International Master Programme at
the Swedish Biodiversity Centre

Master's thesis
No. 54
Uppsala 2009

Summer rainfall variability and the use of rice (*Oryza sativa* L.) varietal diversity for adaptation:

Farmers' perceptions and responses in Nepal

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Abstract

Climate variability, farmers' understanding of this and the crop varietal diversity are so far discussed inadequately in the same context. This study compared summer rainfall variability and farmers' perceptions of rainfall changes between two periods; 2004-2008 and 1995-1999. The use of rice varietal diversity from an adaptation point of view was studied. The findings were from two rice growing agro-ecological zones of Nepal; mid-hills and western terai. The information was collected through a survey in 45 households in mid-hills and 44 households in terai, supplemented with focus group discussions and meteorological data. The analysis revealed a distinct variation in rainfall distribution with a decrease in rainfall amount in mid-hills and an increase in terai during 2004-2008. In the same period, pre and late monsoon rainfall increased in both sites. The rainfall decreased up to 41 percent in mid-hills during June-July, which has resulted in more dry spells during rice transplanting and establishment period. A concurrence of farmers' perceptions with the rainfall data demonstrates their understanding about rainfall variability, gained by crop and weather observations.

Shannon-Weiner index revealed a higher overall rice varietal diversity in terai ($H'=2.58$) than in mid-hills ($H'=2.0$). However, on average a household in each site maintained nearly the equal number of rice varieties (≈4). There was significantly higher landrace diversity in mid-hills ($H'=1.5$) and modern varieties diversity in terai ($H'=2.17$). The perceived varietal vulnerability to rainfall variability differed significantly ($p<0.01$). Farmers cautiously selected less vulnerable varieties whether landraces or modern for use on large areas, often considering their adaptation and production potential. The perceived production loss due to rainfall variability was negatively correlated ($r=-0.29$, $p<0.05$) with the number of varieties grown in terai, where modern varieties were dominant. Farmers' seed selection and on-farm experimentations are seen as adaptation practices to reduce vulnerability in traditional farming systems.

Key words: Rainfall variability, rice varietal diversity, terai and mid-hills, vulnerability, adaptation, farmers' perceptions, responses, Nepal

Contents

Introduction

Climate change and biodiversity are recently considered as cross cutting issues in research and management strategies because of their mutual relationship. Climate change has an impact on reducing biodiversity whereas on the other hand, the effects of climate change can be reduced by the use of biodiversity (CBD 2008). In recent decades, as a consequence of many factors, the climate variability and change has increased, but biodiversity has decreased. These trends are now seen as the two major problems to be faced globally (Azam 2007). In fact, biodiversity can be used to mitigate or adapt to climate variability and change and its effects. In the context of agriculture, biodiversity can be seen as diversity of species, races and varieties or in terms of its genetic composition (Love & Spaner 2007). It also consists of agro-ecosystem diversity including pests, predators, soil micro-organisms that inhibit plant growth and enable nutrient recycling as well as organisms that provide shelter and/or buffer against adverse conditions (Di Falco & Perrings 2003).

As a subset of biodiversity, agricultural biodiversity is one of the most important forms of functional diversity currently used by humans on which all farming and, in turn the global food security depends. Out of one hundred and twenty internationally important agricultural crops, only three; rice, wheat and maize provide over half of the food energy that humans consume today (Love & Spaner 2007). Nowadays, most of the crop diversity in commercial farming therefore exists at varietal level (Brush 2004). However, traditional farming systems operating in parts of tropical Asia and Africa have still maintained rich crop diversity in terms of both species and traditional varieties (Unruh 2004).

Farming systems and crop diversity: global and Nepalese context

Global population increased at a geometric rate after the Second World War. To meet increasing food demand, agriculture passed through a green revolution after the1960s, which intensified the use of improved seeds, fertilizer, irrigation, pesticides and machinery (Aggarwal et al. 2004). This sort of commercialization has focussed particularly on a few crop species and varieties. With technological advancement in recent decades, production systems globally are approaching monocultures to increase production. However, as a negative consequence, an enormous amount of cultivated agro-biodiversity in the form of locally adapted traditional crop species and landraces has disappeared from most parts of the world and, the trend is ever increasing. Green revolution caused a decline in global diversity of cultivated crops and resulted in a fundamental shift in inter and intra specific diversity in the farming systems (MEA 2005). It has degraded soil and water as well as eroded genetic diversity on which ecological processes depends for long term sustainability of productive agro-ecosystems (Gliessman 2006). It has also contributed to the loss of associated traditional knowledge and practices. Moreover, crops adapted to monoculture systems need high external inputs such as fertilizers, pesticides and fossil fuel to produce optimum yield (Tanaka et al. 2005). This is one of the drivers of global warming that has caused changes in climate with increasing risk for crop production recently.

On the contrary, many studies (Altieri 2002; Maikhuri, et al. 2001; Nautiyal & Kaechele 2007; Salinger et al. 2005) have shown that traditional farming systems, which are generally characterized by a high dependence on local genetic resources, local production inputs and technologies as well as an inherent link to forests, have the potential to produce higher combined output from low input systems. There is a more efficient use of land, water, biodiversity and other production resources in traditional farming systems, which make a system more resilient to biotic and abiotic stresses than commercial monoculture (Altieri & Nicholls 2008). Such farming systems maintain a large number of crop species, its varieties and landraces on-farm (Rao & Hodgkin 2002) in various spatial and temporal arrangements. The traditional farming system therefore, is a cost effective, environmentally friendly and sustainable practice. That is why it is still popular in many parts of tropical Asia and Africa and has played an important role in supplying food and nutritional security to poor people who live in environmentally fragile, inaccessible and marginal areas. Altieri (2002) has estimated that it has contributed to supply 15-20 percent of the world food. In such systems, farmers as custodians are maintaining many crop species and/or varieties and landraces particularly to fit into niche production environments as well as fulfilling their diverse economic and socio-cultural needs (Rijal 2007). From this point of view, conservation and use of crop genetic resources is important not only for food and nutrition but also for the sustainable future in the context of increasing climate change.

Nepal is a small country (141 881 square km) with varied topography, altitude and climatic conditions. It is divided into five major climatic zones; tropical, subtropical, warm temperate, temperate and arctic with in an altitudinal range from 6o meter above sea level (masl) to 8840 masl. Nearly three-fourth of the total population is depending primarily on agriculture (CBS 2007). Agriculture therefore is one of the main sectors of national economy and people's livelihoods. The average household land holding in Nepal including both productive and unproductive is about 0.8 hectare (CBS 2007).The unproductive land is not generally under cultivation of agricultural crops but is rather being used for forestry or pasture purposes. Agriculture has not provided the opportunity to fully engage people who depend on farming primarily due to its small scale seasonal production as well as the high population pressure in this sector. Traditional subsistence small scale rainfed farming is the common characteristics of Nepalese farming system in the hills, mountains and many parts of the terai (plain). Livestock raising and agroforestry is the integral part of the Nepalese farming system. Farmers in such traditional farming generally grow a number of crops, its varieties and landraces by allocating in different land parcels to meet household consumption requirements, socio-cultural needs as well as religious values. However, as compared to hills and mountains, farmers in terai are more commercially oriented recently although, they have not yet fully adopted the commercial production system as called "commercial" in other parts of the world. In hills and mountains, most of the areas are inaccessible, dominated by undulating or steep terrains. This has created diversity in terms of widely varying production environments within a short spatial distance and favours production of different crop varieties and/or landraces. Farmers in such hills and mountains heavily depend on local crop genetic resources and other low cost production inputs for farming. Therefore, farming on terraced slopes in the hills and mountains has favoured greater diversity in crops and traditional varieties and/or landraces (Dusen et al. 2007).

In Nepal, there are cultural traditions and legal provisions to inherit land property from the parent to their sons which has increased land fragmentations. The average numbers of land parcels holding per household is 3.3 (CBS 2007). These land parcels generally represent different crop growing niche environments and therefore favours growing many crops within a season. For instance, during summer season, rainfed upland is more suitable for maize crop whereas, irrigated land is for rice. On the other hand, rich socio-culture has played important role in maintaining many traditional crops and varieties particularly the landraces on-farm to meet special use values. Farmers always allocate small part of their total land to grow such culturally important crops and landraces in every household. There are more socio-culturally important landraces in rice than in other crops. Therefore, as pointed out by Rana et al. (2007), diverse production environments, fragmented landholdings, fragile agro-ecosystems and the socio-cultural needs have been associated with growing diverse crop varieties and landraces in the country.

Nepal is rich in agro-biodiversity which has played an important role for food security and nutrition. However, in recent years, there have been rapid changes and loss in crop diversity particularly the traditional crops and landraces due to the cumulative effects of factors such as land use change, expansion of modern crops, a weak regulatory framework (Upreti & Upreti 2002), migration as well as socio-cultural transformation in the country. In recent decades, because of the conflict situation that have prevailed since last ten years in the country, there is a high migration rate of rural people to urban and peri-urban areas as well as young generations leaving for out-off country works. Therefore, population is increasing at an alarming rate in urban and peri-urban areas where there is more security, job opportunities and facilities. As a consequence, there is a rapid conversion of agricultural land into settlement which has contributed to a loss of local crop diversity particularly in urban area and its vicinity. At the same time, farmers in peri-urban areas are more profit oriented and have changed traditional cereals based farming i.e. rice, maize and finger millet to commercial vegetables for the market. Therefore, there is a gradual decrease in the area under traditional crops as well as its varieties and landraces in such areas.

On the other hand, land abandonment in remote rural areas is increasing due to migration and labour shortage, which in turn has contributed to a gradual decline in the diversity of local crops and landraces on-farm. For instance, farmers are not interested in growing finger millet crop but rather keeping upland fallow. It is because millet cultivation is labour intensive and labour is scarce nowadays. In rice crop for example, the situ crop conservation project in its base line study ten years before reported sixty three rice varieties including the landraces in Begnas village of Kaski district (Rijal et al. 1998). Many of these landraces are not available today. It shows that farmers are reducing the number of traditional crops and its varieties on-farm particularly the landraces. Among the reasons are the gradual changes in the food habits as well as loss in the traditional socio-culture among young generations. The gap of local knowledge and values associated with traditional crop varieties particularly landraces has been increasing in recent decade which has contributed to the loss of crop varieties and/or landraces. Furthermore, the agricultural policy of the country has more inclined towards monoculture and promoting improved crop varieties with the aim to increase production and productivity, thus neglecting to maintain varietal diversity on-farm. However, Saxena et al. (2005) reported a high implication of such crop diversity losses to poor people living in marginal and fragile mountain environments during abnormal climatic years. It has also been reported that loss of crop diversity diminishes farmers' capacities to cope with biotic and abiotic stresses (Bellon 2008).

Climate variability and change: risks for crop production

Climate change literally means the fluctuations and changes in mean conditions in the climatic parameters. It includes inter and intra-seasonal, inter-annual as well as spatial variations and changes (IPCC 2001; Smit et al. 1999). The most comprehensive studies on global climate change done by Intergovernmental Panel on Climate Change (IPCC) in 2001 and 2007 have shown that global warming, as a consequence of greenhouse gas emissions has changed precipitation patterns, increased temperature as well as climate related extreme events such as droughts, heavy rainfall, flood and heat waves in their magnitude and frequencies. Agriculture is one of the sectors most vulnerable to climate variability and change since, it is inherently sensitive to local climate

(Challinor et al. 2007). Variations and changes in temperature and precipitation have increased the risks in crop production since last decade (Poter & Samenov 2005). Climate variation and change have therefore, been increasingly seen as one of the most important challenges to farmers for crop production worldwide.

Among climatic parameters, precipitation is the key factor determining the success of crop production (Viglizzo et al. 1997; Thomas et al. 2007) and precipitation changes therefore constrain more than changes in temperature (Challinor et al. 2007). Droughts, dry spells and exceptionally wet periods causing flooding are considered as precipitation related weather extremes with major impacts on crop production. The effect of such extreme events is even more severe in areas where rainfed farming systems are operating. With the general phenomena of rainfall variability, intra-seasonal variations, including timing of onset of first rains (Lal et al. 2000) as well as its distribution over the season also affect crop cultivation and its successful production in rainfed farming systems. Likewise, sequential extremes such as drought followed by intense rain and flooding may cause crop damage or make it more vulnerable to pest and diseases.

In Nepal, the South Asian monsoon is very active and receives about 80 percent of the total annual rainfall in the monsoon season during June-September (Kansakar et al. 2004). As a part of the fourth IPCC assessment, Kripalani et al. (2007) analysed South Asian monsoon precipitation variability and has projected a significant increase in precipitation as well as increasing frequency of excess and deficit monsoon events in the region. Such variations and changes in the monsoon precipitation have increased the frequency of drought and dry spells as well as severe floods in plains and landslides in the hills and mountains (Shrestha et al. 2000). Summer season is associated with growing number of cereals and legumes in the country. Three out of the four most important staple food crops; rice, maize and finger millet are grown under rainfed conditions during the monsoon season. Among these, rice is the number one food security crop widely grown across terai and mid-hills during summer season. More than 65 percent of the area under rice crop in the country is still rainfed (CBS 2007) and, therefore is heavily dependent on monsoon rain for its production success (Nayava 2008).

There are inadequate scientific studies so far to sufficiently describe and predict the climate change scenarios and its projected impact on agriculture in Nepal. However, some of the studies done have shown a trend of increasing temperatures (0.06oC per year) and more unpredictable fluctuation in rainfall (Shrestha et al. 2000). The consequence of such fluctuations and changes in rainfall on crop production has been observed in many parts of the country (Chaudhary & Aryal 2009). It has created stresses for crop production due to increased frequency of drought, dry spells as well as excess soil moisture and subsequent flooding. Rice crop is also increasingly being affected by unpredictable rainfall consequences such as insufficient rainfall during the early planting stages as well as flooding in plain areas. The variability and change in monsoon rainfall behaviour has therefore appeared as the most important risk factor for rainfed farming in the country.

Adapting to climate variability and change

Adaptation is the responsive adjustment in natural or human managed systems (CBD 2008) to minimize the expected changes, its effect or impacts. Responses aimed to reduce the vulnerability or susceptibility to climate change impact can be observed at individual, group or government levels (Bradshaw et al. 2004). IPCC has categorized adaptations in two types; spontaneous and planned. Spontaneous adaption occurs at the level of individuals whereas planned adaption need involvement of society with guiding policies (Berry et al. 2006). Adaptations reduce vulnerability to climate change effects to various extents. Within agriculture, Smit & Skinner (2002) categorized adaptations as: technological, on-farm adjustment practices, government policy including insurance as well as diversifying household income sources as financial management strategies. In general, it is reported that farmers who have the resources and access should be able to adapt better as compared to resource poor marginal farmers (Esterling & Apps 2005). However, it is widely stated that farmers to some extent can adapt to climate variation and change strategically by selecting crop types and its varieties, adjusting planting time and input use or by altering soil management practices as well as diversifying their farm enterprises (Bradshaw et al. 2004; Mortimore et al. 2001; Risbey et al. 1999; Smit et al. 1996). In this strategy, the use of crop genetic resources is one of the management practices to adapt to changes and variations among resource poor farmers in traditional farming systems.

Role of genetic diversity to cope with climate variability and changes

On-farm adjustment includes diversification of crop and its varieties as one of the strategies to adapt to variations and changes at farm level. The use of genetic diversity can help to enhance the resilience of natural systems to buffer against possible risks (Hajjar et al. 2008). With the realization of climate change effects, there is increasing concern about crop genetic diversity in agriculture because of its adaptations values (Kotschi 2007). Studies have shown the usefulness of diversity to maintain productivity, reduce yield variability and farmers exposure to production risks. In a review of situations in various African countries, Challinor et al. (2007) reported that crop responses to weather and climate are affected by genotype, environment and farm management practices. Genetic diversity is important because it provides sources of genes to crops to adapt to changing climate (Rao & Hodgkin 2002).

Increase in crop diversity has a positive relationship both with farm productivity as well as adaptation to stresses.

Diversity-productivity-adaptation relationship

Earlier studies have shown that higher genetic diversity makes agro-ecosystems more resilient to absorb stresses. Di Falco & Perrings (2003) and Di Falco & Chavas (2006) in their empirical studies in southern Italy reported a positive correlation between wheat crop diversity and farm productivity in rainfed farming. Tilman et al. (1997) mathematically proved that increased diversity maximizes the nutrient use which in turn increases biomass and production. Similarly, intercropping systems produce higher combined yield than monoculture in traditional farming systems (Trenbath 1999). Diversity within each crop is also important as it can add spatial and temporal diversity and increase the resilience of the natural agro-ecosystem to resist biotic and abiotic stresses (Chloupek et al. 2004). It is because diversifying crops in cropping systems favours synergism that contribute to increase yield compared with monocultures (Porter et al. 1997).

High level of diversity has higher productivity since it serves as insurance under stress environment (Mulder et al. 2001). Yachi & Loreau (1999), in their insurance hypothesis demonstrated that higher species diversity provides better guarantee to maintain or increase production under stress environments due to "performance enhancing" and "buffering" effects. Furthermore, Tin et al. (2001) reported that there are consequent genetic changes in dynamic crop population through management and selection that build up adaptations to new conditions. That is why landraces and traditional varieties which are being managed by farmers' dynamic selection process are better adapted to climate stresses. A similar study on wheat crop in Italy has proved that varietal diversity reduces risks of crop failure in rainfed environments (Di Falco & Chevas 2008). This is due to genetic variations within varieties and populations that increase the ability to respond to environmental stress (Mainwaring 2001). Di Falco & Chevas (2008) in southern Italy also reported that crop diversity can increase the capacity to buffer against rainfall stress conditions.

It is reported that genetic diversity reduces the probability of pest and pathogens damage on crops (Heisey et al. 1997). On the other hand, reduced genetic diversity limits the ability of crop populations to evolve in response to new pest, disease and climate stresses (Altieri 1999). All this evidence demonstrate that under climate change conditions, enhancing biodiversity can be the option to help maintain long term agro-ecosystem productivity and its ability to produce food. It is therefore important to promote growing diversity of crops so that production risks can be minimized among small holder farmers.

Rationale of the study

Climate change is already a reality and has affected agricultural production both positively and negatively. It is generally reported that there are higher negative consequences of climate change in agriculture in the tropics and subtropics including South Asia. Although there are many studies on the impact of climate change on agriculture; so far it has focused on predicting crop yield responses with changed conditions (Smit et al. 1996; Smit & Skinner 2002). In such model predictions, farmers' responses to changes are hypothetical and either "no adaptation" or "optimal adaptations" are assumed (Reidsma 2007). Furthermore, most of the impact studies dependent on models that predict better on a broad scale and therefore have reduced utility at local scale (Vedwan & Rhoades 2001). It is also complicated to understand due to the use of mathematical models and many jargon words (Chaudhary & Aryal 2009). This is one of the reasons for the considerable gap between the information needed by small scale farmers and that provided by service stations (Stigter et al. 2005).On the other hand, farmers' knowledge and experiences which in many cases have already proved rational are also an important source of information. These are even more important while designing adaptation programmes and policies at national and local levels. It is therefore relevant to understand and validate farmers' perceptions regarding the variability in climate including rainfall as well as their coping strategies with the use of crop diversity in the local context. Modelling studies require good quality historical data to better predict the result. However, historical records of individual farms are lacking in many developing countries and are not available in the traditional farming systems in Nepal. In such cases too, it could be possible to acquire useful information from farmers' knowledge and experiences even if it does not support modelling.

Despite its potential importance, the role of crop diversity in adaptation to climate change is inadequately discussed (Kotschi 2007). Inadequate research and development attention has been given so far to take account of crop diversity as a potential coping strategy although, there is growing concern recently. However, crop diversity including landraces is important and is extensively being used among resource poor farmers in stress prone marginal and fragile agro-ecosystems mainly in parts of South Asia and Africa (Anane & Dittoh 2001). This will be even more important in the future because climate change is increasingly seen as a challenge for crop production which supplies the core of our food and nutritional diversity. Therefore, climate change and crop diversity should be discussed together as one of the themes for research and development strategies for a sustainable agriculture that contributes to reduction of land degradation and increases the resilience of natural agro-ecosystem to cope with abiotic and biotic stress and as well as improves food security, nutrition and health (Hajjar et al. 2008).

In this context, it is worthwhile to study crops and varietal diversity at farm level and its extent of use from the perspectives of coping with climate variability. This is an emerging area for research and development in agriculture. In Nepal however, extensive research on linking crop diversity and climate variability has not been done so far to my knowledge. It is therefore important to understand, discuss and validate farmers' experiences and practices on changing climate, its effect as well as ways of adaptations in farming practices in the local context. Such a study also helps increase farmers' awareness and provides opportunities to the researchers to understand farmers' ecological knowledge and practices.

In rainfed farming system of Nepal, it is obvious that rainfall is the most important climatic parameter affecting crop production. Summer monsoon during June to September receives about 80 percent of total rainfall (Rajbahak & Shrestha 2005). The term monsoon therefore is synonymous with summer rainy season in the country. Traditional farming is highly dependent on summer rainfall. Rice is the most important summer crop extensively grown under rainfed conditions (65 percent of the total rice area) and occupies 45.1 percent of the total cropped area in the country (Nayava 2008). However, the summer rainfall is increasingly unpredictable and erratic affecting crop production negatively (Chaudhary & Aryal 2009).

This study aims to identify farmers' perceptions on summer rainfall variability including pre and post monsoon rainfall as well as the use of rice varietal diversity as a strategy to cope with rainfall related stress. Due to differences in altitude and topography, terai and mid-hills have different production environments and also differ in rainfall amount and its pattern. In this study, rainfall changes and rice crop diversity in these two different production environments have been compared.

Aims and objectives of the study

This study mainly aimed to investigate farmers' perceptions of two important aspects of traditional farming systems of western Nepal. First is the variability and changes on rainfall during the summer season and, secondly the extent of rice varietal diversity used in the farming systems to adapt to climatic variability specifically the summer rainfall and related stresses. The study also compared these aspects in two different rice growing agro-ecological environments; the mid-hills and the terai.

The specific objectives of the study were:

- To compare farmers' perceptions on summer rainfall variability with meteorological data during the past ten years,

- To understand summer rice varietal diversity richness and distribution in traditional farming systems,
- To explore the perceived effect of rainfall variability on rice crop production, its diversity as well as food security between two agro-ecological conditions,
- To identify farmers' perceived risks of vulnerability of rice varieties and landraces to summer rainfall variability and stresses, and
- To identify farmers' coping strategies in rice production to adapt to rainfall variability and stresses

Limitations of the study

This master's thesis study was conducted in two villages; one each from Kaski (mid-hills) and Bardia (western terai) district using sample survey and discussions with farmers. The results presented here are the responses from the selected respondents of the area. Therefore, the findings are only valid for similar locations and may not be representative if generalized. Similarly, information on rainfall changes, crop production loss, effects on food security and varietal vulnerability to rainfall variability were the perceived responses of selected respondents based on their experiences of the past. It may differ with the locations, and also with other farmers within the same research area. Furthermore, climate variability and change is an area of research which requires a long timeframe (minimum of 30 years) and also includes many parameters. However, this study is limited to summer rainfall and its variability for the period of 1995-2008, which might be enough for the variability analysis, but not for the long term change analysis.

Materials and Methods

The study was conducted during autumn 2008 and analysed farmers' perception on summer rainfall variability and the extent and use of rice varietal diversity in two contrasting rice growing agro-ecological zones of Nepal. The two study sites represent mid-hills and terai environments from western Nepal. The terai is a narrow plain belt of low lying terrain with an altitude range up to 300 masl and, extending East-West across the southern border of the country (Manandhar 2002). It constitutes a part of the Indo Gangetic plain encompassing North and Eastern India, Pakistan and Bangladesh which share similar agro-climatic characteristics. It is typically characterized by the South Asian summer monsoon with alterations of dry and wet seasons (Singh & Sontakke 2002). The Indo Gangetic plain is the regional terrain with high importance for agricultural production and has therefore has received high research attention on its climate and crop production.

Nepal's terai experiences tropical to subtropical climate and is the main food production zone in the country. Rainfall ranges from 600 mm in the West to 1300 mm in the East (Pariyar 2002). In contrast, the mid-hills represent higher altitude range with undulating and/or steep topography that has greatly contributed to local variations in the climate. It experiences subtropical to temperate climate. Monsoon rain is the main precipitation during the summer season. The altitude ranges from 300 to 2000 masl with a high rainfall variability ranging from 1000 mm to more than 3000 mm (Pariyar 2002). There is still an inadequate knowledge on the climate and its variability in the mid-hills and mountains of Nepal as compared to terai (Shrestha et al. 2000).

This is a representative study of Nepalese traditional farming system with a particular focus on summer rice crop. A managed traditional farming system combines principles of agro-ecology and ethno-ecology (Altieri 2002). Agro-ecology is the application of ecological concepts and principles to the design and management of sustainable agro-ecosystem (Gliessman 2006). Ethno-ecology in this context is the farmers understanding of ecosystem, environment and its relationships. As described in Fig.1, agro-ecological principles provide scientific basis for sustainable agriculture with a focus on multiple land use and cropping system, soil water conservation, nutrient recycling, and use of biological diversity as well as local resources. On the other hand, ethno-ecological principles include farmers' knowledge, experiences and values associated with crop, climate, resources and culture which create synergies to make a traditional farming system more dynamic and resilient for sustainable production in long term. The traditional farming systems have adopted the elements of ecological concept (Gliessman, 2006), and represents a dynamic agricultural system, more resilient to climate variability and contributing to food sovereignty and security of rural small holders (Altieri & Nicholls 2008). However, this study has been more focussed on ethno-ecological principles particularly on-farmers' knowledge and farming experiences about the climate variability during summer season as well as the selection and use of rice varieties for its adaptations in the selected study sites.

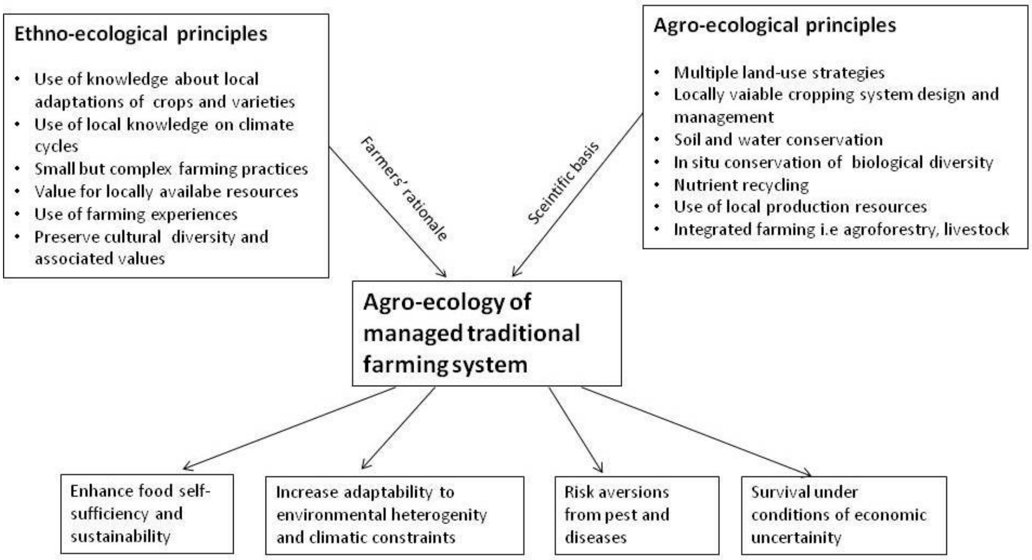

Figure 1. Agro-ecology of traditional farming system that combines both farmers' ethno-ecological knowledge and agro-ecological principles for sustainable production and adaptations to changes (adapted and modified from Altieri 2002).

Descriptions of study sites

The specific study sites were selected in consultation with Local Initiatives for Biodiversity, Research and Development (LI-BIRD). LI-BIRD is a national Non-governmental Organization (NGO) actively working on development-oriented participatory research in areas of community based agro-biodiversity management, participatory crop improvement as well as climate change adaptations in the country. The organisation is working in close collaboration with national research and extension agencies as well as many other like-minded NGOs and community based organizations. It has a wide coverage in terms of geographical areas and represents all agro-ecological zones from the high mountains to the terai. Therefore, LI-BIRD in its projects has emphasized work across different agro-ecological zones and the development regions in the county. Poor, disadvantaged and marginal farming communities are always prioritized as the target groups in its project activities. LI-BIRD has played a significant role in creating awareness, empowering farming communities, enhancing local livelihoods through increased food security, nutrition and income as well as policy advocacy in favour of rural farming communities.

A consultation meeting with LI-BIRD, organized during early August (2008) developed the criteria for site selection for this study. The criteria used for this purpose were basically defined as; agro- climatic zones, stress prone rice growing environments and the places where farmers reported changes in traditional summer rainfall in recent years. In the rice growing agro-climatic zones, it was decided to select one site each from terai and mid-hills. Based on the review of literatures and the personal communication with LI-BIRD, Western terai was identified representing more stress environments in terms of rainfall amount and its variability than in eastern terai. Within western terai, Belwa Village Development Committee (VDC) of Bardia district was selected among LI-BIRD working sites since it had a high proportion of rice area under rainfed and partially irrigated conditions (54 percent). LI-BIRD has been working in this VDC since two years specifically on community based agro-biodiversity management as a part of Western Terai Complex Landscape Project (WTCLP) with particular focus on cereals including rice and indigenous vegetables and fruits. The area has a high significance for agro-biodiversity study and management activities because there are many complex problems reported. The major problems were rapid loss in local diversity of cultivated crops due to commercially oriented farming practices as well as various stress conditions that have appeared in the past.

In the mid-hills, Begnas village of Kaski district was selected because farmers reported distinct variations in summer rainfall during recent years. The village lies within Lekhnath Municipality of Kaski district where LI-BIRD is working since more than a decade due to its high significance on rice crop diversity in the country. This was one of the global crop conservation project site of Bioversity International which aimed to understand scientific basis of in situ crop conservation with particular focus on five crops including the rice that have high local diversity. In this study, these two villages; Begnas and Belwa represent mid-hills and terai environment respectively with the different characteristics features (Table 1).

Kaski is the mid-hills district located in western region of Nepal with its headquarter Pokhara. It has an altitudinal range from 450-8091 masl. The topography is dominated by rugged terraces and sloping lands with a flat valley in the South. Rice based farming systems is common in the lower altitude towards the South. Rice is the first staple crop followed by maize and millet in terms of area and production (DADOa 2007). It is the highest rainfall zone in the country and receives an average annual rainfall of 3540 mm. The district is divided into four climatic zones; subtropical, warm temperate, temperate and tundra. The southern subtropical zone is the main area for agricultural production.

Table 1. Characteristics summary of the study sites.

Characteristics	Begnas	Belwa
Location	Kaski district	Bardia district
Agro-ecological zones	Western mid-hills	Western terai (plain)
Altitude (meters above sea level)	1000-1200	140-150
Climate	Subtropical	Tropical
Mean annual rainfall (mm)	>3500	<1500
Major rice growing conditions	Rainfed to partially irrigated	Rainfed to partially irrigated
Moisture regime	Wet (high rainfall)	Dry (low rainfall)
Farmers dependent on agriculture (percentage)	66.7	93.2
Community structure	Brahmin and Chetteri	Mixed (hill migrants and indigenous Tharu)

Source: DADO (2007a, 2007b); household survey

Mid-hills site: Begnas village, Kaski

The Begnas village of mid-hills study site is located about 20 km distance from Pokhara city. It represents the South-East part of the district and is adjoining with Pokhara valley. The village lies in Lekhnath municipality ward number ten and is linked by a fair season rural road. The altitude of the study site ranged from 1000-1200 masl and represents subtropical climate. Rice is the major crop grown in terraces under irrigated, partially irrigated and rainfed environments during summer season (Poudel and Johnsen 2008). Farmers are practicing subsistence oriented farming systems with the use of low external input and local genetic resources. Brahmin and Chettri, which represent the higher class in primitive social structure, are the dominant communities in Begnas village.

Terai site: Belwa Village, Bardia

Bardia district lies in the southern border of western Nepal and is a part of the Indo Gangetic plain. The district represents tropical to subtropical climate with an annual rainfall of 1128 mm (DADOb 2007). The annual mean maximum and minimum temperature of the district is 30.4°C and 18.1°C respectively. Rice is the major agricultural crop grown in the district. The study site included the four wards numbered; two, three, six and nine of Belwa Village Development Committee (VDC). It is connected with the national East-West highway and has networks of fair season rural roads within the villages. It is at a distance of 35 km from the district headquarter of Bardia district. Out of the total rice growing area, 54 percent of the area has no irrigation facility in Belwa (DADOb 2007). The study site is situated close to Bardia national park and represents the part of the buffer zone area. The Tharu are the indigenous traditional inhabitants, dominant (53 percent) in the area and with distinct socio-cultural traditions (Guneratne 2002). However, due to migration from other parts of the country, especially from mid-hills and mountains, the mixing up of ethnic composition is increasing.

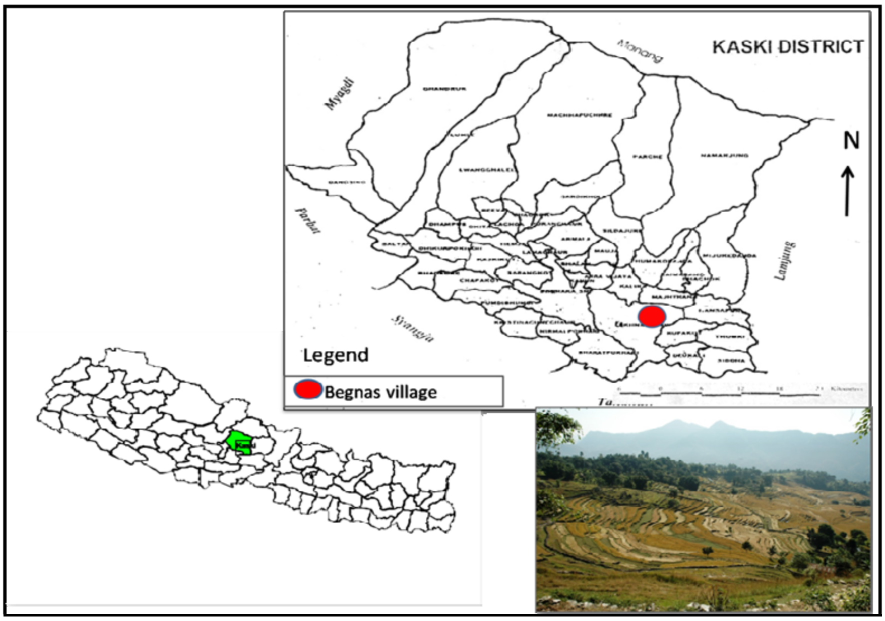

Figure 2. Map showing the study location, Begnas village in the mid-hills site of Kaski district, Nepal. The photo shows rice terraces typical of this area (Photo: B. Bhandari)

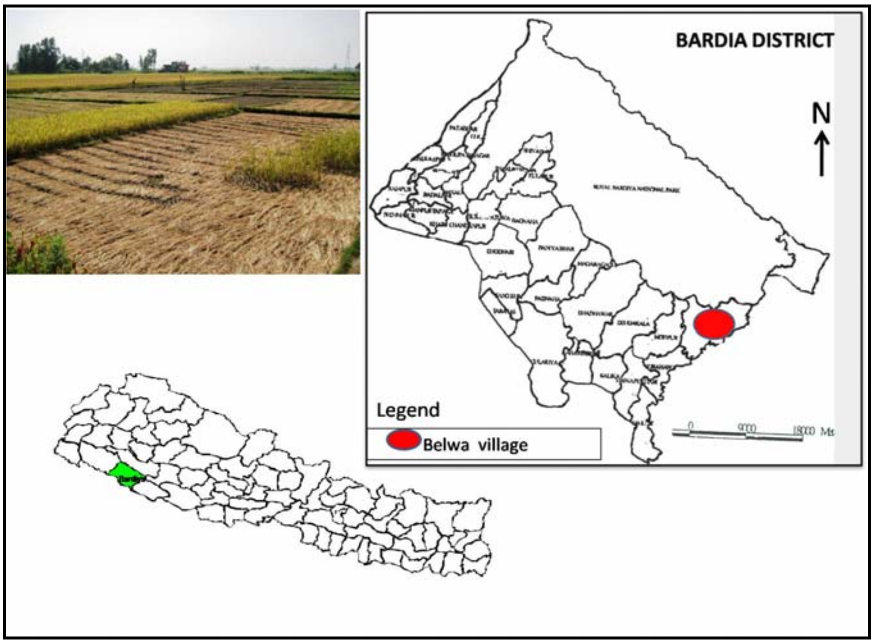

Figure 3. Map showing the study location, Belwa village in the western terai site of Bardia district, Nepal. The photo shows the rice crop in the flat land of terai. (Photo: B. Bhandari)

Khet land and its types in relation to rice growing environments

Khet land is the area where there is possibility of growing rice crop during the summer season. It is further classified in four categories based on moisture regime and irrigation management; un-irrigated tari, partially irrigated, irrigated and waterlogged low land. "Tari" is the bonded upland representing a marginal environment where rice is being grown completely under rainfed conditions. "Partially irrigated" is the rice growing environment between "tari" and "irrigated" land with very poor irrigation facility where success of crop is largely dependent on rainfall. Irrigated land has irrigation facility from canals and deep wells and is generally fertile for rice crop. "Low land" is the area with stagnant water where only rice can be grown easily without land reclamation. The rice area under tari and partially irrigated conditions are more prone to dry spells and droughts. On the contrary, irrigated and lowland areas are more susceptible to flooding during intense rainfall events. In both the study sites, there was higher proportion of tari and partially irrigated khet land area.

Study methods

The study employed both qualitative and quantitative methods to collect primary information from the sites. The methods used were household surveys, Focus Groups Discussions (FGDs) and direct observation. Secondary information basically on historical rainfall and crop production data covering to the study sites were accessed and utilised. Most of the information was collected through household survey using a structured questionnaire where the individual household was the sampling unit. FGD provided general information common to the community to further supplement the study.

The direct observation was carried out in both the study sites frequently in order to triangulate, justify and validate the responses obtained from the household survey and FGD. It was important to monitor on-farm rice varietal diversity and its distribution in crop growing season.

Study population, sampling frame and sample size

A household survey was carried out using sample survey in selected sites. The study population included in the survey were the farmers groups which already existed in the selected villages. These groups were formed by LI-BIRD to work with different projects in the area. The population was selected from more than one group to ensure sufficient sample size (>30) within a certain political boundary of Village Development Committee (VDC) and/or Municipality. These groups were selected from close proximities as far as possible to avoid spatial variations in their land types.

The sample size generally depends on the variability in the study population and the sampling techniques. A larger sample size is needed for stratified sampling than simple random sampling. The study adopted simple random sampling while selecting samples from the population. A general rule for simple random sampling is a minimum of 30 households. However, in this study, the statistically valid sample size was derived from the equation (Shrestha et al. 1999):

$$n = \frac{\{NZ^2P(1-P)\}}{\{Nd^2 + Z^2P(1-P)\}} \qquad (1)$$

Where;
n= sample size,
N= total number of study population (total number of selected respondents)
d= maximum acceptable error (in this case 10 percent)/sampling error
Z= the value of normal variable (1.64) to correspond with 90 percent reliability
P= the highest possible proportion of population (50 percent to give the largest possible sample size)
Three farmers groups from mid-hills site and four from the terai site were selected for the study. Forty five households in the mid-hills and forty four households in terai were sampled for the survey as calculated from the 'eq.' 1 (Table 2).

Table 2. The population and sample size of households surveyed in mid-hills and terai study sites.

Study site	District	Study village	No. of study groups	Ward No.	Population size	Sample size
Mid-hills (1000-1200 masl)	Kaski	Begnas	3	10	130	45 (34.7*)
Terai (approx. 150 masl)	Bardia	Belwa	4	2, 3,6 9	121	44 (36.4*)

*Percentage

In both sites, the proportionate number of respondents from each group to the total number was selected for the interview. As a process, the separate lists of farmers' group were identified through LI-BIRD in the selected working villages as the study population. It was noticed that gender inclusion was considered while forming these groups in both the study sites. In the study groups, the female representation was 45 percent in mid-hills and 42 percent in terai. The sample population of the study however, included 44 percent and 41percent female in mid-hills in terai respectively.

There is a division of labour between men and women in South Asia in the agricultural production systems which are separated by biological, social and cultural factors (Quisumbing 1996). In general, man perform heavy and outdoor works in crop farming such as ploughing, land preparations whereas light and domestic activities (planting, harvesting, seed management etc.) are the works for women (Gurung & Gurung 2002). In rice crop, women have higher labour contribution in transplanting, weeding as well as seed selection and management activities than their male counterparts. When comes it to decision making on variety selection, there are no consistent findings in the literatures. There is an inter-community variation in gender role of decision making on agricultural production in the country (Pradhan 1985). The gender role of decision in selecting varieties also differs among crops. Shrestha et al. (1999) in the study of maize crop in Nepal reported a non-significant influence of gender in the varietal choices of maize varieties although women contribute more than men in production activities. For the major staple crops such as rice, in most of the cases, farmers select varieties in consensus. Females are seen having more privilege to select varieties in minor crops i.e. finger millet and beans. However, Rana et al. (2008) reported that farmers select rice varieties and deploy in agro-ecosystems based on their understandings of varietal characteristics, agro-ecosystems characteristics and the interactions between them. It indicates that varietal characteristics, the knowledge and preference of which may vary with gender, is not the only criterion when it comes to variety selection in rice crop. The agro- ecosystem characteristics and the perceived interactions between varieties and agro-ecosystem is much more influential in selecting rice varieties and men and women do not show disagreement in their understanding in this regard. For this reason gender perceptions of varietal selections for adaptations to rainfall stresses were not differentiated in this study.

The questionnaire and survey

A structured questionnaire constituting both open and close ended questions was developed to acquire information required for each study objective (Appendix 4). The questionnaire had four sections. The first focused on the demographic and socio-economic information such as age, sex, education, occupation, family size, food security and income sources. The second section captured information regarding resources such as land and its types, varietal diversity and its abundance. The third section explored farmers' perceptions of rainfall variations during rice growing season and its effect on rice production and food security. This section also ranked vulnerability of rice varieties and landraces particularly in relation to abnormal rainfall events. The final section was about farmers' adaptations, knowledge and practices. To enhance the validity of the questionnaire, it was pre-tested with non-respondents outside the sample frame close to the mid-hills site with the purpose of identifying how farmers understand and respond to each question asked. It was further refined based on their feedback and level of understanding. Finally, the questionnaire was translated into local Nepali vernacular language to facilitate better understanding by the respondents.

The survey was conducted at the end of September in mid-hills and during second week of October in terai. Personnel trained in survey work were employed as survey assistants and were further oriented before conducting the survey. The survey participants were informed individually three days before to allow them to allocate time. The survey assistants under the supervision of researcher administered household survey through face to face interview technique at both sites.

Focus group discussion

Focus Group Discussion (FGD) is a qualitative study method that requires a small homogeneous group of experienced people to discuss a study topic (McCallister 1998). It is an exploratory research tool and is extensively used by researchers to generate qualitative data and triangulate findings (Morgan 1997). In this study, FGD was used to draw information from the study sites related to varietal dynamics, rainfall related stress events as well as its locally perceived effects on food security. The discussion was led by the researcher with the use of a checklist prepared. Four experienced persons including at least one female from each participating group were invited to participate in each FGD (Appendix 3).

Figure 4. Researcher conducting household survey in terai (left) and focus group discussion in mid-hills study site (right). (Photo: B. Bhandari)

The participating community people provided the requested information based on their recall on past and present experiences on the study topic in each FGD. Three FGDs were organized in each study site during the entire study period. The first was before the survey in August to discuss general facts about the study sites and the participation. The second was during the time of the household survey to conduct historical time line analysis on rainfall changes, its dynamic effect on production and food security. Timeline analysis is a qualitative research tool that facilitates trend analysis, situation assessment and future predictions (Barry 1997). The basic idea of time line analysis in this study was to recall the major rainfall related stress events of the past and present that have had an effect on rice crop, its diversity and other aspects in the society. Finally, the third FGD was a general discussion after one month of survey to validate and share some of the preliminary findings with the participants.

Timeframe for assessing variations and changes in the rainfall

In this study, farmers' perceptions on summer rainfall and its pattern were compared with the meteorological data of two periods; the 2004-2008 and 1995-1999. The timeframe set here was discussed and decided with farmers groups in the FGD, because they maintained that there have been distinct changes in this time period (≈10 years). It is reported that a period of more than five years and less than ten years can be used to describe climate variability (Esterlings & Apps 2005; Smit et al. 1996). The respondents rated rainfall pattern in terms of total rainfall amount, intensity and number of rainy days as: increased, decreased or no difference based on their recall and experiences of the past. They also rated onset of monsoon time as: early, late or bimodal distribution. The timing of the onset of the monsoon has a large effect on rice transplanting under rainfed conditions. Similarly, to compare farmers' responses, rainfall data were collected from the closest meteorological stations located within 20 km distance from both the study sites. Rainfall data were made available from the Department of Hydrology and Meteorology (DoMH). Similarly, district level rice production information for fourteen years was obtained from the District Agricultural Development Offices (DADOs) of the respective site to look at the relationship between summer rainfall and rice production.

Ranking of production loss and effect on food security

Even though there are standard methods and models to estimate and predict production losses and effects on food security, they all need good farms records. In subsistence based traditional farming systems, such information is generally lacking and therefore, it is difficult to quantify production loss exactly. However, participatory research tools are useful to handle such situations and contribute greatly to understand the complexity of many farming systems (Chambers 1994). Moreover, qualitative information can also translate into quantitative form using ranking and scoring technique which provides valuable information for understanding the ways in which communities value and manage their genetic resources (King 2000).

In this study, attempts were made to estimate perceived yield loss and its effect on reducing normal food security based on farmers' recall and experiences in the local context from each household participated in the survey. The estimation method used was ranked scoring, which was identified though participatory exercise with the community people during FGD. For production loss, it was decided to use a scale of 0-3, explained as; 0=no effect on yield loss, <1=low (less than 5 percent loss), 1-2=high (5-25 percent loss) and >2=very high (>25 percent loss). Farmers saw these limits as relevant to estimate production loss due to rainfall variability in their local context. In the process, the farmers in the FGD first listed abnormal rainfall years with related major stress (either drought or flood) experienced after 2000 in each site. These abnormal years were 2002, 2005 and 2006 in mid-hills and 2001, 2002 and 2007 in terai. Each respondent during the household survey was asked to rank their rice production losses for each listed stress years using the scale above. Finally, mean scores were calculated and used for analysis.

A similar scoring method was used to identify the perceived effect on household food security during the selected abnormal rainfall years. In the household survey, each respondent through their recall, ranked on 0-2 scale where, 0 denotes food security not affected, 1 means food security reduced by less than 45 days (less affected), and 2 denotes food security reduced by more than 45 days (more affected). The mean score values were calculated and used in the analysis.

Vulnerability ranking and clustering of varieties

For the purpose of this study, crop vulnerability was defined as perceived risk of crop failure for a certain variety in terms of production loss during abnormal rainfall related stresses such as drought, dry spells, intense rain and flooding. The same rank score method as described above in estimating risks of crop production loss was used to rank perceived vulnerability of rice varieties. Respondents were asked to rank each variety they were growing at present by assigning a rank of 0-3 across selected rainfall related stress scenarios. The rainfall related stress scenarios that can affect rice production were identified by thorough discussions with farmers groups in the FGD in each site. These identified common scenarios were; delayed planting (due to drought or dry spell), insufficient or excess rain during establishment, drought or dry spell during growth, insufficient or excess rain during flowering, drought or dry spell during milking stage and excess rain at harvest. The time periods when these stresses could appear also relate to different summer months and also the critical rice growth and development stages. These stress conditions are important in the local conditions and were identified by the farmers themselves in FGD. Each variety and landrace grown was ranked through household survey across all these stress scenarios that can appear during the rice growing season in order to identify its overall vulnerability.

Clustering is a simple way of describing the similarity of the objects. The Hierarchical Cluster Analysis (HCA) was used in order to group varieties that were in terms of their perceived vulnerability scores to rainfall related stress. Clustering was done in SPSS software version 15.0. In this analysis, the hierarchical cluster algorithm identifies relatively homogenous groups of varieties based on euclidian distance that measures dissimilarly and similarity (Aldenderfer and Blashfield 1995). It was calculated from mean vulnerability rank scores for all varieties in terms of their perceived production loss during abnormal rainfall events. It hence groups varieties that have similar vulnerability.

Measurement of varietal diversity

Many studies have used variety names to identify diversity on-farm within crop species that farmers' can recognize as diversity (Jarvis et al. 2008, Long et al. 2000; Thrupp 1998). In this study, farmers named rice varieties and the area under each was recorded through a household survey. There is a risk that farmers sometimes give many local names to the same variety especially for the landraces, and this might over-estimate the diversity that is actually present on-farm. To avoid this situation, multiple approaches were used. The available information from LI-BIRD on rice varieties and landraces in the study sites were accessed and used. LI-BIRD had already collected and screened rice landraces in the diversity block under its agro-biodiversity management projects in both the study sites. Similarly, farmer groups and local Agricultural Development Officers were consulted during the field survey. Additionally, a plant breeder from the national research system was invited for field visit to identify any inconsistency in the identification and naming of the varieties.

All the varieties and landraces recorded in each household were further categorized into four types; hybrids, modern varieties, landraces and PPB bred varieties. PPB varieties were developed locally through Participatory Plant Breeding (PPB) approach which utilised adapted local landraces as one of the parent in crossing (Sthapit et al. 2002). To estimate the diversity in agricultural crops, the simplest way is to count the total number of different crops and its varieties per farm (Bradshaw et al. 2005, Jarvis et al. 2008). This criterion however, has some limitations since it does not include reference to their abundance (Clergue et al. 2005). Diversity therefore generally expressed as an index value to take accounts both the number of species and/or varieties and their abundance (Magurran 2004).

In this study, alpha diversity, the most commonly used index for diversity richness, was estimated using the software programme "Species Diversity and Richness" version 2.2. Alpha diversity by varietal types; hybrids, modern varieties, landraces and PPB bred varieties where calculated to compare rice diversity in the study sites. The total number of varieties within each type and its area grown were used to calculate Shannon-Weiner (H') and Equitability (J) indices. The Shannon-Weiner index gives general information about the diversity richness where the index value increases with an increase in the diversity. The Equitability index (J) measures the dominance patterns in terms of heterogeneity of varieties. Its value ranges from 0-1, where low evenness indicates dominance by one or few varieties. Moreover, significance level of indices between the sites was calculated using Bootstrap.

Statistical analyzes

The qualitative information obtained from the FGD is presented in simple table. Statistical analysis of the quantitative data from the household survey was performed using the SPSS software version 15.0. Descriptive statistics (percentage, mean, standard deviation) and inferential statistics such as chi-square test and correlation were computed whenever appropriate. As a thumb rule, normality test was conducted before choosing the suitable statistical tool for the analysis. For non-normal categorical and rank data, non-parametric tests such as Mannan-Whitney (U-test) and Kruskal-Wallis were used to analyse the difference between two and more independent groups and/or between groups. Hierarchical Cluster Analysis (HCA) was used to classify crop varieties and landraces in different groups based on their perceived vulnerability rank scores. In addition, Species diversity and richness software version 2.2 (Henderson & Seaby 1998) was used for calculating diversity indices of rice varieties.

Results

Socio-economic characteristics of the study sites

Gender, age, education and livelihood options of the respondents

Of the total number of respondents, female representation in the study was 44 percent in mid-hills and 41 percent in terai. Based on years of schooling, the respondents' education status was identified as primary (<5 years), secondary (>=10 years) and higher education (>10 years) through a household survey. There was a significant difference ($\chi2=9.6$, df=2, $p<0.05$) in the education status of the respondents between the sites. The majority of respondents attended primary level education both in mid-hills (54.5 percent) and terai (77.8 percent). In mid-hills, there were higher numbers (45.5 percent) who received secondary level education and above as compared to terai (22.2 percent).

Based on age of the respondents, they were categorised into three groups; young (>35 years), middle aged (35-50 years) and old (>50 years). There was a significant difference ($\chi2=12.8$, df=2, $p<0.002$) in the age groups of the respondents between the sites. There were a higher number of young farmers (36.4 percent) in terai than in mid-hills (8.89 percent). The percentage of old aged people involved in farming was higher in mid-hills (42.2 percent) as compared to terai (15.9 percent). It was because crop farming was considered to be less attractive in the mid-hills and furthermore, many young people were engaged in other activities to diversify their household income sources.

Agriculture by default was the principal occupation option for the majority of households and of course, the primary source of family income in both the study sites (Table 3). The level of dependency on agriculture was however, higher in terai as compared to mid-hills. Besides agriculture, services and remittance contributed as primary sources of income to 22.2 percent and 8.9 percent households respectively in mid-hills. Therefore, there were higher numbers of households with multiple sources of income in the mid-hills than in terai. However, wage labour which is less secure work, had contributed as a second income source for 20.5 percent households in terai.

Table 3. Number of respondents with primary, secondary and tertiary sources of household income for their livelihood options in the study sites. Percentage given in parentheses.

Livelihood options	Mid-hills n=45			Terai n=44		
	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
Agriculture	30 (66.7)	14 (31.1)	1 (2.2)	41 (93.2)	3 (6.8)	0
Services	10 (22.2)	8 (17.8)	3 (6.7)	0	8 (18.2)	2(4.5)
Business	0	4 (8.9)	2 (4.4)	1 (2.3)	2 (4.5)	1(2.3)
Remittance	4 (8.9)	7 (15.6)	7 (15.6)	1(2.3)	11 (25.0)	0
Wage labour	1 (2.2)	5 (11.1)	3 (6.7)	1(2.3)	9 (20.5)	1(2.3)

Khet land holding and food security

Since, the majority of respondents are dependent on agriculture as a major source of their livelihood strategy, the khet land (see methods) which is more productive than bari land (un-bonded upland), is one of the indicators for wealth category and food security in Nepalese society. In this study, the farms were divided into three categories; small, medium and large, based on their relative land holding size in the community. The local unit of land holding measurement, which is ropani (1 ropani =500 sq. m), was used as basis to categorize farm in the FGD. The limit set for small, medium and large farms were: < 5 ropani (<0.25 ha), 5-15 ropani (0.25-0.75 ha) and >15 (>0.75 ha) ropani respectively. All the respondents were divided into three categories; poor, medium and rich according to the land resource they were holding. The chi-square test showed that there was no significant difference ($\chi2= 2.4$, df=2, $P>0.05$) between sites in the respondents' farm size.

The percentage of small farmers (<0.25 ha) was higher in terai (36.4 percent) than in mid-hills (22.2 percent). Although there were higher percentage of households with medium (48.9 percent) and large (28.9 percent) farm size holdings in mid-hills; food security from their own production was however, reported to be less as compared to terai (Table 4). This is because khet land in mid-hills is more marginal in its productivity than in terai. Terai was reported to be more productive during normal season. There were significantly ($\chi2=$ 15.9, df=3, $p<0.001$) higher number of households with all year food security in terai during normal year of production than in mid-hills (Table 4).

Table 4. Number of respondents with different levels of household food security from their own production in the study sites. Percentage given in parentheses.

Food security	Mid-hills n=45	Terai n=44	Total
<3 months	10 (22.2)	5 (11.4)	13 (14.6)
3-6 months	11 (24.4)	6 (13.6)	17 (19.1)
6-9 months	15 (33.3)	6 (13.6)	21 (23.6)
>9 months	9 (20.0)	27 (61.4)	33 (37.1)

Crop production, summer rainfall variability and its pattern

Relationship between summer rainfall and rice yield in the study districts

Study analysed fifteen years (1995-2008) annual rainfall and rice production to compare the relationships between these two variables in the study districts on the availability of production data. The meteorological information was accessed through the Department of Hydrology and Meteorology (DoHM) whereas the District Agricultural Development Offices (DADOs) provided rice production data. The annual rainfall from May to October was studied to capture pre monsoon, monsoon and post monsoon rainfall that generally have direct and indirect effect on rice production. The relationship between rice production and the amount of rainfall was analysed using spearman's correlation coefficient (rs). The rice production was significantly correlated ($rs=0.56$, $p<0.05$) with the amount of rainfall in terai, where there was less annual mean rainfall than in mid-hills district (Fig 5a). However, in the mid-hills, which received high mean rainfall, this relationship was non-significant ($rs=0.06$, $p>0.05$) (Fig. 5b).

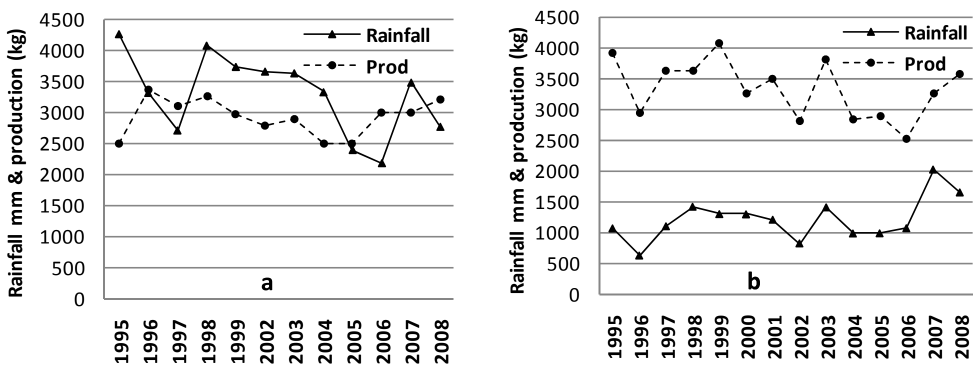

Figure 5. Relationship between amout of rainfall (May-October) and rice production during the period of 1995- 2008 in the study districts. In the figure, a represents Kaski in mid-hills and b represents Bardia in terai.

The relationship has indicated that changes in rainfall amount can affect rice production more in western terai than in the mid-hills. In mid-hills, since it is a high rainfall zone in the country receiving more than 3000 mm annual rainfall, slight decrease in the total amount of rainfall does not affect the production of rice crop significantly, if distributed normally within the growing season. In mid-hills, sometimes it is rather common that if there is excess rainfall for a longer duration, it may decrease production due to increase in disease and pest problems. However, western terai is a relatively drier area than mid-hills site receiving less than 1500 mm annual rainfall. In such drier areas, a slight decrease in the rainfall will quickly lead to moisture deficiency for rice crop, largely affecting crop production negatively. It indicates that the rice crop of western terai is more likely to be affected with a resulting yield reduction for rice crop than that of mid-hills for similar days of dry spells and drought period.

Perceived and measured variability in rainfall pattern in the study sites

To identify their perceptions, farmers were asked to rank variations of summer rainfall patterns; onset of rain, total amount, intensity of rain and number of rainy days in a period of 2004-2008 compared with the period before 2000 (1994-1999). There was a notable difference in the responses about changes in amount, intensity and the number of rainy days between sites (Table 5). The majority of respondents responded that the total amount, short and intense rainfall events and the number of rainy days was perceived to be decreasing in the mid-hills during 2004-2008 (Table 5). However, in terai, both the amount and intense rainfall events were perceived to be increasing in 2004-2008 as compared with the base study period (1994-1999). The few numbers of respondents who reported no differences were excluded from analyses of chi-square test in the table 5.

Table 5. Number of farmers' responding to variations in summer rainfall amount and its patterns in 2004-2008 as compared with the period before 2000 (1995-1999) in the study sites.

	Mid-hills (n=45)			Terai (n=44)			χ2 value
Parameters	Increased	Decreased	same	Increased	decreased	Same	
Amount	14	30	1	27	14	3	9.9*
Intensity	9	36	0	34	8	2	32.3**
No of rainy days	5	40	0	13	27	4	5.8*

*Degree of freedom=1

Importantly, the respondents also reported changes in the distribution pattern of summer rainfall during 2004-2008 in the mid-hills. Sixty six percent of the respondents had noticed bimodal distribution in later rainfall pattern with two peaks, as compared to a single peak in June-July (locally known as Ashad-Shrawan) as was normal before. Thus, according to the farmers, the rainfall pattern has shifted to either early or late in mid-hills. It was noticed that this has increased the vulnerability for rice production with increasing frequency of dry spells in June-July. In terai, 77.3 percent of the respondents stated that pre monsoon rainfall amount has increased but distribution pattern of the monsoon rain over the season is unchanged.

For rice crop, farmers divided the entire rice growing season in six important stages that relate to each summer month which are critical and may affect production, if there are fluctuations in rainfall. These stages and its corresponding months are: before transplanting (May), transplanting (June), and crop establishment (July), growth stage (August), flowering and milking (September) and harvesting (October). At both sites, higher number of respondents reported that pre monsoon rainfall amount in the month of April-May (known as Jestha in local calendar) have increased in 2004-2008 (Fig. 6). In mid-hills, a significantly higher ($\chi 2=17.9$, df=1, $p<0.01$) number of farmers reported increasing frequency of dry spells during rice transplanting (June) and establishment (July) stages during 2004-2008 than in terai (Fig. 6).

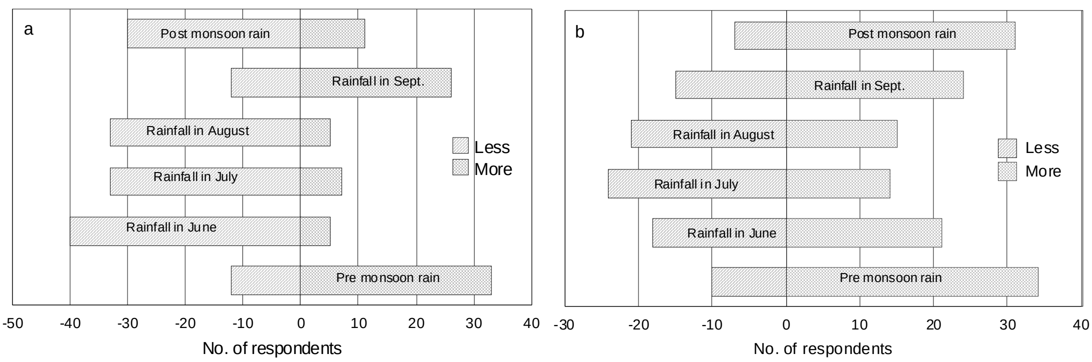

Figure 6. Respondents' perceptions of summer rainfall changes (increase or decrease) in 2004-2008 as compared with 1995-1999. In the figure, a (mid-hills) and b (terai) show perceived rainfall changes during pre monsoon (April-May), monsoon in June, July, August and September and Post monsoon (October-November). The bar indicates the number of respondents that perceive either increase (positive) or decrease (negative) in the rainfall amount.

Similarly, the onset of the monsoon rain is generally expected in early June in the mid-hills. It now appears to have shifted later, affecting the normal time of rice transplanting. In August, during the crop growth period, dry spells were reported to be increasing at both the sites (Fig. 5). Whereas, during flowing and milking periods in September, the majority of respondents reported an increase in rainfall amount irrespective of the sites. Farmers further reported that post monsoon rainfall during October-November has increased in terai during crop harvesting, affecting the production negatively in 2004-2008 (Fig. 6).

To compare farmers' responses with the recorded rainfall and its distribution over the season, historical rainfall data representing the study sites from May to October were analysed during the periods in 2004-2008 and 1995-1999. The major changes in the rainfall pattern observed in the meteorological data clearly coincide with the farmers' responses. It showed a backward shifting (August-September) of the monsoon peak timings and also a decrease in the total amount during May to October in mid-hills (Fig. 9a). In terai, there was no shift in the peak rainfall timings; however the rainfall data showed an increase in the amount during 2004-2008 as stated by the majority of farmers (Fig. 8a, 8b). In mid-hills, meteorological record in 2004-2008 showed more pre monsoon rain in April-May and a deficit trend during June-July and again excess after August. This follows like a bimodal distribution with two peaks as stated by the majority of respondents in the mid-hills (Fig.7b).

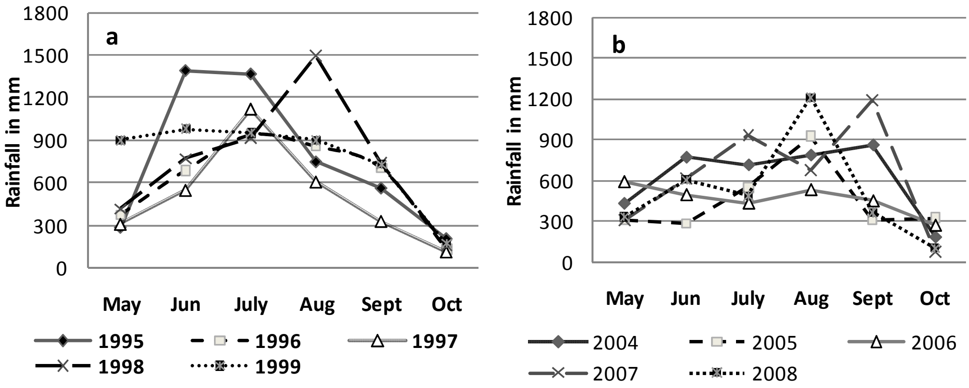

Figure 7. Summer rainfall amount and its distribution patterns during pre monsoon (May), monsoon (June-September) and post monsoon (October) in two periods in mid-hills site. In the figure, a represents 1995-1999 and b represents for 2004-2008.

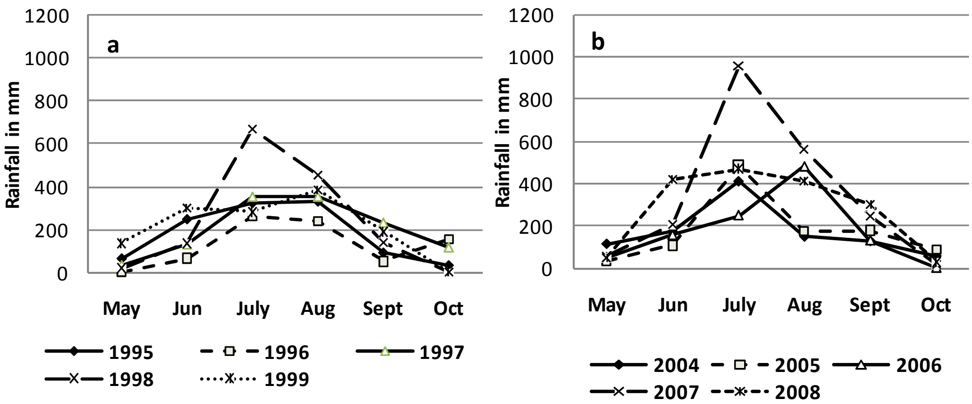

Figure 8. Summer rainfall and amount and its distribution patterns during pre monsoon (May), monsoon (June-September) and post monsoon (October) during two periods in terai site. In the figure, a represents 1995-1999 and b represents 2004-2008.

On average, the rainfall data showed that the total rainfall in mid-hills during May to October decreased by 19.1 percent in 2004-2008 as compared with 1995-1999. The rainfall decreased most in the months of June (36.7 percent) and July (40.9 percent). In the same period however, the average pre monsoon rainfall increased in April (41.7 percent), late monsoon in September (3.8 percent) and post monsoon in October (22.3 percent) in 2004-2008. The average numbers of total rainy days also decreased by five days during May-October.

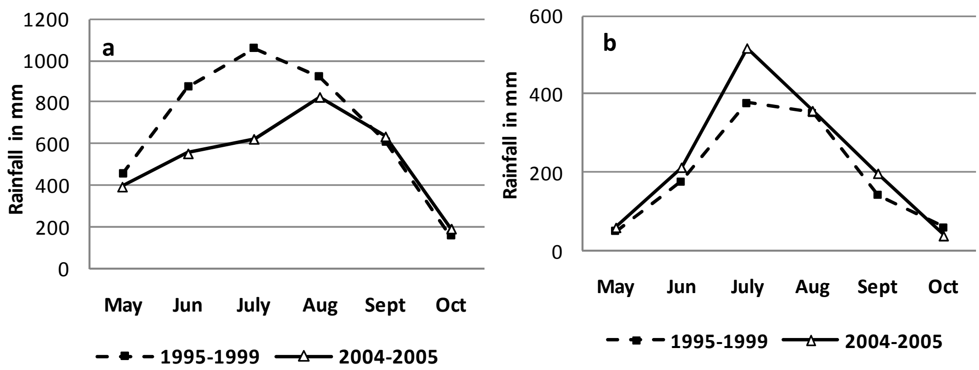

Figure 9. Mean summer rainfall amount and its distribution patterns during pre monsoon (May), monsoon (June-September) and post monsoon (October) in two periods, 1995-1999 and 2004-2008 in the study sites. In the figure, a represents mid-hills and b represents terai.

On the contrary, in terai, the total average rainfall has increased by 19.2 percent during May-October in 2004-2008 compared with 1995-1999. In the same period, pre monsoon (April) rain increased by 50.9 percent whereas late monsoon rain (September) increased by 39.7 percent. During 2004-2008, there was an increasing trend of rainfall in every summer month except in August and October. In the same period, the average number of rainy days increased by three days. However, the overall pattern of rainfall distribution in terai remained unchanged with a peak amount in July-August (Fig. 9b).

The comparison of results of farmers' perceptions and the meteorological data demonstrate that farmers in general possessed good knowledge on rainfall variability and changes. It is also seen that they look variations and changes in each month relating to particular crop growth and development stages. In this regard, one of the leader farmers of Begnas, Mr Kulchandra Adhikari in the FGD expressed; "It does not matter for the farmers how much rain we received in a year, but what is important for us is at which time and how many days there was rainfall in the growing season, since it largely determines for the success of rice crop. Thus, a higher amount of total rainfall in certain year does not necessarily mean there is good harvest in that year". It shows farmers' concern regarding the importance of rainfall timing and its distribution rather than its total amount. The analysis has shown a good correlation between the observed rainfall variability and farmers' understanding which is based on close and continuous crop-weather observations.

Rice diversity and rainfall related stress

Rice varietal diversity in the study sites

In both the study sites, farmers were growing different types of rice varieties side by side on their farm: landraces, modern, PPB bred varieties (mid-hills) and hybrids (terai). There was a contrast in the varietal choices among farmers between the sites. In mid-hills, the major dominant varieties were landraces, whereas modern varieties dominated in terai (Fig. 10). PPB bred varieties were frequently referred to as common in mid-hills. Hybrid varieties were increasingly spreading in terai in the last three years. In total, almost the same number of varieties (≈4) was maintained on-farm by each household in both the study sites (Table 6). However, at community level, the terai site held a larger number of varieties (26) than the mid-hills site (22). Out of 26 varieties reported in terai, 15 were modern, 6 landraces and 4 hybrids. Similarly, in mid-hills, there were 15 landraces, 4 modern varieties and 3 PPB bred varieties. There was a broader distribution of the same varieties among households in mid-hills as compared to terai.

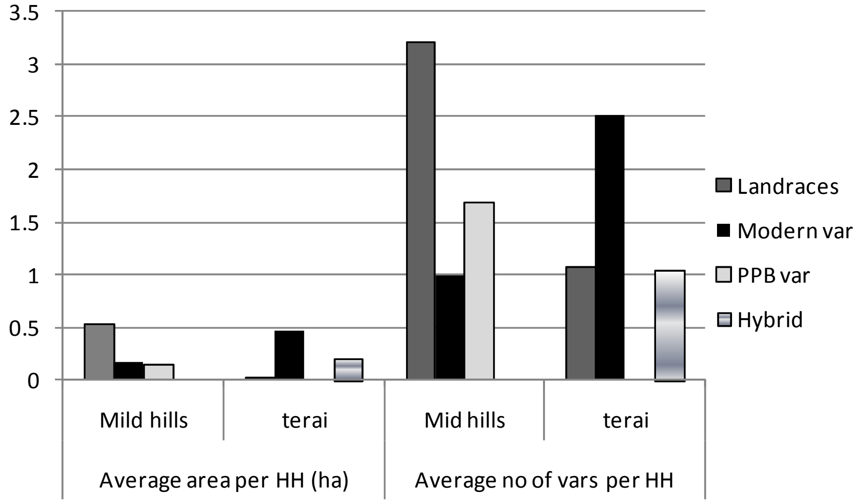

Figure 10. Average varietal richness and its distribution in terms of average number and the average area grown for landraces, modern varieties, PPB bred varieties and hybrids in the study sites. The area is expressed in ropani which the local land measurement unit, where 1 ropani is equivalent to 500 square meter area.

In order to better explain the diversity richness and its distribution, Shannon-Weiner (H') by varietal types was calculated based on total number of varieties and its area grown as an indicator of abundance. In terms of index value (H'), the total estimated amount of varietal diversity was significantly higher (p value 0.00) in terai as compared to mid-hills (Table 6). At the same time, the H' value showed a significant ($p<0.05$) higher amount of landrace diversity in mid-hills site and modern varieties diversity (p value 0.00) in terai.

The abundance of varieties in the community in terms of area coverage was analysed with the Equitability index (J). A lower J value indicates higher dominance of one or few varieties and vice versa. The analysis revealed a more even distribution of the varieties in terai (J=0.68) as compared to mid-hills (J=0.53) (Table 6). In mid-hills, the most popular single dominant variety was a landrace Ekle, dominating 63 percent of the total rice area. It is because many households prefer to grow this particular landrace on a large area. Many other landraces have also been maintained in the mid-hills since they are better adapted to the niche production environments than modern varieties and, some of them are valued for socio-cultural uses. However, in terai, the most dominant variety was Radha-4, which was released by national system in 1995 for the similar area. It has occupied 28 percent of the total rice area in terai site. Unlike in the mid-hills, there were few landraces being maintained on-farm in terai. The study indicated farmers' willingness to grow those landraces in terai that have high quality traits such as Shyamjeera (fine grain aromatic rice landrace) and/or socio-cultural uses i. e. Anadi (a sticky rice landrace). However, it has also been found that only the well-off farmers who hold bigger land size are only growing those landraces that have high quality traits i.e. Shyamjeera. It is because of low production potential of such landraces as compared with modern varieties.

Anadi is the sticky rice landrace that has unique socio-cultural importance among many communities including the indigenous Tharu in terai. It is particularly used to prepare special traditional food dishes such as latte and siraula during many cultural and religious occasions in Nepalese society. Therefore, Anadi was the most popular and commonly grown local landrace by many households in smaller area irrespective of the study sites. Among the total households growing Anadi in terai, 85.7 percent were the Tharu households. It indicates that Tharu community have a stronger socio-cultural link with this landrace than the hill migrants in terai.

Table 6. Total rice area (ha), total number of varieties recorded in the community, average number of rice varieties grown by each household and the calculated diversity richness and evenness indices; Shannon-Wiener (H′) and Equitability (J) for the study sites (mid-hills, n= 45; terai, n=44).

Type of variety	Total area		Total var. recorded in community		Average number of varieties per household		Shannon-Weiner index H'			Equatibility J	
	Mid-hills	Terai	Mid-hills	Terai	Mid-hills	Terai	Mid- hill	Terai	p-value	Mid-hills	Terai
Landraces	23.95	0.82	14	6	3.20±1.52	1.08±0.28	1.5	0.62	0.03	0.49	0.21
Modern	1.53	21.13	4	16	1.00±0.00	2.52±1.07	0.40	2.17	0.00	0.14	0.77
PPB variety	3.33	-	4	-	1.69±0.70	-	1.27	-	-	0.61	-
Hybrid	-	4.64		4	-	1.05±0.22		1.24	-	-	0.59
Overall	28.81	26.59	22	26	4.20±2.23	3.64±1.29	2.00	2.58	0.00	0.53	0.68

Local perception on rainfall stresses and its effect on rice varietal diversity

In the Focus Group Discussion (FGD), historical timeline analysis was carried out with the participation of experienced community people to identify important rainfall related stress events and its consequences during the last thirty years. The analysis showed more frequent drought events in terai as compared to mid-hills in the past (Table 7). It was because terai represent low rainfall zone and is therefore more vulnerable to drought than the mid-hills. Moreover, respondents in FGD reported that these drought and rainfall stress events were milestone periods to introduce new varieties in terai and therefore were significant in changing varietal dynamics. In certain drought aggravated famine, farmers also lost their seed of some local landraces. One of the respondents, Mr Kali Ram Tharu from terai said, "The drought of the year 1971 appeared so severe that it caused famine in the area due to shortfall in farm production. We consumed all the seed stocks. Some people exchanged household utensils for food grain from villagers nearby". It indicates the severity and its effect on food security that can sometimes affect on seed savings and its systems, which are important to hold and create varietal diversity in traditional farming systems.

It was a common strategy to promote new improved varieties after each severe drought event in the area of terai and elsewhere. After the severe droughts of 1971 and 1979; drought tolerant, short duration and early maturing modern varieties were introduced in terai (Table 7). As a consequence, as per farmers' responses, many long duration and high water requiring landraces were replaced gradually by those introduced modern varieties. Other important reasons for the replacement of landraces were the higher yield potential of modern varieties and its relatively short cropping season. As reported in FGD, the majority of the local landraces were lost from terai after the drought of 1991 except those that have socio-cultural values (Anadi) and high quality traits (Shyamjeera). In some of the years, flooding was also reported due to short intense rainfall particularly in recent years. Flooding can have a detrimental effect, but it was not as common as drought in the past. Moreover, unlike drought, flooding had no perceived major effect in changing crop varieties.

In mid-hills, farmers have reported an increasing trend of dry spells in recent years. They experienced few severe drought years in the past (Table 7). In contrast to terai, only a few modern varieties have been introduced in mid-hills, among which Masuli is the dominant one. It is because landraces in the mid-hills were reported to be the best adapted in diverse production niches. These were seen competitive in terms of production potential with a better grain quality and fodder yield compared with improved varieties. They showed a better performance than improved varieties during rainfall variations and stresses. Some of the improved varieties such as Khumal-4 which is recommended for mid-hills conditions frequently reported having a high production risk due to poor grain filling (Fig. 11). Recently, farmers in mid-hills site have improved some of their popular landraces to meet production and adaptation requirement though PPB approach with the support from situ crop conservation project. The project was implemented by LI-BIRD in partnership with Nepal Agriculture Research Council (NARC) and Bioversity International. From the analysis, it appeared that the varietal dynamics in mid-hills was less affected due to such rainfall related stresses as compared to terai in the past.

As reported by farmers, in the season following a severe drought, they used to increase winter cereals mainly wheat as a coping strategy in terai. Government strategy in such situation is to increase winter crop production in the area through providing inputs including improved seeds either free or in subsidized prices to the farmers. At the same time, the government policy for rice crop in the country has focused on replacing local landraces by introducing improved varieties to increase rice production and productivity with a particular emphasis in terai. Due to these reasons, there was an increased availability of improved variety seed that has characteristics like short duration and drought tolerance to the area after each severe drought year. On the other hand, there was no seed supply mechanisms for landraces and these were therefore simply lost due to seed unavailability during extreme drought years even though, farmers were interested to continue growing some of them.

Figure 11. Comparison of performance of improved variety (left) and popular landrace Ekle (right) under similar growing condition in mid-hills site in 2008. As shown in the figure, the improved variety Khumal-4 has poor grain filling whereas the landrace Ekle is performing well. (Photo: B. Bhandari)

Table 7. Thirty years of rainfall related stresses and severities, its perceived socio-economic consequences as well as effect on rice varietal dynamics in the study sites.

Rainfall stress years	Notable consequences of severe events	Important period for changing varietal dynamics
Mid-hills		
1971 drought (June) and hailstone	Crop damage, famine, cultivation of maize and millet increased	Not affected
1992 drought in June	Small holders highly affected, food for work programme lunched to feed people	Area under local landrace Ekle increased
2005 drought in June-July	Un-irrigated tari not cropped, small holders affected	PPB varieties developed and spread in tari replacing local Mansara and similar other varieties
1985, 1993, 1997, 2002, 2006, 2008-Partial drought affecting production		-
1976, 1979, 1995, 1998, 2001	short intense rain causing landslide, loss of crop and land, some people migrated to terai (1976)	Not affected
Terai		
1971 drought	Indigenous Tharu started selling their land, people migrated from hills	Improved variety Tichung introduced
1976 drought in June, Sept, Oct	Started searching alternative income sources, hill migrant went India and Tharu went out for wage labour	Early and short duration varieties; IR-24, Bijannabbe, introduced and replaced some landraces
1986 drought in June-July	Small holders affected, Farmers debited from bank	Janaki, Sabitri Bindeshowri introduced and increased
1991-1992 drought in June-July	Debited from bank, Tharu also started searching alternative options, Initiated to conserve community forest	Introduced drought tolerant early varieties i. e. Radha-4 (as 8884), Khajura replacing many landraces
2002 drought in June-July	Transplanting not completed	New varities added; Mala, Sarju
1996, 1997, 2001, 2004-Partial drought		-
1979, 1987, 1995, 2001, 2002, 2007	Short intense detrimental rain: Flooding in low land and damaged rice	Introduced hybrid (2006)

As one of the coping strategies to adapt to food shortages, Tharu community in the terai has a tradition since long past to store milled rice grain in every household in amounts at least sufficient for six months, since by that time they can harvest the winter season crop. They use a locally designed earthen structure called Kothly and Deheri to store milled rice so that it will not deteriorate for long time (Fig. 12). However, this trend is now decreasing since the land area to produce rice has been divided due to population increase. At the same time, they need to sell more grains to meet their daily needs which are ever increasing. It has increased the vulnerability among small holders in the area during abnormal rainfall years.

Figure 12. Locally made traditional earthen structures, Kothly (left) and Deheri (right) used for grain storage purpose in Tharu community of western terai site. (Photo: B. Bhandari)

Effects of abnormal rainfall years on production loss and food security

The perceived production loss of rice crop during recent abnormal rainfall years particularly after 2000 was estimated through the household survey. The Mannan-Whitney test revealed that according to the farmers' responses, there was a significantly higher effect on both production loss ($Z=-4.95$, $p<0.01$) and food security ($Z=-2.06$, $p<0.05$) in terai than in mid-hills. The ranks scoring for the production loss used were: 0=no production loss, <1.0= low (<5 percent loss), 1-2 =high (5-25 percent loss) and >2.0=very high (>25 percent loss). For the effect on household food security: 0=no effect on normal food security, <1.0= low, >1.0=high. The mean rank score values for the production loss representing both mid-hills and terai were 0.70 and 1.28 respectively. Similarly, the respective mean score values for the effect on reducing normal food security in mid-hills and terai were 0.33 and 0.58.

During abnormal rainfall years, there was a higher effect on production loss and eventually on food security in terai than in mid-hills (Table 8). A higher number of respondents (65.9 percent) in terai reported that their production decreased by 5-25 percent in the selected rainfall stress years compared to the mid-hills respondents (40 percent). There were 15.9 percent households in terai who were highly affected due to a higher loss in the production (>25 percent) during those abnormal rainfall years when compared with 2.2 percent farmers in mid-hills (Table 8). The chi-square test of the responses between two merged categories of production loss; no-low and high-very high showed a significant difference ($\chi 2=14.8$, df=1, $p<0.01$) between the sites. Likewise, there was a significantly higher ($\chi 2=7.0$, df=2, $p<0.05$) number of households who reported a higher effect on decreasing their normal household food security in terai than in the mid-hills during abnormal rainfall years. All this evidence indicates that western terai is more vulnerable in terms of production loss and decrease in normal food security due to rainfall variability and change as compared to mid-hills.

Table 8. Effects on rice production and food security in selected abnormal rainfall stress years after 2000, as reported by the households in the study sites. Figures are in percentage.

Study sites	Effect on rice production				Effect on food security		
	No Effect	Low (<5%)	High (5-25%)	Very high (>25%)	No effect	Low (<45 days)	High (>45 days)
Mid-hills (n=45)	6.7	51.1	40.0	2.2	35.5	55.6	8.9
Terai (n=44)	4.5	13.6	65.9	15.9	36.4	31.8	27.23

Varietal vulnerability and relationship with farmers' choices

Perceived vulnerability of rice varieties in abnormal rainfall years

Vulnerability of rice varieties was defined as the perceived risk of production loss due to abnormal rainfall events (either insufficient or excess). This was measured through farmers' ranking for the risks of production loss as: 0=no risk, <1= low risk, 1-2=high risk and >2=very high risk during the household survey. A higher rank score indicates a more vulnerable variety. To identify the average vulnerability score for the varieties grown on-farm, they were ranked across all the probable scenarios (identified in FGD) of rainfall related stresses. The statistical test revealed a significant difference in the mean scores of vulnerability between groups of varieties; landraces, modern varieties and either PPB varieties in mid-hills or hybrids in terai (Table 9). The landraces are judged by the respondents to be less vulnerable in terms of production loss during stress conditions than the other categories of varieties. Hybrids had the highest vulnerability scores and are seen as the most vulnerable group of varieties. There was no significant difference ($z = -1.43$, $p>0.05$) between the landraces and PPB varieties in terms of their perceived vulnerability rank scores.

Table 9. Vulnerability rank scores of rice varieties by its types in terms of production loss during abnormal rainfall years in the study sites. High score indicates more vulnerable variety.

Study sites	Mean rank ±SD Landraces	Modern varieties	PPB variety	Hybrid	χ^2 value
Mid-hills (n=45)	0.73±0.22	1.40±0.30	0.78±0.26	-	23.05**
Terai (n=44)	0.77±0.13	1.04±0.19	-	1.88±0.27	33.17**

Degree of freedom=2

Vulnerability groupings of varieties and landraces

Hierarchical Cluster Analysis (HCA) was used to classify all the varieties in groups according to their vulnerability to rainfall variability and stresses as perceived by the respondents. The cluster shows the relative similarity of varietal vulnerability in a simple figure and it can assists in further analysing the farmers' choice of varieties when relating area grown with the perceived vulnerability to rainfall variability and stresses.

In mid-hills, farmers were growing seventeen varieties that each occupied more than one ropani aggregate area in the community. Ropani is the local unit of land area measurement, where one ropani is equivalent to 500 square meters. The cluster analysis distinguished them in two groups; modern (bottom five in the Fig.13) and others (top in Fig. 13) including both the landraces (bold) and PPB varieties (italic).There was a significant difference among the mean vulnerability scores between these two groups (Table 9). However, the difference was non-significant between landraces and PPB bred varieties. Within landraces and PPB group, five varieties namely; Rato Anadi, Improved Biramphool, Madhise, Improved Sanogurdi and Seto Anadi differed slightly from the others in the same group since they were perceived relatively more vulnerable to rainfall related stresses (Fig. 13).

Similarly, in terai community, nineteen varieties were reported growing in more than one ropani area under each variety. The analysis divided them into three distinct groups; representing hybrid (italic in the Fig.14), modern varieties (normal font in the Fig. 14) and landraces (bold in the Fig. 14) based on their mean vulnerability scores. The Kruskal-Wallis test revealed that there was a significant difference in the mean vulnerability scores between groups (Table 9). However, it is interesting to note that three modern varieties; Khajura-2, Radha-4 and China-4 have been grouped close with landraces indicating as a less vulnerable varieties. Among these three, Radha-4 is the most dominant variety at present in terms of its area coverage whereas, Khajura-2 is still popular. China-4 was also popular in the area before. On the other hand, a landrace Dhunmuniya that requires high water is grouped in comparable with modern varieties. This variety has its mean vulnerability score in between landraces and hybrids. All the hybrid varieties were treated as the same in terms of their vulnerable and are seen as the most vulnerable among all (Fig. 14).

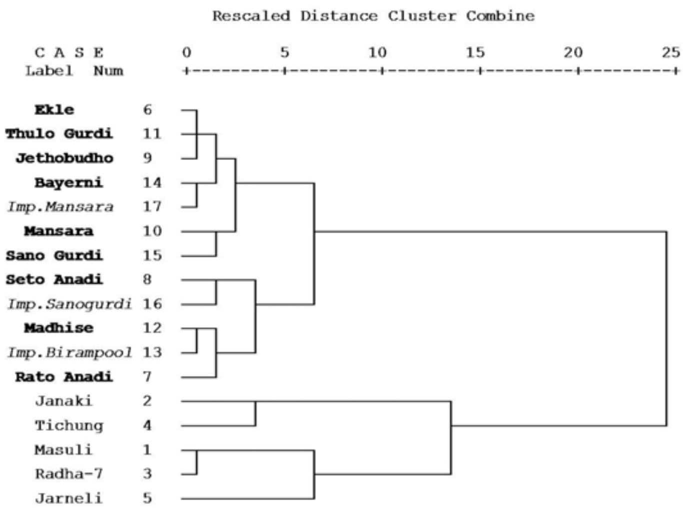

Figure 13. A dendrogram showing the hierarchy of perceived vulnerability to rainfall variations and related stresses of seventeen varieties in the mid-hills site, based on euclidian distance measurement. In the figure, bold represent landraces (the least vulnerable group) italics represent PPB (Participatory Plant Breeding) bred varieties (medium in vulnerability) and the others are modern varieties (more vulnerable).

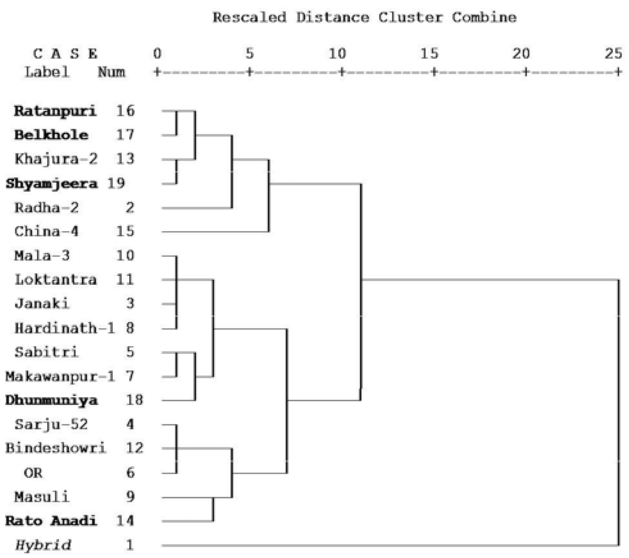

Figure 14. A dendrogram showing the hierarchy of perceived vulnerability to rainfall variations and related stresses of nineteen varieties grown in the terai site, based on euclidian distance measurement. In the figure, bold represent landraces (less vulnerable), italic represents hybrid varieties (highly vulnerable) and the others are modern varieties (vulnerable).

Relationship between farmers' choice of varieties and its vulnerability

Cluster analysis (Figs.13 & 14) showed the similarity of different varieties in terms of their vulnerability to rainfall related stresses. It revealed that the most dominant variety in terms of area coverage; Ekle in the mid-hills and Radha-4 in terai, represents a less vulnerable group (<1 rank score), since their respective perceived vulnerability scores were 0.67 and 0.93. The Ekle had occupied 63 percent area in mid-hills site whereas in terai, Radha-4 was grown in 28 percent of the total area. It is interesting to note that, not only in mid-hills where landraces are dominant but also in terai where farmers are growing modern varieties, they are selecting the less vulnerable variety for planting in larger area. There was a relationship between the most dominant variety and its perceived vulnerability in both the study sites. In contrary to terai, farmers in mid-hills were allocating a higher proportion of their land to other less vulnerable landraces (Appendix 1 and 2). It indicates farmers' strategy in mid-hills to select and grow many different varieties that are perceived less vulnerable to rainfall related stresses in particular production environment. Growing a number of tolerant varieties has been perceived as reducing the yield variability and therefore a common strategy in subsistence oriented production systems. However, in commercially oriented production system of terai, farmers are seen interested to combine less vulnerable varieties and highly vulnerable hybrids, keeping in mind both the adaptation to stresses as well as the potential to increase production during normal years.

The analysis has shown a significant negative correlation ($r=-29$, $p<0.05$) between number of varieties grown and the perceived production loss rank scores in terai (Table 10). However, this relationship was non-significant in the mid-hills were landraces are dominant. In the mid-hills, farmers have been selecting mostly the landraces which represent the least vulnerable group of varieties. Growing higher number of varieties in the mid-hills did not indicate any relationship to reduce production loss during abnormal rainfall years as seen in terai. It has indicated that crop diversification in terai can reduce farmers' vulnerability to rainfall variability significantly where mostly modern varieties are being grown. Further analysis also showed that only in the diverse and marginal production environments of mid-hills, there is a significant relationship ($r=0.53$, $p<0.01$) between size of household landholding and the number of varieties maintained on-farm (Table 10). It means that farmers who hold bigger land size have maintained a higher number of rice varieties only in subsistence production system of mid-hills. In commercially oriented production systems of terai, there is no relationship between the size of landholding and the number of varieties grown. It is because in commercially oriented production system, farmers would like to increase the area under selected varieties rather than increasing number of varieties with the increase in farm size.

Table 10. Pearson correlation coefficient (r) for rice production area per household, number of varieties per household and the perceived production loss rank scores in the study sites.

Relationships X	Relationships Y	Mid-hills	Terai	Overall
Total rice production area	Number of varieties grown per household	0.53**	0.17	0.39**
Tari (un irrigated) area	Production loss	0.31*	0.25*	0.38*
Number of varieties grown	Production loss rank scores	0.11	-0.29*	-0.19

*=p<0.05 and **=p<0.01

Farmers' knowledge and adaptation practices

Adaptations, knowledge and practices to cope with changes

Adaptation is the spontaneous adjustment in response to variations and changes that can reduce vulnerability to farming. There were a significant higher numbers of farmers adopting different on-farm management practices in terai than in mid-hills (Table 11). It is because there was a high dependence of farmers on crop farming in terai, which is perceived more prone to rainfall related stresses. Therefore, more on-farm practices in farming adaptation are needed to cope with changes in terai than in the mid-hills. However, in mid-hills where there was a higher level of education, significantly higher number of respondents reported diversifying their income sources mainly from services, business and remittance (Table 3). The analysis indicates that there are different strategies in mid-hills and terai to adapt to climate variability and changes.

Table 11. Number of households with different adaptation strategies to cope with climate variability in the study sites.

Options	Mid-hills (n=45)		terai (n=44)		χ2 value
	yes	No	Yes	No	
On-farm management	34	11	40	4	3.74*
Diversifying household income sources	35	10	24	20	5.37*

Degree of freedom=1

It is noticed that particularly those farmers who are commercially oriented and more dependent on-farming for their income sources would like to be involved constantly in testing new varieties in their farms. These innovative farmers always search, collect and grow new rice varieties in smaller area in the first season to evaluate its agronomic and adaptive traits and then increase area in subsequent years if it satisfies their needs. In this regard, Meghadish Oli, 42 years old commercial farmer of terai told, "This year, I am planting seven varieties in my farm. Among these two are new varieties released recently; Sunaulo sugandha and Hardinath-1. I am testing these varieties in small plots (about 200 sq m.) to evaluate their adaptation as well as agronomic traits. I want to evaluate these varieties both under irrigated and rainfed environments before promoting them in larger plots". These are the farmers who generally innovate or introduce and/or exchange new practices and information suitable to the area to cope with variation and changes. Furthermore, the correlation analysis showed a significant positive relationship ($r=0.31$, $p<0.05$) between years of farming and the likeliness to test new varieties on-farm in terai. Likewise, the relationship between years of farming and changes in crop management practices was significant ($r=0.30$, $p<0.05$) in the terai. All this evidence supports that on-farm adaption knowledge and practices are largely gained by individual experiences as well as learning from others over time in farming practices. It is reported that LI-BIRD's activities have significantly increased awareness among farmers about the importance of conserving rice landraces and adding values to them through breeding and non-breeding approaches in both the study area. These activities have also motivated farmers to learn and share new adaptation practices.

On-farm adaptation practices in rice crop

A number of practices that has been used in recent years to adapt to changes have been reported during FGD and household survey. These were: spontaneous adjustments in planting time, cultivation practices, changes in crops and its varieties, water management, seed selection practices and the on-farm experimentations. The analysis showed a significant higher numbers of farmers in terai than in mid-hills who were adopting such practices (Table 12). However, farmers in mid-hills were more trained and skilful in dynamic seed selection practices than in terai (Table 12).

In terai, it was reported that rice transplanting time has started 3-4 weeks earlier as compared to ten years before due to recent increase in monsoon rain, suitable crop varieties as well as new ways of water management practices. In the past, farmers were fully dependent on monsoon rain in June even for nursery preparation. Nowadays, most of the households reported that they use shallow tube well to prepare rice seedling in nursery in the month of May instead of June and, sometimes also use small scale irrigation in the transplanted field if necessary, although these tube wells are designed for drinking water supply. By the time of starting monsoon rain, rice seedlings are ready to transplant. It is also a common practice among farmers to soak and germinate rice seed before broadcasting in the nursery bed which actually depends on weather conditions. That is why early transplanting of rice has been possible in terai. In the mid-hills, 51.1 percent farmers reported that rice transplanting time during recent years in general, has started 1-2 weeks earlier than before, probably due to increased pre monsoon rainfall. Therefore, farmers in both the study sites have perceived changes in the rice cropping seasons shifting toward earlier.

Table 12. Number of households adopting different on-farm adaptation practices in rice crop to cope with rainfall variability during recent period as compared to ten years before in the study sites.

Practices	Mid-hills (n=45)		Terai (n=44)		χ2 value
	Yes	No	Yes	No	
Changes in planting time	23	22	36	8	9.4*
Changes in crop management practices	6	39	29	15	25.8**
Frequent changes in varieties (every 2-3 years)	27	18	38	6	7.9*
Changes in crop species (maize to rice)	7	38	36	8	39.1**
Water management	6	39	15	29	5.3*
Seed selection	37	8	19	25	14.5**
Experimentation of new varieties	8	37	32	12	27.2**

Degree of freedom=1

As reported by majority of the respondents, farmers in terai recently have made more efforts for better crop management to produce good yield even under stress conditions. In this regard, one of the active and educated farmers of terai, Binod Tharu said, "We didn't practice weeding twice before but now it is increasingly being adopted in the area to hold moisture, suppress weed and insect pests". He also added that he is using herbicide to suppress weed in his hybrid rice field recently to cut down the labour cost. It indicates that use of chemical fertilizer and pesticides has been increased in terai, which might affect the sustainability of the farming systems negatively in the long run. Similarly, the area under rice crop in terai has been increased because farmers are converting bari land to rice crop in recent years. This has been made possible due to increased options of drought tolerant early varieties and new ways of water management practices. In addition, a significantly higher number of farmers from terai as compared with farmers from mid-hills, reported that they are changing crop varieties more frequently (every 2-3 years) (Table 12).

There were differences in the seed supply systems and farmers' seed selection practices between the study sites. The informal seed supply system was dominant in mid-hills where farmers rarely buy seed from the market. They always save seed and frequently borrow and exchange with neighbours and relatives. In mid-hills, the individual household selected seed from the standing crop in the field based on their preferred criteria. The adaptability of crop varieties in their local situations is likely to be enhanced through selection since it will increase the frequency of desirable genes to be expressed in the selected population. In the mid-hills site, LI-BIRD activities has increased farmers' skills and interest to select seed and even improve some of their local landraces through PPB approach. On the contrast, terai farmers were more influenced by formal seed systems and they had less knowhow and skills on seed selection practices in general as compared to the farmers in mid-hills. In this regard, a lady farmer Dalli Oli expressed, "Nowadays we don't go to our neighbours for the exchange of seed instead we go to city agro-vet shops to buy from them". The trend is now clear and therefore many households reported that they prefer to buy seed from the market rather than asking for someone to borrow or exchange in the villages. At the same time, they are also looking for new varieties and sometimes buy and grow in their field without adequate knowledge about the particular variety. This might have increased the vulnerability to production loss and/or chances of variety failure in terai. However, in the mid-hills, there is a more resilient local seed system and selection practice that enhances adaptability of landraces to abiotic and biotic stresses.

In the study, it has been noted that there are some other unique practices and knowledge are being practiced by some experienced farmers in both the study area. In mid-hills site, farmers are recently practicing frequent sowing of rice seeds, two or three times in the nursery at an interval of every fifteen days. Thus, they can transplant tender seedlings whenever rainfall starts. It is an important coping strategy for them because rainfall during rice planting is uncertain in recent years. Similarly, mid-hills farmers grow blackgram and finger millet as an alternative crop mostly in tari land if they cannot grow rice in a particular year. Terai farmers usually grow more wheat in the following season as an alternative source of food crop if they don't have a good rice crop in a certain year. Otherwise, they prefer to grow more rapeseed and lentil in their khet land after rice crop.

Discussion

Summer rainfall, its role and relationships with rice production

In Nepal, rice farming has a vital role in food security and the national economy. It is the principle food crop and contributes about 20 percent of the national agricultural Gross Domestic Product (GDP) and provides more than 50 percent of the total calorie requirement of the Nepalese people (NARC 2008). The success and failure of rice crop therefore has significant impact on food security as well as national economy. However, rice production which has a high water requirement is highly dependent on timely summer rainfall.

The analysis showed that the western terai which receives less summer rainfall (<1500 mm) than mid-hills (>3500 mm), is more prone to rainfall related stresses. It is because rice in the area is extensively being grown under rainfed (31.6 percent) and partially irrigated (57.1 percent) conditions. There was a significant positive correlation ($r=0.31$, $p<0.05$) between rainfed area and the risk of production loss due to rainfall variations in both the study sites (Table 10). Another study has shown that more than 70 percent of the variation in crop production is determined by the climate variability under rainfed conditions (NARC 2005). The effect of rainfall variability is always higher in a low rainfall zone in rainfed farming systems where it can easily affect food security as observed in western terai in this study. Recently, Nayava (2008) reported a positive correlation between rainfall and rice yield with more frequent yield deficit in western terai as compared to other regions during the study period of 1971-2000. He explained the reason as a deficit in monsoon rainfall below normal level. In addition, the timing of rice transplanting is very crucial for a good harvest (see Shah & Yadav 2000) however; it is largely determined by the onset of monsoon rain in rainfed areas (Lansigan et al. 2000; Nayava 2008). Even if there are facilities for irrigation, the irrigation water depends on stream flow which is determined by summer rain. The summer rainfall and its variability therefore largely determines for the success of rice crop in the county.

Perceived and observed rainfall variability: validating farmers' understanding

Summer monsoon rainfall characteristics traditionally exhibit a sharp increase in amount from April, a peak in Jun-July and gradual decrease after August. The results from the present study however show a clear trend which indicates a shift in the traditional summer rainfall particularly in mid-hills in the recent years. Both farmers' responses and the meteorological observations demonstrate that pre and late monsoon rainfall amount has increased in both the study sites during 2004-2008 compared with 1995-1999 (Fig. 6-9). In terai, frequent short intense rainfall events were noticed with increasing trend of rainfall. Alternatively in mid-hills, more dry spells during rice transplanting time (June-July) have been observed in 2004-2008. The analysis thus indicated more unpredictable patterns of extreme events such as drought, dry spells and intense rainfall events increasing during 2004-2008 over the study area as predicted by many studies for South Asia (Connor et al. 2005; IPCC 2007; Lal et al. 2000; Singh & Sontakke 2002).

In terai, during the period of 2004-2008, mean rainfall has increased by 19.2 percent over the study base period (1995-1999). This closely followed the prediction made by IPCC and other similar studies (Esterling & Apps 2005; Rosenzwig et al. 2001). A recent study suggested that summer rainfall in parts of South-East Asia including Nepal will increase by 20-26 percent (see Kripalani et al. 2007). In the country context, Baidya et al. (2008) reported an increasing trend of very wet and heavy precipitation days (>50 mm/day) during the past forty six years in lower altitude (<1500 masl) in Nepal. All this evidence forecast an occurrence of more extreme precipitation events in terai in the future. However, in the mid-hills, there was a trend of increasing pre, post and late monsoon with more frequent drought and dry spells during June-July. In a recent study, Baidya et al. (2008) also pointed out a complex process of precipitation extremes in higher altitudes (> 1500 masl) since the trend is still not clear in the mid-hills. This indicates a need for further in-depth studies in future.

All this evidence provides a basis to compare observations on rainfall variability with farmers' knowledge. The study findings showed that farmers have valuable knowledge on climate variability on their local context, largely gained by past experiences. The major variations and changes that were reported by farmers correspond well with the meteorological observations. Interestingly, it was also appeared that farmers generally viewed changes and variations in relations to the crop season and its growth stage which was explained by Vedwan & Rhoades (2001) as local knowledge of crop-climate interactions. However, while farmers' knowledge so far is widely being used in biodiversity assessment, it is poorly recognized in climate change studies. In this regard, this study clearly highlights the usefulness of farmers' knowledge in climate change and adaptation studies which can provide relevant practical information to better describe and predict the climatic conditions locally.

Rice varietal diversity, its types and trend

With regards to rice varietal diversity, the current study showed higher overall on-farm diversity in terai (low rainfall, plain area), dominated by modern varieties. The terai also possessed a more even distribution of varieties in terms of area grown than in the mid-hills (Table 6). In contrast, landrace diversity was significantly ($p<0.03$) higher in the mid-hills site, which represents high rainfall but marginal production environment. Mid-hills terraces have a diverse niche production environment and therefore favour growing more landraces as shown in this study which is also reported by Dusen et al. (2007). Mid-hills farming represent subsistence production system and uses less external inputs than in terai. The study findings on varietal diversity agree with the statement that variable production environments along with less access to production inputs and market are generally associated with a high landrace diversity on-farm (Brush & Meng 1998; Cleveland et al. 1994).

There was a significant positive correlation ($r=0.53$, $p<0.01$) between size of landholding and the number of varieties grown in the mid-hills (Table 10). However, this relationship was non-significant ($r=0.17$, $p>0.05$) in terai, where farmers are oriented more towards commercial production systems than in mid-hills. This is because farmers who were market oriented preferred to grow fewer varieties at a larger scale, as reported by Poudel & Johnsen (2008) in a similar study in Nepal. In another study, Rana et al. (2007) reported that farmers with greater landholdings are maintaining higher number of varieties on-farm in Nepal. The present study however, slightly departs from this finding and indicates that this is only true in subsistence farming of mid-hills.

Among various forms of rainfall related stresses, drought can have a significant impact in changing the varietal dynamics. As reported by farmers in terai, this is the milestone period to introduce new varieties in the affected area. On the other hand, severe drought can cause a loss of local landraces and traditional varieties locally. From the evidence of the mid-hills site, local seed systems have proven to be more resilient and reliable here. However, severe drought that causes famine can sometimes makes a system inefficient and lead to local extinction of some landraces. This is because in such cases, farmers cannot produce and are forced to consume all the seeds. There are no alternative seed supply systems from outside for these landraces. It was reported in Ethiopia that widespread drought and famine was one of the reasons for loss of crop landraces due to crop failure and use of seed stock as food (Cleveland et al. 1994). The consequences of drought therefore can have two way effects, the addition and loss of varieties in traditional farming systems.

In the past thirty years, most of diversity of landraces although they are generally perceived to be better adapted to stresses, have been lost from terai. Two factors; high quality traits and inherent link to socio-culture were reported as forces that keep maintaining a few landraces in terai. There was a higher loss of cultural traditions in terai among those people who have migrated from hills and mountains. Therefore, indigenous Tharu community have played a major role in maintaining landraces in terai. There are however, only a few landraces of socio-cultural importance estimated at about 11 percent of the total rice diversity (Rana et al. 2007). Due to changing economic, biophysical and socio-cultural environments that are important in holding landraces diversity (Cleveland et al. 1994; Rijal & Synnavag 2005), rice landraces are decreasing in the mid-hills and are already in critical situation in terai.

There are two major reasons reported behind such a fast decline in landraces from high production environment; low production potential and long crop duration which do not allow increasing cropping intensity. The other reasons are: government policy to promote improved varieties and increasing pressure from the seed companies. This not only reduces landrace diversity but also increases small farmers' vulnerability to climate variations in traditional farming systems (Stigter et al. 2005). The underlying reason for the loss or decrease of landraces therefore is complex and has been caused by many factors. However, it is important that farmers, scientists and authorities understand that modern varieties can produce a higher yield only under optimal growing conditions which often require high level of inputs and management (Cleveland et al. 1994; Rijal 2007). In the current face of climate variability, there is a high implication of such loss in locally adapted landraces to increase the risk of crop failure and/or production loss during abnormal years as already seen in terai. Although, it is seen that, as an alternatively strategy of growing landraces, terai farmers are today increasing modern crop diversity since the production environment is more favourable to grow modern varieties (Rana et al. 2008).

The evidence shows the urgent need to take appropriate measures to conserve landraces in the high production environment. One of the practical and sustainable approaches is participatory improvement of landraces through farmers' managed selection in the target environment as well as through the introduction of new gene pool to increase production potential (Cleveland et al. 1994). As a complementary approach to conventional breeding strategies, Participatory Plant Breeding (PPB) has shown local success to improve landraces by developing farmers' preferred rice varieties in terms of production potential and quality traits in the mid-hills of Kaski. PPB bred varieties have been reported suitable for adapting to climatic stress in the marginal environments (Challinor et al. 2007; Gyawali & Sthapit 2005) and, also produce better yield than the traditional landraces (Fig. 15). PPB that utilizes local genetic resources and involves farmers and other stakeholders, also promotes diversity at gene and allelic level (Joshi & Witcombe 2004).

Despite this fact, agricultural policies and the market forces in many developing countries including Nepal are however, still promoting a few modern crop varieties. Policy incentives to grow promoted varieties have motivated or sometime forced farmers to allocate their land to a single variety instead of growing more varieties, reducing crop diversity on-farm (Di Falco & Perrings 2005). Likewise, market forces can lead farmers to create ecologically

Figure 15. The Improved Mansara (right) developed through Participatory Plant Breeding (PPB) gave a higher yield under rainfed conditions than the traditional local Mansara (left) in the mid-hill site in 2008. (Photo: B. Bhandari)

fragile monocultures instead of promoting crop diversity (Altieri 1999). There is still a need of favourable agricultural policy incentives to encourage continued growing of landraces, developing PPB varieties as well as diversifying crops and varieties in the farming systems as some of the adaptation strategies. Increasing genetic diversity through genetic complementarily increases the resilience of natural agro-ecosystems to buffer against extreme climatic events (Hajjar et al. 2008). It is well justified to encourage farmers to use landraces and grow diversity of crops rather than providing incentives to those farmers who produce only a small number of export commodities.

Relationship between farmers' choice of varieties and its vulnerability

It is interesting to see in the present study that farmers are constantly cautious while selecting varieties and therefore allocate larger area for those varieties that are perceived as less vulnerable to rainfall related stresses. However, they don't express it in the same way when we ask the question, "Do you consider vulnerability to climate stress as a criterion while selecting varieties for growing in larger area?" The analysis has shown that their adaptation criterion is linked to broader term "land suitability". Land suitability is generally the farmers' first criteria to select varieties to grow on a larger area. Varieties- either modern or landraces- are found to be selected based on the suitability to local niche production environment as a "best fit" as reported by Rana et al. (2008), which also indicate its adaptability to cope with stresses (Gyawali & Sthapit 2005).

However, there is always a good trade-off between production potential and the adaptiveness of the varieties selected to deploy for larger area. Thus, adaptation requirement, production potential and socio-cultural needs are the three major factors to be considered while selecting the variety.

As shown in table 10, production loss was negatively correlated with the number of varieties on-farm in terai. This suggests that there is a scope of diversifying rice varieties that can reduce crop production loss due to abnormal rainfall events in terai. As argued in many other studies (Bradshaw et al. 2004; Hajjar et al. 2008; Di Falco & Chavas 2006), this study also shows that diversification of crop varieties is one of the potential adaptation options to reduce vulnerability to climate variability and change in stress prone areas. According to Unruh (2004), it is common across Africa among farmers to increase crop diversity which reduces the chance of crop failure due to drought.

Farmers has maintained and/or improved landraces by selection through generations. It has been seen that landraces generally are well adapted and competitive in terms of production potential with the modern varieties in marginal environment as in the mid-hills. Farmers in the mid-hills have perceived less yield variability in landraces than in modern varieties during recently appeared drought and dry spells in the area. It indicates that landraces in the mid-hills are competitive with modern varieties in terms of production and are superior in its adaptation. Therefore, they have been continuously growing many landraces in their farms. In terai, which is more productive environment than the mid-hills during normal season, landraces reported less yielding as compared to improved varieties although, they are perceived having less yield variability due to rainfall related stresses. Many studies reported that landraces have the capacity to withstand stress and fluctuations and, produce better yield in marginal environments (Bellon 2008; Ceccarelli et al. 2007, Cleveland et al. 1994). That is why, unlike the commercially oriented production system of terai, farmers in subsistence and diverse production environments of mid-hills are often reluctant to use modern varieties simply due to fear of possible crop failure or production loss. It is because modern varieties and hybrids are perceived to be more vulnerable to rainfall variations and changes. On the other hand, commercially oriented farmers in terai would like to change newer varieties frequently (every 2-3 years) to increase production in normal year. It might sometimes increase the risk of production loss/failure during abnormal rainfall years in terai than in mid-hills. This is because most modern varieties have a narrow genetic base and therefore are likely to be more sensitive to fluctuations in temperature and precipitation as compared with landraces (Rao & Hodgkin 2002).

The present study findings indicate that there are different adaptations practices combined together as a strategy in mid-hills and terai to cope with rainfall variation and related stresses. In mid-hills, farmers are likely to select many different locally adapted landraces, practicing regular on-farm selection as well as diversifying household income sources. On the other hand, farmers in terai are carefully selecting modern varieties with the aim to increase production during normal season although, they are perceived as more vulnerable than the landraces. However, they have adopted many different on-farm adaptation practices such as changes in plating time, practices, water management, frequent change of varieties etc. In these two strategies, less yield variability during abnormal rainfall years is reported in the mid-hills. It suggests that selecting many different locally adapted varieties can give better yield guarantee under stress conditions for small farmers who are not in position to take the risk of variable climate and weather conditions. Alternatively, there a need to focus to develop and increase the access of suitable rice varieties as one of the strategies to cope with rainfall variability and stress in terai.

Farmers' knowledge and practices on adaptations

Farming is sensitive since it is highly affected by climate, market, policies and the resource base (Risbey et al. 1999). Adaptation is a continuous location specific process of adjustment targeted to cope with uncertainty and change and is generally described as autonomous and planned. Spontaneous adaptation is primarily a household level dependent strategy which has played an important role for agricultural adaptation in traditional farming systems. There were more farmers in terai who are adopting suitable on-farm adaptation practices in recent years than in mid-hills. These are: adjustments of cropping season, input use and management practices to cope with the variability in climate which has appeared. These are the widely used practices in agriculture among farmers in many parts of the world (see Cleveland et al. 2002; Lansigan et al. 2000; Risbey et al. 1999; Salinger et al. 2005). As favoured by technology, management practices and climate recently, some farmers in terai have switched their bari land from growing maize to rice in summer season. The other study has also supported that both rice area and yield has increased in western terai in recent years (Nayava 2008).

The analysis in this study explains that farmers' seed selection systems are important on-farm adaptation practices as seen in the mid-hills site. Since many years, farmers have maintained and/or improved their landraces for adaptation and production potential through adopting appropriate on-farm selection practices. This increases the frequency of desirable genes in the population to adapt better to stress conditions (Bellon 2008). Except a few extreme cases discussed earlier, local seed systems in general, are very resilient and continue to function better than formal systems even in severe climatic setback (Sperling et al. 2004). Seed supply systems and farmers' seed selection practices are vital, not only to maintain traditional varieties on-farm but also for adapting to changes. It increases diversity particularly the intra-specific diversity in the selected populations due to the mechanisms of farmers' selection and seed management practices (see Smale et al. 2004). Therefore, strengthening farmers' seed selection and seed systems should be included as one of the important adaptive strategy in agricultural adaption planning in traditional farming systems.

Farmers are constantly experimenting to innovate and modify their farming systems in response to observed variations and changes. The analysis showed a significant ($p<0.05$) positive relationship between years of farming and farmers' likeliness to test new varieties in terai. Some innovative farmers have high capacity of on-farm experimentation to adapt to or modify crop management practices to cope with such changes. These knowledge and skills have been gained and accumulated largely by individual experiences as well as by learning and sharing with others. Hence, agricultural policy should support enhancing varietal choices as well as farmers' experimental ability to cope with climate variability and change which was also pointed out by Wood & Lenne (1997). As seen a general trend worldwide, this study also indicated that the young generations particularly in the mid-hills, are unlikely to continue farming. One of the underlying reasons is that the rainfed subsistence farming only does not fulfil the household requirements. Some other studies in the country explained that rural households are striving to diversify their income sources as one of the coping strategies to unpredictable climate in recent time ((Menon 2006). However, the level of education plays a major role towards diversifying household income sources and in preparing the community to adapt to changes.

All the evidences presented above indicates that farmers in the study sites are rational in their understanding about climate variations and are constantly looking for ways to adapt to changes accordingly. Diversity based adaptation; crop varieties and its manipulations is seen one of the major coping strategy so far adopted by the majority of farmers. However, they have limited access to crop varieties as well as scientific information about weather and climate forecasting in subsistence based traditional farming systems. So far, they have a high reliance on local resources, traditional knowledge and past observations to tackle the situation. The evidence shows that particularly the people who are indigenous to the area are more knowledgeable and can explain and predict the situations better than others. They have a holistic knowledge of the area since long past and can relate fluctuations and changes in climate, people and biodiversity (Box 1).

Box 1. Local knowledge of indigenous Tharu community on climate change and rice crop

Tharu community of western terai has an interesting knowledge related to climate change and rice cropping based on the observation of migratory birds. In the past, a species of migratory bird, the Demoiselle crane, locally called Karangkurung (*Anthropoides virgo*), used to migrate in flocks from terai to mountains in the month of June. Thus, it was the right time to start nursery preparation for rice crop with the hope of summer rain. This was, in fact coinciding always. Again they used to return back to terai in October when the summer season ended. But nowadays, these birds migrate to mountains in April and return back in September, one month earlier than before. This indicated to farmers change in climate and times of season for rice crop.

In the current context of increasing magnitude and frequencies of extreme events, the local adaptations based only on farmers' knowledge and genetic resources might not be sufficient to cope with the climate effects. These may further increase the farmers' vulnerability in the days to come. That is why farmers' have an increasing need to get access of reliable weather forecasting services as well as other better adaptations community based programmes to cope with future uncertainty in the climate. Therefore, there is an urgent need to develop an integrated and balanced adaptation strategy with due emphasis on promoting crop diversity, seed systems and farmers' ability to experiment. Furthermore, scientist and policy makers should collaborate with farmers and stakeholders to learn their perspective, knowledge and experiences to better understand the complexity and devise a locally suitable adaption plan and policies to cope with climate variability and change in the country.

Conclusions and recommendations

Conclusions

The study investigated many aspects related to summer rainfall variability and change, rice varietal diversity and its relationship to cope with rainfall variability in mid-hills and terai sites. The analysis showed distinct variations with a trend of shift in both the summer rainfall amount as well as its distribution pattern in 2004-2008 when compared with 1995-1999. Pre and late monsoon rainfall has increased irrespective of study locations. The rainfall amount is increasing in terai but decreasing in the mid-hills. It indicates for the occurrence of more extreme events in terai as predicted already by several other studies. In the mid-hills, rainfall during the critical rice season (June-July) has been decreasing significantly in later period indicating the risk of more drought and dry spells in future. The study demonstrates that there was a correlation between farmers' responses with the meteorological data on summer rainfall variability in both the sites. It shows that farmers are acquiring knowledge on climate variability from close observation of crop-weather relationships.

In both the study sites, farmers are using multiple rice varieties however; there are differences in their choices. There was significantly higher landrace diversity in the mid-hills and higher modern crop diversity in terai. This indicates that landraces are still popular and competitive in marginal and diverse production environment however, commercially oriented productive environments are supporting more for modern varieties. Therefore, most of the landrace diversity is already lost in terai. In terai, only a few landraces are being maintained due to its socio-cultural and preferred quality traits. Farmers unanimously reported that modern varieties and hybrids in general, are perceived to be more vulnerable to rainfall related stress than the landraces and PPB bred varieties. Modern varieties and hybrids have contributed to increase risks to farmers in terai for production loss during abnormal rainfall years. On the other hand, the maintenance of landraces and PPB bred varieties are one of the reasons for low effect on production loss during abnormal rainfall years in mid-hills. This shows the importance of landraces and PPB varieties to cope with rainfall stresses and variability. This shows an urgent need to conserve landrace diversity through adopting multiple strategies for its immediate as well as future use in the face of increasing climate change effects.

It is seen that when farmers select varieties- either landraces or modern- for growing over large areas, they always consider the trade-off between its suitability as an adaptation criteria and its production potential. This shows the relationship between farmers' choice of crop varieties and its vulnerability at least for those varieties which are selected for a larger area. Additionally, the study indicated that there is a need to increase suitable varietal options as a coping strategy to reduce the effects of rainfall variability in rice crop. Likewise, informal seed systems and farmers' seed selection and experimentation are the important and practical strategies to adapt better to rainfall variability. Crop varietal diversity, farmers' knowledge and local practices are the effective means for adaptations, and therefore widely being used by farmers in traditional farming systems in Nepal. However, in the current face of increasing climatic variability and change, there is an urgent need to formulate better agricultural adaptation strategy, plans and policies, which are unfortunately lacking so far in the country.

Recommendations

As explained in this study, farmers have their own way of looking at climate variability and change in crop growing conditions. There is a gap between farmers and formal research as well as development systems to understand the situation and exchange of information. Therefore, based on findings from the study, the following recommendations are made to increase farmers' ability to cope with climate variability and change with a particular reference to rainfall related stresses in the context of Nepal:

Farmers' local knowledge and experience regarding climate variability and coping strategies are poorly understood and verified so far in the local context. The study has shown its usefulness and therefore suggests integrating such local knowledge on climate change studies as well in the adaptation plans and polices.

Landraces however, resilient to climate stresses are only seen as competitive to meet farmers' requirement in marginal and diverse production environments. There is an urgent need to further study their status and potentials as well as providing institutional and policy support to continue growing landraces and their use in plant breeding.

Community based seed systems, farmers' seed selection and experimentations are effective practices to reduce the vulnerability to climatic stresses. These practices should be recognised and included in the adaptation strategies for agriculture.

Diversification of crop varieties can reduce the risks of production loss where farmers are relying more on rainfed farming and modern varieties. Suitable varietal options should be increased and promoted through participatory research and development in such stress prone areas.

The present study realizes the need for detailed scientific research in the areas studied. There should be a mechanism for collaborations between scientists, policy makers, farmers as well as other relevant stakeholders. It is necessary to learn the perspective, knowledge and experiences of farmers in order to better understand the complexity of crop production locally and devise a suitable adaption plan and policies to cope with climate variability in the country.

Acknowledgements

This work was the outcome of the support from many people and organizations. I would like to thank to the farmers of Begnas and Belwa who shared their valuable time and information, without which this study would not have been possible. I am very grateful to my supervisor, Marie Byström from the Swedish Biodiversity Centre (CBM) for her excellent guidance, contribution and continuous encouragement during the entire period of the study. I am also thankful to home country supervisor, Dr. Bhuwan R Sthapit, from Bioversity International for his technical support, appreciative comments and suggestions. I appreciate to Åke Berg, Torbjörn Ebenhard and Malin Almstedt for their statistical and technical support during data analysis.

I would like to highly acknowledge LI-BIRD for the institutional and logistics supports to carry out the field study in its project sites. I am thankful to Dr. Pratap Shrestha, Tara Lama and Bimal Regmi for the support at LI-BIRD. I am grateful for the cooperation of LI-BIRD staffs, especially Pitamber Shrestha, Sumam Mamandhar, Arjun Pun, Sree R Subedi, Parsu R Bishowkarma, Rachana Thapa and Sunanda Singh during the field work. Similarly, the support from Diwakar Poudel, Sarmila Sunuwar and Sanjaya Gyawali was also appreciated. I never forgot the contribution and support of Kulchandra Adhikari and Kali R Tharu during the field study.

Last but not the least, the support and encouragement that I received from all my family members are highly appreciated which always inspired me in my endeavour. Deepest thanks to my wife, Shanti Prabha Bastakoti for her entire support all the time. Finally, I acknowledge to Swedish Biodiversity Centre (CBM) and Swedish International Development Cooperation Agency (Sida) for the opportunity and financing the study.

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Appendix 1. Rice varieties and vulnerability rank score in the mid-hills

Rice varieties in the mid-hills study site, showing its type, percent area coverage, production domain, perceived major sensitive stages to production loss as well as overall vulnerability rank score to six rainfall related stress scenarios. The higher rank scores indicate a more vulnerable variety.

SN	Name of variety	Type of variety	Percent area coverage	Production domain in relation to moisture regime	Major sensitive stages to production loss	Overall vulnerability score
1	Ekle	Landrace	63.87	Irrigated tari	Dry spells during establishment and excess rain during flowering	0.73
2	Jethobudho	Landrace	2.58	Irrigated tari	Late planting due to drought and rain at harvest	0.71
3	Mansara	Landrace	9.15	Rainfed Tari	Drought or dry spells during growth and flowering	0.68
4	Rato Anadi	Landrace	1.09	Irrigated low land	Excess rain during flowering and at rain at harvest	0.91
5	Seto Anadi	Landrace	0.86	Irrigated low land	Excess rain during flowering and at rain at harvest	0.85
6	Thulogurdi	Landrace	1.43	Partially irrigated tari	Insufficient rain during establishment and flowering	0.73
7	Sanogurdi	Landrace	1.85	Partially irrigated tari	Dry spells during growth and flowering	0.69
8	Madhise	Landrace	2.87	Partially irrigated land	Dry spells at establishment and rain at harvest	0.97
9	Bayerni	Landrace	0.85	Irrigated tari	Excess rain at flowering and rain at harvest	0.76
10	Biramphool	Landrace	0.17	Irrigated low land	Dry spells growth and excess rain at flowering	-
11	Improved Biramphool	PPB bred	2.31	Irrigated land	Dry spells at growth and excess rain at flowering	0.95
12	Improved Mansara	PPB bred	4.46	Tari	Dry spells during growth and flowering	0.77
13	Improved Sanogurdi	PPB bred	2.71	Partially irrigated land	Excess rain during flowering and at rain at harvest	0.81
14	Kalo Jhinuwa	Landrace	0.06	Irrigated tari	Dry spells during growth and flowering	-
15	Seto Jhinuwa	Landrace	0.06	Irrigated tari	Dry spells during growth and rain at harvest	-
16	Gajale Gurdi	Landrace	0.12	Partially irrigated tari	Late planting due to drought and dry spells during flowering	-
17	Naltume	Landrace	0.02	Partially irrigated tari	Dry spells during establishment and flowering	-
18	Jarneli	Landrace	0.2	Partially irrigated tari	Dry spells during growth and rain at harvest	1.5
19	Masuli	Modern	4.49	Irrigated medium land	Late planting due to drought and dry spells during flowering	1.3
20	Janaki	Modern	0.23	Irrigated land	Late planting due to drought and excess rain at flowering	1.7
21	Radha-7	Modern	0.41	Partially irrigated tari	Late planting due to drought and dry spells during flowering	1.3
22	Tichung	Modern	0.2	Partially irrigated tari	Late planting due to drought and rain at harvest	1.8

PPB bred variety is the variety developed through participatory plant breeding approaches

Appendix 2. Rice varieties and vulnerability rank score in the terai

Rice varieties in the terai study sites, showing its type, percent area coverage, production domain, perceived major sensitive stages to production loss as well as overall vulnerability rank score to six rainfall related stress scenarios. The higher rank scores indicate a more vulnerable variety.

SN	Name of variety	Type of variety	Percent area coverage	Production domain in relation to moisture regime	Major sensitive stages to production loss	Overall vulnerabi lity score
1	Radha-4	Modern	28.75	Rainfed-partially irrigated land	Late planting due to drought, drought during flowering	0.93
2	Janaki	Modern	3.41	Partially irrigated-irrigated land	Late planting due to drought, excess rain at flowering	1.14
3	Sarju-52	Modern	8.07	Partially irrigated- irrigated land	Late planting due to drought, rain at harvest	1.24
4	Sabitri	Modern	11.48	Rainfed -partially irrigated land	Late planting due to drought, dry spells during flowering	1.04
5	OR	Modern	1.57	Irrigated land	Excess rain during flowering, rain at harvest	1.25
6	Makawanpur-1	Modern	7.52	Partially irrigated-irrigated land	Late planting due to drought, excess rain during flowering	1.04
7	Hardinath-1	Modern	6.2	Partially irrigated-irrigated land	Late planting due to drought, rain at harvest	1.13
8	Masuli	Modern	6.05	Irrigated land	Late planting due to drought, dry spells during flowering	1.4
9	Mala-3	Modern	3.41	Partially irrigated-irrigated land	Late planting due to drought, excess rain during flowering	1.1
10	Loktantra	Modern	0.55	Partially irrigated-irrigated land	Dry spells during growth, excess rain during flowering	1.11
11	Bindeshowri	Modern	1.46	Rainfed-partially irrigated land	Late planting due to drought, drought during flowering	1.23
12	Khajura-2	Modern	4.57	Rainfed-partially irrigated land	Late planting due to drought, excess rain during flowering	0.81
13	China-4	Modern	2.26	Rainfed-partially irrigated land	Late planting due to drought, drought during flowering	0.68
14	Trial	Modern	0.09	Rainfed-partially irrigated land	Late planting due to drought, dry spells during flowering	-
15	Sunaulo Sugandha	PPB bred	0.2	Partially irrigated land	Late planting due to drought, excess rain at flowering to grain filling	-
16	Ratanpuri	Landrace	0.07	Rainfed-partially irrigated land	dry spells during flowering, rain at harvest	0.85
17	Belkhole	Landrace	0.46	Partially irrigated land	Late planting due to drought, drought at flowering	0.85
18	Dhunmuniya	Landrace	0.25	Irrigated low land	Excess rain during flowering, grain felling and harvesting	1.0
19	Anjana	Landrace	0.09	Irrigated land	Drought at flowering and rain at harvest	-
20	Shyamjeera	Landrace	0.3	Irrigated land	Drought at flowering, excess at flowering to grain filling	0.8
21	Anadi	Landrace	2.04	Irrigated low land	Excess rain during flowering, rain at harvest	1.33
22	Prithivi, Tara, NK-6444, Shankar	Hybrid	10.75	Irrigated land	Late planting, dry spells during flowering	1.89

Appendix 3. Key informants

List of key informants in the study sites

SN	Name	Gender	Study site
1	Kulchandara Adhikari	Male	Mid-hills
2	Radha Adhikari	Female	Mid-hills
3	Bharat Raj Tiwari	Male	Mid-hills
4	Krishna Raj Neupane	Male	Mid-hills
5	Hari Maya Neupane	Female	Mid-hills
6	Lila Nath Dhakal	Male	Mid-hills
7	Fadindra Mohan Adhikari	Male	Mid-hills
8	Manju Adhikari	Female	Mid-hills
9	Kamala Chettri	Female	Mid-hills
10	Gita Pariyar	Female	Mid-hills
11	Krishna Prasad Tiwari	Male	Mid-hills
12	Shankar Neupane	Male	Terai
13	Kali Ram Tharu	Male	Terai
14	Binod Tharu	Male	Terai
15	Dalli Oli	Female	Terai
16	Meghadish Oli	Male	Terai
17	Mina Tharu	Female	Terai
18	Neelam Tharu	Female	Terai
19	Goraitu Tharu	Male	Terai
20	Bhim Bahadur Kadayat	Male	Terai
21	Man Bir B K	Male	Terai
22	Sita Baruwal	Female	Terai
23	Lok Kumari Sharma	Female	Terai
24	Pabitra Oli	Female	Terai
25	Sree Ram Tharu	Male	Terai

Appendix 4. Questionnaire

Household survey questionnaire

Questionnaire ID number:
Date of interview (dd/mm/yy):
Interviewer:

SECTION 1: Personal information

1.1. Name of the respondent:...District:......................

1.2 Address: VDC/municipality................., Ward.......,Village/tole.......................

1.3 Sex: a) Male .... b) Female.........

1.4 Age:................Yrs Ethnicity:........................

1.5 Education: a) Primary b) Secondary c) Intermediated) University

1.6 Major occupation: a) Agriculture b) Service c) Business d) Outside job e) Others (specify)

1.7 Number of family members who share kitchen together:

1.8 Sources of family income:

Sources	Rank (1-5)#
Agriculture	
Service	
Business	
Remittance	
Others (specify)	

#highest number means most important source

SECTION-2 General information

2.1Own farm size: a) Khet…..........R/K/B b) Pakho Bari…...……….R/K/B

2.2 Leased or shared land :) Khet….........R/K/B b) Pakho Bari…...….R/K/B

2.3 Area under rice crop: a) Ghaiya bari (Upland).............b) Tari (Rainfed)..........

c) Sinchit (Irrigated)........ .... d) Dhab (naturally wet lowland)..........................

2.4 Household food security :a) < 3 months b) 3-6 months c) 6-9 months
d) >9 months

2.5 What are the summer rice crop varieties being grown at present and past in your farms? (Provide the name of the varieties/landraces and estimated current area under each)

Time frame	Types	Rice varieties/landraces	
		Name	Area (R/B/K)#
Current year	Modern varieties	1 2 3 4 5	1 2 3 4 5
	Landraces	1 2 3 4 5	1 2 3 4 5
Last year	Modern varieties	1 2 3 4 5	-
	Landraces	1 2 3 4 5	-
2 years ago	Modern varieties	1 2 3 4 5	-
	Landraces	1 2 3 4 5	-

Area will be measured in local unit as Ropani, Kattha or Bigha

2.6 Why are you maintaining a number of rice varieties and landraces in your farm?

a) To match different land types
b) For food security
c) For maintaining food culture
d) Considering market values
e) For medicinal value
f) To cope extreme climates (flood, drought, hailstone etc.)
g) Others (specify)..................................

SECTION-3

2.1 In your opinion, what are the major risk factors in rice farming in your farm?-prioritize (Most important= 3, least important=1)

a) Seasonal climate and related stresses (abiotic factor) ☐

b) Market ☐

c) Biotic factors (Disease and pest) ☐

d) Others (specify)............ ☐

2.2 Among climatic factors, which one is the most important for rice farming?

Rainfall/moisture regime
Temperatures (hot/cold)
Hailstone
Wind
Others

2.3. In your experience, is there any fluctuation or changes in the moisture regime and summer rainfall pattern in the past 10-15 years?

a) Yes ☐ b) No ☐ No idea ☐

2.4 If yes, what are the changes and variations in rainfall pattern observed from the normal years?

Timing of summer monsoon (Early/late/bimodal distribution)
Amount of rainfall (+ / -)
Rainfall intensity (+ / -)
Rainfall duration/rainy days (+ / -)

2.5. If yes, what are those frequent changes and variations observed as compared to last 10 years in relation to rice crop?

SN	Variable characters	Frequency	
		More	Less
1	Excess rain before rice transplanting (rainfall before 15th of Jestha)		
2	Delayed rain or drought at normal planting time (no or insufficient rain before 15th Ashad or more)		
3	Excess rain at planting (flood)		
4	Dry period during crop establishment (Shrawan)		
5	Excess rain during crop establishment (flood)		
6	Insufficient rain (drought) during crop growth		
7	Excess rain during crop growth (flood)		
8	Insufficient rain (drought) during flowering		
9	Excess rain during flowering		
10	Insufficient rain (drought) during milking stage		
11	Excess rain at harvest		
12	Hailstorm at harvest		

2.6. Have rainfall variation and changes been experienced as problematic (having a negative impact) on rice crop production and farm income?

a) Yes ☐ b) No ☐ c) No idea ☐

2.7. How big is the effect of rainfall variation/changes you have experienced in rice production and food security during abnormal years in last 10 years?

Abnormal years (described & identified through FGD)	Impact on rice production (0-3)#	Impact on food security (0-2)┼	Impact on seed security Seed save or lost of varieties for next year
......................site			
In average			

#Note: 0=No, 1=Low, 2=High 3=Very high (Low=<5% loss, High=5-25% loss, Very high=>25% loss)
┼ 0=No, 1=Less, and 2=high

3.1 Individual assessment for risk of crop loss/failure of rice varieties and landraces due to rainfall variability and changes (Matrix ranking and scoring)

SN	Common rainfall variability characters to study site (IDENTIFIED THROUGH FGD)	Rice varieties/landraces-Perceived risks of crop loss (0-3)								
		V1	V2	V3	V4	V5	V6	V7	V8	V9
1	Delayed rain/drought at normal planting time (no/insufficient rain before 15th Ashad or more)									
2	Excess rain at planting (flood)									
3	Dry period during crop establishment (Shrawan)									
4	Excess rain/flood during crop establishment									
5	Insufficient rain/drought during crop growth									
6	Insufficient rain /drought during flowering									
7	Excess rain at flowering									

8	Insufficient rain at milking stage									
9	Excess rain at harvest									
	Total Score									
	Average									

Note: 0=No, 1=Low, 2=High 3=Very high (Low=<5% loss, High=5-25% loss, Very high=>25% loss)

SECTION -4

4.1 What are the practices that you have adopted as options to adapt climate variability/change at farm and community level?

Adaptation options	Do you practice? (Yes/No)
Technological use (polyhouse, direct seeding, SRI, use of chemicals, irrigation schemes etc.)	
Practices for on-farm adaptive management (Adjustment in cropping calendar, changes in crops and varieties, crop and seed selection etc.)	
Policy (Government support program, information, insurance)	
Diversifying household income sources	
Community based actions-(irrigation, group savings, awareness, check dams, information, participatory crop improvement, seed system etc.)	
Others (specify)-	

4.2 Among adaptive management, what are the practices for rice that you are practicing in your farm?

a) Changes in seeding, transplanting and harvesting time and practices
b) Changes in crop cultivars
c) Crop substitutions- changes from one species to another
d) Use of crop diversity-Growing multiple varieties in the farm

e) Using crop varieties/landraces that has specific traits to adapt/tolerate climate stresses
f) Use of water management practices-...
g) Changes/modification in seed selection/seed systems-...........................
h) Participatory crop improvement............................
i) Others (specify)-..

4.3. What do you grow in your field if you cannot grow rice crop? What can be possible as alternative crop as option?
....
....

4.5 What will be your alternative sources of livelihood to cope if rice crop is not successful in particular year?
....
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Thank you for your valuable time