Master Thesis No 52

Master Thesis in Rural Development with Specialization in Livelihood and Natural Resource Management

MASTER THESIS IN RURAL

Climate change and farmers' adaptation

A case study of mixed - farming systems in the coastal area in Trieu Van commune, Trieu Phong district, Quang Tri province, Vietnam

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Credits: 45 hec
Level: E
Course code: EX0521
Programme/education:
MSc program in Rural Development, Livelihoods and Natural Resource Management

Place of publication: Uppsala, Sweden
Year of publication: 2011
Picture Cover: Le Thi Hong Phuong
Online publication: http://stud.epsilon.slu.se

Key Words: climate change, drought, agriculture, impact, adaptation, capacity

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ABSTRACT

The objectives of this research are (1) to describe and analyze science and local perceptions on long-term changes in temperature, precipitation and drought, (2) to assess impact of drought on mixed farming system, various farm-level adaptation measures and capacity of community to drought adaptation. The study was conducted in a coastal commune, named Trieu Van commune in Trieu Phong district, Quang Tri province. Data and information were collected using in depth interview, group discussion and questionnaire with 59 households. The findings showed that drought heavily influenced daily livelihood of local people in the study area. The statistical analysis of the climate data showed that temperature and drought has been increased over the years. Precipitation was characterized by large inter-annual variability and a decreased amount during summer. Farmers' perceptions on temperature and precipitation as well as drought were consistent with trends found in climatic data records. Agricultural land and water resources were affected increasingly and negatively by drought. The indicators of these negative impacts are: the reduction of yields and quality of products of crops, livestock, and aquaculture due to increasing pests and diseases. As a result, production costs are increased.

The study has also shown how local farmers have made significant efforts to implement adaptation measures to drought and to its impacts. Several farming adaptation options were found, such as using drought-tolerant varieties and local breeds; 42.3% of surveyed households applied VAC(R) model; adjusting seasonal calendar and scale of crops, livestock and fish production (100% interviewed farmers applied this); intercropping, rotational cultivation and diversifying crops and animals in the farm; changing land preparation and mulch techniques in crop production as well as techniques in livestock and fish management. Finding alternative livelihood options and migration were found as important adaptation options. Access to natural resource, supports from policies and non-government organizations, farming experiences, forest planting and potential livestock production development, are the main conditions and potentials to manage and adapt to drought. Several difficulties for scaling up the options found include: Poor sandy land, lacking irrigation system, lacking of financial support, low capacity of agricultural staff creating barrier to access to the extension service and transfer technology; lack of policies mechanism to support research and development technologies, appropriate to the changing local context due to climate change.

Key words: climate change, drought, agriculture, impact, adaptation, capacity

ACKNOWLEDGMENT

Above all, I would like to express my deep gratitude to Dr Hoang Minh Ha, senior researcher at the Swedish University of Agricultural Sciences (SLU) and World Agroforestry Centre (ICRAF) Vietnam and Dr Le Dinh Phung, Hue University of Agriculture and Forestry, Vietnam - my two supervisors for their academic guidance, stimulating suggestions and encouragement during the time conducting this study.

Next, I would like to express an extra thanks to Dr Malin Beckman, Dr Le Duc Ngoan, Dr Ian Christoplos, Dr Britta Ogle, Dr Wijnand Boonstra from their lectures and discussions helped me much in doing this research. Special deep thanks are given to Dr Le Thi Hoa Sen for reading my whole final draft thesis, sharing and encouragement so that I could overcome difficulties in life and writing of this study.

My research could not be done without the cooperation and help of farmers and officers of Trieu Van commune, Quang Tri province, whose valuable helps and willingness enable me to conduct successfully the fieldwork, which enriched my reflection on the findings of this study.

My many thanks are to my classmates for their friendship and sharing during the time we learnt together and conducted the study

Last but not least, I would to send special thanks and love to my parents and sister for their patient love and endless encouragement, which are strong support and motivation for me to complete this study.

CONTENTS

LIST OF ABBREVIATIONS

ADB: Asian Development Bank

ADPC: Asian Disaster Preparedness Centre

CtC: Challenge to Change

CRD: Central for Rural Development (Hue University of Agriculture and Forestry)

FAO: Food and Agriculture Organization of the United Nations

IPCC: Intergovernmental Panel on Climate Change

ISDR: International strategy for Disaster Reduction

MONRE: Ministry of Natural Resources and Environment

NGOs: Non-Government Organizations

NTP: National Target Program

PRA: Participatory Rural Appraisal

SPSS: Statistical Package for the Social Sciences

SWOT: Strength, Weakness, Opportunity and Threat

UNDP: United Nations Development Program

UNFCCC: United Nations Framework Convention on Climate Change

WB: World Bank

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1 INTRODUCTION

In the recent years, the global climate has changed and the changes are both due to natural phenomena and human activities (Dow & Downing, 2007). These changes are shown by more frequent and intensity as well as irregular changes of disasters such as floods, droughts, storms and tsunami within and over years. These changes have largely impacted on social, economic and environmental systems and shaped prospects for sustainable agricultural and rural development (Fischer *et al.*, 2002).

Vietnam, with a long coast, is considered one the countries vulnerable to climate change (ADB, 2009; OXFAM, 2008; Chaudhry & Ruysschaert, 2007). According to UNDP, Vietnam is one of five countries considered the most vulnerable to climate variability and extreme weather events. Within the country, the central coastal is one of the most vulnerable areas to typhoons, storm surges, flash floods, drought and saline water intrusion (Chaudhry & Ruysschaert, 2007).

In many developing countries, there are about two-thirds of the population directly or indirectly earning a living from agriculture, rural and agricultural societies (Fischer *et al.*, 2002). Agricultural outcomes are determined by complex interactions among people, policies and nature (Nelson, 2009). Nelson (2009) stated that "crop and animals are affected by changes in temperature and precipitation but they are also influenced by human investments such as irrigation systems, transportation infrastructure and animal shelters and market conditions". Among which, climate change is one of the most important impact factor to agriculture in the present and future (Burton & Lim, 2005), or even the deciding factor to agricultural production (Smit & Skinner, 2002; Adams *et al.*, 1998). Vice versa, agricultural production is one of the sectors most vulnerable to climate change and has profound impacted on climate change (Oyekale & Ibadan, 2009; Dharmaji & Huy, 2008; Cruz *et al.*, 2007; Dow & Downing, 2007; Burton & Lim, 2005; Ziervogel & Calder, 2003; Adams *et al.*, 1998) in terms of long-term changes in temperature or precipitation, or the frequency and magnitude of extreme weather events (Bradshaw *et al.*, 2004). The results of these effects have caused difficulties in the livelihoods of local people (Oyekale & Ibadan, 2009; Adams *et al.*, 1998). Confronted with a situation of climate change, farmers continue their farming (Rao *et al.*, 2007). The question is "what are the impacts of climate changes on agricultural production and how farmers have adapted and/or can adapt to the climate change?"

According to Smit (1993), adaptation are "adjustments to enhance the viability of social and economic activities and reduce their vulnerability to climate, including its current variability and extremes events as well as longer term climate change". Adaptation is not only an important component of climate change impact and vulnerability assessment and but also one of the policy options in response to climate change impacts (Fankhauser, 1996; Smith and Lenhart, 1996; Smit et al., 1999 cited in Smit and Skinner, 2002). One common purpose of adaptation analyses in the climate change field is to estimate the degree of impacts of climate change scenarios and based on these impacts, human can propose better adaptation strategies (Smit & Wandel, 2006). Besides, adaptation to climate change is essential to complement climate-change mitigation and both have to be central to an integrated strategy to reduce risks and impacts of climate change (Fischer *et al.*, 2002). Adaptation measures are important to help people as well as communities to better face with local extremes conditions and associated climate change. Therefore, adaptation should have the potential to contribute to reduction in negative impacts, realize positive effects and avoid the danger from changes in climate conditions. According to Rabbinge (2009), building model and climate change scenario are critical for agricultural research. In order to build the model, first of all, we must understand what the local impacts of climate change are likely to be. It is necessary to have a basis to give comprehensive and anticipative view as well as appropriate adaptation strategies for each region. Second, if we want to have appropriate adaptation strategies and polices, the gap that exists between information from policies, governments and farmers should be narrowed as much as possible.

Quang Tri province is located in a hazard-prone area of Central Vietnam and among the poorest provinces of Vietnam (FAO, 2004; Gill *et al.*, 2003). In recent years Quang Tri has increasingly faced climate extremes such as droughts, storms and floods, among those drought is one of the main climate extreme events. Drought has heavily and negatively influenced daily livelihood of local people and the ecosystem. Especially, for coastal areas with mostly sandy land, drought is the main problem for agricultural production. For those reasons, this study is conducted to answer the following questions:

- What are farmers' perception of drought on mixed - farming system in terms of crop, livestock, fish, and land and water resources?
- What strategies do the local farmers have to adapt to drought?
- How is the adaptive capacity of local people to drought?

This study investigated climate change tendencies, its impact assessment, as well as local adaptation options and adaptive capacity of local people towards drought. Hopefully, the study can contribute with an analysis useful for agricultural production communities in the coastal areas of Quang Tri province as well as to "Provincial Target Program to Respond to Climate Change'. In particular it can provide useful information for policy makers and policy level planning.

2 LITERATURE REVIEW

2.1 General information

2.1.1 Climate change and drought concepts

According to Ramamasy (2007) "***climate*** is statistical information, a synthesis of weather variation focusing on a specific area for a specified interval; climate is usually based on the weather in one locality averaged for at least 30 years". So, climate is often defined as the weather averaged over time (typically, 30 years, WMO) (MONRE, 2008).

Weather is the day-to-day state of the atmosphere and its short-term (from hours to a few weeks) variations such as temperature, humidity, precipitation, cloudiness, visibility or wind (Ramamasy *et al.*, 2007).

Climate change is the natural phenomenon but is also accelerated by human activities (O'Brien *et al.*, 2006). Climate changes are likely to manifest in four main ways: slow changes in mean climate conditions, increased inter-annual and seasonal variability, increased frequency of extreme events, and rapid climate changes causing catastrophic shifts in ecosystems (Tompkins & Adger, 2004). In IPCC report (2007), climate change was understood as any changes of climate over time due to natural changes or results of human activities. With this definition, climate change can be the resulting changes of internal processes or external forces (Nicholls, 2007). In accordance with United Nations Framework Convention on Climate Change (UNFCCC), climate change refers to direct or indirect activities of humans, leading to change in global atmosphere components and create changes of natural climate variability observed over comparable time. Regarding climate change views, Smith et al, (1999) and Cruz *et al.,* (2007) and as well as in my view in this study, climate change is defined as changes through increasing in frequency and intensity of extremes weather events including storm, flood, drought and irregular rain over time and irregular climate signal.

Climatic variability means the fluctuation that occurs from year to year and the statistic of extreme conditions such as severe storms or unusually hot seasons (ISDR, 2008). According to Oxfam organization, climatic variability is natural variations in the climate that are not caused by greenhouse gas emissions (e.g., it rains more in some years and less in others).

Climate extreme (weather extreme event) is small changes in average conditions that can have big influence on extremes such as droughts or floods. These changes are already noticeable, and the trend is expected to continue (Selvaraju *et al.*, 2006).

Drought is a phenomenon of climate. It occurs almost everywhere but it's features are different between regions. Drought means scarcity of water which adversely affects various sectors of human society (Panu & Sharma, 2002). In general, drought is defined as a temporary reduction in moisture availability significantly below the normal for a specified period (Ramamasy *et al.*, 2007). The deficiency of precipitation over an extended period time, usually a season or more is also called drought. Therefore, drought is considered as unbalance between precipitation and evapotranspiration in a particular area in a period. It is also related to the timing, as delays in the start of the rainy season and the effectiveness of the rains, such as precipitation intensity or number of precipitation events. According to technical aspects, drought is the decrease of water availability, which might qualify when precipitation falls below about 80% of the average availability of the preceding 30 (or more) years. According to farmers, drought is changes in precipitation patterns, so lack of sufficient water or of sufficient precipitation for paddy cultivation is regarded as drought (Rajib Shaw, 2008). In my opinion, as well as the drought definition applied in my research, drought is understood as high temperature and lack of rain for a long time combined with strong wind.

Understanding the concept of drought may also be important in establishing policy for drought response. Policy will provides financial assistance to farmers only under exceptional drought circumstances and when drought conditions are beyond those that could be called part of normal risk management. Moreover, drought definition also helps people identify the beginning, end and degree of severity of drought. Farmers can have plans to cope with or adapt to drought.

Human activities may lead to desertification of vulnerable arid, semiarid and dry sub-humid areas (Kundzewicz, 1997 cited in Panu & Sharma, 2002). According to Panu & Sharma (2002), there were two main reasons that led to drought and these reason are closely associated with natural events. First, it is the occurrence of below normal precipitation, which is affected by various natural phenomena. Second, a causative factor of droughts is the oceanic circulations, which have average patterns of current and heat storage that affect the weather and climate. The sea surface temperature anomaly has been referred to as the El Nino, so generally, when El Nino appears, drought as well as the impact level also increases (Panu & Sharma, 2002). Another reason is increasing soil erosion and over exploitation of water resources because of human activities (Brooks, 2006). Thus, reasons of drought include changes in temperature, moisture, precipitation and human activities through building dams, dykes or other infrastructure or deforestation.

2.1.2 Farming system concept

A farming system is defined as " a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate" (Dixon *et al.*, 2001). They also indicate that a farming system is a complex situation in which the farm and household unit is made up of several components, consisting of food and cash crops compound homestead garden and animal production with several non-agricultural activities. Farming system is a unit consisting of a human group and the resources that they manage in its environment, involving the direct production of plant and animal products (Beets, 1988). Therefore, farming system is a system in which a combination with interrelated farming and household activities are inter-dependent and interacting with each other to achieve household goals.

Basing on these above farming system concepts, farming system includes many sub-systems and these sub-systems are put in the same space, time, social-economic conditions and are called mixed-farming system, which is applied in this research.

2.2 Impact of climate change and drought on farming system components

2.2.1 Approaches for assessing climate change impact

Climate change impact assessment mentions studies and investigations designed to find out what the effects of climate change at the moment and in the future on human activities and the natural world are (Burton *et al.*, 1998). Besides, climate change impact assessment usually goes together with present assessment of adaptation options and promotes future possible adaptation strategies for response to a changing climate.

Approaches for assessment of the impact of climate change was referred in Intergovernmental Panel on Climate Change Technical Guidelines for Assessing Climate Change Impacts and Adaptation (Carter *et al.*, 1994). Two main objectives to assess climate change impacts include assessing climate change impacts and adaptations in a scientific aspect and providing a mode as well as information for policy makers and decision-makers to choose a set of adaptation options and develop an appropriate mixed or new strategies for responding and combining adaptation and mitigation measures.

There are three methodological approaches for assessing climate change impacts and adaptation strategies (Kates, 1985 cited in Carter *et al*., 1994).

First, the simplest methodology is called impact approach. It is considered simple because it follows a straightforward "cause and effect" pathway or it can be thought of as an "If - Then - What" approach. We can understand that if the climate change happens, then what would be its impacts? In this approach, the researchers have to assume that the effects of non-climatic factors on the exposure unit can be held constant, thus, impact approach is usually adopted for studies of individual activities and hierarchy of level studies. However, the limitation of this approach is that the effects depend on not only climate factors but also on human activities and other factors.

The second approach is interaction approach. This approach recognizes that climate factor is only one of a set of factors that influence or is influenced by the exposure unit. This means that exposure unit is not only affected by climate factors but also by other factors such as the environment and non-environment. However, exposure unit may influence the climate factors and non-climate factors through its activities. Interaction approach can be thought of as a "What-Then-If". We can understand what issues in a system are sensitive to climate change and then what fields will be impacted if climate change happens? This approach is different from impact approach in that if impact approach considers non-climate factors to be constant, interaction approach mentions non-climate factors that may have impact on the exposure unit. Moreover, interaction approach selects climate factors based on climate-sensitivity of the exposure unit. Both impact and interaction approach have their limitations, so the integrated approach is mentioned to surmount the limitations of the above approaches.

The integrated approach is the most comprehensive regarding the interactions between society and climate factors. This approach seeks interaction within sectors, between sectors and feedbacks. It also refers to adaptation strategies to moderate negative impacts climate change. Basic knowledge is insufficient to envisage conducting a fully integrated assessment, which can only be achieved when parallel linked together different sectors in the same region. Therefore, this approach has been applied in many studies of scientists associated with climate change. A major limitation of most impact assessment to climate change is the lack of in-depth adaptation strategies. Since integrated assessment mentions on adaptation strategies to climate change including adjustments in the systems, it cannot be separated from the impact assessment of climate change on these systems.

In agricultural production system, integrated assessment approach was analyzed based on climate scenarios in terms of climate change impacts on crop productivity, animal husbandry (animal and fishing raising), irrigation management, cropping system, regional crop production as well as land and water resources (Watanable, undated). These assessments are based on the basic structure of the present agricultural system and the path of climate change impacts on the system.

In short, research on assessment of impacts of climate change cannot be separated with adaptation study and vice versa. Therefore, the integrated assessment approach is applied in this study. Results of assessment of impacts of climate change on livelihood as well as farming system are used as basic data for setting up scenario of climate change, giving adaptation strategies in the future and improving shortcomings of current adaptation strategies and these results are critical for policy makers to give appropriate policy for each sector and region.

2.2.2 Impact of climate change and drought on mixed-farming system components

Much of the available literature suggests that the overall impacts of climate change on agriculture especially in the tropics have been highly negative (Maddison et al., 2007 as cited in Rao *et al.*, 2007). Drought is ranked as the natural hazard with the greatest negative impact on human livelihood. According to Carvajal (2007) in the Human development report, the 2000-2006 period saw that percentage of droughts have had an increasing tendency in Africa and Asia as well as in Europe. Impact of drought on agriculture depends on the state of crops, the duration and amount of water storage during certain effect (Mokhtari, 2005).

2.2.2.1 Impact of drought on agricultural land resource

According to Adejuwon (2004), agricultural land could be extended to areas formerly considered too cold for agriculture and the various agricultural belts could be extended towards the polar regions if temperature increases. However, in the tropical region, increasing temperature and drought may limit or reduce agricultural land area or increase land degradation and limited water for cultivation, especially, coastal soil (Dharmaji & Huy, 2008; Chaudhry & Ruysschaert, 2007; Kundzewicz *et al.*, 2007; Rao *et al.*, 2007). An increase in temperature and drought leads to a reduction in the production capacity of many regions, especially in coastal area in agricultural land (Hansen, 2006).

2.2.2.2 Impact of drought on water resource

Climate changes as well as global population increases have greatly affected global water resources (Vorosmarty *et al.*, 2000; Arnell, 1999) including both direct and indirect impacts on water availability (Rao *et al.*, 2007). First, drought has led to scarcity of surface water through changing river flows and water in the lakes (Kundzewicz *et al.*, 2007). With higher temperature, the capacity for water-holding of the atmosphere and increasing evaporation into the atmosphere has led to more intense precipitation and more droughts (Trenberth et al., 2003 cited in Kundzewicz *et al.*, 2007). Climate change has led to more drought in sandy land and semi-arid tropics (Cooper *et al.*, 2008) and resulted in water supply shortage (Ziervogel & Calder, 2003). Many lakes in the world are observed that they have decreased in the water volume during the last decades, mainly due to human water use and changing of climate (Kundzewicz *et al.*, 2007). The second impact of drought on water resource is the exhausted groundwater system (Kundzewicz *et al.*, 2007). Groundwater levels correlate more strongly with precipitation than temperature. Combined with global warming and decreasing precipitation in summer and dry season, groundwater and surface water system are reduced. Therefore, many regions have become drier and face shortcomings in production and living activities (Chen *et al.*, 2004; Arnell, 1999). Moreover, the quality of water is also influenced by drought (Kundzewicz *et al.*, 2007). Drought is affected due to increase water temperature and indirectly through an increase thermal pollution. As a result, many regions have faced difficulties due to the lack of fresh water for production especially in the coastal-sandy regions where people often face water-scarcityin dry seasons (Kundzewicz *et al.*, 2007).

2.2.2.3 Impact of drought on crop production

First, temperature increase has both positive and negative effects on crop yield (Nyong, 2008; Adejuwon, 2004). However, in general, increasing temperature has been found to reduce yield and quality of many crops, most importantly cereal and feed grains (Adams *et al.*, 1998). Results of high temperature increased the physiological development (Adejuwon (2004) such as higher respirations, shorter periods of seed formation and lower biomass production (Adams *et al.*, 1998) and hastened maturation and consequently reduce crop yield (Sadowski, 2008; Adejuwon, 2004).

Second, high temperature and dry condition have indirectly affected change in the incidence and distribution of pest and pathogens (Sutherst et al, 1995 cited in Adams et, 1998). According to Adejuwon (2004), crop management and range of distribution do not often relate directly to climate factor but it has a close relationship with pest, pathogens and epidemics. The two most important elements of climate to determine the occurrence and localization of pests and diseases are moisture and temperature. And pests and disease vectors can develop well under high temperature and optimum water supply conditions. Therefore, global warming has extended the range of distribution of certain pests and disease of crops.

Third, drought also influenced crop distribution because of the changes in land use types (Nyong, 2008). Crops distribution and agricultural production depend largely on range of distribution of geography in terms of temperature and moisture. Temperature has been high so it can bring positive effects for crop distribution in the Poland region (Sadowski, 2008) but negative effects in the Tropics one (Cruz *et al.*, 2007).

2.2.2.4 Impact of drought on livestock production

First, one of the most evident and important effects of climate change on animal husbandry is changes in feed resources (Thornton & Mario, 2008; Thornton *et al.*, 2007). Increasing drought leads to the reduction of quality and development capacity of grass and crop-feed[1]. According to Thornton *et al* (2007), although indirectly, effects on feed resources could have a significant impact on livestock productivity, ability of the ecosystems for grazing system, prices of stoves and grains, changes in feeding options and grazing management. Impacts of climate change on availability of feed resource for livestock are shown in two aspects (Thornton *et al.*, 2007). First, increasing temperature and changing precipitation pattern lead to a change in different crops and grassland species in Asia and East Africa. These changes can lead to a different composition in animal diets and change small holder household capacity to manage feed deficits in the dry season. Second, productivity of feed crops, forages and rangelands are also changed. These changes are probably the most visible effect on feed resources for ruminants. Thus, changes could have enormous impacts on the livelihoods of livestock keepers who depend on feed sources from crop production and rangelands.

Second, the major impact of climate change is on animal health through disease and vector borne capacity (Thornton & Mario, 2008; Thornton *et al.*, 2007). Increasing temperature have supported the expansion of vector population such as malaria and livestock tick-borne diseases in high altitude systems (Thornton *et al.*, 2007). The poor people who live in sandy coastal areas have less capacity to access veterinary service, therefore diseases in livestock break out, which results in increasing the mortality rate of their livestock (Gorforth, 2008).

Third, increasing temperature in the summer has led to decreasing the amount of food intake because of the increasing water demand of livestock (Thornton *et al.*, 2007) and the increasing process of respiration and water input quantity (Barry *et al.*, undated) of around 10-20% (Seo & Mendelsohn, 2006). Adams *et al* (1998) observed that under a 5^0C increasing in temperature, livestock yield in the US fell by 10% for cow/calf. Besides, when temperature increases, livestock's body temperature also increases, which leads to the reduction of feed-used efficiency. Therefore, physical appearance, reproduction and products quality are all decreased when the temperature increases (Seo & Mendelsohn, 2006).

Fourth, climate change also affects the scale of production and diversified livestock levels (Seo & Mendelsohn, 2006). Research of Yahe University, Pretonoa and the World Bank (WB) in ten countries in Africa indicated that large farms have been influenced more seriously than small farms in global warming condition. This can be explained by that small farms often raise more diversified livestock than large farms. Farms with small scale and diversified production can well adapt to climate change and thus reduce risk.

2.2.2.5 Impact of drought on freshwater fish raising

Aquaculture plays an important role in farmer's livelihood, especially in coastal regions. However, it is very sensitive to climate change for freshwater, brackish water and salt water fish raising (Handisyde *et al.*, 2006). Climate change influences freshwater fish raising that is seriously assessed for all three types of water (Ficke *et al.*, 2005), in terms of changing productivity of fish (yield fish), reproduction capacity (Capili *et al.*, 2005) as well as fish diseases (Marcogliese, 2001 cited in Ficke *et al.,* 2005).

Many freshwater fish species have died especially those raised in lakes and ponds (Ficke *et al.*, 2005). According to many researches, with a temperature from 25-27^{0}C, the growth and development activities of freshwater fish, especially the reproductive capacity would get the highest achievement but crossing the threshold 30^{0}C, the rate of small fish dying is increased. (Handisyde *et al.*, 2006).

An increase in air temperature combined with prolonged drought has led to reduce water in ponds and lakes, which is one of the problems for freshwater fish raising (Ficke *et al.*, 2005). Besides, fish yield was reduced, and even lost, while fish diseases increase due to water temperature change especially in hotter water (Ficke *et al.*, 2005). According to Handisyde *et al* (2006), fish tolerant capacity is reduced and epidemic diseases have increased, leading to reduced fish quality, growth rate, slow development and increasing fish mortality rate because of increasing water temperature and limited water volume.

Besides, temperature increase has impact on food intake capacity and the slow growth is simultaneous with increased metabolic rate, thus the fish yield is reduced or even lost (Handisyde *et al.*, 2006; Ficke *et al.*, 2005).

2.2.2.6 Impact of drought on production cost

Climate change also influences the investment cost in agricultural production (Oyekale & Ibadan, 2009). Decreasing crop productivity because of the droughts, foods and other problems leads to increasing fertilizer and water level as well as applying new variety of crop to make an adaptation to these changes (Adams *et al.*, 1998). Moreover, since agricultural land area degrades, farmers also increase costs to ensure that crop value per area unit also increases (Adams *et al.*, 1998). As analysed above, climate change is one of the main reasons leading to decreased or even lost yield and increased pests and diseases as well as soil erosion and water scarcity. One of the measures used to overcome these difficulties is that farmers have used more pesticides, fertilizers and other investment such as water and electricity cost thus production costs has increased, which leads to an increase in investment cost.

For animal husbandry production, global warming may be the opportunity for poultry production because producers save cost for energy to increase temperature in the winter (Seo & Mendelsohn, 2006). However, cost for breeding facilities investment and cool system in the summer and cost for epidemic diseases and risk management are higher than that for decreasing energy or reducing coldness [2]. Research result of Seo & Mendelsohn (2006) indicated that increasing temperature in the summer has led to increasing investment cost for breeding facilities, feed, preventing diseases and management.

2.3 Adaptation strategies to climate change and drought

2.3.1 Adaptation and adaptive capacity

2.3.1.1 Adaptation terminology

The adaptation concept is rather new for the research community and has origins in natural sciences (Smit & Wandel, 2006) and it also used for a longer history in ecology, natural hazards and risk management fields (Smit *et al.*, 1999).

"Adapt" means to make something or system more suitable by altering it (Smit *et al.*, 1999). ***Adaptation*** refers to the process of adapting and the condition of being adapted. According to Burton (1992), adaptation in social sciences was concerned with "the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides" as cited in Smit et al. (1999). Similarly, Carter et al. (1994) described that adaptation refers to any adjustment, whether passive, reactive or anticipatory that can respond to anticipated or actual consequence associated with climate change.

Regarding human dimensions, Smit (1993) stated that adaptation involves "adjustments to enhance the viability of social and economic activities and reduce their vulnerability to climate, including its current variability and extremes events as well as longer term climate change". According to Smit and Wandel (2006) and Füssel (2007), adaptation refers to processes, actions or outcomes in the system including households, community, groups, sectors, regions and country to make the system more able to cope with, manage or adjust to change some conditions, stress, hazards, risks and opportunities. IPCC (2001) mentioned adaptation as adjustments or interventions, which take place in order to manage the losses or take advantages of the opportunities presented by a changing climate. Adjustments or interventions in this concept include natural and human systems adjustments or interventions of government organizations, non-government organizations, private sectors, public sectors and policies as well. According to IPCC (2007), adaptation means the adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation in narrow sense refers only to those measures that are taken at the farm level. However adaptation in a wider sense, involves choices at national and international level as well as local one.

According to Fankhauser *et al.* (1999), adaptation can be anticipatory or reactive basing on timing and depending on the degree of spontaneity, adaptation can be autonomous or planned. *R**eactive adaptation*** means institutions, individuals, plants and animals actions, which are implemented after the fact. ***Anticipatory adaptation*** are decisions that are carefully discussed to take in advance for reducing potential effects of climate change before fact. Adaptation to climate change is a continuous process, therefore it is hard to distinguish between which actions are carried out after and which actions are carried out before. Anticipation requires foresight and planning while reaction does not. However, in reality, anticipation and reaction are mixed and people often combine both reactive and anticipative adaptation strategies to cope with and adapt to climate extremes and climate variability. ***Autonomous adaptation*** is defined as "natural or spontaneous adjustments in the face of a climate change" (Carter *et al.*, 1994) which means that autonomous adaptation takes place without intervention of an informed decision maker (Schneider *et al.*, 2001; Kelein & Maciver, 1999). On the other hand, ***planned adaptation*** refers to intervention of human and activities/ actions have been planned before (Carter *et al.*, 1994). Planned adaptation requires action strategies that base on climate change perception and need actions to respond well to such changes (Kelein & Maciver, 1999). Autonomous adaptation invariably occurs in reactive adaptation to climatic stimuli as a matter of course, without directed intervention by a public agency (Schneider *et al.*, 2001; Kelein & Maciver, 1999) while planned adaptation in human system can be reactive or anticipatory (Kelein & Maciver, 1999).

In short, basing on many concepts of different authors, adaptation to climate change in this research is understood as adjustments by community and individual to respond to the changing of climate over time in order to moderate negative impacts or enhance adaptive capacity of community and individual. Understanding adaptation concepts is important to make the foundation for evaluating and identifying impacts of climate change as well as choosing the appropriate adaptation measures in order to decrease negative climate changes impacts, reduce significantly vulnerability and risk for human, environment and nature in climate change context.

2.3.1.2 Adaptive capacity

The IPCC (2001) defined ***adaptive capacity*** as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantages of opportunities or to cope with the consequences. This means that adaptation measures should be to increase the capacity of a system to survive external change. According to Brooks and Adger (2005), "adaptive capacity is the property of a system to adjust its characteristics or behavior in order to expand its coping range under existing climate variability, or future climate conditions". The adjustments in practices, processes or structures can moderate or offset the potential for damage or take advantage of opportunities to cope with and adapt to climate change (Schneider *et al.*, 2001). In practice, adaptive capacity is the ability to identify, choose and implement effective adaptation strategies or reduce risk in the livelihood and the magnitude of harmful outcomes resulting from climate-related hazards. According to Brooks & Adger (2005), the community could or could not adapt to climate change, it could depend on its resources including financial capital, social capital (e.g., strong institutions, transparent decision-making systems, formal and informal networks that promote collective action), human resources (e.g., labor, skills, knowledge and expertise) and natural resources(e.g., land, water, raw materials, biodiversity). Brooks and Adger (2005) also indicated that, indicators in national level included health, literacy, governance and economic development. At regional and community level, there are indicators that encompass income and dependency ratio, overall population density, transport network density, regional income and inequality, nature of economic activity, kinship/community network and people's perception risk. For agricultural sectors, the adaptive capacity to climate change depends on some factors such as population growth, poverty and hunger, arable-land and water resources, farming technology and access to inputs, crop varieties adapted to local conditions, knowledge, infrastructure, agricultural extension services, marketing and storage systems, rural financial markets and economic status and wealth (Fischer *et al.*, 2002).

In addition, adaptive capacity depends on the ability of community and society capacity (Brooks & Adger, 2005). According to Smit & Wandel (2006), population pressure or scarce resource may generally reduce the capacity of community as well as of individuals and narrow its coping range, while economic development or technology or institutions improvement, financial access may lead to an increase adaptive capacity. Moreover, communities have a strong kinship network may increase adaptive capacity though collective action and conflicts solution between its members (Smit & Wandel, 2006; Brooks & Adger, 2005; Pelling & High, 2005). Adaptations are manifestations of adaptive capacity thus populations having better adaptations or changes in the systems can deal well with problematic exposures.

2.3.2 Adaptation strategies in mixed-farming to drought

2.3.2.1 Crop variety and livestock/fish breeding

Crop variety and livestock breeding are critical and determinant factors to productivity, quality as well as tolerant capacity with changing of external factors (FAO, 2007). Therefore, in climate change circumstance, adaptation in terms of crop variety and livestock breeding is the first priority to ensure agricultural production activities to continue (Smit & Skinner, 2002).

Regarding crop varieties, using heat/drought- tolerant crop varieties under water stress is one of the main adaptation strategies in crop production (ADB, 2008; Cooper *et al.*, 2008; Boko *et al.*, 2007; Stigter *et al.*, 2005; Adejuwon, 2004; Hall, 2004; ADPC, 2003; Panu & Sharma, 2002; Smit & Skinner, 2002; Dolan *et al.*, 2001; Cuculeanu *et al.*, 1999). According to IPCC (2007), in Asia, with an increase of 1^{0}C temperature in June and August, farmers used more heat/drought-tolerant crop varieties in areas lacking water, especially in sandy and inland ones (Cruz *et al.*, 2007). In Canada, new varieties are developed including hybrids, types and cultivars to increase the plants' tolerance and suitability to drought. In Africa, research in biotechnology indicated that farmers used drought and pest-resistant rice, drought-tolerant maize and insect-resistant millet, sorghum and cassava to adapt to prolonged droughts (ECA, 2002 cited in Boko *et al.,* 2007). When the climate tends to be warmer and drier, farmers select cowpea, cowpea-sorghum and millet-groundnut in hot regions (Boko *et al.*, 2007). In addition, farmers chose forest trees species that can prevent desertification and moderate loss in drought period (Onyewotu et al., 1998; Stigter et al., 2002; Onyewotu et al., 2003 cited in Stigter *et al.,* 2005). Research result in Ha Tinh province, Vietnam also proved that cross-bred acacia with belt function for sandy system is appropriate for poor people and land condition (VietNamNet, 2009). According to Natural Disaster Mitigation Partnership (2007), farmers, in Ninh Thuan province, Vietnam, were successful in using Cactus crop in sandy and dry land and product of this crop is used for livestock feeding. Besides, in dry regions and regions lacking of water , farmers used tolerant crops such as local onion, peanut and beans to overcome drought period.

In livestock and freshwater fish production, farmers have used breeding livestock for greater tolerance and productivity as well as native grassland species (Cruz *et al.*, 2007). Producers re-introduce native grasses if possible and these grasses are drought resistant when rotational grazing is practiced on them (Wall & Smit, 2005). Diversification in livestock genetic resource is critical for food security. According to FAO (2007), there were five main animals that can promote deployment and provide meat and milk for people including cattle, goat, sheep, pig and chicken for adapting to climate change. In Africa, farmers used animals that do not choose feed to drought period (Boko *et al.*, 2007). Besides, using local breeds is one of the main choices of many livestock keepers to drought (Stigter *et al.*, 2005). For freshwater fish raising, farmers have chosen breeding tolerant to high water temperature (Cruz *et al.*, 2007).

In short, farmers applied various crop varieties and livestock breed to drought. Although, there are many researches in agricultural adaptation, these researches' results seem still vague in varieties and breed. In general, varieties and breed that farmers are applying have the ability to adapt to particular climatic conditions of regions. However, in climate variability and change, it is a big challenge for the poor who are vulnerable to climate change when applying new and model varieties as well as breeding because of high technique- and investment requirements. As a result, studies on agricultural adaptation have to indicate varieties and breeds that can develop in droughts, floods or other conditions. Finding indigenous and current varieties and breeds to take its full advantages as well as combination with model technique in genetic technology are adaptations strategies considered and studied the most, especially by farmers living in coastal areas.

2.3.2.2 Mode of production

Agro-forestry system is one of the critical mode of production either in mountainous or coastal regions for adapting to marginal and sandy soil in drought situation (Rao *et al.*, 2007; Verchot *et al.*, 2007). Smith (2009) indicated that agro-forestry system has positively had efficient improvements for environment in climate change condition. According to Rao *et al.* (2007), it is necessary to combine trees, crops and livestock from well planned and managed agro-forestry systems in scarce water resource. Thus, agro-forestry, applied in coastal area (sandy area), is one of the best adaptation to improve micro-climate conditions, the efficiency of soil use, water sources and contribute to fertilizer improvement in soil especially in dry conditions (Rao *et al.*, 2007).

Diversification model, through diversified production locations, crops, livestock, enterprises or income sources, is one adaptation that has been commonly identified as a potential response to climate variability and change in drought and flood circumstance (Smit, 1993; Kelly & Agger, 2000; Mendelsohn, 2000; Wandel & Smit, 2000 as cited in Bradshaw *et al.,* 2004) and well-being (Ellis, 2000). According to Wandel and Smit (2000), in terms of individual farm scale in drought condition, there were a variety of forms of available agricultural diversification for producers to manage climatic risks. Changing from mono-production to multi-production includes a combination of crops and livestock in the farming system or livestock varieties as well as crops and improving agricultural techniques or increasing investments that are efficient adaptation strategies (Thomas, 2008; Smit & Skinner, 2002). For example, crop-animal systems are found in West Africa, India, Indonesia and Vietnam (Smith, 2009) and Central Asia (Thomas, 2008). Rural people in dry-lands combine rain-fed agriculture system, livestock rearing and other income generating activities for adapting to climatic variability and drought (International Insitutide for Environmental Development, 2008; Thomas, 2008). Combining livestock and crops can improve income generation in semi-arid and arid areas with prolonged droughts (Smith, 2009; Bradshaw *et al.*, 2004). Smith (2009) also showed that a mixture of horticulture crops and crop rotations is the optimal option to improve agro-ecosystem function in dry condition and promote carbon sequestration. Farmers in Central, West Asia and North Africa already adapt to climate change by changing their cropping patterns and rotations by earlier sowing, using shorter duration crops and switching to crops that are more tolerant to heat, salinity and drought (Thomas, 2008). This means that diversification production model and changing cropping patterns can serve to buffer farm business risks associated with price and market fluctuation, and it is more important for small-scale farmers to adapt to variable climate conditions. Other modes of production applied to adapt to droughts also increases such as incorporate crop rotations, crop-fish system (FAO, 2007; Stigter *et al.*, 2005) and VAC model (V- garden, A-pond and C-cage) (Seo & Mendelsohn, 2006).

2.3.2.3 Seasonal calendar and forecast

Seasonal climate forecast provides an indication of how variable the precipitation and temperature will be. Therefore, it is considered as essential information that can help producers to prepare for and adapt to climate availability (Goddard et al, 2001; O'Brien and Vogel, 2003 as cited in Ziervogel & Calder, 2003). Regarding agricultural sector, climatic forecast provides information for numerous decisions in agricultural production through operational short-term decisions and tactical and strategic long-term decisions (Cooper *et al.*, 2008; Ziervogel & Calder, 2003). Moreover, seasonal climate forecast associated with agro-meteorology extension can support national or regional preparedness through an approach that links seasonal forecasts with the use of crop growth simulation models that provide probabilistic crop/livestock yield and production estimation well in advance of harvest.

Seasonal calendar of crop and livestock system depends on many factors, of which weather and climatic are the most important to identify appropriate sowing and harvesting dates (Smit & Skinner, 2002). Farmers in Southeast Asia have experienced for a long time to adjust farm management practice including changing cropping calendars to optimize the use of available water to crop growth as well as adaptation measures to climate changes especially in increasing temperature (ADB, 2008). Through the warning system for climate change in the future, especially in drought-prone or flood-prone regions, farmers in many regions in the world autonomously adjust seasonal calendar to be suitable to these changes (FAO, 2007; Klein & Tol, 1997). Seasonal calendar changes such as the timing of operations including planting and harvesting dates (Smit & Skinner, 2002; Cuculeanu *et al.*, 1999) or timing for keeping livestock and the choice of crop varieties or livestock breeding following each crop (Smit & Skinner, 2002) are necessary to adapt to climate changes.

Arranging seasonal calendar based on information of the warning system and traditional knowledge in production is crucial to maximize optimal conditions especially temperature and precipitation to crop and livestock development. However, field researches in Africa suggest that there are gaps between the information needed by farmers and that provided by the meteorological service (Blench, 1999 cited in Stigter *et al.,* 2005). Changing seasonal calendar based on traditional forecast seem to be unsuitable in the current climate change condition (Stigter *et al.*, 2005). Thus, the integrated approach among the meteorological science, crop and animal science, traditional/indigenous knowledge in the warning system and the forecast is the best way to identify appropriate seasonal calendar.

In recent years, many innovative climate analytical tools have been developed and improved. These tools allow for a clear understanding of the temporal and spatial agricultural implications of short and medium-term climatic variability (Cooper *et al.*, 2008). Therefore, shorter-term seasonal weather forecasting is one of the agricultural options to adjust seasonal calendar suitable for change of temperature and precipitation annually.

2.3.2.4 Agricultural techniques

The range of technological interventions can contribute to reducing the vulnerability to climate change by simultaneously preventing and reversing land degradation and sequestering carbon in dry-lands (Thomas, 2008). Agricultural techniques can improve not only adaptation strategies but also mitigation ones with climate change situation. It means that the relationship between mitigation and adaptation in agriculture is critical for farmers (Smith, 2009).

Soil and land management

Soil organic matter is considered the main adaptation option to drought in crop production in response to lack of water (FAO, 2007). Soil organic matter can improve and stabilize the soil structure, enabling the soil to absorb more water and reduce soil erosion due to drought.. Smith's research (2009) indicated that the application of animal manure helps to reduce the use of fertilizers, improve soil structure, increase water-holding capacity as well as keep the soil moisture of sandy soil in coastal and inland areas. Land use and land cover tools are considered adaptation options in desertification phenomenon in sandy and coastal areas (Pyke & Andelman, 2007). Conservation tillage practices were cited by all producers as having several positive outcomes for reducing risks from drought (Wall & Smit, 2005). In LEISA (Low external inputs sustainable agriculture), farmers try to enhance soil fertility and other soil conditions that are basic to sustainable farming systems (Stigter *et al.*, 2005). According to Adejuwon (2004), farmers in Nigeria applied high ridging to increase soil moisture and the variability of plants; used deep ploughing to break up impervious layers and increase infiltration; changed fallow and mulching practices to retain moisture and organic matter. Moreover, low or zero-tillage crop management practice is one of the adaptation strategies to conserve soil moisture to stand drought (Nyong, 2008; Tarleton & Ramssey, 2008), increase soil organic matters and reduce investment costs (FAO, 2007).

Using mulch stubble, straw and avoiding mono-cropping (UNFCCC, 2006) and covering trees, bushes, crops, crop residues left, grass cover and mulching (Stigter *et al.*, 2005) in changing farming practices conserve soil moisture and nutrients, reduce run-off and control soil erosion. Moreover, crop residues decrease diseases and the organic matters in the crop residues can also improve soil structure and contribute to control pest and weed (Parry *et al.*, 2005).

In order to adapt to summer season, especially in dry area and prolonged drought, producers extend crop rotation (UNFCCC, 2006; Parry *et al.*, 2005; Stigter *et al.*, 2005; Bradshaw *et al.*, 2004; Smithers & Blay-Palmer, 2001), alter the mix of crops (Adejuwon, 2004), change crop density (UNFCCC, 2006; Cuculeanu *et al.*, 1999) and apply different fertilization levels (Cuculeanu *et al.*, 1999). Crop rotation increases crops yield, reduces the population of pests and the risks of crop diseases and improves weed control (Parry *et al.*, 2005).

The establishment of shelter belts (Nyong, 2008) and perennials (Stigter *et al.*, 2005) reduces negative impacts from drought by maintaining water tables, increasing biomass in soil and ensuring surface moisture (Nyong, 2008; Wall & Smit, 2005). Shelterbelts also protect livestock from heat and wind and increase the heat units in adjacent fields (Wall & Smit, 2005).

On the whole, soil and land management techniques are a good way for adapting to climate change if farmers have access to the right information and tools. However, some will find it more difficult because coastal areas are mainly sandy soil, which means that soil has poor quality, inadequate water supplies or lack of financial source for investment. In addition, they may face with difficulties in using modern techniques since their education is still limited. In these cases, if government or other organizations want to help farmers access and apply new techniques in changing climate conditions, these organizations need to deliberate and plan interventions, combine indigenous or practical techniques and modern/new techniques.

Water management

Improving water-management approaches in agricultural conservation is likely to be the centre of adaptation strategies in dry-land agriculture (Rabbinge, 2009). Sustainable agricultural practices also include practices for conservation of water quality and quantity (ADB, 2008; Howden *et al.*, 2007; Wall & Smit, 2005). The increasing temperature and decreasing precipitation in drought conditions lead to a decrease in water resources and water volume in irrigation systems (Stigter *et al.*, 2005; Wall & Smit, 2005). Technologies in harvesting, transporting and using water are applied in low precipitation and decreasing precipitation trend area (ADB, 2008; Howden *et al.*, 2007; Stigter *et al.*, 2005). In India (Prabhakar & Shaw, 2008) and Philippines (ADB, 2008), local communities and government improved water source through “Watershed development program” as long-term adaptation strategies to increasing drought condition. According to ADB (2008), farmers in drought-prone districts in Indonesia were trained in technologies in rain harvesting to absorb surplus water from irrigation and precipitation. In Vietnam, the government planned for the extension of small-scale irrigation schemes in Ninh Thuan drought-prone province. In addition, traditional knowledge and indigenous technologies in water harvesting of farmers contribute significantly to the water preservation (Stigter *et al.*, 2005).

In order to increase moisture retention in more frequent drought areas, there are many specific water management innovations including centre pivot irrigation, dormant season irrigation, drip irrigation, pipe irrigation and sprinkler irrigation (Smit, 1993 cited in Smit & Skinner, 2002). When dry land areas increase and lack of water for cropping, farmers apply drip irrigation techniques to save water (UNFCCC, 2006; Adejuwon, 2004; Smit & Skinner, 2002).

However, these technical innovations have not been sufficient on their own because these conditions and their capacity still have many limitations, especially in coastal and sandy soil areas where the rate of poor household is still high and because their capacity for investment in technical innovations has not been enough. Therefore, in order to apply these new techniques, adaptation strategies in agricultural policies should be considered and supported to improve and enhance their capacity as well as to take full advantages of traditional or indigenous knowledge from local people.

Livestock management

Adaptation techniques associated to feeding resources are mentioned in Intergovernmental Panel on Climate Change, including increasing stocks of feed for unfavorable time periods; improving pasture and grazing management; increasing land coverage per hectare and providing specific local support in supplementary feed and veterinary services (Cruz *et al.*, 2007). Renaudeau *et al.* (2008) suggested that nutrient issues in dietary regimes is one of the main strategies to reduce heat stress of livestock, especially for pigs in the tropics and sub-tropic as well as sub-arid regions. Changing the time for diet is also an important adaptation option to temperature increase condition. Besides, changing the dietary nutrient density in the diet could also be a good alternative to alleviate the depressed feed consumption and performance in pigs by increased or decreased diet (Renaudeau *et al.*, 2008).

There are techniques that can create "artificial" environment for livestock such as fan and evaporative cooling system to reduce the ambient temperature (Hoofmann, 2008; Renaudeau *et al.*, 2008) and floor cooling, drip cooling, snout cooling (McGlone et al., 1988; Silva et al., 2006 as cited in Renaudeau *et al.*, 2008). In order adapt to drought, farmers build shelters to protect their animals (Thornton *et al.*, 2007). In addition, during dry spells, farmers in many regions in the world reduce investment or even stop cropping and focus on livestock management (Thomas, 2008; Thomas *et al.*, 2007). Thornton *et al* (2007) suggested that investment in livestock and poultry were seen as good ways for households to increase income during drought periods when crops were less available.

2.3.2.5 Alternative livelihoods and migration

Alternative livelihoods and migration (new place or seasonal migration) are critically considered for agriculturalists. Diversification of income sources from non-farm activities are identified as potential adaptation options to reduce vulnerability associated with climate change and weather extreme events (Smit & Skinner, 2002). Migration and human settlement patterns have a strong relationship with changes in climate conditions (McLeman & Smit, 2006). Generally, population in rural areas often migrate seasonally to the cities for employment when agricultural production faces difficulties (ADB, 2008; McLeman & Smit, 2006). Evidence for a relationship between climate and human migration patterns suggests that migration is the main strategy of people in rural area in climate change circumstance, (ADB, 2008; Cooper *et al.*, 2008; McLeman & Smit, 2006; Ziervogel & Calder, 2003; Adger, 1999) especially migrant farmers who relocate from drought-affected areas to favorable regions and return when conditions are improved (Nyong, 2008). Livelihood stability enhances through remittances associated with migration and paid management (Adger, 1999). Researches in Africa in recent decades indicated that population in rural area have adopted strategies to cope with and adapt to recurring drought that incorporate migration (McLeman & Smit, 2006) and it is the main adaptation strategies for farmers in coastal area in Vietnam (Adger, 1999). Farmers in the rain-fed farming systems of sub-Saharan Africa have successfully adapted and diversified their livelihood strategies through off-farm activity, caste occupations and seasonal job migration in drought period (Cooper *et al.*, 2008). Income of these farmers has changed in the percentages of different sources with a dramatic increase in the seasonal migration for work and caste occupation from 0% and 0% to 8% and 25%, respectively in 1975-1978 and 2001-2002 when drought condition has increased. Farmers in Basotho have had alternative livelihood strategies include the sale of vegetables and firewood, making bricks, sewing and selling local beer (Gay and Hall, 2002 cited in Ziervogel & Calder, 2003). Thus remittances from migrants used to support large activities of rural population, with an average of 60 percent of payment for their lives and production activities (Ziervogel & Calder, 2003). While some of these strategies are directly influenced by the climate factor, other can be indirectly affected or unrelated to the climate (Ziervogel & Calder, 2003). Especially, in this case, poor households often focus on agricultural development strategy so they are more vulnerable to problems if weather extreme events happen. However, according to McLeman & Smit (2006), poor populations who lack of capacity to adapt to environmental risks or hazards, as farmers in Africa who cannot overcome during drought season, is interconnected with population displacement or seasonal migration to search new job in new place. Thus, whether migration can or cannot become adaptation strategies to climate change, especially in places with prolonged drought, is still a debated issue.

2.4 Climate change and adaptation strategies in Vietnam

2.4.1 Climate changes in the past and prediction in the future in Vietnam

According to Ministry of Natural Resources and environment (MONRE) (2008), in Vietnam, during the last fifty years (from 1951 to 2000), the annual average temperature increased 0.7^0C and the average sea level rose about 20cm, which is comparable with global tendency. The annual average precipitation changed in the last 9 decades (from 1911 to 2000) was not consistent over the country. In the whole country of Vietnam, the trend of precipitation change varies from regions to regions.

Based on Vietnam climate change scenarios, climate change tendency in Vietnam is shown in terms of temperature, precipitation and sea level (MONRE, 2009a; MONRE, 2009b; MONRE, 2008). In all regions, the annual average temperature would increase by 2^0C in 2050 and is projected to rise by 3^0C in 2100. The precipitation would change in different regions. It may increase 0-10% in rainy season and decrease 0-5% in dry season and becomes more fluctuant. The sea level is estimated to rise about 100cm in 2100.

2.4.2 Potential impacts of climate change on agricultural production in Vietnam

The Intergovernmental Panel on Climate Change (IPCC) and initial studies of Vietnamese scientists indicated that potential impacts of climate change in Vietnam are serious and need to be further studied (MONRE, 2008). According to assessment of Ministry of Resources and Environment (2008), agricultural production and food security in Vietnam are aspects that have seriously influenced climate change. Climate change, in turn, has large impacts on the growth and productivity of plants, cropping seasons and increase pestilent insect. Climate change also affects growth and productivity of livestock, increases risk of pathogenesis.

For agricultural production, global warming and droughts increasingly influence cropping pattern and livestock and seasonal calendar may be changed in some regions, e.g. the winter crop in the North can be curtailed or even no longer exit. This requires that cultivation methods have to be adjusted. The increase temperature in combination with decrease in precipitation in summer season and climate variability has had impacts on pestilent insects and widespread diseases. Water resources also face risks due to ever increasing drought in some regions and seasons. These difficulties will directly affect agriculture, water supply for rural and urban areas.

2.4.3 Adaptation strategies of Vietnam in NTP in agricultural production

Vietnam Initial National Communication - Under the United Nations Framework Convention on Climate Change suggested main adaptation measures in agricultural production including the development of crop patterns suitable to climate change; effective use of irrigation water; upgrading irrigation system for agriculture; development of new varieties that could stand against severe environmental conditions; reserve and storage of local crop varieties, establishing crop seed bank and development of farming techniques appropriate to climate change (MONRE, 2003).

National Target Program (2008) also gave adaptation strategies in agricultural production. Ministry of Agriculture and Rural Development and other ministries and sectors will collaborate to implement these adaptation strategies. Contents of adaptation strategies include "develop and improve the framework of synchronous legal documents; laws and circulars to protect the agriculture of commodity, diversity and sustainable development; amend and improve policies and mechanisms to support the application of new technologies, modern scientific and technical solutions to change crops pattern, livestock and new farming techniques suitable with climate change condition; develop and implement scientific and technical activities to adapt to climate change in agricultural sector; and plan effective use of agricultural land and water for fishery in consideration of immediate and potential impacts of climate change to ensure a sustainable agricultural production".

These adaptation strategies are still vague and unsuitable if they are applied in particular regions. Therefore, in order to have appropriate adaptation strategies for particular regions and local conditions, a combination between impacts assessment and adaptation strategies seem to be a suitable approach to enhance adaptive capacity and provide data base for each province being able to integrate adaptation strategies to climate change in province's social-economic development plan.

2.5 Including landmark

Temperature tends to increase while the precipitation tends to decrease in dry season. This is the main reasons that lead to increasing drought and lacking of water in regions where water cannot be self-provided.

Drought has influenced land and water resources by reducing agricultural land and soil quality; decreasing water volume and water quality. Moreover, drought influences crop production in three aspects of crop yield; change in the incidence and distribution of pest and pathogens and crop distribution. As for livestock and fish production, four aspects are influenced including feed-grain availability; animal health, livestock productivity; and scale of production and diversified livestock levels. Investment cost is also affected by drought.

Many researches often suggest that these diseases development is due to climate change. However, is climate change the main reason of these losses? In practice, these pests and diseases existed for a longtime and some of them are old. Thus, impact assessment of climate change requires that the researchers have to consider and analyze carefully to identify main reasons. This is critically significant for researchers and developers as well as the policy-makers who make decisions for supporting to farmers.

Adaptation strategies to climate change are established through actions of society, individuals, groups and government. Particularly, many typical adaptation options in agriculture include changes in seasonality of production; dates of sowing; choice of crop varieties or species;

developing new varieties and breeds as well as improving local varieties and breeds, applying integrated model production, improving water supply and irrigation systems; tillage practices; other inputs and management adjustment and improved short-term weather and seasonal climate forecasting. In terms of mix-farming system, the literature indicated that there are several possible adaptation options responding to drought in mixed-farming system including crop variety and livestock/fish breeding; mode of production; seasonal calendar; agricultural technique; and finding alternative livelihoods (especially migration and development off-farm activities).

Barriers and disadvantages of households and community in agricultural production and applying adaptation options are main contents to evaluate adaptive capacity of households and community to drought. Natural resources, infrastructure, accessing services, policies, institutions and organizations, household characteristics and potential agricultural development are the main indicators, which were considered to analyze adaptive capacity to drought.

3 METHODOLOGY

3.1 The study site

Quang Tri province belongs to Central coastal region which is the contiguous part to the South and North of Vietnam. This province has 81% mountainous land, 11% lowland and 7.5% sandy soil area. Quang Tri suffers disasters that have happened in Vietnam with a high frequency and fierce intensity. Climatic conditions in Quang Tri are rather severe and are also impacted by hot and dry westerly wind (around 40-60 days/year). It often has storm combined with heavy rain (from September to October), and strong climate variability. Because the terrain conditions in this province are slope, short and narrow riverbed. Because of these conditions, Quang Tri province stands effects of drought in the dry season and waterlogged in the raining season. Especially, coastal communes are often profoundly affected by drought, salinity intrusion and flood because of surge wave.

Results of analysis of the data on temperature recorded in Dong Ha Meteorological Station of Quang Tri province from 1976 to 2008 showed that the average temperature was 24.9^{0}C. The hottest months were June and July and the coldest ones concentrated on December to January of the next year (Figure 3.1). Since 1976, the highest temperature recorded was 42.1^{0}C (24/04/1980) and the lowest one was 9.4^{0}C (02/03/1982).

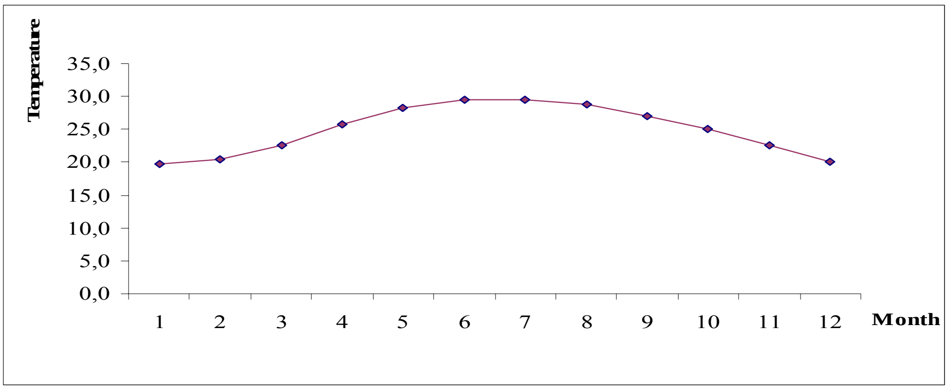


Figure 3.1: Average temperature of months from 1976 to 2008

Source: Data from the Dong Ha Meteorological Station from 1976 to 2008

In terms of precipitation, analysis of data from the Dong Ha Meteorological Station indicated that, the average precipitation from 1976 to 2008 was 2321.3 mm/year. From 1976 to 2008, the highest total precipitation was 3458.2 mm in 1980 and the total lowest precipitation was 1424.5 mm in 1988. Precipitation has monthly changed. Precipitation focused mainly from the end August to November and reaching the highest in October. Months had the lowest precipitation from January to April and from June to July (Figure 3.2).

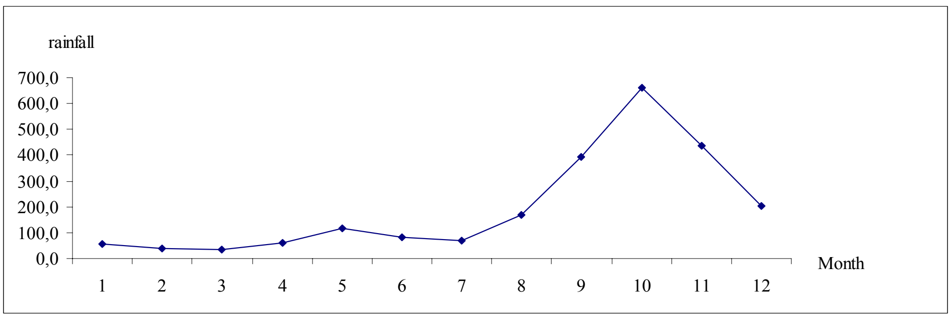


Figure 3.2: Average precipitation of months from 1976 to 2008

Source: Data from the Dong Ha Meteorological Station from 1976 to 2008

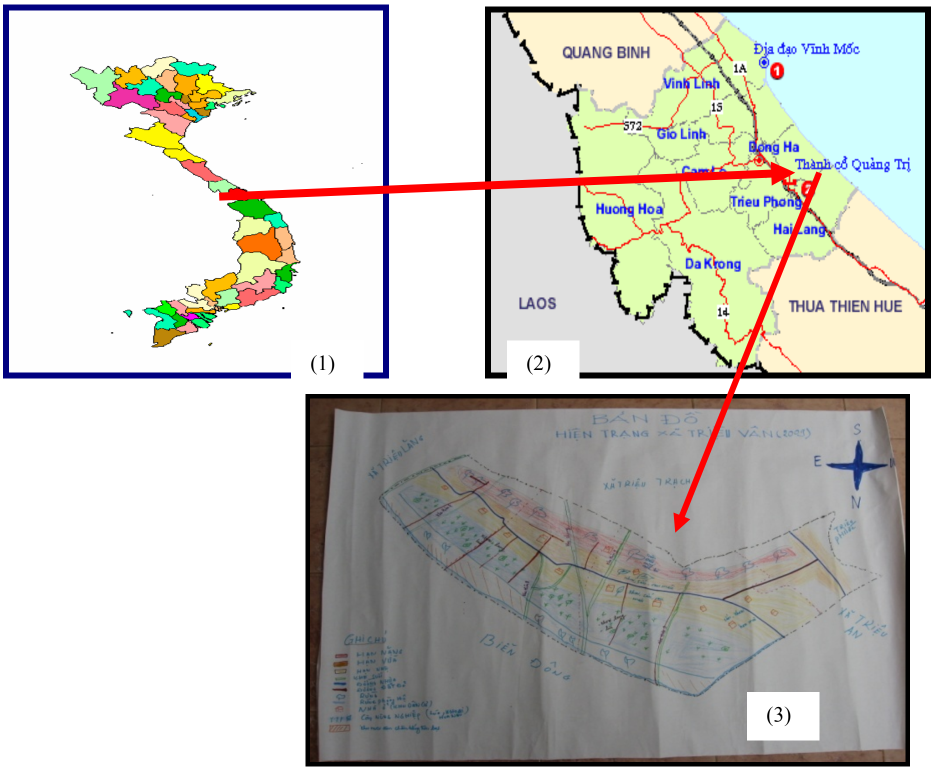
The main climate extreme event was drought, an effect of low precipitation during dry season in Quang Tri because dry and hot wind (southern-western wind) blows from April to July (average 45days/year) and even August. Hot wind results in increasing temperature (normally from 35-37^{0}C and even going up to 40^{0}C), increasing water evaporation as well as drought in terms of frequency and intensity.

Quang Tri province has complicated characteristic in climate change and climate variability especially climatic extreme events. Quang Tri in general and Trieu Van in particular have been influenced by most of the common disasters in Vietnam with higher and fiercer frequency and intensity.

Regarding storms, farmers in the study area experienced enormous storms in 1968, 1985, 2006, 2008 and 2009. The deluges happened in 1970, 1971, 1983, 1999 and the nearest was in 2009. The cold spell happened less than storms and floods in recent year. Only in 2008, the weather decreased less than 10^{0}C. The climate extreme events have fewer effects on agricultural production because agricultural production activities are often finished and harvested. However, livestock and fish production are significantly influenced by these climate extremes events. Precipitation was estimated increasing during rainy season and precipitation often focuses on certain time. Thus, frequency and intensity of floods also increased.

In Trieu Van commune, drought has often happened since 1993 with the typical years of 1993, 1998, 2003 and 2005. Economic-social reports of in Trieu Van commune emphasized heavily drought in 1993 and 1998 with happened from July to August with Southern-Western wind blew prolonging 20-30 days. Due to high temperature combined with Southern-Western wind, hence, water resource was exhausted which lead to the decreasing water level in rivers and dry lakes, the reduction of agricultural productivity and even complete loss.

Trieu Van is a “Bai ngang” commune that belongs to Trieu Phong district, Quang Tri province (bai ngang commune means that it is a coastal commune, with high poverty rate). There are four villages in the commune including the seventh village, the eighth village, the ninth village and the ecological village. This commune is 18km from Quang Tri town to the Northern-West. It is bordered with Trieu An commune in the North, with Trieu Trach in the west, bordered with Trieu Lang in the south, and the East Sea in the East (see the map).



Picture 1: Map of the study area (1- Vietnam map; 2- Quang Tri province map; 3- Trieu Van commune map)

According to the commune statistical record, Trieu Van had totally 2,398 inhabitants with 627 households in 2009. The poverty rate was 33.3% (statistic of commune in 2009). The illiterate rate was low with 1.8% of total population. The population density in 2009 was 2.2 person per ha. The total natural area of the whole commune is 1099.17 ha including 227.89 ha of agricultural land (21%), among which, there is 25.55 ha (2%) salinity intrusion and 70.6 ha (6%) waterlogged; 421 ha of forestry land (39%), 139.02 (14%) ha unused land, and the rest for other purposes.

Land resource is one of the most important resources for agricultural production. The main constraints for crop production in the study area were shortage of water resources, strong Southern - Western wind and high temperature. In the Spring - Winter crop, uncultivated land was only 15% (figure 3.3), 85% land area was used for cultivation with many crops. However, in the Summer - Autumn, uncultivated land increased remarkably, from 15% to 69% in total agricultural land area (figure 3.4).

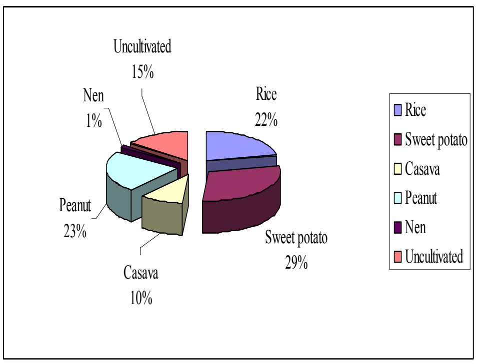


Figure 3.3: Cultivated land in spring crop 2009

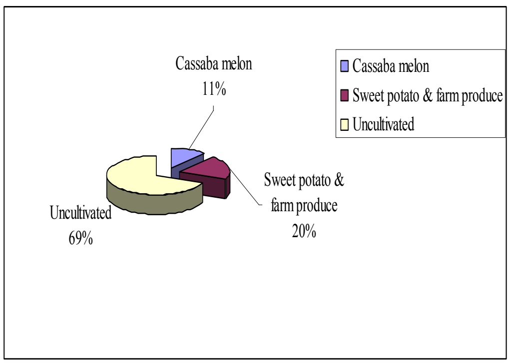


Figure 3.4: Cultivated land in summer crop 2009

Source: Secondary data statistic 2009

Economic structure in Trieu Van commune included crop, livestock production, non-farm activities and others. Crop production occupied 65% of the total income and livestock production was 20%. These were the main income sources for farmers in the study area. The rest percentage included 13% non-farm and 2% other.

Beside natural and society characteristics of research site, infrastructure for agricultural production such as irrigation, inter-field roads and dams were very poor quality. There was no irrigation system and dams to prevent salt water from the sea, which led to lacking of water for agricultural production, salty intrusion in summer and waterlogged in winter.

3.2 Research process

The study was designed six steps (figure 3.5). Basing on the research objectives, the study area was selected. Then, research indicators and criteria were identified through literature review and characteristics of the research site. After identifying indicators and preparing themes for group discussions and main modules for interview, data and information were collected. There were two types of information including primary and secondary data. The fifth step was data analysis and the final step was writing the report.

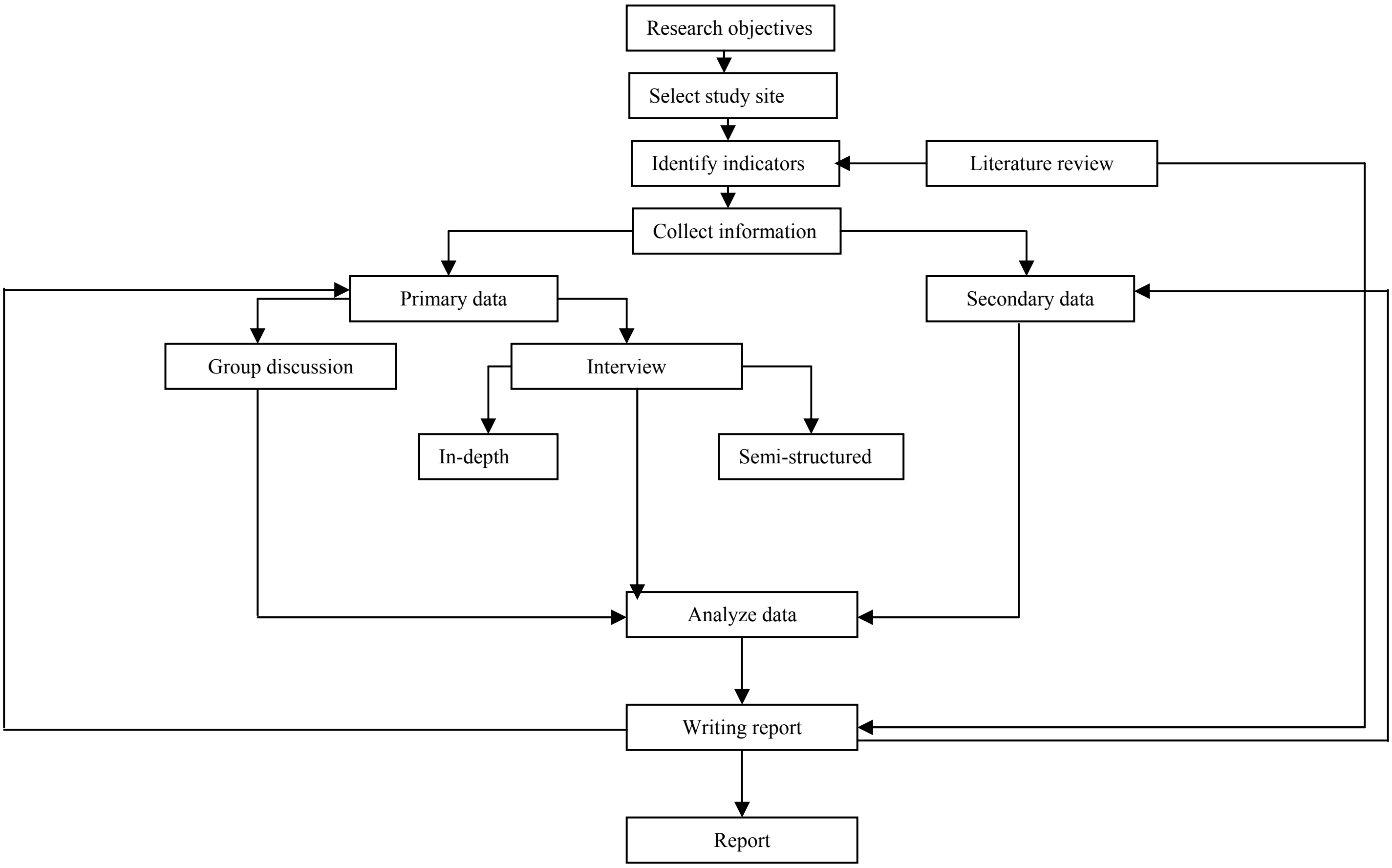


Figure 3.5: Research process

3.3 Research contents, research indicators and criteria

In order to achieve the above objectives, following four main contents were designed to conduct this research:

- The first content was climate change and drought trend profile by analyzing farmers perceptions of changes on climate and data from the Meteorological Stations in Dong Ha city, Quang Tri province. Climate extremes, frequency and intensity were described and analyzed. Temperature and precipitation changes during 33 years including: annual temperature change trend (average, min, max), annual temperature change trend in dry season (average, min, max), annual precipitation change trend (average, min, max), annual precipitation trend in dry and rain season (average, min, max) were indicators to assess climate change.

- The second one was analyzing impacts of drought on mixed farming components. Land and water resource, crop production, livestock production and aquacultrue were components that were used to assess impacts of drought changes. Regarding land resources, deceasing land area, dry land, change soil structure, reducing quality and salinity land were measured indicators. Water volume through digging deep wells, less water and change of using time and salinity water were indicator measures for assessing water resource. Pest and diseases, crop productivity, quality of crops product were indicators for crop production. Feed resource, grain-feed price, livestock and fish health, livestock and fish productivity and scale of production were indicators for livestock production and fish raising. Production costs were indicator for all components.

- The third content was identifying and analyzing farmers' perception of adaptation options in agricultural sector to drought.

- The final content was analyzing adaptive capacity of local community to drought through advantages and disadvantages of local community in applying such adaptation options.

3.4 Data collection

3.4.1 Secondary data

The secondary data information was collected from province, district and commune levels through natural condition reports, annual social-economic reports in 2009, damage reports, related documents from NGOs and mass organizations working in commune. Polices relating to coping with and adapting to climate change in the study area, data on temperature, precipitation recorded by the Dong Ha Meteorological Station in 1976-2008 were also collected.

The secondary data and information about common climate extreme events and related information on the impacts on agriculture sector and the consequences from related departments and institution were also collected.

3.4.2 Primary data

The primary data/information was collected by using different tools such as group discussion, in-depth interview, household interview, and observation.

Three group discussions were conducted in this research.

The 1st group discussion was conducted with key informants in commune including commune leader, staff responsible in agricultural production, preventing disaster, Red Cross, four village leaders, four elderly, leaders of Farmer union, Women union and interest group.

In this group discussion, timeline and historical profile/ recall methods were used in order to identify climate extreme events and their variability over time, frequency and intensity.

The mapping was also applied to get a general picture of the village's location and distribution of different villages as well as households. It was also used to identify which areas had the most impacts by drought on farming system and affected areas. Seasonal calendar was applied to know the calendar of each activity in the study area.

SWOT was also applied to identify strengths, weaknesses, opportunities, and threats that are considered to be important in the community to adapt to drought and to understand adaptive capacity of local people.

The 2nd group discussion was conducted with farmers, including poor and non-poor groups, who have farming systems (crop, livestock, fish, and tree components). Each group was five farmers.

Information related to impacts of drought on crops, livestock, fish, land and water resources was collected by applying historical profile.

The 3rd group discussion was conducted with farmers who have many experiences in coping with and adapting to drought in the commune. Ten farmers participated in this group discussion. The researcher applied timeline and historical profile to know indigenous experiences and practices of drought adaptation.

In-depth interview: after getting general information about villages and households and finishing PRA exercise, six farmers, and three village leaders were conducted with in-depth interview. Main information in in-depth interview was about the tendency of drought in recent years (1976-2009 basing on their memory), the impacts of drought on components of mixed-farming system, adaptation options and lessons learnt, local organization activities (communities and NGOs), policies relating to support, prevent and adapt to natural disasters and experiences forecast for drought (see Appendix for detail contents of in-depth interview). Farmers selected for in-depth interview were those who have been envolving in agricultural production with rich experiences in the study area.

Household interview: after collecting and classifying information and data, a semi-structure questionnaire was designed and conducted. This tool was applied to get information about impacts of drought on farming system, adaptation options, their experiences and their expectation. Fifty nine out of 627 households were randomly selected for interview. The questionnaire had two main modules:

(A) Information on impact of drought on farming system:
(1) Land: total of area; area used; area unused though able to be used; area unable to be used and the reasons.
(2) Water: lack of water: how long; quality of water, before and after increasing drought; through crop growth and reasons
(3) Productivity: increase/decrease; how much and which year; why and which drought extreme; productivity before and after the year of changes
(4) Products quality: impact or not impact though the rate of pests and diseases (depend on local perception)
(5) Production costs: fertilizers, pesticides, electricity, petrol, building cage, buying feed
(6) Diseases: old diseases but increasing level (frequency and intensity occur); new disease occur
(B) Information on adaptation strategies of farmers to drought:
(7) Access to information
(8) Adaptation options: including each crops, each livestock and fish (alternative livelihood; change seasonal calendar; technique; varieties; breeding; crop and animal structure; diversifying income generation activities (non-farm, migration,...) and production model (VACR)

Conceptual framework for data collection and analysis

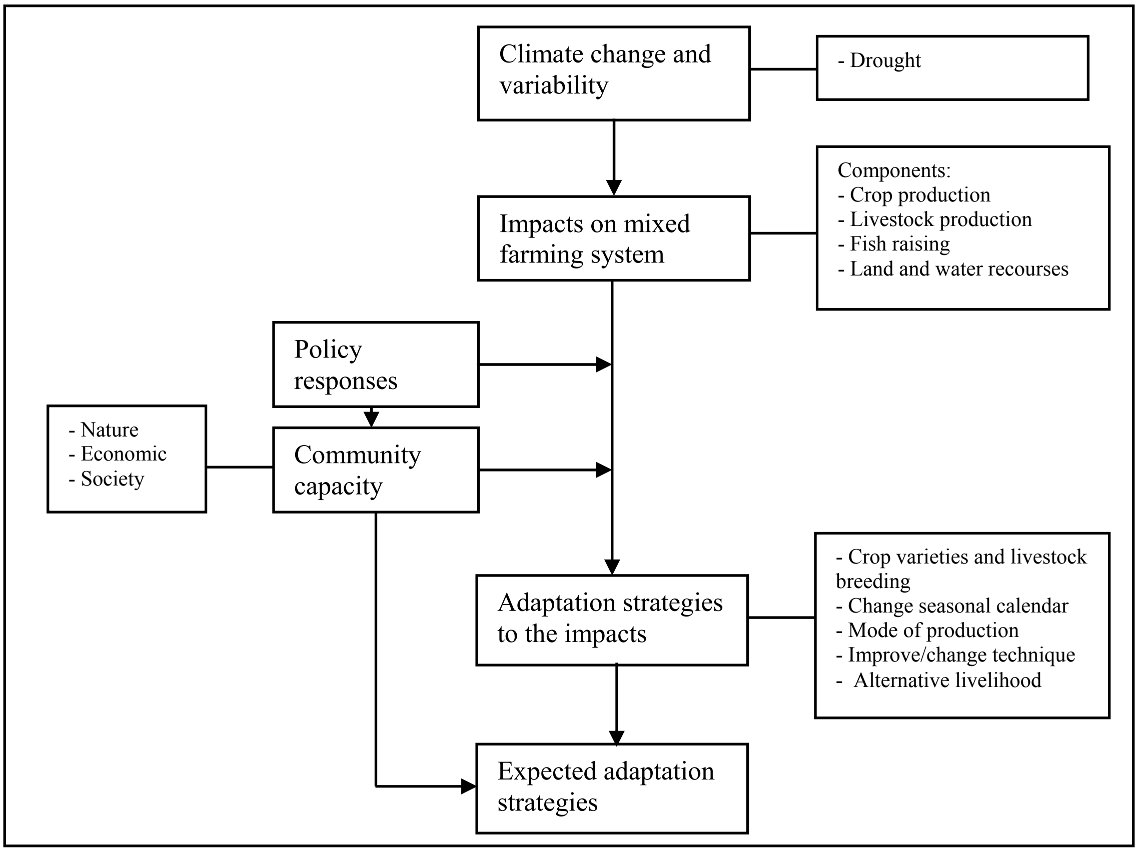


Figure 3.6: Conceptual framework for data collection and analysis

Adapted from Parry and Carter, 1988; Smith, 1993; Jawahar and Msangi, 2006

This conceptual framework was used for data collection and analysis. Climate change and variability in this study based on farmer's perception of drought and how they respond to drought. Therefore, the information value of farmers was important to the analysis of data of this research.

3.5 Data analysis

After the collection of both qualitative and quantitative data from various methods, the data were synthesized and inputted in SPSS and Excel software. In this study, both quantitative and qualitative methods were applied for analyzing collected data and information. Descriptive and inference analyses were applied to quantify perception of farmers for household interviewing.

4 DESCRIPTION MIXED -FARMING SYSTEM

4.1 Family size and its composition

Family size and its composition are important parameters in the decision of making process of the farm household. They determine the labor's capability and availability for the farm and off-farm activities. Labor is one of the main elements in the family sources.

Table 4.1: Family size, education level, age and farming experience of surveyed household in the study area in 2009

Indicators	Mean n=59	Std. Deviation	Poor n=29	Non-poor n=30	P value
			Mean	Mean	
Age of household heads (grade)	50.7	8.7	50.5	50.8	0.29
Family size (person)	5.7	1.3	5.8	5.5	0.71
Farming experience (year)	27.8	9.7	27.4	28.1	0.62
Labor force (person)	2.9	1.0	2.6	3.1	0.17
Dependent (person)	2.8	1.3	3.2	2.4	0.72
Male labor (person)	1.5	0.6	1.3	1.6	0.03
Female labor (person)	1.4	0.7	1.3	1.5	0.28

Source: Field survey 2009

Table 4.1 presents the family size and composition of farm household in the study area in 2009. It can be seen that the average family size was about 5.7 persons per household with a minimum of 3 persons and a maximum of 9 persons. The average of labor force and of dependent person were nearly the same of 2.9 and 2.8 persons per household, respectively. Labor division and gender play an important role in on-farm and off-farm activities. The average of male labor and female of the surveyed households was the same size (about 1.5 persons for male labor and 1.4 persons for female labor). The head of each household is the representative to take part in many activities of the society. Results from field survey showed that people having the highest education finished the 12^{th} and the lowest finished the 4^{th} grade. The education percentage of heads of surveyed households was mainly about 9th grade with 40.7% of surveyed households (see figure 4.1 in appendix). The average age was around 50.7 and most of them have many years of experience on agricultural production. All the indicators in table 4.1 were not significantly different between the two groups of household except male labor. The average numbers of male labors per household was significant between groups (P=0.03).

4.2 Equipments for agricultural production

Equipments for agricultural production are one of the components that contribute to farming system development. They can reduce labor force and enhance labor capacity as well as improve agricultural production in terms of crop and livestock production.

Table 4.2: Equipments for agricultural production surveyed household in the study area in 2009 (Unit: cái)

Indicators	Mean N=59	Std. Deviation	Poor N=29	Non-poor N=30	P value
	Statistic	Statistic	Mean	Mean	
Waterpump	1.1	0.4	1.1	1.1	0.56
Fan	2.0	0.7	1.7	2.3	0.62
Motorbike	0.2	0.4	0.1	0.2	0.02
Radio	1.0	0.2	10	1.0	1.00
Tivi	1.1	0.4	1.1	1.1	0.56

Source: Field survey 2009

Each surveyed household had 1.1 water pumps; 2.0 fans, and 1.0 television. Equipments for agricultural production of surveyed households were quite limited and poor, which may increase negative impacts and limit the adaptive capacity to change conditions in agricultural production.

4.3 Land resource and land use system

Farm size is a foremost component of agricultural production. The farm size is an indicator of land source availability. It affects the efficiency of resource allocation and productivity.

Table 4.3: Surveyed household's land resource ((m^2)) in the study area in 2009

Type land	Mean (S. deviation) n=59	Poor (n=29)	Non-poor (n=30)	P value
		Mean (S. deviation)	Mean (S. deviation)	
Garden land	2064 (2280)	1929 (1860)	2195 (2651)	0.29
Agricultural land	3340 (2117)	3060 (1853)	3611 (2344)	0.30
Salinity land	217 (564)	103 (386)	328 (683)	0.01
Forest land *	4549 (7370)	3913 (7156)	5163 (7642)	0.43

** 1 m^2 = 1 tree*

Source: Field survey 2009

According to report in land using situation of Trieu Van commune (2009), soil quality in Trieu Van commune was exhausted with sandy soil and extreme poor quality. Most of surveyed farmers had two land plots land including garden land and agricultural land. Table 4.3 presents that the size of land area in the study was not a problem. Average farm size including garden, agricultural land and salinity land were about 5500.0 m^2 (equivalent to 11 sao - 1sao = 500m^2). Forest land in the commune occupied large areas with 421 ha equivalent to 39 percent in total area. Average surveyed households had around 4000 m^2 equivalent to 4000 trees. The average area of salinity land was shown to be significant between groups (P=0.01). Other average area land from table 4.3 was not different between the two groups.

4.4 Production system

4.4.1 Crop production

Table 4.4 presents the crop structure following season of each crop in the study area in 2009. In the study area, there were two main crops including Winter - Spring season and Summer - Autumn one. However, the agricultural land was used in the Winter - Spring crop to a larger extent than that in Summer Autumn one.

Table 4.4: Crop structure following season for each crop in Trieu Van commune in 2009 (n=59; Unit m^2)

Crops	Area Spring crop	Area Summer crop
	Mean (S. deviation)	Mean (S. deviation)
Rice	2896 (5203)	67 (376)
Sweet potato for Root	1360 (1277)	504 (666)
Sweet potato for Leaf	0.0 (0)	639 (1343)
Cassava	173 (408)	0.0 (0)
Peanut	346 (418)	4 (32)
Bean	974 (1351)	76 (319)
Bitter melon	198 (212)	0.0 (0)
Cassaba melon	76 (305)	516 (603)
Local onion	88 (206)	0.0 (0)

Source: Field survey 2009

Interviewed households have crop diversification. The crops that were cultivated included sweet potato for root and leaf, rice, cassava, peanut, kinds of bean, bitter melon, cassaba melon, local onion and some crops with small area. Rice and sweet potato were the dominant crops of this area. Rice production and sweet potato were mainly produced for domestic consumption. Besides, sweet potato was a main feed source for animal husbandry. The average area of rice production was the largest with nearly 3000 m^2 per household (equivalent to 6 sao) and the second largest area belongs to that of sweet potato for root with 1360 m^2 per household. Bean production also accounted for a large area (nearly 1000m^2 per household). However, bean crop was cultivated separately; it was intercropped with sweet potato. The average area of cassaba melon per household in the spring season was small but increased dramatically in summer crop (from around 80 m^2 per household to 520 m^2 per household). In the spring crop, interviewed households did not cultivated sweet potato for leaf. However, they increased more than 1 sao per household in summer crop to support livestock production. In short, crop structure in spring season was richer and the area of each crop were larger compared to that of summer crop.

4.4.2 Livestock production system

The average number, number per farrow, and farrow per year of cattle, pig, poultry and fish kept per farm-household of surveyed households are presented in table 4.5.

Table 4.5: Number of livestock, number per farrow, and farrow per year of farm household of surveyed households in Trieu Van commune in 2009

Indicators	Mean (S.Deviation) (n=59)	Poor (n=29) Mean (S.Deviation)		Non-poor (n=30) Mean (S.Deviation)		P value
Pig number	7.9 (13.0)	5.1	7.7	10.7	16.4	0.01
Number/ farrow	10.1 (13.7)	5.3	5.9	15.5	17.6	0.00
Farrow/ year	2.7 (1.3)	2.8	1.7	2.6	0.7	0.22
Sow number	1.7 (1.3)	1.3	1.2	2.1	1.4	0.89
Number/ farrow	10.4 (1.2)	10.2	1.0	10.7	1.4	0.89
Farrow/ year	2.0 (0.1)	2.0	0.1	2.1	0.2	0.89
Cattle number	0.5 (1.1)	0.8	1.3	0.3	1.0	0.04
Chicken number	33.3 (22.4)	28.5	18.4	38.2	25.1	0.14
Number/ farrow	28.7 (16.4)	26.2	12.1	31.1	19.5	0.03
Farrow/ year	2.1 (0.5)	2.1	0.3	2.3	0.7	0.00
Duck number	10.1 (39.4)	3.8	6.6	16.3	54.7	0.07
Number/ farrow	27.1 (62.9)	12.2	6.2	38.3	82.8	0.11
Farrow/ year	1.6 (0.6)	1.4	0.7	1.8	0.6	0.55
Fish number	631.5 (1533.4)	686.2	1901.6	536.7	1031.7	0.43
Number/ farrow	1613.6 (2142.3)	1990.0	2892.7	1300.0	1296.2	0.25
Farrow/ year	1.3 (0.5)	1.2	0.4	1.5	0.7	0.04

Source: Field survey 2009

Almost all surveyed households keep pigs. Due to weather conditions and food resources, the pig breed used in this area is mostly the local breed named Mong Cai. Pigs were raised about three or four months and then sold for cash. The average number of pig in 2009 was 7.9 heads per household. The average number pig of per farrow was 10.1 heads. There was difference because, in the interviewing time, many households had just sold their pigs. The average farrow was 2.7 times per year. Besides, sow pig was also the main animal in pig production for breed maintenance. The average of number sow pig per farm household was 1.7 heads with 10.4 piglets per farrow, accounting for 2.0 per year.

In the study area, cattle are kept for many purposes. Cattle are considered as a multiple function animal. The most common cattle breed was the local named Yellow cattle. The average number of cattle per farm household was 0.5 head.

The average number of pig, cattle and duck per household was significantly different between two groups (P=0.01, 0.04, 0.07 respectively).

Poultry including chickens and ducks was kept around the homesteads. Almost all farm households raised a few poultry for domestic consumption. In some cases, poultry were raised for the market as well. Ducks were mainly raised in farm households where water resource was available. The average number of chicken and duck per farm household was 33.3 heads and 10.1 heads, respectively. The water resource is critical important for duck raising.

However the dry season in sandy area makes it impossible to keep ducks because of water shortage and hot soil surface. Therefore, farrow per year for chicken raising was 2.1 which was higher than that of duck raising.

Similarly, water resource is critical important for fish raising. In Trieu Van commune, fish raising was an important component in mixed farming system. Fish raising not only provided food for people and for selling but also created suitable conditions for pig raising and water for cultivation in dry season. The average number of fish per household was 631.5 heads, mainly focusing on households who had VAC or VACR. The average number of fish per farrow in farm household was 1613.6 heads and 1.3 farrows per year.

5 FINDINGS AND DISSCUSSION

5.1 Climate change and variability in Quang Tri province and the study area

5.1.1 Comparison between perceptions of Changes in Climate and Meteorological Stations' Recorded Data

5.1.1.1 Temperature changes

According to the statistical record, as well as in farmers' opinion, January and July are the two months having the highest and lowest temperature. January has the coldest temperature with the average around of 19^0C and July has the highest one with the average around of 29^0C. The average temperature of January, July and annual average temperature from 1976 to 2008 of Dong Ha Meteorological Station were parameters of climate change. The statistical record of the temperature from 1976 to 2008 showed an increasing of 0.0095^0C per year. The annual average temperature increased 0.3^0C during 33 years (figure 5.1, see in appendix). This is also consistent with results of MONRE (2009).

In addition, analyzing data on temperature from Dong Ha Meteorological Station showed that January temperature increased 0.4 ^{0}C during 33 years (from 1976-2008) and July temperature increased 0.2^0C (Figure 5.2, see in appendix).

According to results of household interviewing, about 89 percent of interviewed farmers perceived long-term changes in temperature. Figure 5.3 presents that most of them perceived the temperature in Trieu Van commune had an increasing trend with 74.8% of respondents.

Box 5.1: Since 1995, it has been very hot, Western-Southern wind blew strongly in summer season. Before 1995, there were many projects for planting forest (acacia and casuarina), so the weather was more comfortable than other places. However, from 2006 to now, the summer season has been hotter even the temperature could reach 40^0 or more; I can not stay in my house at noon. I often stay under trees on shading place. This was clear that "it was scorching hot" said Mr Tran Van Kim, the eighth hamlet, Trieu Van commune.

Source: In - depth interview 2009

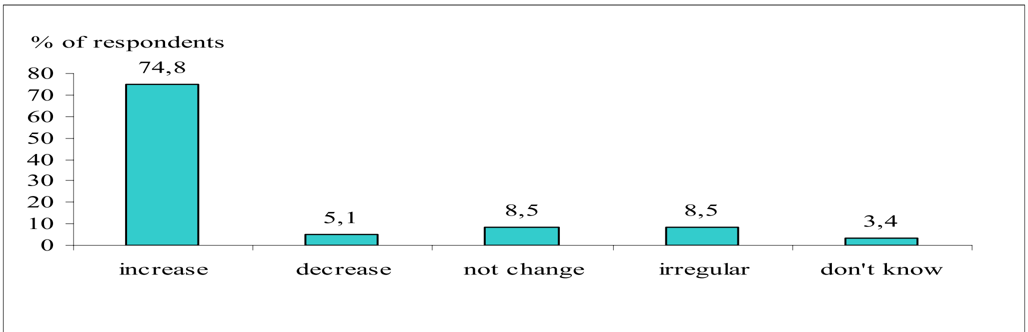


Figure 5.3: Farmers' perceptions on changes in temperature in Trieu Van (n=59)

Source: Field survey 2009

Farmers' perceptions appeared to be accordance with the statistical record. However, the change of temperature had some united and unclear points. Data recorded from Dong Ha Meteorological Station from 1976 to 2008 did not only represent for coastal region of Trieu Phong district as well as Trieu Van commune but covering for the whole province. Other reason could be the way of recording or processing as well as record equipment not appropriate. Therefore, the data may not be solid and analysis was not accurate.

5.1.1.2 Precipitation changes

Analyzing data on precipitation from the Dong Ha Meteorological Station from 1976 to 2008 showed that annual precipitation and total precipitation in rainy season and dry season increased during 33 years (figure 5.4, see in appendix). There was a large variability in the amount of precipitation from year to year.

The precipitation tendency of months within a year from 1976 to 2008 is presented at figure 5.5. The precipitation had a decreasing trend in June and September and an increasing trend in December. The result was also suitable with farmers' perception in precipitation over years. The precipitation had a decreasing trend in the dry season but it only concentrated on certain time (June and September) and ending of rainy season was later than that in the past period. This led to increase in extreme drought and shortage of water during April to September. The precipitation had a rapid increasing trend in rainy season and focused in December. As a result, flood and waterlogged water often tend to increase with high intensity in rainy season.

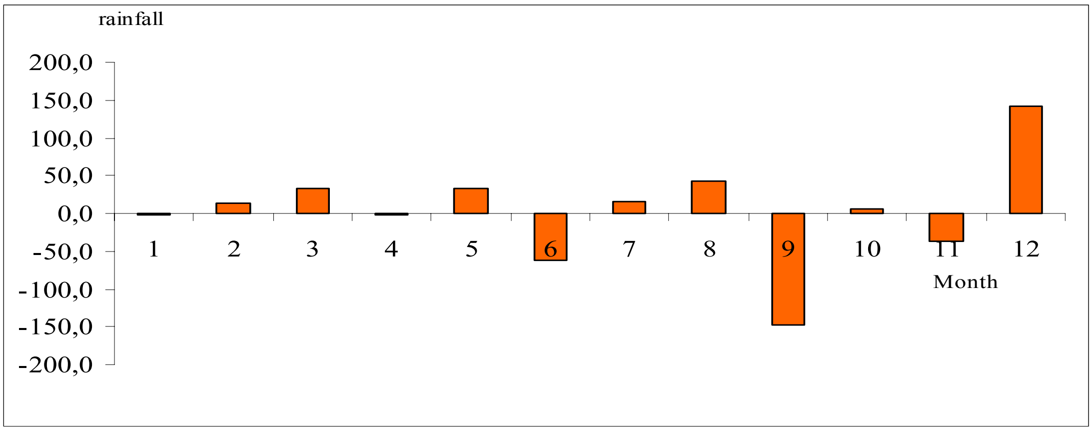


Figure 5.5: The precipitation tendency of months within a year from 1976 to 2008

Source: Data from Dong Ha Meteorological station 1976-2008

Figure 5.6 presents farmers' perceptions on changes in precipitation in the study area. In total, 86.0 percent of the respondents noticed changes in precipitation pattern and 45.0 percent noticed a decreasing trend in the amount precipitation. However, there were 19.0 percent of interviewed farmers perceived that the precipitation was increasing. Furthermore, the increasing precipitation only concentrated on a short time and precipitation intensity was higher than that of the previous years. They also explained that increasing heavy rain in short period normally causes floods. Twenty two percent of the respondents noticed that the change was irregular (the timing of the rain, with rain season coming either earlier or later than expected). The timing of the rain was irregular and it did not follow any tendency. Thus, many respondents observed that the rainy season was coming later and shorter. This also matched with what the Dong Ha Meteorological Station had recorded.

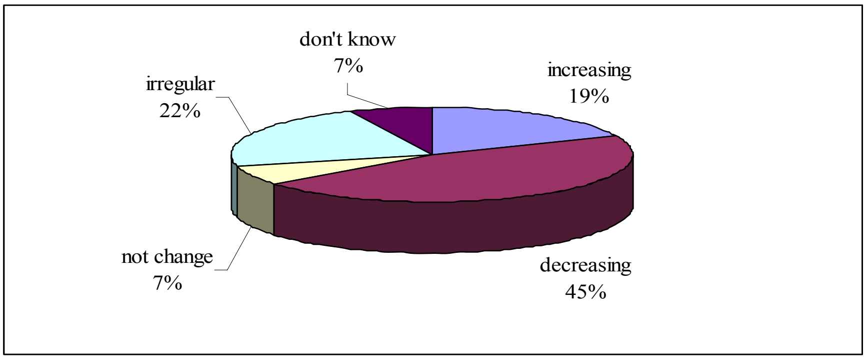


Figure 5.6: Farmers' perceptions on changes in precipitation in Trieu Van (n=59)

Source: Field survey 2009

In short, annual precipitation and total precipitation in the study area in dry and rainy season tended to increase. However, the trend precipitation within a year had a decreasing in the dry season and increasing trend in the rainy season. In addition, proportion of farmers noticed a decrease trend in precipitation in dry season could be explained by the fact that during the last few years (from 1993 up to now), there was a substantial decreasing in the amount of precipitation in dry season.

5.1.2 Climate extreme events and droughts

Climate extremes events in the study area are presented in table 5.1 (see in Appendix). Droughts, Southern-Western wind, floods, cold spell and storms were main climate extreme events in Trieu Van commune.

Results of analyzing information from discussion with farmers and commune staffs seemed frequency of storms and cold spell had a decreasing trend. Droughts, floods and Southern-Western wind had an increasing trend but their intensity have been reduced over the past five years. Vice versa, storms have become more frequent but decreasing intensity. Precipitation was noticed to increase during rain season and focus on short duration which resulted in flood. Thus, the frequency and intensity of floods also increased.

Through group discussion with local farmers, drought often occurred from March to the end of July but within the last 5 years (2004 - 2008), drought time has been increased in duration, intensity and variability of trend and time.

> *Box 5.2: Normally, it starts raining in July and flood comes up in August. But now, drought prolonged to July even August (Mr Ho Anh Quang, 58 year olds, the ninth village)*
> *Normally, it was still cold in January even very cold but now it was hotter. In April or May, I could cultivate some crops but, now there were not any crops that can be cultivated in this time (Mr Tran Dinh Ha, 54 year olds, the ecological village) .*

Source: In - depth interview 2009

Results analysis from interviewed farmers revealed that, 68.0 percent of respondents noticed the increasing drought trend and 19.0 percent indicated irregular drought trend (unpredictable). However, there were 7.0 percent farmers perceived the decreasing drought trend while 3 percent indicated no change and 3 percent do not care about that issue (Figure 5.7).

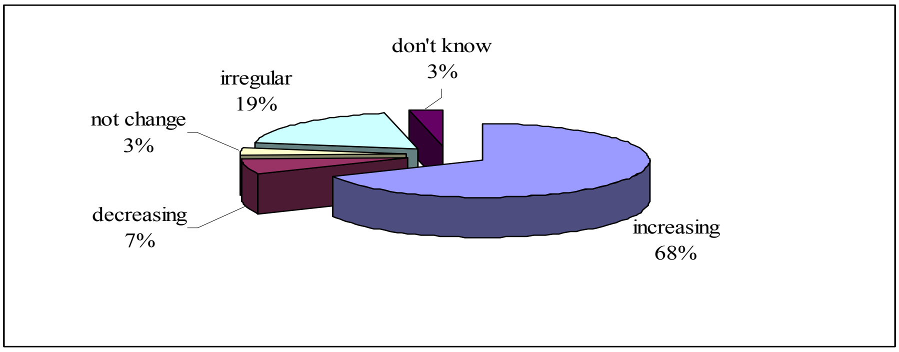


Figure 5.7 : Farmers' perceptions on changes in drought in Trieu Van (n=59)

Source: Field survey 2009

Results of farmers' perception on frequency and intensity of drought are showed in table 5.2 and 5.3 (see in Appendix). Different periods were divided by using landmark of heavy droughts basing on secondary data and memory of local farmers. Results indicated that drought was increasing in terms of frequency and intensity in ten recent years. Especially in past five years, the impact tendency increased remarkably. These results were suitable with farmer's assessment in drought changing trend in the study area in recent years. They were also consistent with results of farmers and leaders group discussion at the commune level. In the past 20 years, drought decreased in both frequency and intensity because many planting models (acacia and casuarinas forest and protective forest) as well as ecological models have been adopted by local people.

Table 5.4: Drought reasons basing on farmers' perception (% of respondents answered) (percentage and number of household)

Reason	Yes	No	Don't know
n=59	Percent (#)	Percent (#)	Percent (#)
Deforest at riverhead	49,2 (29)	25,4 (15)	25,4 (15)
Flood lead to raised the level of the field	27,1 (16)	22,0 (13)	50,8 (30)
Southern-Western wind increase	96,6 (57)	1,7 (1)	1,7 (1)
Increase temperature	96,6 (57)	0,0 (0)	3,4 (2)
Decrease precipitation	91,5 (54)	1,7 (1)	6,8 (4)
Sandy land lead to fast evaporation	94,9 (54)	3,4 (2)	1,7 (1)
Lack of irrigation	78,0 (46)	3,4 (2)	18,6 (11)
Use over underground water	8,5 (5)	13,6 (8)	78,0 (46)
Use unsuitable technique	18,6 (11)	13,6 (8)	67,8 (40)
Salinity intrusion	5,1 (3)	32,2 (19)	62.7 (37)
Over building	3,4 (2)	18,6 (11)	78,0 (46)

Source: Field survey 2009

Analyzing results from group discussion indicated that there were numerous reasons that have led to drought increasing in five recent years. Ninety six percent of surveyed household noticed that the increasing of temperature and Southern - Western wind were the two main reasons. Besides, decreasing precipitation in summer, natural characteristics of sandy land and no irrigation were also main reasons (table 5.4). And these reasons were indicators to evaluate drought and they based on farmer's perception.

5.2 Analysis of drought impact on mixed farming system components

5.2.1 Drought impact on agricultural land in the study area

Analyzing information and consequences from group discussion and surveyed households indicated that areas of almost all crops were decreased remarkably. Depending on characteristics of each crop as well as land allocation, cultivated area for different crop was reduced differently (table 4.4 in chapter IV).

Box 5.3: Agricultural land areas of three villages were reduced due to lacking of water and high temperature. In the past five years, the average agricultural land area decreased 35% compared to those in drought year and normal. However, in the recent years, in the seventh village, the fallow of 40% area of the total was reduced in dry season and this figure has been increasing in the last years; the eight' village has about 50% and 60% for the ninth village in summer season..

Source: Group discussion - village leader and commune staff

Through group discussion with local farmers, drought has influenced on land resource especially agricultural land in terms of reducing area, reducing soil quality, soil structure and coherence of soil practices. About 93.2 percent of respondents noticed that land area had a decreasing trend in summer season (table 5.5). Besides, land was also drier, less coherence and poor structure and reducing soil nutrients.

Table 5.5: Farmers' opinions on impact of drought on land resource (n=59)

Impact indicators	Yes	
	Frequency	Percent of respondents
Agricultural area	55	93.2
Soil moisture	55	93.2
Soil structure	51	86.4
Soil nutrients	55	93.2
Salinity	50	94.7

Source: Field survey 2009

Many days with scorching led to fast increase in evaporation rate, especially in sandy lands like that in the study area. As a result, dry land area increased. Through observation and group discussion, it was noticed that agricultural land has become degraded and poorly coherence. 'Farmers could not walk on their feet through their field because of extreme heat on land surface". Besides, farmers also indicated that crops grew slowly or even could not develop due to dry and hot land.

5.2.2 Drought impact on water resource in the study area

Commune leaders and elder people expressed in the group discussion that previously water level in their ponds did not change much between summer and winter seasons previously. However, in recent years, the water level in summer season has been much lower in a majority of ponds and lakes in the study area.

Box 5.4: In 2008, high temperature and no rain made my fish pond dry during one month. Before that, my fish pond was never dry, said Mr Ho Van Nguyen, the ninth village.

Source: In - depth interview 2009

The fluctuation of water level between summer season and winter season was quite large. In Trieu Van commune, there was no irrigation system, hence increasing drought seriously impacts on agricultural production.

Drought increasing has influenced water resource and reducing water volume in agricultural production. Figure 5.8 shows impacts of drought on water resource. Drought increasing leading to farmers had to dig deeper wells to take water in the field to support agricultural production. Besides, drought increasing also had influenced well-water level in the study area. Well water supporting for production activities watering for crops in garden and water for pig and aquaculture production were decreased at noon during drought period (often deficient water while pumping). About 69.5 percent of respondents noticed that they have had to change time for pumping water. Water has been pumped in the early morning or the later in the afternoon instead of pumping every time before. As for fish raising, water surface volume was dry in ponds of 100% of surveyed household. Many fish ponds have become drier or water volume is lower.

Box 5.5: "In agricultural production, before 1973, I could dig well around 2m deep. Then I could use water for sweet potato production in summer crop. However, after 1993, in order to have water in holds, I have to dig more than 4m" (convened Mr Tran Van Hai, 89 yeas old, the eighth village).

Source: In - depth interview 2009

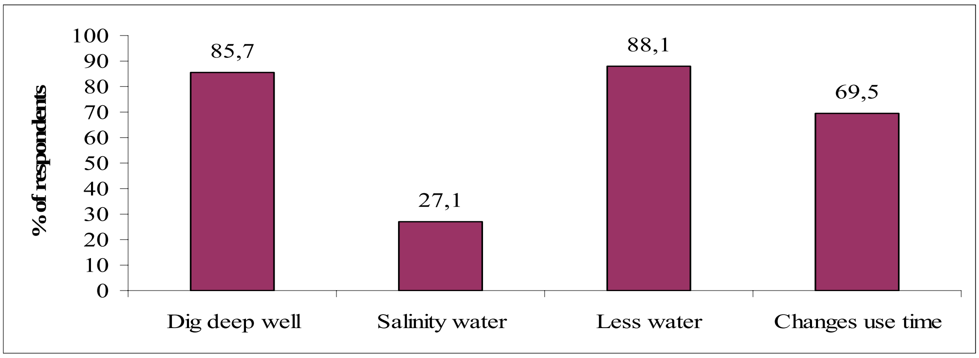


Figure 5.8: Farmers' opinions on impact of drought on water resource (% of respondents answered yes, n=59)

Source: Field survey 2009

Box 5.6: Before 2003, I often pumped water whenever I wanted even at noon. Water volume was free and never deficient. In recent time, I have to store water to take care of pigs but I can not use pump water at noon especially in June. In 2008, drought was so critical, I had to get up at 4 a.m to irrigate crops in the garden, said Mrs Le Hong Yen, the ninth village

Source: In - depth interview 2009

Literature review indicated that drought can increase salinity intrusion for inland areas. In this area, 27.1% of respondents experienced that drought caused salinity intrusion increasing and affected water resource for living and agricultural production. This consequence is consistent to the result of Kundzewicz *et al.*, 2007. The rest of the farm households noticed that drought does not impact on the quality of water resource.

Thus, drought has affected water resource by reducing water volume. Water quality was also affected especially salinity intrusion. Besides, the availability of water resource was also changed even within a day.

5.2.3 Drought impact on crop production in the study area

Crop production in the study area depends largely on natural conditions because there was no irrigation system here. Therefore, pests and diseases, quality of crops product and crop productivity was significantly affected by drought and temperature increasing.

Pests and diseases: Table 5.6 presents farmers' opinions about impacts of drought on pests and diseases and their consequences. According to group discussion and in-depth interview, in the study area, drought has increased pests and diseases in almost all crops except local onion and cassava. *"Local onion and cassava are two crops that have a few pests and diseases during drought period and they also can stand well. Until now, I haven't seen anyone in the commune using pesticides for these crops" - stated of Farmer Union leader.* Table 5.6 presents that pests and diseases appeared and increased during drought period in the study area. However, the impact levels depend on different crops. Up to 67.4% of interviewed households expressed that bean especially green bean were least affected by pests and diseases during drought time because the nature of this crop is disease-tolerant. About 93.2% noticed that sweet potatoes for leaf were the most affected. Sweet potato for leaf is mainly cultivated in summer season with the purposes of using leaves as feed for livestock production. Therefore, almost all farmers did not use pesticide. Cassaba melon was also cultivated in summer season thus about 90.9% of surveyed households noticed the increasing pests and diseases tendency. Moreover, cassaba melon is market crop, farmers used a lot of pesticides to control pests and diseases to keep productivity stable or increase if possible. Pesticides and fungicides had been applied with an increasing rate in the study area because of increasing drought and areas without any water source for watering.

Table 5.6: Farmers' opinions on impact of drought on pest and disease and consequences (% of respondents answered yes)

Crop production	Impact on pests and diseases (%)	Result of pest and disease impacts (%)			
		Increase pesticides	Increase labor	Reduce productivity	No impacts
Rice (n=51)	84.6	9.1	0	90.9	0
Sweet potato (n=59)	93.2	5.6	0	94.4	0
Peanut (n=34)	82.9	17.9	3.6	78.6	0
Bean (n=40)	32.6	20	6.7	73.3	0
Bitter melon (n=37)	86.0	67.6	0	32.4	0
Cassaba melon (n=31)	90.9	10.0	0	83.3	6.7

Source: Field survey 2009

Results from farmers' group discussion show that pests and diseases increased in the study area because of many reasons. However, some pests and diseases increase due to the increasing drought. For rice production, "Kho Van" disease appeared with an increasing rate. Other diseases also appeared, but the intensity and frequency did not change and were similar to other crops, neither did they depend on summer or winter season. Besides, these diseases appeared because of the application of technologies while farmer's experiences in rice production were still low. Worm carving in tree-trunk in sweet potatoes for leaves increased remarkably in summer season because of sweet potato variety.

Consequences of drought increasing impacts on crop production, according to interviewed households, were increasing production cost, labor and reducing crop productivity. Among crops, sweet potatoes were the most affected crop one (see table 5.6).

Bitter melon was cultivated in spring crop and harvested at the beginning of summer crop. During this period, the temperature increased and this created good environment for pests and diseases development. Bitter melon was also a market crop with high economic profit. Thus 67.6% of respondents noticed that they controlled pests and diseases through increasing pesticide uses. For peanut and bean production, farmers applied manual methods to control pests and diseases such as clearing of caterpillars or working with the soil more carefully. In short, drought increasing only increased pesticide application, reduced crop productivity but also increased labor cost.

Crop productivity: Table 5.7 presents impacts of drought on crop productivity in the study area according to farmers' perception. All annual crops are more sensitive to variability in annual precipitation and temperature. It can be seen from the table that sweet potatoes productivity were more severely impacted by drought increasing than others. Sweet potatoes productivity were reduced 35.7% in comparison to spring crop and non-drought year. Thus, all sweet potatoes cultivated in summer crop were only for taking leaves purpose. For peanut, 77.1% of respondents experienced a productivity loss due to drought increasing. Level of peanut productivity loss was the highest among crops with 27.8%. In high temperature and lacking of water conditions, peanut often has “Chet eo” disease. This disease cannot be controlled by any pesticides and one having this disease peanut crop would be extremely low or even no productivity. .

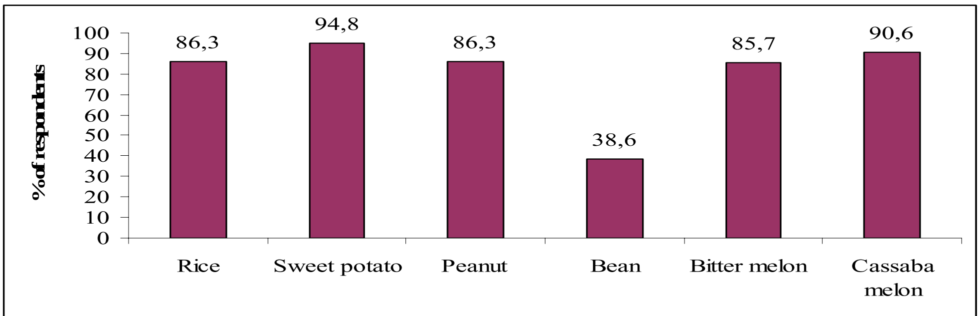
Although bitter melon is cultivated in spring season and is not a drought-tolerant crop, its productivity was only slightly reduced . Because it is cultivated in the garden and farmers have the best adaptation option by watering from wells. Cassava was the least impact by drought because it is a drought-tolerant crop. From table 5.7 also shows that rice, cassava and local onion were drought-tolerant crops. Cassaba melon productivity was also reduced but the level was the lowest. Because farmers applied drought adaptation techniques and it also has high capacity to stand against drought.

Table 5.7: Farmers’ opinions on impact of drought on crops productivity (% of respondents answered yes)

Crop production	Yes	Level of increasing %	Level of decreasing (%)
Rice (n=51)	76.3	-	21.9
Sweet potato (n=59)	91.5	-	35.7
Cassava (n= 14)	31.3	-	19.0
Peanut (n=34)	77.1	-	27.8
Bean (n=40)	56.8	-	25.2
Bitter melon (n=37)	61.9	15.0	18.2
Cassaba melon (n=31)	53.1	10.0	21.9
Local onion (n= 14)	17.6	-	23.3

Source: Field survey2009

Quality of crops product: Increasing temperature and lacking of water influence not only crop productivity but also quality of crops product in the study area. Quality of crops product partly depends on affecting pests and diseases on these crops. Thus, products from local onion and cassava crops were not influenced by drought because drought did not increase pests and diseases in these two crops.



Source: Field survey 2009

Figure 5.9: Farmers’ opinions on impacts of drought on quality of crops product (% of respondents answered yes)

(n rice=51; n sweet potato= 59; n peanut=34; n bean=40; n bitter melon=37; n cassaba melon= 31)

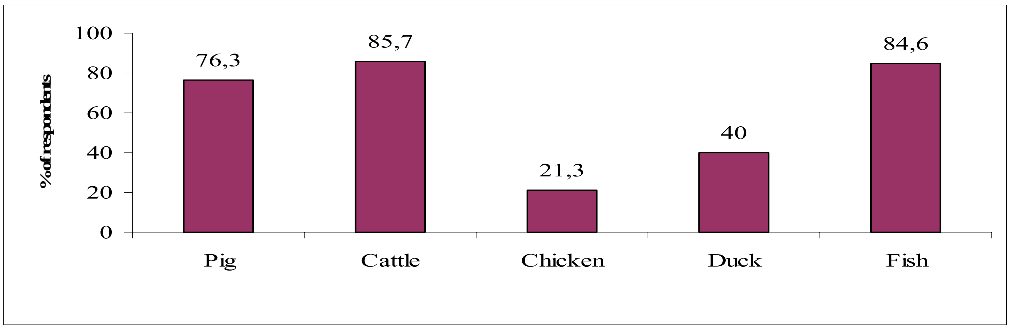
In addition, the results of farmers’ group discussion also showed that the quality of crop products was affected not only in terms of pests and diseases development, but also directly of plants’ growth and development stages. For instance, quality of rice was reduced because of increasing proportion of unfilled grain. Rice seeds were smaller and lighter. For sweet potatoes, worm disease brings about smaller sweet potato root and cassaba melon fruit became less sweet than normal.

5.2.4 Drought impact on livestock and aquaculture production in the study area

House animals and fish in the study area were quite sensitive to climate conditions, especially when the temperature increased and water reduced. According to results of group discussions, drought directly and indirectly influenced the above house animals. While it has some direct impacts such as increasing of diseases, livestock health and scale of production, it also makes some indirect impacts likes reduction in feed resources and production cost increase.

Feed resource: Figure 5.10 presents farmers' perception on impacts of drought increasing on livestock and aquaculture production. However, different livestock were affected differently by drought. Livestock production and fish raising took small scale in the study area. Feed resources were mainly from agricultural by-products and nature grass. Nature grass was the main feed for cattle and fish production. High temperature and lacking of water reduced grass development capacity or even made nature grass drier or died.. Therefore, cattle and fish were the most affected by drought. Pig was the main livestock in the study site whose feed was sweet potatoes' leaves and roots. As shown in table 5.7, sweet potato was the crop the most impacted by drought, which means that feed for pig production was also affected by drought. However, feed for pig production in this area was gradually replaced by industrial feeds. Taking about the industrial feeds, a majority of interviewees pointed out that it reduced labor costs for preparing pig feeds and pigs growth faster than when fed by the traditional feeds. However, increasing production cost was the barrier of feeding by industrial feeds.

There are two kinds of feeding stuffs including forage and grain ingredients. Regarding the forage feed, cattle feed lacked of the greatest amount with 3.6 months; pig production with 3.1 months and then fish production with 2.3 months (see table 5.8 in Appendix). However, the amount of grass for fish raising was not large and local farmers often replaced with sweet potato when grass was scarce. As a consequence, the duration of grass for fish was shorter than that of other animals. Chicken and duck production did not depend much on forage. The main feed was grain ingredient for chicken and fishy-feed for duck. Thus, feed for chicken and duck were generally less impacted by drought.



Source: Field survey 2009

Figure 5.10: Farmers' opinions on impact of drought on feed resource (% of respondents answered yes)

(n pig=59; n cattle=15; n chicken=53; n duck=10 and n fish=22)

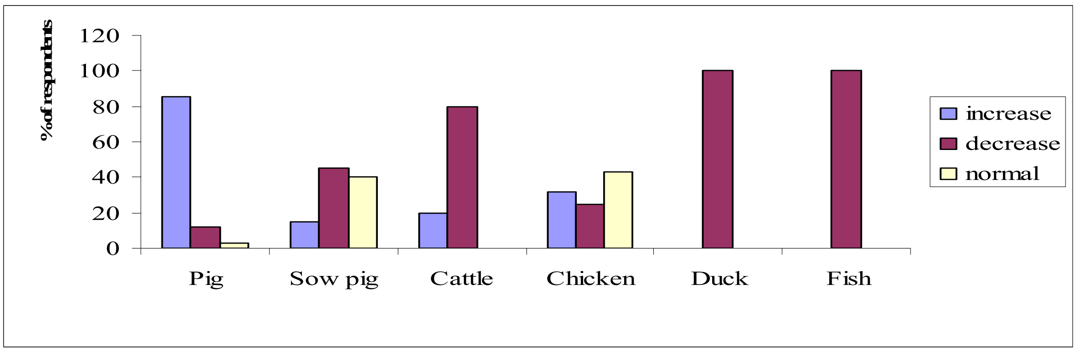
Grain-feed price: Results of farmers' group discussion indicated that the price of grain ingredient in summer season tends to decrease while kinds of grain ingredient are normally more plentiful in comparison with other time within a year in the study site because grains crops are normally harvested at the beginning of summer season and each village had at least one food-service for livestock. Besides, households with large scale production also gave supplies to small scale production. Moreover, it was better for transportation in summer season. Therefore, cost for transportation was lower than that of other seasons. This was the main reason that helps reduce the price of grain feed for livestock production. According to Mr Chu, the head of food-services in the ninth village, “price of grain ingredient in the summer season decreased 10% in comparison with in winter season”. This was main advantage for development livestock production in the summer season.

Livestock health: Results from group discussion and depth interview show that high temperature for a long time and sudden rains were the main reasons of increasing diseases for pigs, poultry and fish. One hundred percent of surveyed households noticed that sudden change in temperature increases livestock diseases, especially “Ga ru” in chicken production and “Bai chan” in duck production. Sudden change in air temperature also leads to water temperature change in fishponds and lakes, which causes fish diseases more seriously. Besides, 100% of respondents expressed that increasing air temperature resulted in increasing water temperature and lowering water level in fishponds and lakes. Thus, fish diseases also increased.

In addition, cattle and pig production were considered by farmers as less sensitive to temperature increase because their cages were suitably designed. However, pig and cattle diseases were also increased due to drought increasing. “Lo mom mong” disease in cattle production, for instance, increased because of taking hot and polluted water and walking on hot sandy land. “Pho thuong han” disease in pig production also rose because farmers commonly watered their pigs in extremely hot conditions. One hundred percent of surveyed household indicated that lacking of fresh water for livestock production was the main reason to increase the probability of having gut disease of livestock.

Livestock productivity: Increasing temperature and lacking of forage and water reduce livestock and fish productivity by decreasing the food intake. Depending on characteristics of different livestock and conditions of fishponds, productivity was affected differently. Figure 5.11 (see Appendix) presents that fish and pig productivity was much influenced by drought with 91.3% and 76.7% of respondents noticed respectively. Chicken and cattle had better development in dry condition than others.

Increasing temperature was considered by farmers to have a suppressing effect on livestock appetite. As a result, the rate of growth of livestock was accordingly affected. However, a majority of farmers in the study area were very experienced in pig and chicken production. Therefore, they could justify techniques in making cages/pigsty and taking care of livestock to adapt to drought increasing (this will be discussed further in later parts). Thus their productivity has an increasing trend. Fish and duck production depend much on water conditions or in other words, water shortage decreased productivity (see figure 5.12)



Source: Field survey 2009

Figure 5.12: Farmers’ opinions on change livestock and fish productivity toward drought (% of respondents answered)

(n pig=59; n cattle=15; n chicken=53; n duck=10 and n fish=22)

Scale of production: Drought had affected on the scale of livestock production and aquaculture in the study area. As discussed earlier, high temperature in summer season, shortage of water for livestock and lowering water in fish ponds resulted in decreasing the number of livestock and area for aquaculture production in summer time.

Box 5.7: Mr Ho Van Nguyen, in the ninth village stated "drought has had impacts on our duck and fish raising. I raised four farrows per year. From July to December, the scale was about 2500 fingerlings/ 250 m^2. However, from January to March, the scale reduced to 2000 fingerlings/ 250 m^2. And from April to July, I only raised about 1000 fingerlings/ 250 m^2 to reduce damage. Simultaneously, I combined with duck production in the fish pond. I kept from 100 to 150 heads per farrow but from April to July, it was only from 40 to 50 heads because the water level in the fish pond was lower and lands extremely hot.

Source: In - depth interview 2009

However, scale of cattle production did not change throughout the year, because cattle were kept over many years. Scale of pig production and chicken production increased in summer season. Pig and chicken do not require much water and farmers can control temperature and heat by their experiences technique measures. Moreover, during drought period, the scale of crop production and aquaculture production reduced. Therefore, farmers can invest more in pig and chicken production.

Box 5.8: Mr Nguyen Ngoc Thien, in the ecological village stated "my family and some others in the village increased pig heads from February to August and then we sold them to avoid flood. I thought that, although drought increases, our area is close to the beach so the atmosphere in later afternoon and early morning is always fresh. Neighbors and I change from old production form to semi-intensive one. Because the price of feed in the summer season is cheaper than in the winter one. Therefore, we can combine industrial feed and by-agricultural products and increase production scale. In the winter season, I only raised 5 pigs and then increased to 10 pigs in the end of the spring season and to 20 pigs in the next two farrows.

Source: In - depth interview 2009

Adjusting cost: One hundred percent of respondents noticed that increasing livestock and fish diseases led to increased production cost. Production cost included cost for electricity, watering and especially cost for veterinary services. Table 5.9 (see in Appendix) presents impacts of drought on investment costs for crop production. Costs for agricultural production were increasing. However, 15.8% of surveyed households noticed that cost for fertilizers is reduced 28.3%. In the study area, farmers increasingly applied manure and phosphate to keep soil moisture and increase the development of crop root and decreasingly applied nitrogenous fertilizers. However, applying manure need more labors working on the field.

In short, drought increasing reduced cultivated area and soil fertility of land; water resources in terms of volume and time for taking water. Crop production was also influenced in terms of increasing diseases and pests in crops, decreasing productivity and quality products of crops. Livestock and aquaculture were influenced especially by irregular rain while drought prolongs. This was the main reason to increase epidemic diseases. Productivity of livestock and fish were also influenced. However, pig productivity was maintained or even increased. The production scale was negatively affected. Fish and duck production was with a decreasing trend while the scale of pig and chicken production was with an increasing one.

5.3 Adaptation options in agricultural production to drought

There are many adaptation options that were found in the study area including (1) using tolerant varieties and breeds, (2) applying integrated production model, (3) adjusting seasonal calendar, (4) farm production practices and livestock management and (5) diversifying non-farm activities (migration and off-farm).

5.3.1 Tolerance of variety and breed to drought

5.3.1.1 Drought-tolerant crop and variety

Using drought-resistant, pest-resistant and disease-resistant crops were main adaptation options to drought and climate variability in agricultural production in the study area. Moreover, these varieties have short growth time. Therefore, farmers can thread seasonal calendar. In the study area, farmers selected and changed crop varieties that can better adapt to the changes of temperature, moisture and other conditions associated with drought. Table 5.10 (see Appendix) presents the percent of surveyed households applied or did not apply drought-tolerant varieties in crop production.

As regard to rice variety, farmers changed variety in 2006. Previously, Rit variety was popular in the commune because it had high capacity to stand against drought and salinity intrusion. However, it had long growth time and low productivity. Both poor and non-poor farmers chose these new rice varieties. In addition, several rice varieties, which well stand against drought and salty conditions, have been introduced on the market such as Khang Dan, HT1 and Mai Lam. These varieties have also high productivity and better quality than Rit but they also need more techniques and investment. Moreover, these varieties have short growing time therefore farmers can cultivate two crops per year (one crop for rice production and other for sweet potato production instead of only sweet potato).

Regarding sweet potato crop, almost all surveyed household applied tolerant drought varieties including Tam Ky, Khoai chia and Khoai moi. These varieties were applied in 1995 starting with some farmer’s experiments. These varieties have high capacity in drought-tolerant, high productivity and short growth time (around three months). There were 98,3% surveyed household applied these varieties

For peanut and green bean varieties, the percentage of households in the study area that applied tolerant variety was lower than those who applied rice and sweet potato varieties. About 88.2 percent surveyed households applied drought-tolerant peanut named Ly Tay Nguyen and L14. The percentage of poor surveyed households who applied it was higher than that of the non-poor surveyed households. The main reason was that most of poor households were supported from World Vision project and government. Besides, poor households also participated in Interest group under the support of World Vision project. Participants in this group were supported with peanut and green bean varieties and participated in training courses. Although non-poor households have better financial capacity than poor households, they had less capacity to access drought-tolerant peanut because these varieties were not much available at the market in the study area.

Other crops were cultivated in the study area including cassava, cassaba melon and local onion. These crops require less water and are suitable with sandy soil. Thus these were main crops in summer season, especially cassaba melon crop.

5.3.1.2 Drought-tolerant breeds

Using tolerant breeds were the common strategy to adapt to climate change especially drought in livestock production in the study area. Local breeds of pig, cattle, chicken, duck and fish were selected as the best options because of their natural characteristics to cope with drought and the demand of market orientation of their products.

Local sow named Mong cai was the main pig breed and 100% of surveyed household applied this breed in the study area. It is the local breed with high capacity adaptation to climate variability. The F1 generation crossed between local breed and Dai Bach breed has very good adaptive capacity to climate change and variability. In addition, this F1 pig grows well, easy to raise and can take advantages of the available food at local. Moreover, this pig was highly accepted by the market. Results from group discussion, in depth interview and surveyed households showed that because of its adaptability capacity and profitability, both poor and non-poor groups applied local breeds and F1 generation.

Local breeds are more suitable with small-scale farming. Therefore, 100% of surveyed households applied local breeds of pigs and also cattle, chickens and ducks. Similarly, aquaculture using tolerant fingerlings was also noticed by farmers. About ninety percent of surveyed households applied drought adaptation option and the percentage of poor households applying was lower than non-poor households. Because poor households have financial barrier to access breed source and they raise fish unprompted. Main freshwater fish breeds in the study area are applied including catfish, African carp and "Chim trang".

Both poor and non-poor have well capacity to apply livestock and fish breeds. These breeds are local breed; therefore, cost of investments are low. Moreover, these breeds are appropriate to local conditions. This consequence is also in line with research of Stigter *et al.,* 2005 and FAO in 2007. Farmers have many experiences in choosing which breeds that can be appropriate for their conditions. However, local farmers have kept these local breeds by themselves. Thus, quality of these breed has reduced while capacity to access purebred has difficulties.

5.3.2 Integrated production model

Combination among livestock production, crop production, aquacultural production and forest has been applied in many regions. This model is called VAC or VACR model. VAC/VACR is an integrated farming system practice. VAC/VACR is an acronym of three or four Vietnamese worlds: Vuon means garden or orchard or cropping system, Ao means fish pond, Chuong means animal sheds or livestock and Rung means forest.
According to literature review which is also consistent with farmers' opinion, applying VAC(R) model is the best adaptation in the study area to drought. Because water from fish pond can support to crop production and it also makes the climate equable. The forest trees provide shading, are used to protect crops from moving and flying sand and also create micro-climate around system. Therefore, farmers applied these models to limit moving sand to their house in strong wind especially Western - Southern wind in summer season. Moreover, these models could also reduce impacts of high temperature on livestock production by forest trees system, cool and fresh air from fish ponds. Besides, the favourable production conditions by the VAC(R) model system could help farmers increase crop intensity and crop productivity.

Therefore, VAC(R) model is not only an adaptation model to drought, but also sustainable model in any conditions through interaction in VAC(R) components.

Box 5.9: Mr. Tran Thanh Diep, the eighth village, has around 10 saos of land for garden which belongs to higher land area compared with other places in the commune. He plants melon and peanut, and uses vegetables as feed source for pigs. Besides that, he digs ponds to use water for irrigating crop and raising pigs. Pigs' manure is used for improving quality of soil. Especially, he suggested that taking soil in high places in his garden to make surface of land relatively lower to keep the moisture for plants.

Source: In - depth interview 2009

There are 42.3 percent of surveyed household applying VAC(R) model in the study area. Mainly, these households were supported by the Ecological Economic Institute (in 1992) and World Vision Organization (1996). Application of this model requires large land area, high initial investment for land preparation, fish ponds establishment and forest planting. It needs large land area because part of land is used for forest cultivation and fish ponds. Almost all of farm households in the study area have large garden land area (see table 4.3). Therefore, they can apply this kind of adaptation. However, the capacity for application of these models depends particularly on conditions of households. In the study area, the rate of poor surveyed households applied VACR model (52.0%) is higher than non-poor surveyed households (48.0%). Because almost all poor surveyed households who applied VACR model belong to VAC project support when they set up VACR system. Most of the investment for VACR components is supported by GO and NGO projects in the first year with fifty to 70% for cost of establishing VACR system. Almost all non-poor surveyed household applied VACR model by themselves.

About 57.7% surveyed households did not apply VACR model. Results from group discussion and in-depth interview showed that the poor households often lack of finance and technology and non-poor households often lack of labour. Therefore, priorities of both government and non-government in supporting farmers to establish VAC(R) models were given to the poor households.

5.3.3 Adjusting seasonal calendar

Arrangement for appropriate seasonal calendar plays a crucial role in adaptation to climate change (Smit and Skinner, 2002). Seasonal calendars for agricultural production were accordingly designed by province and district department of agricultural and rural development. However, each specific area of the commune has to justify for its suitability with the local condition to reduce production risks (mainly land, irrigation system and topography). This was considered by the leaders as the most important factor to limit droughts and floods effects in the study area. Therefore, arrangement for appropriate seasonal calendar for agricultural production was an important adaptation option applied in the study area and it was often earlier than other communes in Trieu Phong district. Farmers in group discussion further explained that because most crop production depended on rain-fed, there was not any irrigation system in the field and large garden. Thus, adjusting seasonal calendar to take full advantages of moisture of soil before rainy season as well as finishing and associating changes in temperature and moisture was an important adaptation option for both poor and non-poor groups. Both poor and non-poor groups also had the same adjustment for their seasonal calendar because these information was propagated through communication means and village meeting.

Box 5.10: Mr Tran Binh Cong, village 8 stated that "I changed rice production seasonal calendar. Before 2005, I cultivated rice from January to June with old rice variety and in 2006, I changed to Khang Dan variety and seasonal calendar started in December instead of January. Secondly, I also changed seasonal calendar of sweet potato. Before 2005, I cultivated one crop per year from January to June, and since 2006, I had cultivated three crops per year: one crop from December to April in lower soil and the second crop from October to the end February in higher soil and the last crop after rice harvesting".

Source: In depth interview 2009

Adjustment seasonal calendar have aims at reducing negative effects of drought on crop production before drought happens, and it was guided by province and district department of agricultural and rural development. Therefore, it is called anticipatory adaptation.

5.3.4 Production techniques and livestock management

5.3.4.1 Crop production techniques

Results from group discussion, in-depth interview and surveyed households showed the various farm-level adaptation techniques applied in the study area to drought (see table 5.11 in Appendix).

Using manure in crop production have been the popular measure in the study area for improving soil, enhancing capacity for keeping water and moderating evaporation in summer season. Both poor and non-poor surveyed households applied manure in crop production. Manure was not a tradable product in the study area. Therefore, farmers could use manure from their livestock or take freely from their neighbors. Moreover, cost for this option was low. However, in the coastal area in general and in the study area in particular, transportation between home and fields and between fields was difficult due to the characteristics of the sandy roads. In addition, manure is quite heavy for farmers to carry to their field. Thus, manure was applied much more in the garden and fields, which are close to farmer's house.

Protection of crops and soil by using crop residue and grass to cover land surface or mulching were main options to retain moisture and organic matters soil in the study area. These options were applied depending on the specific crops. In the study area, mulching practices were applied in three main crops including sweet potatoes intercropping with beans; cassaba melon and bitter melon. Farmers mainly used seaweeds to cover bitter melon roots. Seaweeds not only keep moisture and water but also provide green manure for crop during growth period. Around 91.9 percent of surveyed households covered bitter melon's root at the early development stage. Branches and leaves of forest trees or grass were used to crust soils in cassaba melon. The most important aim of this measure was to reduce heat from sandy land to sprigs and fruits. Through group discussion with experienced farmers and in depth interview, it was noticed that farmers used branch of *casuarina equisetifolia* or grass instead of Cajuput branches because it decreased soil quality. The percentage of surveyed household who applied this was about 58.0%. The rest of surveyed households did not apply because they did not have enough time and labor. The percentage of poor surveyed households applying was more than that of non-poor households, because the non-poor households had financial capacity to buy more water pump for watering crops instead of applying this measure. Mulching was applied in sweet potato intercropping with bean. Therefore, sweet potato and bean could cover each other. Farmers often combined weeding with ridging beds and these grasses were used for mulching. Results of group discussion and household interviewing also indicated that a majority of non-poor households had more capacity to implement this measure because they had more financial capacity to hire labor. Farmers' opinion from group discussion noticed that these mulching measures were estimated to be economically efficient for crops. Because the cost was low; technique was simple and they took full advantages of using available materials for mulching in the local area. However, these required a lot of labors.

The most commonly used adaptation techniques in the study area were changes in cropping patterns. The adaptation measures include changing calendars and patterns. There were some rotation crop patterns: rice- sweet potato- rice; rice- cassaba melon - rice; peanut - local onion - peanut; and sweet potato - cassaba melon - peanut. Depending on particular household conditions, farmers adjusted patterns to be suitable to their conditions. This measure is applied to reduce soil degeneration, pest and diseases and take full advantages of previous crops including fertilizers, moisture and saving time to work with soil. Poor households had more conditions to access these techniques because they participated in many training courses funded by World Vision Organization. The non-poor households also accessed these techniques because they learn from each other through farming practices, village meeting and sharing among households. Crop diversification, mixed cropping, relaying crop were also applied in the study area. One hundred percent of surveyed households applied these techniques including both poor and non-poor groups because these techniques were popular and suitable for local farmer's conditions in the study area and local farmers have much experience to adjust and structure as well as arrange crop in their farming system.

Land preparation technique was also an adaptation option to drought in the study area. Designing beds for sweet potato intercropping with bean, beds for cassaba melon were critically important for adapting to drought. Beds were designed larger and lower than before.

Big beds can keep moisture better and low beds can moderate impacts of heavy wind (southern - western wind). This technique was applied by all surveyed households because it is easy and traditional.

Changes in management practices including altering the amount or type of inputs such as fertilizers and pesticides were applied in the study area as adaptation options to drought. There were some tactical responses of managerial adjustment such as reducing or increasing inputs such as fertilizers or pesticides on crops suffering from moisture stress (see table 5.12 in Appendix). Both poor and non-poor of surveyed households applied these options. Farmers adjusting fertilizers, using growth fertilizers and pesticides were different among crops. Pesticides were used to control pests, weeds and disease damages. The percentage of non-poor surveyed households applied this method was higher than that of the poor households because of their higher financial capacity. Mainly changes in management practices in non-poor group included an increasing trend in phosphate and potassium fertilizers and pesticides and reducing nitrogen fertilizers.

5.3.4.2 Livestock management

Many options applied to manage livestock to drought included changing infrastructure of mainly pig, cattle and chicken shelters; applying new techniques or equipment, altering the amount or type feed in the study area (see table 5.13 in Appendix)

Building appropriate breeding facilities in pig and cattle cages as well as improving shelter for chicken and duck were the main adaptation options in livestock production in the study area. In order to moderate impacts of high temperature and Southern - Western wind in the summer season, farmers designed pig cages with high and comfortable foundation and high roof to prevent heat. About 54.2 percent of surveyed households applied this option. The percentage of poor surveyed households was lower than non- poor because the poor group often has difficulty especially finances when applying this measure. Cattle shelters were designed simpler with lower cost thanks to using available local materials. Poultry was kept with small scale and mainly for home consumption. Therefore, farmers often used pig and cattle shelters or perennial trees to make shelters for chicken and duck. Beside that, farmers used branches of forest trees, residue of cucurbits in spring or designing perennial trees to shade shelters or cover the roof. This measure uses available material sources, had low cost and was easy to implement.

Utilizing available feed source and supplementary feed were the main adaptation options to increase livestock productivity since pig production was interested by many farmers and was the main livestock in the study area, farmers had an increasing tendency in investment in grain-feed. Price of grain-feed in the summer season was shown to be cheaper than that of others. Other animals were also supplemented by available local feed sources. Costs for these feed were low and easy to find. The percentage of non-poor surveyed households applied was much higher than that of poor surveyed households. Poor households often lack of credit or savings to buy feed as well as lack of application knowledge.

Management of livestock production were applied to reduce impacts of drought. These measures are simple but they play important roles in enhancing adaptive capacity of livestock and reducing impacts of diseases and high temperature. Most surveyed household applied these options because they were easy and had low cost. Using water from water pumps to bathe pigs was the main technique to create artificial environmental (reduce heat) for pig production. In addition, it was considered the most economical option which was easy to implement. Besides, farmers also vaccinated animals to control livestock diseases. 88.9% surveyed households applied this adaptation option. Vaccination program was propagandized broadly, became popular through extension, and veterinary. Besides, farmers had high awareness of applying vaccination. As this option increased production cost, the percentage applied of non-poor group was higher than that of poor group.

Moreover, farmers applied adaptation options for fish raising including reducing scale of raising, floating water-fern in surface, adding more water in the fish pond and adjusting fish feed. These options were simple with low cost, thus both poor and non-poor applied to moderate damage when drought happens.

Many adaptation options in agricultural techniques for drought have already been applied in the study area. Most available options take full advantage of the general flexibility of agricultural systems. It is likely that autonomous adaptation by farmers. However, some farmers faced economic, technologies and labor constraints. In such cases, autonomous adjustments may not be implemented in time because of lacking of these conditions. Thus anticipatory planned adaptation would be required to provide the right conditions to farmers for autonomous adjustment.

5.3.5 Finding alternative livelihood to drought period

Based on results of group discussion, in-depth interview and household interviewed, off-farm activities were the main options to increase income during drought period in the study area. Off-farm activities included collecting scrap, small business within commune and picking coffee, bricklayers and carpenters outside the commune. Besides, a majority of young labor including male and female migrated to big cities to find jobs and their remittances have supported to farm production activities.

About 81.3 percent of surveyed households had sub-jobs and they carried out these works whenever climate conditions are not appropriate for agricultural production. The rate of poor and non-poor surveyed households having sub-jobs occupied 47.9% and 52.1% respectively. The number of average labor was 1.3 labors per households. However, the rate of male labor was higher than that of female labor. Results from group discussion and household interviewing noticed that male labors often had high education and wider relationship compared to female ones. Besides, female labors often stayed at home to do farm activities especially livestock production and garden works.

Migration to other places for jobs was the main option of local people in the study area to adapt to drought. Time to conduct these jobs often happened simultaneously to drought period. Around 62.5% surveyed households had seasonal migration during drought period. Drought period in Trieu Van commune coincided with time for picking coffee and construction activities in other regions. Moreover, in summer seasons, agricultural production activities were decreased or even stopped because of drought increasing. Therefore, leisure after harvest time was much higher in comparison with other times within the year.

Alternative livelihood in Trieu Van had been applied in the past but it was strongly developed since 1993 when drought trends have started to increase, stated by Leader of Farmer Union. After harvesting Spring - Winter crop, livelihood of local people returned to the sub-jobs as their main livelihood when agricultural production could not continue due to drought. At the beginning, local farmers were spontaneous. Nevertheless, these farmers later coordinated into groups such as picking coffee group (the eighth village), collecting scrap group (the ninth village) and bricklayer group. Hence, if this adaptation was considered autonomous adaptation type, after groups had been established, it was considered as planned adaptation type.

5.4 Analysis of adaptive capacity of local community to drought

5.4.1 Obstacles in drought adaptation in Trieu Van commune

There were many obstacles for applying adaptation measures to drought in the study area. These were land resource problem, infrastructure, finances, access to extension service and transferring technology of agricultural staff and policies supporting. The most widely recognized obstacles were analyzed in detail. Moreover, these obstacles reduced adaptive capacity of farmers to drought.

Land resource problems: In the province as well as the study area, the critical problem of land resources was soil erosion and land degradation. Soil erosion by wind and water caused serious problems for farmers not only in the study area but also in the surrounding coastal ones. As mentioned before, the white sand occupies 100% of total the commune. With the characteristics of big soil particles and loose structure, agricultural production in this area was subject to both wind and water erosion. Wind erosion is usually from March to August. This time drought also occurs.

Infrastructure: (1) Irrigation system has an important role in agricultural production. However, in the study area, there are not any irrigation systems. Agricultural production depended heavily on rain. This was the main difficulty that impacts on agricultural production in the summer season and reduced adaptive capacity of local people to drought. (2) All households in the study area can access electricity for daily activities. However, electricity for production in the field was limited. Therefore, electricity could only support for watering in a part of the garden.

Finance: Poverty and lack of financial resources were one of the main constraints to adjustment to drought in the study area. In Trieu Van, the study found that despite numerous adaptation options that farmers were aware of and willingly to apply, lack of sufficient financial resource to purchase and invest in the necessary inputs and other associated equipment (eg., purchasing seeds, feeds or building pig cage) were significant constraints to adaptation. In the study area, 100% of poor surveyed households did not apply some costly adaptation options. Therefore, lacking of financial resources for initial investments would limit the implementation of the measures. Cooper *et al.,* 2008 indicated that poor households often face difficulties and constraints in agricultural production related to varying climate, as compared to other households. This means adaptive capacity and reinvestment in production is limited. In the study area, the percent of poor households occupied 33.3%, therefore, the adaptive capacity of local people to drought was limited.

Box 5.11: In recent years, drought has increased and I knew many options to adapt to drought. Using water for creating artificial environment to reduce heat considered the efficiency option. However, I could not apply this adaptation option when temperature increased and Southern - Western blew strongly. Because our cage for pig production was poor and foundation of pig sty was earth. Cost for building cement sty was high (around 7-10 million), my family's financial capacity was not enough. Besides, I also knew knowledge and information from training courses as supplement feed and mineral for pigs during drought time. However, I din't have enough money to do that" according to Mr Ho Anh Quang, 58 year olds, the ninth village.

Source: In - depth interviewed 2009

Access to extension service and transfer of technology of agricultural staff: Access to extension service and transfer technology of agricultural staff has significantly increased the probability of taking up adaptation options. However, in the study area, there were no extension workers, and farmers could not access to extension service including both private and public service. Farmers only accessed to information on plant protection techniques from private sector but this information was sometime un-useful or inappropriate. Besides, the ways to transfer technology of agricultural staff were only without practicing and short time. This led to many difficulties for farmers in the study area to adapt to new techniques especially applying mineral fertilizers for crops. Other example was that conventional techniques as crop rotation and relaying crops were old techniques by farmers here. However, for farmers in the study area, crop rotation between cassava and peanut or bean relaying have not been applied yet. One hundred percent of surveyed farmers indicated that they just hear these techniques and learnt from training courses but to practice them still involved many difficulties.

Supporting policies: Policies of district and commune insisted on intensive farming, both for crop and livestock production. In the study area, the commune development strategy and priority policy was intensive sweet potato farming and development following commodity production. However, intensive and mono farming in the poor conditions often faced many risks in production as well as livelihood especially in climate change situation. Trieu Van commune had faced many difficulties in crop and livestock production. Therefore, if intensive farming policies were applied, farmers in the study area may encounter risks.

5.4.2 Advantages of adaptation to drought

Besides many constraints of household and community in adaptation options to drought, in the study area, there were some advantages and potentials to enhance adaptive capacity of local people to drought. Natural resources, policies supporting, non-government organizations, farming experiences, forest planting development and potential livestock production development were pointed out by farmers and commune leaders.

Natural resource: The natural area land of the study area is quite large in comparison to the total population. There were 139.02 ha unused in 2009. This is the potential land area for agricultural production if the irrigation systems exit. Trieu Van has a long coast, (7.5km) therefore community has capacity for tourist development in summer season (when drought happens). This strategy was mentioned in the plan for social-economic development of the commune. If the tourist services are developed, there would be many alternative livelihoods for farmers in the summer season. This would offer many opportunities to take up adaptation options. Offshore fishing source was also operated in the summer season. This is considered as an important alternative income when drought happens. At present, in the seventh village, many people participated in fishing activities and their income were relative stable in the summer season (according to leader of the seventh village). Besides, the study area had developed shrimp production from unused sandy areas or low productivity areas. This was big potential resource in creating other jobs for local people. There was 29 ha that were used for shrimp production. Thirty ha will be used in next three years. However, shrimp production has faced many risks if producers do not consider carefully in the changing of climatic conditions especially sea level rise.

Policies supporting: Drought has been affected resources and livelihood of people in Trieu Van commune and is increasing threat to them. Supporting from Ecological Economic Institute in 1992, the ecological village was established with 34 households. This ecological village has developed basing on development of VACR model. Moreover, this model was the best model that can adapt well to drought in the study area. Besides, in order to improve as well as enhance adaptive capacity of local people to drought and take full advantages of the large land resource, "stretched out population" policy was carried out in 2005. This policy supported finance to improving production activities and constructing infrastructure. In addition, farmers in this village participated in training courses in agricultural production. Other policy was policy for creating employment through out-migration in 2004. The government supported finance and guidance for implementation. The remittances from these labors were an important source to increase adaptive capacity to drought and other problems in the study area. Credit policy was carried out in 1996. This policy supported finance for local people especially poor people for production development. Together with above supporting policies, numerous programs related to climate change and adaptation have been carried out in Quang Tri province in general and in Trieu Van in particular such as the National Target Program in “To Respond To Climate Change” They not only supported and increased adaptive capacity of local people but also created many chances for local people.

Non-government organizations: In the study area, numerous projects have been implemented. These projects have increased adaptive capacity to drought and reduction of drought impacts. The most important organization to support local people in many aspects has been World Vision. In order to sustain the ecological model that had been built by Ecological Economic Institute, in 1994, World Vision continued supporting to develop VACR model at the ecological village and other village in Trieu Van commune. Moreover, this organization also supported micro-credit for female poor in production and enhance their capacity through “Interest association”. People who participate in this association could get support with credit, crop varieties and livestock breed. Besides, they could also attend many training courses in agricultural production as technique in crop production, livestock production and fish raising. Therefore, local people could increase their adaptive capacity and awareness to drought. In 2009, CRD and CtC organizations have carried out many activities to enhance adaptive capacity to climate change for local people in the study area. Capacity building in climate change for people and staff in different levels, HCVA, identifying model to drought, salinity intrusion and land degradation were implemented.

Farming experience: Farmers in the study area have numerous experiences in agricultural production as information and knowledge on changes in climatic conditions and crop and livestock management practices. Literature review indicated that if experienced farmers had many skills in farming techniques and production management, they would have high capacity to adapt to climate change and promoting appropriate adaptation options. In the study area, most farmers had long farming experience (around 27.8 years) and much experiences in drought forecasts based on indigenous knowledge. Moreover, they have also drawn out many lessons in adaptation options to drought. These were advantages to help farmers who made appropriate production decisions to drought.

Box 5.12: Some experiences in drought forecasts were synthesized from group discussion and in-depth interview:
- Corona around the moon, there will be a drought year; Halo around the moon, rain soon.
- Dragonfly flies high, sunny sky; Flies low, rain; Flies neither high nor low, cloudy sky
- The before bissextile, there will be a drought year
- Closing the coast hear murmur (especially in the evening), there will be heavily drought in the next month
- Overlooking the sea has mountain-shaped cloudy, the top of cloudy has red color, there will be drought in the next time
- Ant crawls from high to low, there will be a drought year
- “Co ong” grass has little internodes, there will be a drought year

There were many lesson leant from local people to drought in the study area:
- Planting forest can protect their house and garden but also improve land and create micro-climatic conditions for agricultural production especially acacia and casuarina
- Applying VACR model
- Carrying out adaptation options have to combine multi-disciplines to increase success and reduce risks
- Applying soil conservation to keep moisture and improve soil quality through using manure and NPK fertilizer are very important adaptation options to drought in the study area
- In the drought period, farmers increase pig and chicken production to take all advantages from the local

Source: Group discussion and in - depth interview 2009

Forest planting: Planting forest not only mitigates drought impacts through reducing soil erosion risks due to heavy wind but also reduces sand moving and flying. According to commune leaders, the rate of moving and flying sand has been reduced around 80%. The total area covered was 44% and annual forest area has extended and replanted through Forestry Development Program of government and non-government organizations including VIE96 program; Norway program and East-West co-operation. According to Mr Le Van Don, the eighth village, "People here considered trees as iron, steel and cement to build foundation against drought. Trees were irrigation systems for all crops in the field and the garden". Therefore, this was the potential adaptation of community and local farmers to drought in the present as well as in the future.

Livestock development potentiality: By-products from agricultural production, processing and vegetable (sweet potatoes) were relative plentiful for pig production in the study area. This could reduce input costs and improving economic efficiency in pig production. Pig and sow breed always were available at local area. Therefore, farmers could take the initiative in breed source and limit epidemic diseases from other area. Local chicken can be potential development in the study area. Besides, the price of these products was high and it has high adaptive capacity to drought. In addition, local chicken was the most easy sold products and normally with high price. Therefore, local chicken and pig production were the main livelihood income source for local people to develop in the future and increasing income for farmers in drought period.

6 CONCLUSIONS

Over the 33 years examined (1976 to 2008), temperature statistically showed an increased trend while precipitation was characterized by large inter-annual variability and a decreased amount during summer. The decreasing trend of precipitation was found in June and September while it increased in December. These trends were confirmed by local perceptions, found from qualitative study.

Farmers perceived that the weather was getting warmer and drier with increased frequency and intensity of droughts especially in recent five years. Three main reasons were mentioned as that lead to increase drought, are (1) the increasing temperature, (2) the impacts of Southern-Western wind and (3) the decreasing precipitation in dry season.

There were sufficient evidences to conclude that land and water resources were influenced by drought. Agricultural land was reduced between spring and summer season (93.2% of respondents). Furthermore, soil quality degraded and water volume for agricultural production reduced (88.1% of respondents).

Crops pests and diseases were increasing during drought period and influenced different crops at different levels. For example, sweet potato, cassaba melon and bitter melon were most affected by pests and diseases, but local onion and cassava were influenced less. Consequences of increasing pests and diseases were increasing pesticides, laboring and decreasing crops productivity as well as quality of all crops products.

Green-feed for livestock and fish became scarce because of decreasing productivity of crops and nature grass. However, feed for duck and chicken production were less influenced by drought. Besides, livestock and fish production were affected by increasing diseases. The sudden change of temperature was the main cause. The factors mentioned above led to the decrease of livestock productivity. Production scale of duck and fish were reduced by drought.

The expenditures for crop, livestock and fish production increased in order to maintain and continue farm activities due to the changes. The main increased expenditures encompass fertilizers, pesticides, electricity and labor. These costs increased about 14.1% to 30.2% in comparison to years without drought.

Important adaptation options being used by farmers are: Applying different drought-tolerant crops varieties and local breeds; applying integrated production models as VAC and VACR model, intercropping bean and sweet potato, rotational cultivation and diversifying crops and animals in the farm; obtaining alternative livelihood options and/or migrating to other places for earning living during drought period; adjusting seasonal calendar and scale of livestock production; applying soil management measures including (i) covering root plant in the early crop, (ii) crusting soil surface in growth period and (iii) ridging bed combination with covering in growth period; improving livestock management techniques including designing animal shelters, using equipment to reduce heat, altering the amount or type feed, supplementary feed and water, injecting vaccine, changing time for grazing schedule; and adjusting farming inputs including fertilizers, pesticides and feed sources. The causes of farmers applying adaptation options were not only adapting to drought but also for ensuring food security and meeting market demand. Most of the above adaptation options had been developed by farmers' experiences and they autonomously adopted for improving agriculture production outcomes. Few adaptation strategies were anticipatory or planned by the government such as adjustment of seasonal calendar and changing of cropping patterns. For autonomous adaptation, in many cases, the better off households adapted more than the poor.

Adaptation options are applied in the study area not only because of drought reason but also other ones. Change varieties either enhance adaptive capacity to drought or ensure food security. As regard livestock breed, farmers use local breed both adapting to drought and appropriate to market demand. Other adaptation options associated to techniques measures are applied to increase adaptive capacity of mixed-farming system to drought.

There were many barriers for scaling up adaptation measures in the study area. They are: land resource quality and quantity, no irrigation systems and electricity system in the field, lack of finance, lack of access to extension service and transfer technology of agricultural staff and policies supporting. Particularly, lacking of credit, accessing seed input and without irrigation system were identified by farmers as important constraints for most farmers. Beside constraints of household and community in adaptation options to drought, in the study area, there are advantages and potentials to enhance adaptive capacity of local people to drought including natural resource, policies supporting, non-government organizations, farming experiences, forest planting and potential livestock production development.

In order to enhance adaptation capacity of the local people in drought seriously increasing condition, several issues were suggested by local government and farmers: (1) applying new varieties which can stand drought, (2) building irrigation system, (3) investing in pig raising, (4) investing in catching aquaculture offshore, (5) building credit network to satisfy production activities and (6) improving and developing VACR model.

The important message from this research to Provincial Target Program (i) in the context of climate change, it is important to document all effective adaptation options that farmers have applied in the study area to disseminate to others. (ii) Authorities at different levels should formulate sound policies that can strengthen capacity of all local people, especially the poor to adapt to climate change in general drought in particular. (iii) Promote anticipatory/ planned adaptation for farmers through integrating climate change issues into Agricultural and Social - Economic Plans of all levels.

In addition, appropriate policies and mechanisms need to be developed for this purpose. The policies and mechanisms have to balance among economic, society and environment aspects. Policies for setting up animal breeding and crop varieties zone providing high tolerant breeds and varieties to drought are the first priority in adaptation policies in agricultural production. Policies should encourage applying sustainable integrated, developing tree systems around farming systems, diversifying crops and livestock model especially in the coastal area.

REFERENCES

[1] www.vcn.vnn.vn

[2] http://www.profeed.vn/index.php?option=com_content&task=view&id=3697&Itenmid=63

Adams, R., Hurd, B., Lenhart, S. & Leary, N. (1998). Effects of global climate change on agriculture: an interpretative review. *Climate Research* 11(1), 19–30.

ADB (2008). Climate Change Adaptation Options and Practices. In: *A Regional Review of the Economics of Climate Change in Southeast Asia.* Pasig: Asia Bank Development.

ADB (2009). *The Economics of Climate Change in Southeast Asia: A Regional Review*. Mandaluyong: Asian Development Bank. ISBN

Adejuwon, S. (2004). Impacts of climate variability and climate change on crop yield in Nigeria. In: *Proceedings of The stakeholder's workshop on assessment of impact and adaptation to climate change (AIACC)*, Obafemi Awolowo university, Ile - Ife, 20-21.

Adger, N.W. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27(2), 249-269.

ADPC (2003). *Climate change and development in Vietnam: Agriculture and adaptation for the Mekong Delta region*. Bangkok: Asian Disaster Preparedness Centre. ISBN

Arnell, N. (1999). Climate change and global water resources. *Global Environmental Change* 9, 31-49.

Barry, B., Ernesto, F.V. & ArgentinaAuthor, C. (undated). *Rangeland and Livestock*. Fort Collins, Colorado, USA.: Ecosystems Research International. ISBN

Beets, W.C. (1988). *Raising and sustaining productivity of smallholder farming systems in the tropic*. A.Bc. Box G.C Alkansas.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Elasha, B.O., Tabo, R. & Yanda, P. (2007). Africa. In: Parry, M.*, et al.* (Eds.) *IPCC (2007) Impacts, adaptations and vulnerability - Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK. pp. 435-460.

Bradshaw, B., Dolan, H. & Smit, B. (2004). Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. *Climatic Change* 67(1), 119-141.

Brooks, N. (2006). Climate change, drought and pastoralism in the Sahel. In: *Proceedings of Conference of the Parties to the United Nations Framework Convention on Climate Change*, Nairobi.

Brooks, N. & Adger, W.N. (2005). Assessing and enhancing adaptive capacity. In: *Adaptation Policy Frameworks for Climate Change.* New York: Cambridge University Press. pp. 167-180.

Burton, I., Feenstra, J.F., Smith, J.B. & Tol, R.S. (1998). Introduction. In: Feenstra, J.F.*, et al.* (Eds.) *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies.* Amsterdam: Institute for Environmental Studies

Burton, I. & Lim, B. (2005). Achieving adequate adaptation in agriculture. *Climate change* 70, 191-200.

Capili, E., Ibay, A. & Villarin, J. (2005). Climate change impacts and adaptation on Philippine coasts. In: *Proceedings of The International Oceans 2005*, Washington DC pp. 1-8.

Carter, T.R., Parry, M.L., Harasawa, H. & Nishioka, S. (1994). *IPCC Technical guidelines for Assessing Climate change Impacts and Adaptation*. University College - London: World Meteorological Organization and United Nations Environment - Department of Geography. ISBN

Carvajal, L. (2007). *Impacts of Climate Change on Human Development*. United Nations Development Programme. (Human Development Report ISBN

Cooper, P.J.M., Dimes, J., Rao, K.P.C. & Shapiro, B. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculutre, Ecosystems and Environment* 126, 24-35.

Cruz, R.V., Harasawa, H., Lal, M. & Wus, S. (2007). Asia. In: Parry, M.*, et al.* (Eds.) *IPCC (2007) Impacts, adaptations and vulnerability - Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK: Intergovernmental Panel on Climate Change. pp. 469-506.

Cuculeanu, V., Marica, A. & Simota, C. (1999). Climate change impact on agricultural crops and adaptation options in Romania. *Climate Research* 12, 153-160.

Chaudhry, P. & Ruysschaert, G. (2007). Climate Change and Human Development in Viet Nam. *Human Development Report* 46, 1-18.

Chen, Z., S.Grasby & K.Osadetz, a. (2004). Relation between climate variability and groundwater levels in the upper carbonate aquifer, southern Manitoba,. *Climatic Change* 290(43-63)

Dharmaji, B.R. & Huy, L.Q. (2008). Mainstreaming Climate change and development - Key intervention areas for IFAD in Vietnam

Dixon, J., Gulliver, A. & Gibbon, D. (2001). *Farming systems and poverty - Improving farmers' livelihoods in a changing world*. Rome and Washington DC: FAO and World Bank.

Dolan, A., Smit, B., Skinner, M., Bradshaw, B. & Bryant, C. (2001). Adaptation to climate change in agriculture: evaluation of options. *Occasional Paper* 26
Dow, K. & Downing, T. (2007). *The atlas of climate change*. University of California Press.
Ellis, F. (2000). *Rural livelihoods and diversity in Developing countries*. New York: Oxford university press.
Fankhauser, S., Smith, J. & Tol, R. (1999). Weathering climate change: some simple rules to guide adaptation decisions. *Ecological Economics* 30(1), 67-78.
FAO (2004). Food insecurity and Vulnerability in Vietnam: Profiles of four vulnerable groups
FAO (2007). *Adaptation to climate change in agriculture, forestry and fisheries:Perspective, framework and priorities*. Rome: Food and Agriculture Organization of the United Nations. ISBN
Ficke, A.A., Myrick, C.A. & Hasen, L.J. (2005). *Potential impacts of global climate change on freshwater fisheries*. Gland, Switzerland: World Wide Fund for Nature.
Fischer, G., Shah, M. & Velthuizen, H.v. (2002). *Climate change and agricultural vulnerability*. Johannesburg: International Institute for Applied Systems Analysis. (World Summit on Sustainable Development ISBN
Füssel, H. (2007). Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability science* 2(2), 265-275.
Gorforth, C.J. (2008). Impacts on livelihoods. In: Rowlinson, P*., et al.* (Eds.) *Proceedings of Livestock and global climate change*, Hammamet, Tunisia pp. 25-26.
Gill, G., Farrington, J., Anderson, E., Luttrell, C., Conway, T., Saxena, N. & Slater, R. (2003). Food Security and the Millennium Development Goal on Hunger in Asia. *London: Overseas Development Institute*
Hall, A. (2004). Breeding for adaptation to drought and heat in cowpea. *European journal of agronomy* 21(4), 447-454.
Handisyde, N., Ross, L., Badjeck, M. & Allison, E. (2006). *The Effects of Climate change on World Aquaculture: A global perspective*. Department for International developmet (DFID). ISBN
Hansen, J. (2006). The threat to the planet. *New York Review of Books* 53(12), 12.
Hoofmann, I. (2008). Livestock genetic diversity and climate change adaptation In: Rowlinson, P*., et al.* (Eds.) *Proceedings of Livestock and global climate change*, Hammamet, Tunisia pp. 76-80.
Howden, S., Soussana, J., Tubiello, F., Chhetri, N., Dunlop, M. & Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences* 104(50), 19691.
International Insitutide for Environmental Development (2008). Cliamte change and Drylands. Commission Climate change and Development.
IPCC (2001). *Climate change 2001: Impacts, adaptation and vulnerability - Intergovernmental Panel on Climate change*
Cambridge, UK: Cambridge University Press.
IPCC (2007). *Climate change 2007: Impacts, adaptations and vulnerability - Introduction Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.
ISDR (2008). Climate change and disaster risk reduction. *International strategy for disaster reduction.* Geneva: United Nation International strategy for Disaster reduction.
Kelein, R.J.T. & Maciver, D.C. (1999). Adaptation to climate variability and change: methodological issues. *Mitigation and Adaptation Strategies for Global Change* 4(3), 189-198.
Klein, R.J.T. & Tol, R.S.J. (1997). Adaptation to Climate Change: Options and Technologies An Overview Paper. Bonn, Germany: United Nations Framework Convention on Climate Change.
Kundzewicz, Z.W., Mata, L.J., Arnell, N., Döll, P., Kabat, P., Jiménez, B., Miller, K., Oki, T., Sen, Z. & Shiklomanov, I. (2007). *Freshwater resources and their management*. (*Climate Change 2007, Impacts, Adaptation, and Vulnerability. Report of the Intergovernmental Panel on Climate Change* ISBN
McLeman, R. & Smit, B. (2006). Migration as an Adaptation to Climate Change. *Climatic Change* 76(1), 31-53.
Mokhtari, M.H. (2005). *Agricultural drought impact assessment using remote sensing.* Diss. Enschede, Netherlands.
MONRE (2003). Viet Nam Initial National Communication - Under the United Nations Framework Convention on Climate Change In: Ministry of Natural Resources and Environment Vietnam (Ed.) Hanoi: Ministry of Natural Resources and Environment
MONRE (2008). NATIONAL TARGET PROGRAM TO RESPOND TO CLIMATE CHANGE (Implementing the Governmnt's Resolution No. 60/2007/NQ-CP dated 3rd December 2007) In: Ministry of Natural Resources and environment (Ed.) Hanoi: Ministry of Natural Resources and environment
MONRE (2009a). Climate change Scenario in Vietnam - Sea Level Rise (Kịch bản biến đổi khí hậu - mực nước biển dâng cho Việt Nam). In: Ministry of Natural Resources and environment (Ed.) Hanoi: Ministry of Natural Resources and environment

MONRE (2009b). Climate change Scenario in Vietnam - Temperature Rise (Kịch bản biến đổi khí hậu - nhiệt độ tăng cho Việt Nam). In: Ministry of Natural Resources and environment (Ed.) Hanoi: Ministry of Natural Resources and environment

Natural Disaster Mittigation Partnership (2007). *Checking and Joining Disaster Management in Social-Economic Development Plan in Vietnam Report (Báo cáo kết quả nghiên cứu rà soát lồng ghép quản lý thiên tai vào lập kế hoạch phát triển kinh tế xã hội ở Việt Nam)*. Hanoi: Natural Disaster Mittigation Partnership (NDM-P). ISBN

Nelson, G.C. (2009). Overview. In: Nelson, G.C. (Ed.) *Agriculture and climate change: An Agenda for Negotiation in Copenhagen.*International Food Policy Research Insititute.

Nicholls, N. (2007). *Detecting, understanding and attributing climate change*. the Australian Greenhouse Office, Department of the Environment and Water Resources.

Nyong, A. (2008). *Climate Change, Agriculture and Trade: Implications for Sustainable Development*. Barcelona: International Cetre for Trade and sustainable development (ICTSD). ISBN

Nhemachena, C. & Hassan, R. (2007). *Micro-level analysis of farmers' adaptation to climate change in Southern Africa*. Washington, DC: Environment and production technology devision. ISBN

O'Brien, G., O'Keefe, P., Rose, J. & Wisner, B. (2006). Climate change and disaster management. *Disasters* 30(1), 64-80.

OXFAM (2008). *Vietnam Climate change, Adaptation and Poor people*. Hanoi: Oxfam in Viet Nam and Oxfam International, Oxfam International Secretariat. ISBN

Oyekale, A. & Ibadan, N. (2009). Climatic variability and its impacts on agricultural income and households' welfare in Southern and Northern Nigeria. In: *Proceedings of* pp. 322004.

Panu, U.S. & Sharma, T.C. (2002). Challenges in drought research: some perspectives and future directions. *Hydrological Sciences* 47(Towards Integrated Water Resources Management for Sustainable Development), 19-30.

Parry, M.A.J., Flexas, J. & Medrano, H. (2005). Propects for crop production under drought: research priorities and future directions. *Annals of Applied Biology* 147, 211-216.

Pelling, M. & High, C. (2005). Understanding adaptation: what can social capital offer assessments of adaptive capacity? *Global Environmental Change* 15(4), 308-319.

Prabhakar, S.V.R.K. & Shaw, R. (2008). Climate change adaptation implications for drought risk mitigation: a perspective for India. *Climate change* 88, 113-130.

Pyke, C. & Andelman, S. (2007). Land use and land cover tools for climate adaptation. *Climatic Change* 80(3), 239-251.

Rabbinge, R. (2009). Agricultural Science and Technology Needs for Climate Change Adaptation and Mitigation. In: Nelson, G.C. (Ed.) *Agriculture and climate change: An Agenda for Negotiation in Copenhagen.*International Food Policy Research Institute.

Rajib Shaw, S.V.R.K.P.H.N. (2008). Drought Management Considerations for Climate Change Adaptation: Focus on the Mekong Region (Cambodia report)

Ramamasy, S., Baas, S. & Pathumthani (2007). Climate variability and change: adaptation to drought in Bangladesh - A resource book and training guide. *Institutions for Rural development.* Rome, Italy FAO.

Rao, K., Verchot, L.V. & Laarman, J. (2007). Adaptation to Climate Change through Sustainable Management and Development of Agroforestry Systems *An Open Access Journal* 4(1), 1-30.

Renaudeau, D., Gourdine, J.L., Silva, B.A.N. & Noblet, J. (2008). Nutritional routes to attenuate heat stress in pigs. In: Rowlinson, P.*, et al.* (Eds.) *Proceedings of Livestock and global climate change*, Hammamet, Tunisia pp. 134-138.

Sadowski, M. (2008). An approach to adaptation to climate changes in Poland. *Climate change* 90, 443-451.

Schneider, S., Sarukhan, J., Adejuwon, J., Azar, C., Baethgen, W., Hope, C., Moss, R., Leary, N., Richels, R. & Van Ypersele, J. (2001). *Overview of impacts, adaptation, and vulnerability to climate change*. Cambridge, UK: Inter-governmental Panel on Climate Change. (Climate Change 2001 Impacts Adaptation and Vulnerability ISBN

Selvaraju, R., Subbiah, A.R., Bass, S. & I.Juergens (2006). *Livelihood adaptation to climate variabilitys change in drought - prone areas of Bangladesh*. Food and Agriculture Organization (FAO). ISBN

Seo, S.N. & Mendelsohn, R. (2006). Climate change impacts on animal husbandry in Africa: a Ricardian analysis. In: Chitiga, M.*, et al.* (Eds.) *Climate change and Agriculture in Africa.* University of Pretoria: Central for Environmental Economics and Policy in Africa, University of Pretoria.

Smit, B. (1993). Adaptation to climatic variability and change. *Environment Canada*

Smit, B., Burton, I., Klein, R. & Street, R. (1999). The science of adaptation: a framework for assessment. *Mitigation and Adaptation Strategies for Global Change* 4(3), 199-213.

Smit, B. & Skinner, M.W. (2002). Adaptation options in agriculture to climate change: a typology. *Global Change* 7(1), 85-114.

Smit, B. & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16(3), 282-292.

Smith, P. (2009). Synergies Among Mitigation, Adaptation and Sustainable Development. In: Nelson, G.C. (Ed.) *Agricultural and Climate Change: An Agenda for Negotitation in Copenhagen.*Intrernation Food Policy Research Institute.

Smithers, J. & Blay-Palmer, A. (2001). Technology innovation as a strategy for climate adaptation in agriculture. *Applied Geography* 21(2), 175-197.

Stigter, C., Dawei, Z., Onyewotu, L. & Xurong, M. (2005). Using traditional methods and indigenous technologies for coping with climate variability. *Climatic Change* 70(1), 255-271.

Tarleton, M. & Ramssey, D. (2008). Farm-Level Adaptation to Multiple Risks: Climate Change and Other Concerns. *Journal of Rural and Community Development* 3(2), 47-63.

Tompkins, E. & Adger, W. (2004). Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change? *Ecology and Society* 9(2), 10.

Thomas, D.S.G., Twyman, C., Osbahr, H. & Hewitson, B. (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climate change* 83, 301-322.

Thomas, R.J. (2008). Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. *Agriculutre, Ecosystems and Environment* 126, 36-45.

Thornton, P., Herrero, M., Freeman, A., Mwai, O., Rege, E., Jones, P. & McDermott, J. (2007). Vulnerability, Climate change and Livestock–Research Opportunities and Challenges for Poverty Alleviation. *Climate change* 4(1)

Thornton, P. & Mario, H. (2008). Climate change, vulnerability and livestock keepers: challenges for poverty alleviation In: Rowlinson, P.*, et al.* (Eds.) *Proceedings of Livestock and global climate change*, Hammamet, Tunisia pp. 21-24.

UNFCCC (2006). *Technologies for adaptation to climate change*. Bonn, Germany: United Nations Framework Convention on Climate Change. ISBN

Verchot, L., Van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, K. & Palm, C. (2007). Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change* 12(5), 901-918.

VietNamNet (2009). *Change the sand dune into cultivative land (Biến cồn cát hoang hóa thành đất canh tác)* [online]. Available from: http://www.tin247.com/bien_con_cat_hoang_hoa_thanh_dat_canh_tac-12-21422029.html [Accessed 11/05].

Vorosmarty, C., Green, P., Salisbury, J. & Lammers, R. (2000). Global water resources: vulnerability from climate change and population growth.

Wall, E. & Smit, B. (2005). Climate change adaptation in light of sustainable agriculture. *Sustainable agriculutre* 27(1)

Watanable, T. (undated). Intergrated Approach to Climate Change Imact Assessment on Agricultural Production System. *Mainstreaming Climate Change Adaptation into Developmental Planning.* Kyoto: Research Institude for Humanity and Nature.

Ziervogel, G. & Calder, R. (2003). Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts in Lesotho. *Area*, 403-417.

APPENDICES

Data analysis

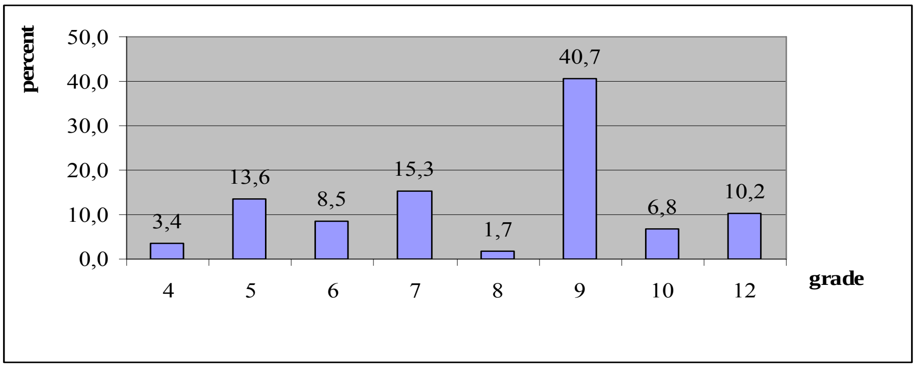


Figure 4.1. Education percentage of head of surveyed household

Source: Field survey 2009

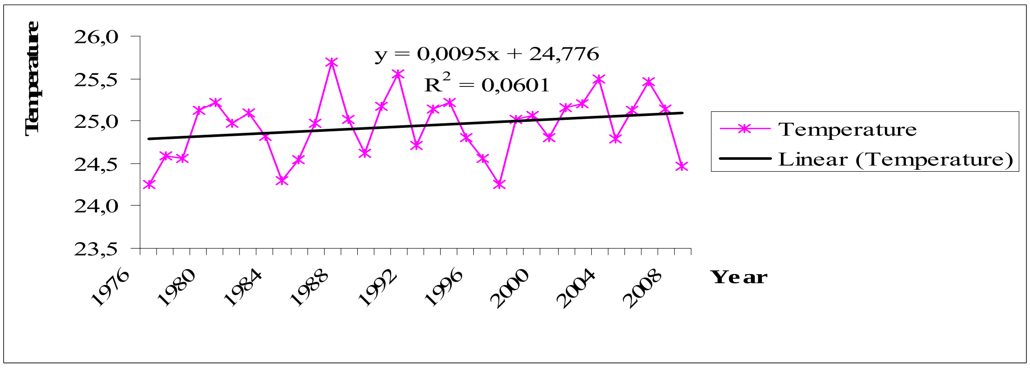


Figure 5.1: Annual average temperature trend from 1976 - 2008

Source: Data from Dong Ha Meteorological station 1976-2008

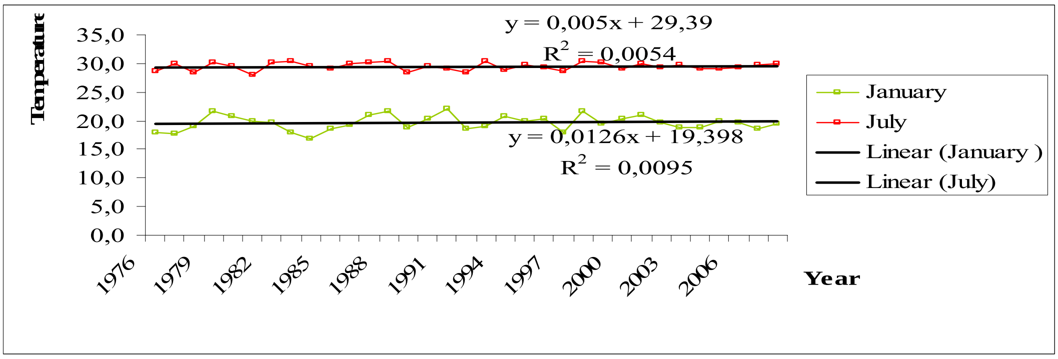


Figure 5.2: January and July average temperature trend from 1976 - 2008

Source: Data from Dong Ha Meteorological station 1976 - 2008

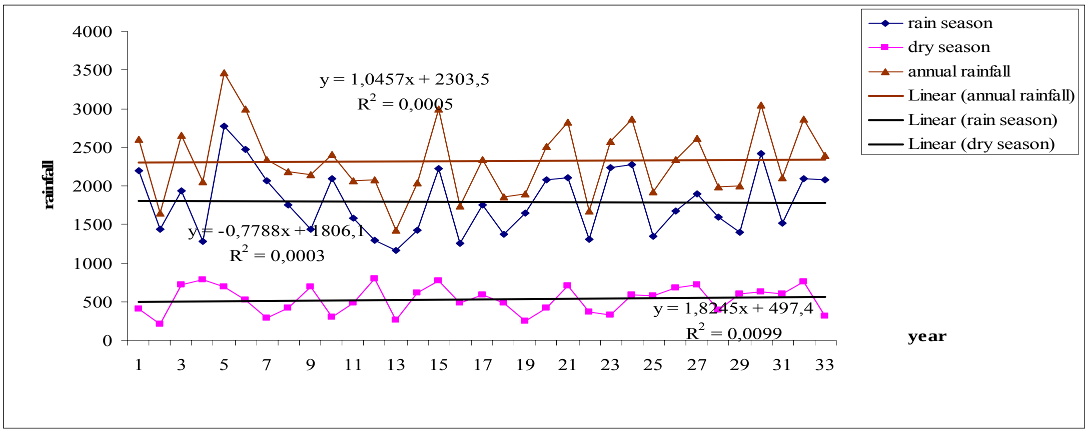


Figure 5.4: Trends of precipitation of Quang Tri province from 1976 - 2008

Source: Data from the Dong Ha Meteorological station 1976-2008

Table 5.1: The trend of climate extremes in Trieu Van commune compared past and now

CEEs	Frequency		Intensity		Irregular	
	Past 5 years	Now	Past 5 years	Now	Past 5 years	Now
Storms	+++++	+++	+++	+++++	Forecast	Not forecast
Drought (4-8)	++++	+++++	+++++	++++	Frequent	Frequent
Flood (9-10)	+++	+++++	+++	+++++	Frequent	Frequent
SW wind(4-7)	++++	+++++	++++	++++	Frequent	Frequent
Cold (11-2)	++++	++	+++	+++	Frequent	Frequent

Source: Group discussion 2009

* The number plus (+) indicates an increasing trend gradually.

Table 5.2: Farmers' perceptions of frequency changes in drought through period (% of respondents answered n=59) (percentage and number of household)

Indicators	Last five years (2005-2009)	Last ten years (1999-2009)	Last twenty years (1989-2009)	Last thirty years (1979-2009)
	Percent (#)	Percent (#)	Percent (#)	Percent (#)
Increase	76,3 (45)	52,5 (31)	32,2 (19)	11,9 (7)
Decrease	6,8 (4)	18,6 (11)	23,7 (14)	23,7 (14)
Non I&D	3,4 (2)	13,6 (8)	16,9 (10)	20,3 (12)
Irregular	6,8 (4)	3,4 (2)	11,9 (7)	15,3 (9)
Don't know	6,8 (4)	11,9 (7)	15,3 (9)	28,8 (17)

Source: Field survey 2009

Table 5.3: Farmers' perceptions of intensity changes in drought through period (% of respondents answered n=59) (percentage and number of household)

Indicators	Last five years (2005-2009)	Last ten years (1999-2009)	Last twenty years (1989-2009)	Last thirty years (1979-2009)
	Percent (#)	Percent (#)	Percent (#)	Percent (#)
Heavy	72,9 (43)	0,0 (0)	0,0 (0)	6,8 (4)
Light	6,8 (4)	52,5 (31)	32,2 (19)	22,0 (13)

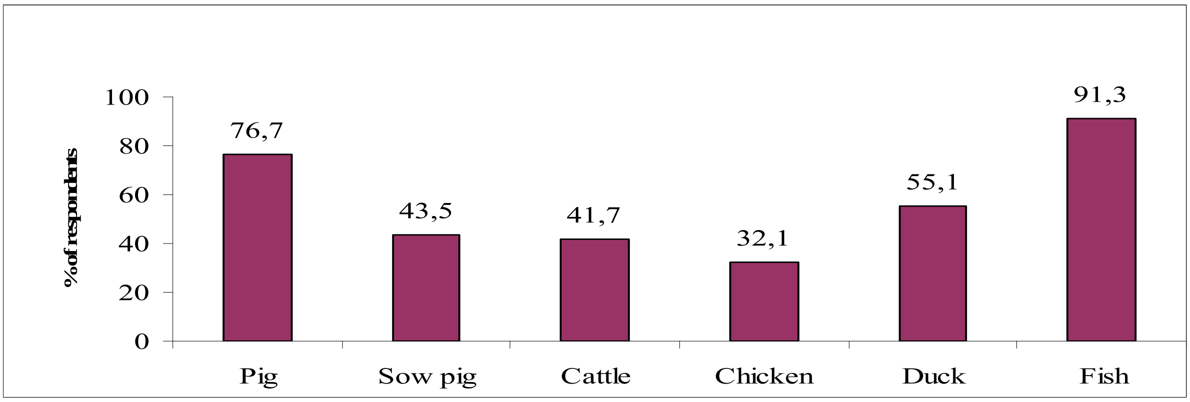
Nomal	5,1 (3)	27,1 (16)	40,7 (24)	25,4 (15)
Don't know	10,2 (6)	13,6 (8)	13,6 (8)	22,0 (13)
Irregular	5,1 (3)	6,8 (4)	13,6 (8)	23,7 (14)

Source: Field survey 2009

Table 5.8: Impact of drought on feed source of different animals (% of respondents answered)

Livestock production	Impact forage (%)	Number of months (months)
Pig	88,9	3,1
Cattle	100,0	3,6
Chicken	10,0	1,1
Duck	16,7	1,2
Fish	94,7	2,3

Source: Field survey 2009
(n pig=59; n cattle=15; n chicken=53; n duck=10 and n fish=22)



Source: Field survey 2009
Figure 5.11: Impact of drought on livestock productivity (% of respondents answered)
(n pig=59; n cattle=15; n chicken=53; n duck=10 and n fish=22)

Table 5.9: Impact of drought on crop investment costs (% of respondents answered n=59)

Kind of investment costs	Impact on productivity (%)		Decrease or Increase (%)		How much (%)	
	No	Yes	Increase	Decrease	Increase	Decrease
Cost	3,4	96,4	-	-	-	
Fertilizer	33,3	66,7	84,2	15,8	26,3	28,3
Pesticide	55,4	54,6	83,3	16,7	25,0	20,0
Electricity	7,0	93,0	100	0	25,9	-
Water volume	7,0	93,0	100	0	28,4	-
Labor credit	12,3	87,7	100	0	30,2	-
Other	61,4	38,6	100	0	14,1	-

Source: Field survey 2009

Table 5.10: Percent of surveyed household applied and non-applied tolerance crop variety drought in farm household groups (% of respondents answered)

Crop production	% applied households	% Applied		% Non-applied	
		Poor household	Non-poor household	Poor household	Non-poor household

Rice (51)	100	100	100	-	-
Sweet potato (59)	98,3	96,6	100	3,4	-
Peanut (34)	88,2	100	77,8	-	22,2
Bean (40)	45,0	50,0	37,5	50,0	62,5
Cassaba melon (n=31)	100	100	100	-	-

Source: Field survey 2009

Table 5.11*:* Percent of surveyed household applied and non-applied crop production techniques in farm household groups (% of respondents answered)

Crop production	Adaptation options	% applied households	% Applied		% Non-applied	
			Poor household	Non-poor household	Poor household	Non-poor household
Sweet potato (n=59)	Mulching by grass	55,9	51,7	60,0	48,3	40
	Designing bed	93,2	93,1	93,3	6,9	6,7
	Intercropping	66,7	100	100	-	-
Peanut (n=34)	Crop rotation	11,7	18,8	5,6	81,3	54,4
Cassaba melon (n=31)	Mulching by branch and leaves of forest trees and grass	58,0	63,2	50,0	36,8	50
Bitter melon (n=37)	Mulching by seaweed	91,8	89,5	94,4	10,5	5,6
	Soil practice	51,3	52,5	50,0	47,4	50,0
Crop diversification, mixed cropping, overlapping and multi-cultivation in garden		100	100	100	-	-

Source: Field survey 2009

Table 5.12: Percent of surveyed household applied and non-applied changes in management practices (% of respondents answered)

Crop production	Adaptation options	% applied households	% Applied		% Non-applied	
			Poor household	Non-poor household	Poor household	Non-poor household
Rice (n=51)	Reducing nitrogen fertilizer	47,1	56,0	38,5	44,0	61,5
	Using pesticide	70,6	60,0	80,8	40,0	19,2
	Using growth fertilizer	52,9	46,2	60,0	53,8	40,0
Sweet potato and bean* (n=40)	Adjusting fertilizer	78,0	73,3	82,8	26,7	17,2
	Using pesticide	57,6	51,7	63,3	48,3	36,7
	Using growth fertilizer	44,1	41,6	46,7	58,6	53,3
Cassaba melon (n=31)	Adjusting fertilizer	54,8	50,0	57,9	50,0	42,1
Bitter melon (n=37)	Adjusting fertilizer	51,4	50,0	52,6	50,0	47,4
	Using pesticide	75,7	18,9	72,2	21,1	27,8

Source: Field survey 2009

Table 5.13*:* Percent of surveyed household applied and non-applied livestock management measures in farm household groups (% of respondents answered)

Livestock	Adaptation options	% applied	% Applied	% Non-applied

production		households	Poor household	Non-poor household	Poor household	Non-poor household
Pig (n=59)	Designing cage	54,2	44,0	75,0	56,0	25,0
	Caring daily	100	100	100	-	-
	Injecting vaccine	88,9	89,7	90,0	10,3	10,0
	Supplementing feed	55,9	41,4	70,0	58,6	30,0
Chicken production (n=53)	Planting perennial tree and using shade from forest tree	100	100	100	-	-
	Injecting vaccine	56,6	44,0	67,9	56,0	32,1
Duck production (n=10)	Reducing scale production	80,0	75,0	83,3	25,0	16,7
	Supplementing feed	50,0	50,0	50,0	50,0	50,0
Cattle production (n=15)	Planting grass	26,6	10,0	60,0	90,0	40,0
	Supplementing feed	100	100	100	-	-
	Injecting vaccine	100	100	100	-	-
Fish raising (n=22)	Reducing scale production	100	100	100	-	-
	Using water-fern to shading	68,1	77,6	76,9	23,1	22,4
	Supplementing feed	33,6	22,2	46,2	77,8	53,8

Source: Field survey 2009

Check list for group discussion
I. Draw diagrams Rural
- Type of chart status, past and future drought
- Requirements of the scheme: the drought, the area of limited extent and production activities are affected (plants and animals)
- Determine the area of drought can be used and the area were unusable due
- Area planted a tree and two service area

Currently
- Irrigation system, the system tree, where most were limited, where light is limited
- Transport system
- Previously limited than now? Why? Determining the mold of irrigation system
- Future government policies will upgrade the infrastructure like? It will solve the problem of how drought
- In the future will be what comes to overcoming drought

II. Seasonal Calendar
- Request: the component
1. Weather: Temperature, precipitation of the month
2. Crops, livestock, aquaculture and agricultural activities other
3. Expression of drought

III. Boss in order of priority levels are affected by drought
- Plants and animals affected by what the most drought

(Tree planting: (1) limited extent - the extent of damage (dead trees, dry state), (2) area, (3) area and the extent of damage)

Area crop damage levels Buy

Pets Scale Time level of damage

IV. Construction plant drought problem
- According to her how the term?
- The cause of rural areas is limited in what?
- Problem: drought affecting agricultural production

V. The impact of drought
Product:
- Know the impact of drought to farming activities, livestock and aquaculture
- Crop / livestock will be affected
- Plants that are affected like?
- Listing of crops / livestock impacts (on the result of 1)
- Play cards color: Drought affects every tree / I like? (1 card write an impact)
Cultivation
1. Productivity: What year, how many% does barefoot
2. Disease: What disease?, In any
3. Investment costs: fertilizer, plant protection agents, building barns, irrigation systems, food supplements
4. The working time of the day
PLANT VARIETIES
crops grown on land is often– limited compared to other regions, the yield like?
More than not defend?– Is not the term? There is not a new disease? Is not the term?
The number and type of disease– appear and the frequency of disease appeared in our time limit occurred
The most severe drought that– year, how many% yield reduction compared with normal years?
Pets / aquaculture
- Pets will be affected most? Why?
- Impacts scale farming? (Scale up / down? Why?)
- Impacts to food (food missing something? For how long? Why?)
- Maturity (related to the ability to eat: increase / decrease)

VI. The experiences and measures to adapt to drought
Product:
• Knowing all the experience in adapting to local drought
• Knowing all measures to adapt to local drought
Method:
List the effects of drought in the morning discussion
Difficulties and facilitate the implementation
Effect of plant drought causes drought Adapting Why? % Of households in the village applied Male / Female
Trouble advantages apply
Some forms of adaptation have been made
- Change plant varieties / animal? Like what? Why (because of limits or for other reasons), consider changing the time or the events leading to that change.
- Change or adjust the crop? Specifically how?
- The technical changes in crop and livestock
- Change the form of farm produce as from application to crop rotation, intercropping cases, pillow cases or diversified livestock, raising your knees, the agroforestry model (look at why the time change and change)
- There are various types of alternative livelihoods to adapt to any drought as migrants go elsewhere for jobs, move from this industry through the trades .....
Review of adaptation strategies in the future, the difficulties and what advantages? What supports are needed?

VI. Lessons learned
Products: Know the causes of success and failure; advantages and disadvantages of the experience / measure current residents have been applied
Methodology: Building tree for all four issues matter: success, failure, advantages and disadvantages.

VIII. The measures to restrict and to adapt to drought
Product:
Find out the solutions of drought restrictions
Find out the solutions to adapt to drought

IX. Policies related to agricultural support, policies related to prevention and adaptation to natural disasters
Organizations in local communities, NGOs
The support of these organizations in the community is what?
The support that has contributed in improving the adaptability of people in the community?
Members of the cooperative's access to information policies that like?

Using SWOT to analyze the strengths, weaknesses, opportunities and challenges when people apply the form /

adaptation measures that
The disadvantages and advantages of the people upon the application of appropriate measures that?

Check list for depth interview
Interviewees :.. ...

I. Evolution of drought in recent years (1979 - 2009)
1. The term occurs in any strong? List year term occurs
2. Time limit occurred in those years? In Time limit not rain wind blows * Time * Intensity ** happens
* (1) As of the day or month, (2) Number of waves that occur in
** Calculated based on point: Point 1 is the most intense and slightly reduced to 10 points
3. Temperature changes over the years like? (Increase / decrease / no tang-giam/khong know)
4. There are five high temperature does not irregular? If so, list the year when the abnormally high temperatures that? How much the temperature (if you remember)
5. Precipitation Evolution in years like?
6. There are five long time without any rain occurs not unusual? If you have listed the year occur? Long time how much?
7. In the opinion of his (her), the drought situation in the past years events like?

II. The impact of drought
9. He (she), water resources affected how over the years? (Letters I determined milestones?)
- Considering the amount of water in fish ponds as digging ponds? (In garden)
- Depth of drilling water wells? (In garden)
- The amount of water pumped during the irrigation? (Can only pump water morning and evening new strength, but weak in the day time).
- Depth of water when watering holes dug in the field?
10. The impacts of drought to crops?
- Area affected?
- Diseases and pests increase / decrease? Specifically, what epidemic?
- Type of diseases and pests?
- Maturity?
- Investment cost increase / decrease? How much time compared with no limit?
- What kind of cost? What specific types of expenses?
- Productivity is influenced work? Specifically, how many percent compared to the unlimited time?
11. The impact of droughts to different types of animals (including fish and shrimp)
- The number affected?
- Diseases increase / decrease? Specifically, what epidemic?
- Type of disease?
- Time for development?
- Impacts on Food: What food? Set time for how long?
- Investment cost increase / decrease? How much time compared with no limit?
- What kind of cost? What specific types of expenses?
- Productivity is affected? Specifically, how many percent compared to the unlimited time?

III. Adaptation measures
12. Some forms of adaptation have been made
plant varieties /–Change livestock? Like what? Why (because of limits or for other reasons) and consider time changes or events leading to that change.
change or adjust the crop?– Specifically how?
The technical changes in crop– and livestock
Change form production– applications as from farming to crop rotation, intercropping case, pillow cases or diversified livestock, raising your knees, the agroforestry model (considering the reasons and the time change change)
What are the types of– alternative livelihoods to adapt to any drought as migrants go elsewhere for jobs, move from this industry through trades .....
Consider the problems and agree upon the implementation of such adaptation strategies.
Consider the adaptation strategies in the future, the difficulties and what advantage? What supports are needed?
13. Lessons learned in adapting to drought are drawn?
14. Experience to predict droughts?
15. Policies related to agricultural support, policies related to prevention and adaptation to natural disasters

organizations in local– communities, NGOs
The support of these– organizations in the community is what?
The support that has– contributed in improving the adaptability of people in the community?
Members of the cooperative's– access to information policies that like?
16. According to her, there is nothing about farming model or general model in response to drought?