
12:15-13:20	昼食	
13:20～	個別発表	
13:20-13:40	2009/2010 年雨季の降水量と過去 3 年間の特徴	
	菅野洋光	（東北農業研究センター）
13:40-14:00	ザンビア南部州のトウモロコシの生産性に作期移動が及ぼす影響	
	下野裕之	（岩手大学農学部）
14:00-14:20	Obesity in Chronically Under-Nourished Pre-School Children in Low Income Countries: A Case of Zambia	
	Thamana Lekprichakul	（総合地球環境学研究所）
14:20-14:40	ザンビア降水量の長期変動傾向について	
	谷田貝亜紀代	（総合地球環境学研究所）
14:40-15:00	休憩	

15:00-15:15　　ザンビア東部州の開墾・耕作―土壌からの評価―

安藤薫　　（京都大学大学院農学研究科）

15:15-15:30　　ザンビア東部州の雑草植生について

倉光源　　（京都大学大学院農学研究科）

15:30-15:50　　アフリカ農村部における起業家の出現と地域社会のレジリアンス

伊藤千尋　　（京都大学大学院ｱｼﾞｱ･ｱﾌﾘｶ地域研究研究科）

15:50-16:30　　1990 年代と 2000 年代のザンビアの開発政策と農業政策：
政策の転換はいつ？　その効果は

児玉谷史朗　　（一橋大学大学院社会学研究科）

16:30-17:00　　個別発表総合討論

司会：　宮寄英寿　　（総合地球環境学研究所）

17:00　　閉会

平成 22 年度レジリアンス研究会要旨

第 30 回レジリアンス研究会
日時：2010 年 4 月 10 日（土）16:00-17：30
場所：講演室
タイトル：生態資源の回復からみた生業の営み
―セネガルのセレール社会の事例―
講演者：平井　將公，京都大学大学院　アジア・アフリカ地域研究研究科　研究院

［要旨］

サハラ砂漠南縁の西アフリカのサバンナ帯には、人口密度が数百人/㎢にもおよぶ人口稠密な農村地域が多い。本発表では、これらの地域に共通する生業上の特徴である「集約的な農業」と「精緻な資源利用」に着目し、それらがいかなる技術的・制度的革新のもとに展開し、また近年の社会経済環境の変化を受けてどのように変容しているかについて、セネガルのセレール社会を事例として考察する。とくに、セレールの人々が生業の要として長年にわたって利用してきたマメ科高木の *Faidherbia albida* に焦点をあて、その回復について生業との関連から詳しく説明する。

第 44 回地球研セミナー（第 31 回レジリアンス研究会）
日時：2010 年 6 月 17 日（木） 13:30-15:00
場所： 講演室
タイトル：ザンビアの食料安全保障、気候変動、土地利用：小規模農村世帯の脆弱性とレジリアンスのための空間分析とモデル 発表者―
講演者： Dr. Tom Evans,総合地球環境学研究所招へい外国人研究員 Department of Geography, Indiana University, Indiana, USA
使用言語： 英語

［要旨］

ザンビアの小規模農家は生活を脅かすさまざまなショックにさらされている。多くの小農は直接あるいは間接的に地域レベルでの穀物生産に従事しているため、特に気候変動は福祉と食料安全保障への脅威となっている。小農の気候変動に対する脆弱性を評価する際には、スケールに依存する関係を考慮しなければならない。このセミナーでは、多重空間スケールでの食料安全保障と小農レジリアンスを分析する手法を報告する。特に、世帯、コミュニティ、地域レベルでのレジリアンスを明確にする概念的アプローチを議論する。2007 年に収集された世帯調査データからの結果を衛星データからの土地利用データと統合し、異なる空間スケールでの小農の脆弱性を評価する。将来的な気候の変動による小農

の脆弱性を研究するメカニズムとしてエージェントベースモデル手法が示される。この手法は小農のレジリアンスを空間的に見る統合的重層アプローチの一部として提示される。

第 32 回レジリアンス研究会

日時：10 月 22 日（金）16:00-17:30

場所：地球研講演室

タイトル : 用水路灌漑農業の洪水に対する脆弱性と回復能力 : パキスタンの事例 発表者―

講演者：黒崎　卓，一橋大学経済研究所教授

使用言語：日本語

[要旨]

パキスタンの用水路灌漑地域の家計はどのように洪水のリスクに対応しているのか？　この問題を考えるため、本報告ではまず 2001 年 04 年の家計パネルデータを用いて家計レベルの厚生変動を洪水、干ばつ、虫害といったショックに関連付ける。今回の大洪水に対する分析結果の含意をまとめたうえで、前例のない規模の洪水のインパクトに関する今後の研究計画を披露する。

平成22年度 E-04(梅津FR4)研究活動一覧												2011.1.18
2010	4	5	6	7	8	9	10	11	12	1	2	3
レジリアンス研究会	16:00-17:30		13:30-15:00				16:00-17:30					
	4/10/2010		6/17/2010				10/22/2010					
	(第30回)		(第31回)				(第32回)			(第33回)	(第34回)	
コアメンバー会議	＊4/10		＊6/19	＊7/29			全体会議 10/2	＊11/5		＊1/14	＊2/3	
ワークショップ			WS 6/19				WS 10/1-2					Resilience2011
			地球研 10:00-17:00				地球研					3/11-3/16
レジリアンス勉強会			第12回WS				第13回WS					Arizona State U
FR4報告書							Abstract 10/15	FR4報告書原	稿締切12/13	1月末製本	HP 掲載	
予算計画		H22 FR4予算	(所要額調)		(追加予算申請				H23予算計画	雇用計画	H23 FR5予算	
		ヒアリング5/28	6/11/2010		8/6/2010				12/10/2010	1/7	ヒアリング2/21	
プロ関連行事		JpGU			国際写真測量		GLP Open Mee		国際開発学会			
		5/23-28 幕張			8/9-12		10/17-19		12/4-5			(FSヒアリング)
	(IS申請 4/6)				京都国際会館	(ISヒアリング9/4)	Arizona State	U.	早稲田大学			3/5/2009
	ISヒアリング4/15											
地球研行事				地球研フォーラム			RIHN 国際シンポジウム		プロジェクト		評価委員会	
				7/10/2009			10月13-15日		研究発表会		2/16-17	
			World Cup	京都国際会館			地球研		12月8-10日			
フィールド調査日程			6/11-7/11						コープイン京都			
真常	4/24 – 5/27						10/12 – 11/2	(-11/24)				3/25-4/27
田中												Tempe/U.S.A.
宮嵜		4/27 – 6/3			8/17-8/30	GLP/U.S.A.	10/15 – 10/24		11/22 – 12/20		3/29-4/25	Resilience2011
三浦												
柴田												
竹中 (D1)												
安藤 (D1)	4/24 – 5/27						10/12 – 2011/4/16		作期の終了まで			
倉光(M1)	4/24 – 5/27						10/12 – 2011/6/2		作期の終了まで			
櫻井						8/29 – 9/8						Resilience2011
菅野												
下野												
山内					8/3-8/12							Resilience2011
木附 (D1)						8/29 – 9/29					2/1 – 3/15	
三浦 (M2)						8/29 – 9/29						3/6 – 3/20
今 (M2)					8/3-9/29							
久保(M1)					8/3-8/30							
島田		(5/9 – 6/9 Sweden)		(Nigeria)				11/4 – 11/22				
半澤					(8/19-9/8)				12/18 – 1/3			
児玉谷									(12/18 – 1/3)			
石本		5/17 – 6/14									2/9 – 2/25	
成澤(D4)												
伊藤(D3)												
姜 (D2)												
吉村												
佐伯												
山下												
松村								AIWEST/Aceh	Hyderabad			
梅津								11/21 – 11/27	12/15-12/20		2W	Resilience2011
Lekprichakul			6/28 – 7/3	ASDP/U.S.A	8/3-8/28	GLP/U.S.A.	10/16 – 10/21					Resilience2011
久米						GLP/U.S.A.	10/15 – 10/24	11/21 – 11/27		1/8-1/14		Resilience2011
谷田貝								AIWEST/Aceh		Sri Lanka		
Palanisami										1/24-1/30	地球研	
Kajoba												
Mulenga												
Evans (招へい)	1/18 – 6/30	地球研								1/8-1/15	地球研	Resilience2011

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Project E-04 (FR4)
Project Leader: Chieko Umetsu

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