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Local Adaptation Strategies in Semi-arid regions: study of two villages in Karnataka, India

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Abstract

Rural households in India, particularly farmers, are exposed to current climate variability and risk, which is likely to increase due to climate change. This study assessed current adaptation strategies adopted by rural households in two dry land villages of Bagepalli Block, Chikballapur district, Karnataka, in southern India. The adequacy of adaptation strategies was also assessed. The study showed that rural households and in particular, farmers adopted several practices to cope with current climate risks which include; irrigation provisioning (depending on ground water), shift in cropping pattern (to more resilient but low economically valued crops and varieties), mixed cropping, agro-forestry (as a long term strategy), diversified livestock holdings and reliance on government development programmes. The adaptation measures also included leaving croplands fallow, sale of assets, such as livestock and trees in their property, and migration. Current climate related responses to agricultural distress are not adequate to cope with even the current climate risks. This further indicates that rural households may not be able to cope with increasing climate variability and climate change. Thus, there is an urgent need for an improved understanding of current adaptation strategies and to enhance resilience and develop structured adaptation strategies to cope with current climate risks and long-term climate change.

Key Words: Adaptation, Climate Resilience, Climate Variability, Dryland Agriculture, India.

Introduction

Throughout history, people and societies have adjusted to and coped with climate change, climate variability, and extremes, with varying degrees of success (IPCC, 2014). Climate change refers to a change in the state of climate that can be identified by changes in the mean and/or the variability of its properties, which persists for an extended period, typically decades or longer (IPCC, 2014). The primary impacts of climate on society however are a result of extreme events, a reflection of the fact that climate is inherently variable (Parry and Carter, 1985). Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events (IPCC, 2014).

Rural communities, especially in developing countries, are heavily reliant on the natural resource base for their livelihoods. Consistent exposure to climate variability adversely impacts their livelihoods. For instance, key annual crops in India such as wheat, soybean and rice have a threshold temperature above which seeds do not form properly. A brief episode of hot temperatures (>32-36ºC) can devastate crop yields (Walker Institute, 2007), and thereby livelihoods. Breaks during the monsoons, unseasonal storms, and freezes during winters can lead to large reductions in crop yields.

The 2001 drought in the state of Karnataka emphasized the adverse societal impacts of climate variability. Incidents of crop loss, cattle deaths, decline in livelihoods from forest products and mass migration of labour to urban areas was observed (Rajendran, 2001). A similar situation arose during the 2012-cropping season, where Karnataka state recorded 43% deficit in rainfall between 1st June and 15th July. This was the lowest rainfall recorded in 42 years in the region (KSNDMC, 2012). Monsoon (Kharif) crops in the state failed, fodder scarcity reached precarious levels and groundwater depletion posed serious problems.

In light of the above, rural famers, landless and others exposed to climate variability have inadvertently developed their own adaptation strategies to deal with the year on year changes in climate. Smit (2003) indicates that local coping strategies are the basis for adaptation to long term climate change. Local coping strategies are adaptation initiatives by communities, usually triggered by market or welfare changes induced by actual or anticipated climate variability.

Aside from its significance for adaptation and assessing long-term climate change and current climate variability, traditional adaptation strategies are also a reflection of the social organisation of the group facing changes. The consequences of climate variability vary with ways in which a society has organised itself in relation to its resource base, its relation with other societies, and its relation with its institutions and the relations among its members. Inequality—or social differentiation—and marginalisation are among critical determinants of adaptation. Different people groups and places within regions differ in their ability to adapt and divisions between rich and poor translate into differential sensitivity to climate variability or change. Current adaptation strategies are heavily indicative of the status of natural resources, economic status, and access to credit and government programs.

Responses to adaptation have however mostly been interventions designed based on globalised scenarios. These have largely disregarded local complexities that include the social, cultural and other economic and political realities that drive systems. A study of climate variability in rainfed farming systems of sub-Saharan Africa, recommended the need to understand and enhance current adaptation strategies as an essential first step in adapting to long-term climate change and predicted future increases in climate variability.

This paper makes an attempt at understanding adaptation strategies to current climate variability from the perspective of local stakeholders. We then attempt to assess the adequacy of these adaptation strategies in coping with climate risks. Finally, we discuss options that will help enhance adaptation to climate change in the long-term. The main basis for focusing on current adaptation strategies to climate variability originates from the conclusion of IPCC (2014), "a first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability. Available strategies and actions can increase resilience across a range of possible future climates while helping to improve human health, livelihoods, social and economic well-being and environmental quality".

The research and analysis conducted in this paper will contribute to literature on the adequacy of current adaptation strategies in light of continuing climate variability and potential extreme events such as droughts. This will help understand how societies can be made more resilient to long term climate change through adaptation. This was attempted through generating empirical evidence from two semi-arid villages in South India. It is expected that the analysis will also address broader risk-reduction and development objectives.

Definitions and Methods

Adaptation as defined by IPCC is “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014). Since IPCC Working Group II's Fourth Assessment Report (IPCC, 2007), the framing of adaptation has moved further from a focus on biophysical vulnerability to the wider social and economic drivers of vulnerability and people's ability to respond. The new definition in the Fifth Assessment Report clarifies that human and natural systems have a capacity to cope with adverse circumstances but, with continuing climate change, incremental adaptation will be required to maintain this capacity.

The IPCC (2014) has distinguished a variety of concepts, characterized attributes, and highlighted specific forms of adaptation. The forms of adaptation have been distinguished according to numerous attributes such as purposefulness and timing (Carter et al., 1994; Stakhiv, 1994; Bijlsma et al., 1996; Smithers and Smit, 1997; UNEP, 1998; Leary, 1999; Bryant et al., 2000; Reilly and Schimmelpfennig, 2000). "Incremental adaptation actions are where the central aim is to maintain the essence and integrity of a system or process at a given scale; such as through adjustments to cropping systems via new varieties, changing planting times, or using more efficient irrigation. Transformational adaptation helps change the fundamental attributes of a system in response to climate and its effects. It includes changes in activities, such as changing livelihoods from cropping to livestock or by migrating to pursue livelihoods elsewhere; and also changes in our perceptions and paradigms about the nature of climate change, adaptation, and their relationship to other natural and human systems" (IPCC, 2014). Resilience, identified as a key component of adaptation, is defined as the capacity of a socio-ecological system to cope with hazardous events or disturbances, responding or reorganising in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014).

Our conceptual framework is based on the attributes of adaptation characterized by IPCC (2014) and allows for both incremental and transformational adaptation strategies. We conducted fieldwork in the Chikballapur district of southeast Karnataka. Its geographic area is 4,254 square kilometres and a population of 1.25 million in six blocks (Figure 1), and 1,324 villages. The fieldwork was conducted in two villages of Bagepalli block, which is a semi-arid, drought prone block, with semi-arid weather i.e., hot summers and mild winters. Agriculture is the main occupation in this district (CGWB, 2012) and is characterized by low cropping and irrigation intensity due to insufficient water for irrigation (DAC, 2011). Ninety one percent of available ground water resource in the entire district is currently over exploited, and in particular 45% of Bagepalli block is classified as over-exploited and resource poor (CGWB, 2012).

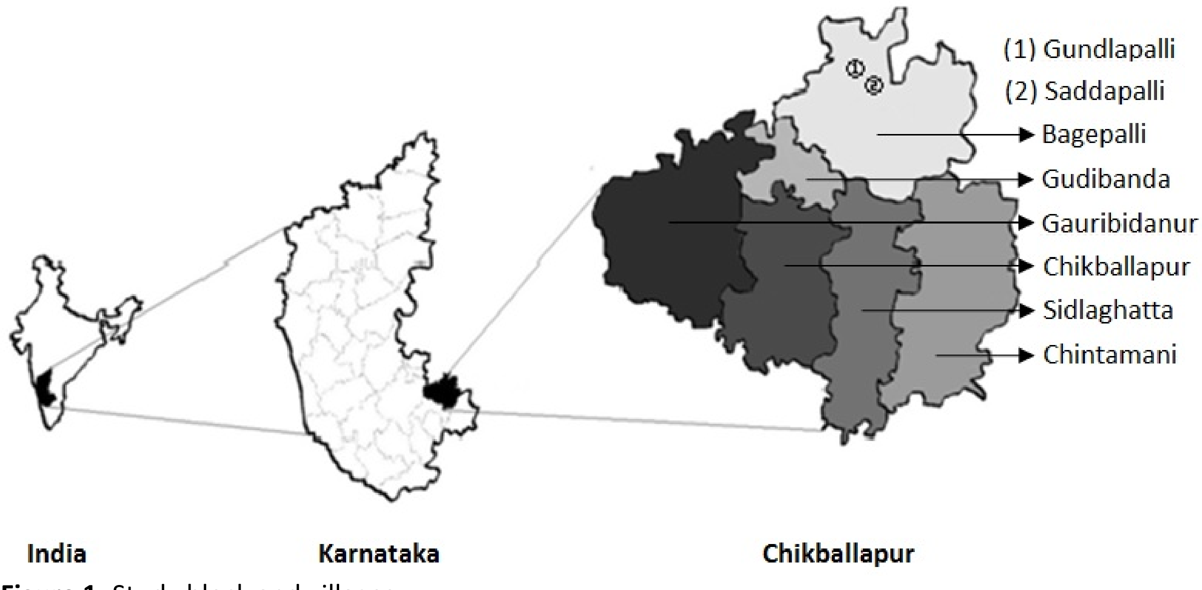

Figure 1: Study block and villages

Bagepalli block, which is mainly dependent on rainfed agriculture, has the lowest annual rainfall in the district. Studies point to dryland dependent populations as the most ecologically, socially, and politically marginalized, lagging behind on most economic and health indices (Verchotet al., 2007) and that climate change creates additional stress in a vulnerable system (Mertz et al, 2009). Bagepalli was selected to specifically understand adaptation strategies of dryland populations. Based on secondary information on socio-economic and climatic conditions of the region, we visited a few potential villages and selected Gundlapalli and Saddapalli as they well represented dryland populations. Gundlapalli (37% rain fed; 57% rainfed + irrigation; 6% irrigation) had relative better irrigation water availability while Saddapalli (74% rainfed; 21% rainfed + irrigation; 5% irrigation) was predominantly rainfed. The main occupation in both villages is agriculture.

The study was carried out in the summer of 2013, which was after their cropping for the agricultural year 2012-2013. The study employed complete enumeration of all households in the two villages, participatory rural appraisal and focus group discussions. The questionnaire was designed to assess the ability of village households to cope with current climate variability. The results and analysis are an attempt to highlight current adaptation strategies in response to current climate variability as stated by the respondents.

Description of the study villages

The demographic and agricultural characteristics of Gundlapalli and Saddapalli are presented in Table 1. The two study villages are 4 kilometres apart and are exposed to similar climate variations and risks such as drought or delayed rainfall and hence comparable for this study. Ground water extracted through bore wells is the main source of irrigation in both villages.

Table 1: Demographic and agricultural features of Gundlapalli and Saddapalli

Demographic and agricultural features	Gundlapalli	Saddapalli
Total village area	235 ha	682 ha
Total Population (Census 2011)	320	332
Household profile	3 Large farmers; 28 Small farmers; 22 Marginal farmers; 3 Landless labourers Total: 56 Households	5 Large farmers; 13 Small farmers; 48 Marginal farmers; 0 Landless labourers Total: 66 Households
Literacy rate	66.5%	49.8%
Number of households	56	66
Livestock population	329	333
Percentage of total village area under cultivation	71%	38%
Percentage of total village area under irrigation	9%	5%

Note: Large farmers own over 5 acres of land; Small farmers own between 2.5 and 5 acres; Marginal farmers own less than 2.5 acres; 1 ha = about 2.5 acres

Mean monthly and annual rainfall in Bagepalli Block: The mean annual rainfall for Bagepalli block over the 11-year period between 2001 and 2011 was 598mm (Figure 2). Five (2001 to 2004 and 2006) of these 11-years received annual rainfall below the 11-year mean of 598mm, with consecutive years having a deviation of -33 to -66% from the 11-year mean, indicating significant decreases in rainfall.

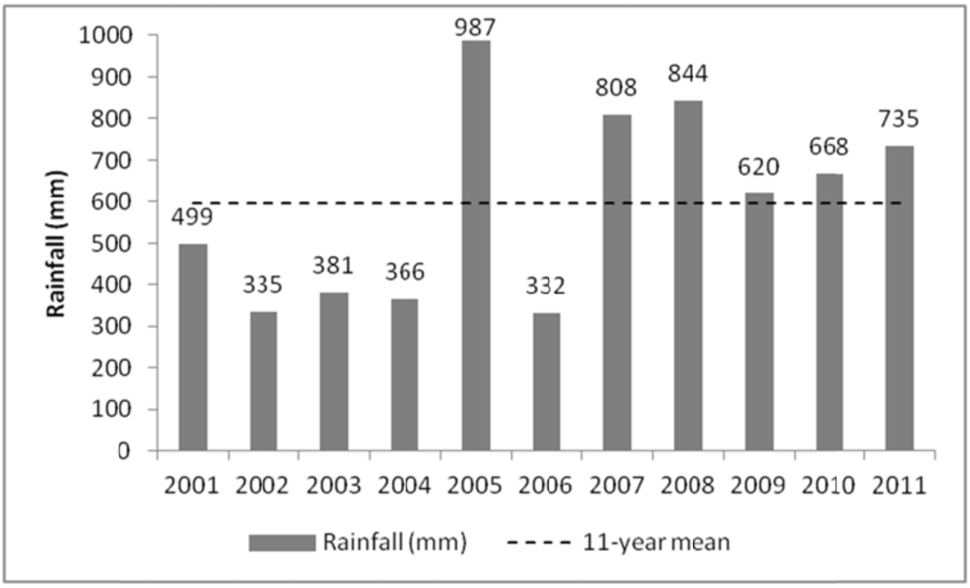

Figure 2: Annual rainfall recorded in Bagepalli block over the 11-year period (Data Source: District at a Glance – Chikballapur, Government of Karnataka, 2011-12)

Monthly rainfall data for Guloor, a town about 6 km from the selected study villages was acquired from the nearest rainfall recording station. The station has recorded rainfall over the past 8 years and this is presented in Figure 3 against an 8-year monthly average rainfall. This data indicates high variability in monthly rainfall. This inter-annual variability in monthly rainfall coincides with the main sowing period i.e., June to August. In semi-arid regions like Bagepalli, where agriculture is predominantly rainfed, variability in monthly rainfall during the cropping season could drastically increase vulnerability of crop production, leading to reduced crop yields or crop failure.

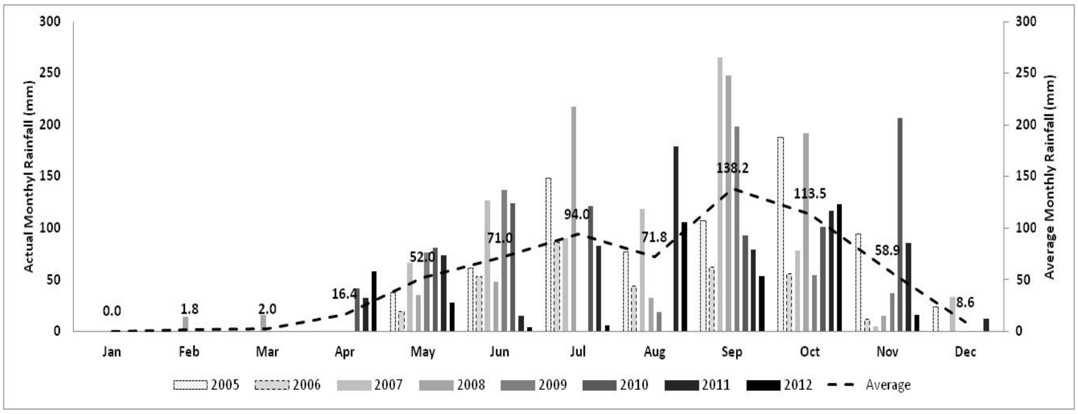

Figure 3: Observed monthly rainfall (mm) over the past 8 years against the average monthly rainfall (mm) of Guloor town, Bagepalli block

In the absence of data at the village level, the relationship between annual rainfall and crop yields has been computed at district level for the two main food crops of the district, Finger Millet (Elusine Coracana) and Maize (Figures 4a and 4b). Regression analysis assessing the impact of rainfall on crop yields (tonnes/ha) for the period 2001-2012, showed a positive relationship between rainfall and crop yields for both Finger Miller (R^2=0.63) and Maize (R^2=0.53). This demonstrates that crop productivity was influenced by the amount of rainfall.

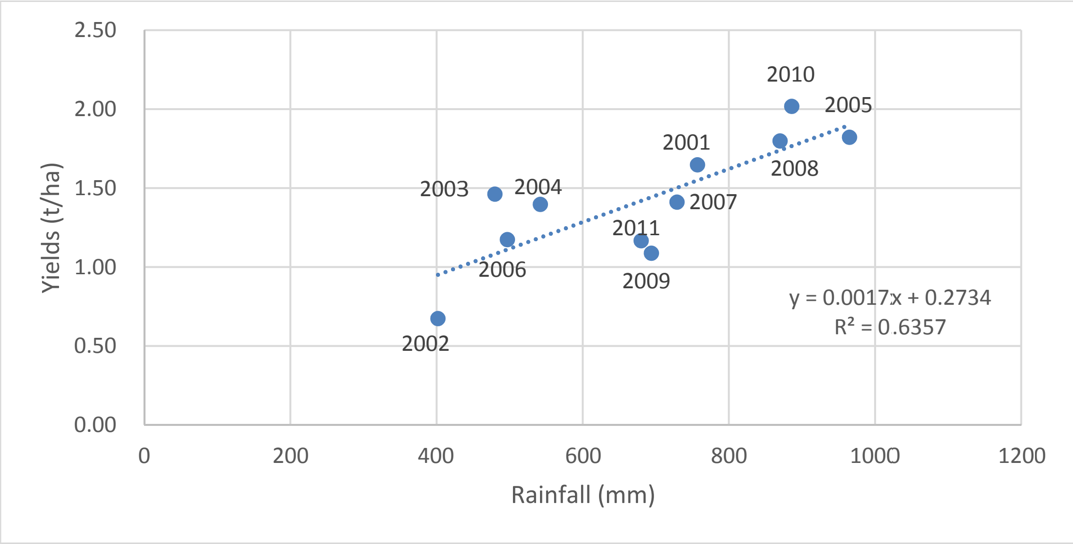

Figure 4a: Crop yields and rainfall (2001-2012): Finger Millet

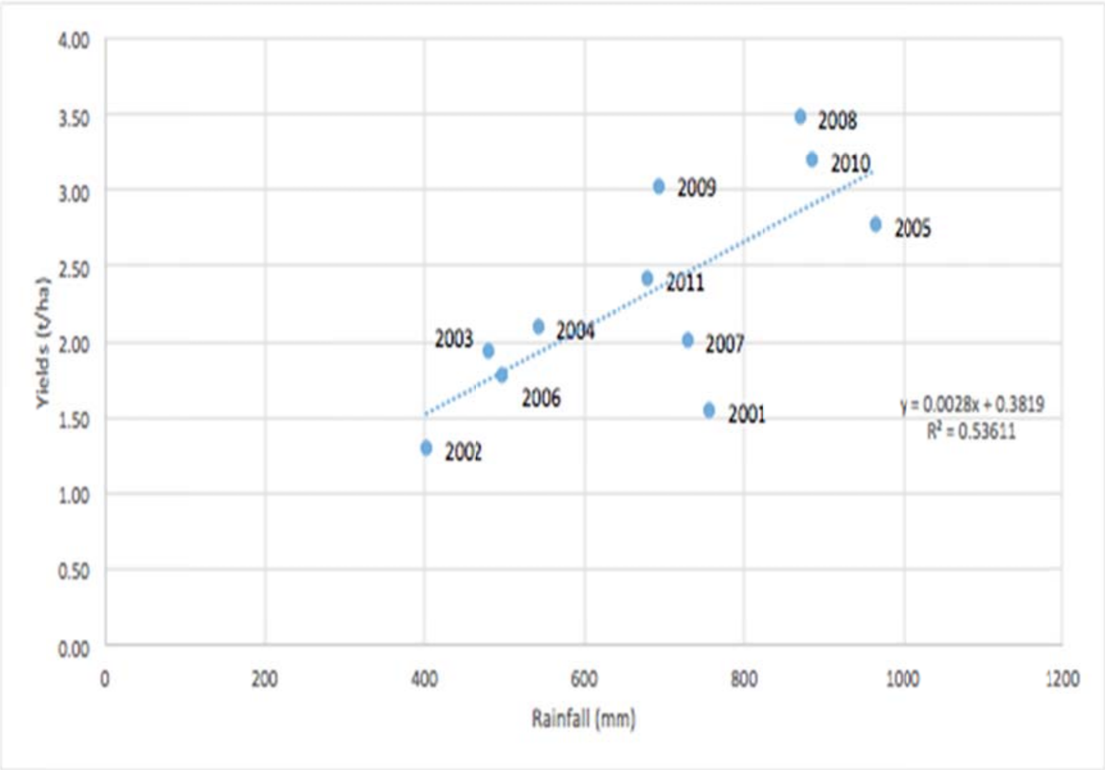

Figure 4b: Crop yields and rainfall (2001-2012): Maize

Assessment of Local Adaptation Strategies to Current Climate Risks

Current climate variability is one of the key factors determining cropping, agro-forestry, livestock systems, and livelihoods. As stated by IPCC (2014) human ability to adapt to climate impacts can be increased by actions that were not anticipated or purposefully undertaken in response to observed or anticipated climate change, sometimes called unplanned actions. Furthermore, farmers' adaptability and perception varies depending upon their socio-economic capability (Salau et al., 2013), gender (Getu and Mulinge, 2013; Sireeranhan, 2013), geographical location (Claessens et al., 2012), availability of water resources (Lunduka, 2013) and access to available institutional programmes (Dinar and Jammalamadaka, 2013). Farmers' adaptive capacity is also influenced by external factors such as the development and availability of irrigation and other infrastructure, relief and insurance, credit and other types of subsidized income transfer schemes, information and knowledge dissemination (Bantilan et al., 2013). The scope of this assessment however includes for strategies where the respondents perceived climate variability as a key driving force in their adaptation strategies.

Farmers' understanding of climate change is important for adaptation (Bryan et al, 2013; Jones and Boyd, 2011) as their behaviours are determined by their perceptions of climate risk and agricultural productivity. Farmers in India rarely attempt to seek scientific data regarding climate patterns when adopting crops for cultivation (see also Adger et al, 2009). Farmers' perception of rainfall variability in the region was found to be largely consistent with the observed scientific climate patterns. Farmers interviewed reported a reduction in rainfall and shortening of monsoon over the past five years. They indicated that a decade ago, land preparation for *monsoon* crops was initiated in March/April to prepare for arrival of monsoon in May/June as opposed to their having to delay land preparation to June/July during the two most recent cropping seasons.

Table 2: Adaptation strategies in Gundlapalli and Saddapalli villages of Bagepalli block

Ex-Post	**Ex-Ante**
Income diversification ex-post	Income diversification ex-ante
Change in sowing times	Borrowing loans for irrigation
Distress sale of assets	Crop diversification
Receive loans and compensation	Change in cropping patterns
Migration	Soil fertility management (investing in fertilizers and other inputs)
Reliance on Common Property Resources	Purchase of livestock
Reducing consumption	Agro-forestry

The empirical evidence of adaptation strategies adopted by farmers provides the basis and knowledge to design policies and actions for enhanced adaptation to current climate variability for the region (Table 2). Details of strategies adopted in Gundlapalli and Saddapalli as reported by the farmers are described below:

i) Changing Cropping Patterns as an Adaptation Strategy

Changing cropping patterns (Figure 5) is seen as one of the most commonly adopted practices for coping with climate variability in agriculture especially with small and marginal farmers (Ramaswami et al., 2004; Reddy, 2009).

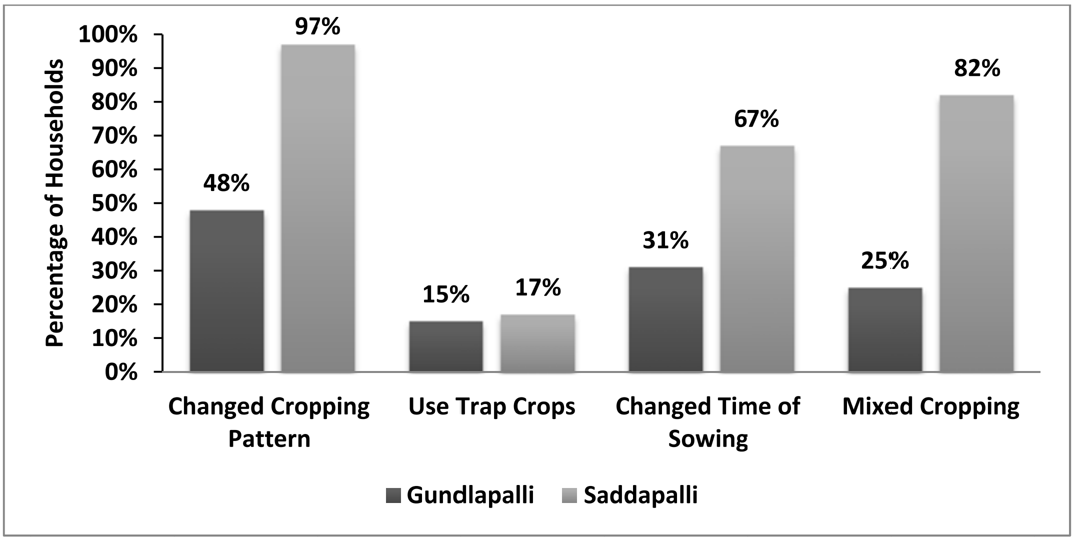

Figure 5: Changing cropping practices in Gundlapalli and Saddapalli

The following changes in cropping practices were observed in the two villages surveyed:

- ***Mixed cropping***: Under mixed cropping, even when one crop fails due to moisture stress or pests, additional crops grown could survive and provide economic returns, though often lower (Figure 4). This was practiced by a large majority (82%) in Saddapalli and was a popular practice (25%) in Gundlapalli.
- ***Use of trap crops:*** Use of companion planting that attracts agricultural pests, usually insects, away from nearby crops to save the main crop from decimation by pests without the use of pesticides. Seventeen percent of farmers in Saddapalli and 15% of farmers in Gundlapalli have cultivated trap crops.
- ***Change time of sowing:*** During low rainfall or delayed rainfall, farmers delay transplanting or sowing of crops which could adversely impact crop yields. This was a common practice in Saddapalli (67%) and Gundlapalli (31%).
- ***Crop Diversification***: In Saddapalli, 97% of farmers substituted their crops for potentially more drought resistant crops such as horse gram and Maize (Figure 5) depending on the rainfall in a given year. In Gundlapalli, 48% of farmers substituted their crops during the cropping season. Generally, there is a shift from water intensive (such as paddy) to less water intensive crops. Further, the shift was mostly from high economic yielding crops such as groundnut, vegetables, millet and rice to crops with lower economic returns such as maize and horse gram (Figure 6).

Changing cropping patterns and crop diversification is reportedly practiced by majority of farmers in dry land areas due to the high climate risk (Patnaik 2011, Pathy 2003, Mohanti and Padhi 1995). Mixed and multiple cropping are common strategies for crop protection from pests as it helps to prevent the spread of the risk (Pionetti and Reddy, 2002). The crops commonly used for such practices in both villages include, generally low yielding, red gram, cowpea and horse gram. Mixed cropping using cereals, additionally helped to meet the household food requirements and fodder needs for cattle.

Better access to irrigation in Gundlapalli provided a buffer against climate shocks and a majority of the farmers managed with mono cropping. Reduced irrigation water availability in Saddapalli necessitated greater changes in cropping practices as essential adaptation to prevalent climate vulnerabilities. However, changing cropping patterns by farmers due to shifting rainfall patterns has accompanied cost to farmers due to several reasons, namely:

- Farmers have to assess climatic conditions at the time of sowing.
- Farmers have to buy seeds for the new crop or variety based on that year's rainfall, which causes uncertainties.
- It poses additional risk if their decision of the crop chosen proves to be wrong.
- In most cases, the shift is from a high yielding crop or variety to a low-yielding crop or variety, leading to lower economic returns.

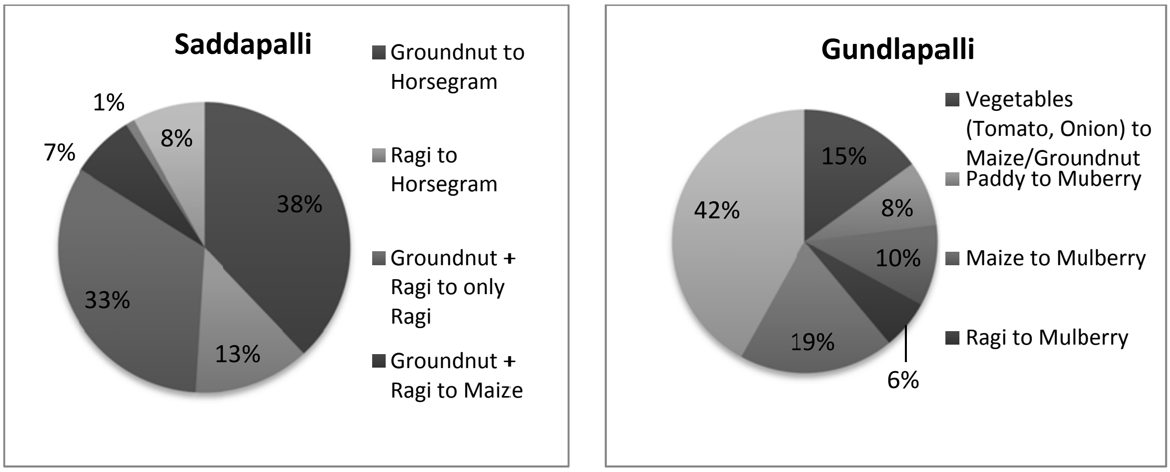

Figure 6: Shifting cropping patterns in Gundlapalli and Saddapalli

The relationship of crop yields and sowing date depends on soil moisture conditions and consequently seasonal rainfall. For semi-arid conditions, as in Bagepalli, where the normal annual rainfall is as low as 598mm, which is just below the minimum crop water requirement for groundnut (600mm), crops could potentially face acute water stress during critical growing stages, if there is even a slight deviation from the normal monthly rainfall, leading to reduced yields. The sowing period in the two study villages is June to August. A study by Viramani and Shurpali (1999) shows that groundnut crop planted during mid-July to end August results in greater yields and any subsequent delay in sowing results in reduced yields by almost 55%, as sufficient rainfall may not be available for the crop at the time of maturity.

Shifting from cash crops such as groundnut to subsistence crops such as horse gram reduces farmers' income. Harvest price of groundnut for the study region in 2012-13 was Rs.35/kg (1 GBP was approximately Rs. 100) and that of horse gram was Rs.10/kg. Further, in Saddapalli, due to reduced irrigation water availability, farmers had changed their crops to hardier varieties like horse gram. On average, a farmer in Saddapalli would produce 47-65kg of groundnut per acre and earn approximately Rs.1650-2300/acre on sale. But if the same farmer switches to horse gram, they would produce 35-62kg/acre and earn approximately Rs.350-620/acre on sale. Thus farmers' livelihoods are jeopardised due to reduced yields (as a result of delayed sowing) and reduced income.

ii) Irrigation as an Adaptation Strategy

Irrigation is a key intervention that determines the extent of loss suffered by farmers during low rainfall, delayed rainfall or drought years. Dryland farming suffers from moisture deficits and inadequate water and soil nutrients. Shortage of soil moisture in drylands during sensitive stages of crop development, i.e. flowering and grain filling, often leads to devastating effects on crop yields. Farmers with access to irrigation in the study area were found to be less vulnerable to moisture stress and drought and therefore had somewhat greater potential to adapt to climate variability.

In Gundlapalli, 45% of area under crops was irrigated (Table 3). Approximately 57% of the total area under irrigation was sourced by perennial groundwater wells and 43% of this irrigated area was reliant on rainfall, as it was being irrigated by seasonal bore wells. In the past five years, farmers in Gundlapalli had been increasingly reliant on irrigation sources to overcome variations in rainfall patterns. In fact, dependence on groundwater-based borewells was one of the key adaptation strategies to rainfall or moisture deficit. In Saddapalli on the other hand, only 11% of the total cultivated area had access to sources of irrigation. Of this, 62% of the irrigated area was dependent on seasonal rainfall i.e., seasonal borewells, and hence in years with low rainfall, irrigation supply was very limited in Saddapalli.

Table 3: Sources of Irrigation

	Gundlapalli	Saddapalli
Total crop area (Acres)	153	143.7
% area under irrigation	45	11
% area irrigated by perennial groundwater-based borewells	57	38
% area irrigated by seasonal groundwater-based borewells	43	62

Despite farmers perceiving and reporting irrigation as an adaptation strategy, it may not be a long-term strategy as dependence on ground water leads to over exploitation and decline in ground water levels, particularly in areas such as this. However, rain water conservation and harvesting may be a more appropriate adaptation strategy in these villages.

iii) Agroforestry-based Adaptation Strategies

Traditionally agroforestry is proving to be an essential land-use option to sustain agricultural productivity and livelihoods of farmers through providing alternative sources of income (Syampunaniet al, 2010). A majority of households in Gundlapalli (75%) and Saddapalli (88%) were found to be practicing agroforestry (Figure 7). This was in a limited form of homesteads (few trees around the house) and block/boundary/row planting in farmlands. In agroforestry, the species and diversity of tree species is critical to determine not only the income, but also for adapting to climate variability. A majority of households practicing agroforestry in both villages have grown more than one tree species. Different species found in the two villages are as follows.

- Gundlapalli - Neem, Pongamia spp., Coconut, Eucalyptus spp., Mango, Tamarind, Custard Apple, Banana, Drumstick, Jackfruit, Syzygium spp., Acacia spp.
- Saddapalli - Neem, Pongamia spp., Coconut, Hibiscus, Pomegranate, Banyan, Mango, Tamarind, Custard Apple, Syzygium spp., Acacia spp.

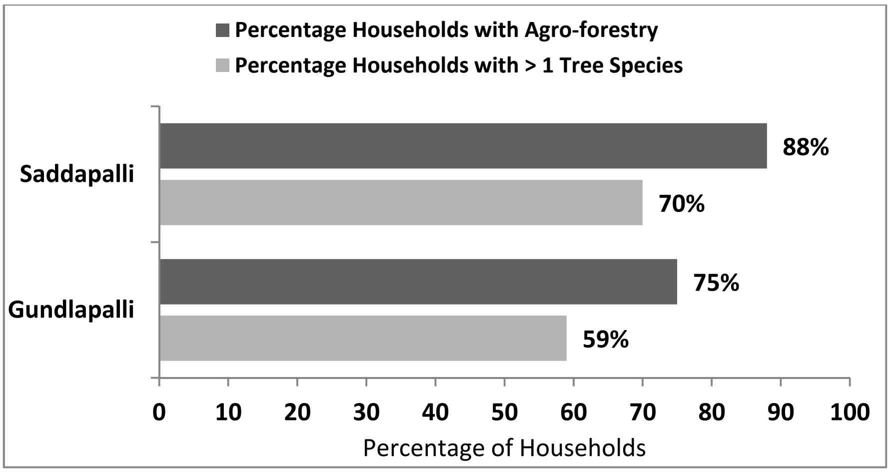

Figure 7: Agroforestry in Gundlapalli and Saddapalli

A majority of farmers practicing agroforestry in their farmlands used it as a source of additional income. Respondents, in particular marginal farmers, indicated that income obtained from agroforestry helped meet their socio-economic needs and sustain their livelihoods when faced with low productivity from agricultural crops. Coconut, Mango and Syzygium were the most common trees, which provided subsistence and income to households.

In both villages, agroforestry was a critical adaptation strategy to cope with the adverse impacts of climate variability. Of the total irrigated households practicing agroforestry, 77% in Gundlapalli and 94% in Saddapalli had invested in agroforestry-based practices. However, on average only 2 species of trees were grown in both villages. Only 8 households in Gundlapalli and 11 households in Saddapalli were found to be growing more than 3 species of productive trees. Despite the diversity in terms of income-generating species of trees and trees with potential to help food security issues, the extent of prevalence per household was inadequate and hence agroforestry in both villages had not achieved its full potential, especially in Gundlapalli. Limitations of labour, lack of time and location of trees distant from homes were stated as challenges for not engaging in greater agro-forestry activities.

iv) Livestock Diversification as an Adaptation Strategy

Rearing livestock was undertaken as investment in productive assets by a majority of respondents in both villages. Ownership of milk yielding dairy cattle and sheep and goats for meat provided additional sources of income while also being a risk mitigating measure, in the event of crop failure. Further, diversification and ownership of livestock provided a potential for sale of livestock as a compensation for crop loss during drought years, thus creating a safety-net in times of stress.

Overall, 50% of households in Gundlapalli and 53% in Saddapalli owned cattle (cows, buffaloes and bullocks) (Figure 8). Of the 50% households owning cattle in Gundlapalli, approximately 28% owned high-yielding cross-bred cows. Additionally, 26% of households in Gundlapalli owned a combination of cattle, sheep and goat as a means of livelihood and less than a fifth of the households in Saddapalli (18%) owned a combination of cattle, sheep and goat. Sheep and goats together were owned by less than 10% of households in both villages.

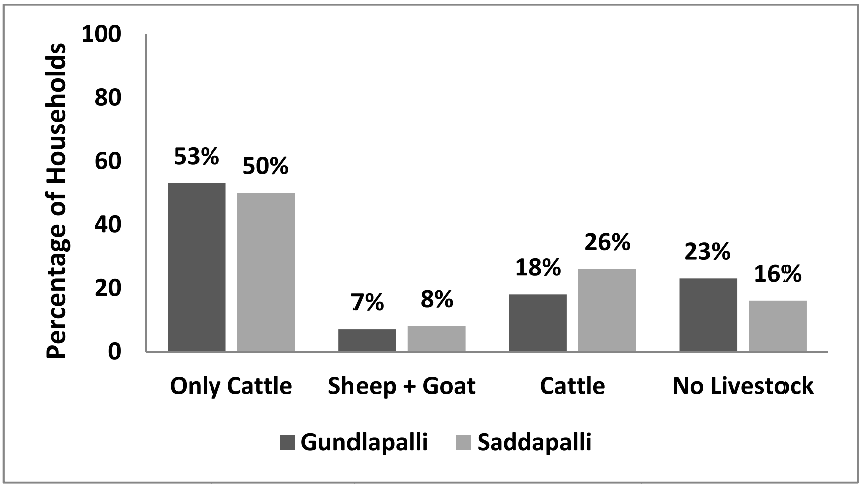

Figure 8: Diversification of livestock

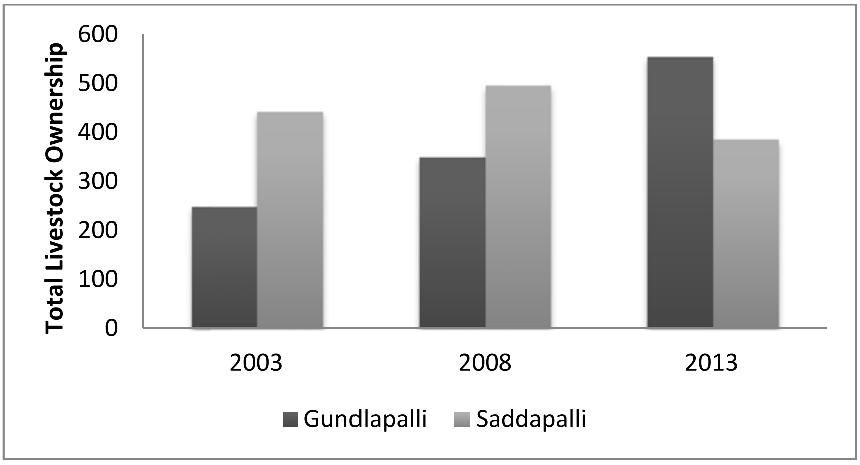

Figure 9: Trends in livestock ownership

Trends in total livestock ownership in the two villages in the past decade showed total livestock in Gundlapalli had nearly doubled while total livestock ownership in Saddapalli had decreased (Figure 9). This could partly be due to greater distress sales of livestock observed in Saddapalli. The reasons attributed to shifts in types of livestock owned are described in Table 4.

Table 4: Shifts in type of livestock owned

	Crossbred cow	Sheep + Goat	Bullocks	Local Buffalos
Gundlapalli	• Greater income from diary • Potential insurance mechanism during times of distress (crop failure, weddings, bore well purchase) • More volume and frequency of milk produced (as less frequent periods of non-productivity) • Lack of agricultural work in the fields	• Additional income (meat as well as sale of livestock if necessary) • Easier to maintain than cows • Hardier animals and can graze even in dry lands and low productivity sites, especially during rainfall deficit years • Potential insurance mechanism	• Useful for tillage	• For milk as a source of income
Saddapalli	• Greater income from diary • Greater income from sale during distress	• Potential insurance mechanism in case of shocks	• Useful for tillage • Income from renting for tillage	• N/A

v) Income Diversification as an Adaptation Strategy

The main factor affecting income trends from croplands in the two villages was observed to be largely due to rainfall variability, which also results in shortage of water, fodder and grazing land for livestock. The most common adaptation strategy at the local level had been to pursue alternative livelihood activities. Dercon (2000) identified income diversification as households combining activities with low positive covariance and income-skewing, i.e. taking up low risk activities even at the cost of low return. In practice, this implies that households are usually involved in a variety of activities, including farm and off-farm activities and seasonal migration.

It was found that 63% of households in Gundlapalli and 67% of households in Saddapalli derived their income from multiple sources, which included crop production, livestock ownership and labour (Figure 10). In Saddapalli, where a majority of farmers were marginal and mostly relied on rainfed agriculture, only 3% of households were found to be solely dependent on agriculture for income, while it was 16% in Gundlapalli. A small proportion in Saddapalli (3%) and about a tenth in Gundlapalli mentioned other sources of income, which included petty businesses; government sponsored programmes such as NREGA (National Rural Employment Guarantee Act) and migration.

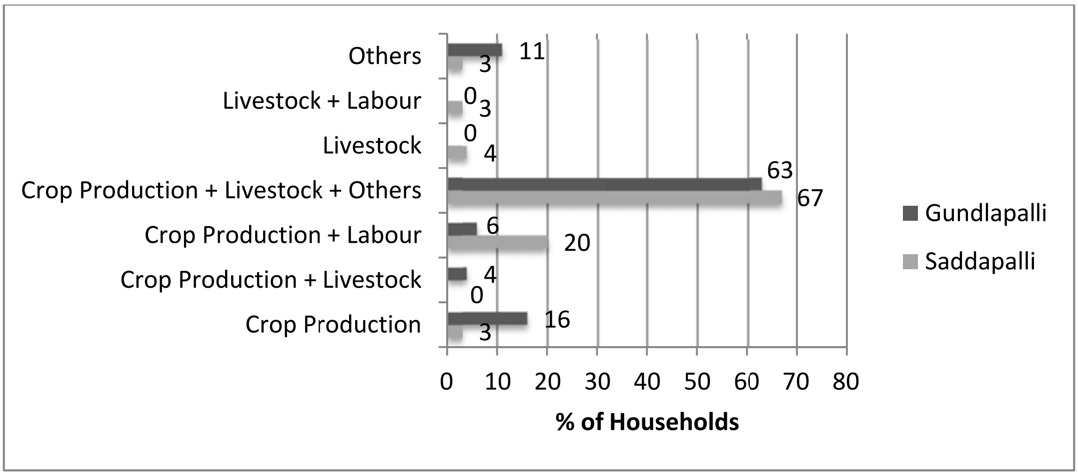

Figure 10: Income diversification in the villages of Bagepalli

Income diversification was observed on a more *ex-ante* basis in the form of setting up of petty businesses, borrowing loans and investing in irrigation, livestock and sericulture. Respondents seemed to be seeking long-term solutions to the problems associated with traditional cropping systems.

vi) Migration as an Adaptation Strategy

Migration to urban areas is a long established practice, especially within the more nomadic community of Saddapalli. In Saddapalli, 30% of the households reported migration (at least one member of the household migrated seasonally) whereas in Gundlapalli, it was only 18% (Figure 11). In Gundlapalli, migration was less frequent and temporary with people migrating to nearby towns such as Bagepalli, Chikballapur and Bangalore. Further, higher number of people migrated during periods of drought.

In Gundlapalli, where farmers had greater access to sources of irrigation, migration was less permanent. The main reasons cited by those who permanently migrated from Gundlapalli were lack of opportunities beyond farming and loss of crop yields due to drought.

The most commonly cited reasons for migration in Saddapalli included lack of rainfall which led to fall in crop yields, insufficient alternate opportunities for agricultural labour, low access to food, and debt. Migration in Saddapalli was semi-permanent with many households indicated long seasonal employments in urban areas.

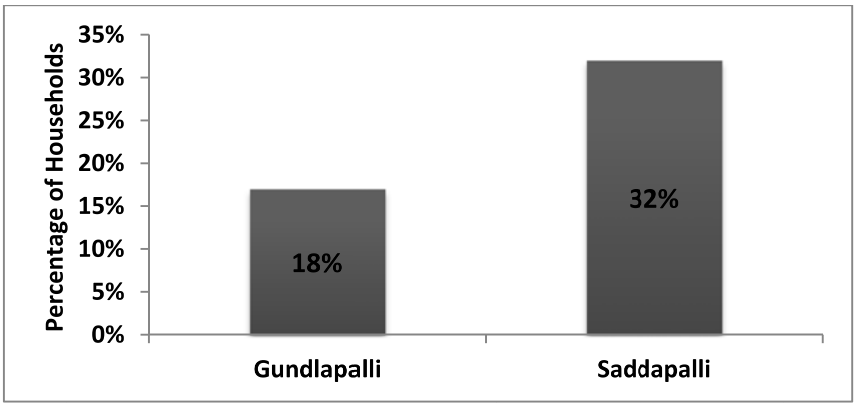

Figure 11: Migration rates in the study villages (Percentage of households with at least 1 member migrating seasonally)

Despite its prevalence as an adaptation strategy, Scherr (2000) posits that migration to solicit wage employment is a source of vulnerability on two fronts; firstly because of a lack of effective regulation of employment conditions that greatly disempower and disenfranchise the migrant labourers; and secondly, the increased burden on women left behind to negotiate and maintain social relationships in the village throughout the year to make ends meet.

vii) Government Developmental Programmes as Adaptation Strategies

There are several developmental programmes initiated by national and state governments to create employment, livelihoods and safety nets against agricultural failure. The programmes currently being implemented in Gundlapalli and Saddapalli, which enabled them to cope with climate variability, are presented in Figure 12.

- MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) provides additional employment and income to rural population. It was observed that MGNREGA helped provide employment to people after a negative income shock and hence increased their ability to cope with crop loss resulting from rainfall variability. In Saddapalli where farmers were generally observed to have lesser income security due to higher dependence on rainfed agriculture, 82% of households gained employment from MGNREGA. Respondents in Saddapalli indicated an average of 40 days of MGNREGA-based employment and a majority of this employment was during the winter season. In Gundlapalli, 50% of respondents reported an average of 30 days of employment from MGNREGA during the study year. As this programme offers employment for 100 days in a year, there is potential for greater opportunity for farmers to access this programme.
- Compensation for crop loss is an institutional risk mitigation measure where the state government gives compensation to land owners reported to be affected by drought. Forty one percent of households in Saddapalli and 14% in Gundlapalli had received crop compensation. However, respondents in Gundlapalli indicated that the programme had not been adequate as compensation provided was only Rs. 1,000 (circa £10) per farmer, irrespective of their investment in crop production.
- Loans - both formal and informal, provided by banks, family members and other sources enables farmers to cope with income losses from their main sources of livelihood. A majority of respondents in Gundlapalli indicated to have taken loans for installation of bore wells.
- Insurance support from government against loss of crops and livestock had been accessed by a small number of households in both villages.

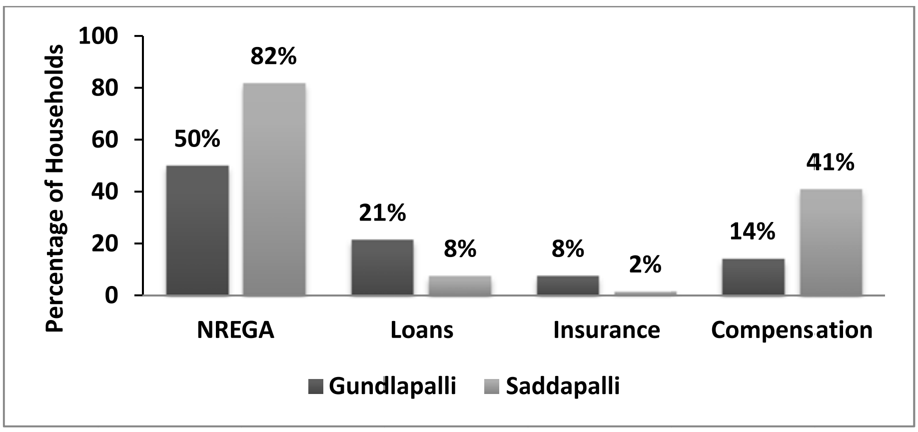

Figure 12: Existing programmes, which help mitigate risk

viii) Distress Sale as an Adaptation Strategy

Sale of assets during distress was a strategy adopted by several households. The most commonly sold assets included livestock and mature trees. A total of 38% of households in Gundlapalli and 33% in Saddapalli had sold livestock in times of distress in the past 5 years. About 13% of households from Gundlapalli and 12% from Saddapalli reported having sold their trees in times of stress. The most commonly sold tree species in both villages were Eucalyptus, Neem and Pongamia due to the potential value derived from the wood of these trees.

Factors Determining Adaptation Strategies

Adaptive capacity is an amalgamation of the biophysical, socioeconomic and technological factors that influence agricultural and livestock production. It is considered, ''a function of wealth, technology, education, information, skills, infrastructure, access to resources, stability and management capabilities'' (McCarthy et al., 2001).

It is difficult to determine definitive factors that influence decisions by communities to adopt certain adaptation strategies. Thornton et al. (2010), Gentle and Maraseni (2012), and Bryan et al. (2013), have attempted similar analyses and acknowledged that drawing conclusions of factors underlying the adoption of certain strategies is difficult since individual adaptation choices underlying aggregate variables for adaptation are vastly different. Bryan et al. (2013), state that it is unlikely that the factors that influence one adaptation strategy, such as changing cropping patterns, will be the same or similar for an entirely different strategy, such as agro-forestry. Mertz et al. (2009) highlight that climate is likely to be only one of many factors influencing household adaptation strategies to environmental changes and this may be even more pronounced in relatively poor and vulnerable dryland communities. Seemingly marginal changes in subsidies, market conditions, labour supply, seed availability and energy supply may lead farmers with low economic resilience to radically change their strategies regardless of climatic parameters (Mertz et al., 2009).

In our study, size of landholding and access to irrigation were stated as two critical factors influencing a majority of adaptation practices. For instance in Gundlapalli, 45% of the net sown area was irrigated while only 11% of net sown area in Saddapalli was irrigated. Farmers with irrigation facilities were observed to have stronger ability to adapt to disturbed or changing rainfall patterns. For instance, there was a strong correlation between irrigated area and number of crops grown in Saddapalli (r = 0.8) and Gundlapalli ($r = 0.7$). Additionally, larger famers were found to be more involved in crop diversification and mixed cropping than marginal farmers. Existing infrastructure including water resources and institutional support also contributed to adaptive capacity.

Adequacy of Current Adaptation Strategies to Current Climate Risks

While current adaptation strategies and drivers behind these are being understood, it is important to address the issue of adequacy of current strategies to cope with current climate variability and potentially future climate risks. The following adaptation strategies observed in the selected villages lead to loss of assets, loss of production potential, reduction in income, shift to low income yielding crops, etc.

a) Leaving land fallow: Respondents were asked to indicate their main adaptation strategy during drought and 57% in Gundlapalli and 78% of the households in Saddapalli reported leaving a part of their land fallow. A key adverse impact of drought in dryland areas pertained to land being left fallow by farmers, who pursued alternate sources of livelihood during drought. This strategy is highly unsustainable in the long-run for farmers who have a desire to continue to own and cultivate their land.
b) Shift from high income yielding to low income yielding crops or varieties (Figure 6)

c) Distress sale of assets such as livestock and fruit yielding trees.
d) Migration to far off places in search of employment and livelihoods.

The sustainability of different adaptation strategies also depends on intensity, duration and frequency of climate hazard. Indigenous adaptation strategies may not be adequate, because climate change may bring new risks that have not been dealt with before by some communities, although other communities may already have adaptation strategies for those new risks. UNFCCC (2003) also highlights that communities have adapted according to experienced frequency and magnitude of extreme climate events. Some strategies, based on short-term considerations, survival needs, lack of information or imperfect foresight, can worsen environmental degradation and thereby diminish future adaptive capacity and livelihood options (Eriksen, 2001).

The adaptation practices against climate vulnerabilities in Gundlapalli and Saddapalli are strategies which enable them to survive climate risks but at a cost. Also, these strategies are reactions to immediate risks and are only short-term solutions. However, they do not provide adequate protection and they do not provide long-term solutions.

Strategy for Facilitating Adaptation to Current Climate Risks

The multiple effects of rainfall variability and drought are physical, economic, social and environmental. This study demonstrates that households in dryland villages in Karnataka adopt a number of adaptation strategies in response to current climate risks. They include both *ex-ante* and *ex-post* risk management strategies. The differences in the adaptation mechanisms between the two villages were determined by access to irrigation and size of land-holding.

The key findings from this empirical study are:

(i) That current climate variability and climate risks resulted in farmers in both villages suffering from loss of agricultural productivity (leaving land fallow, sale of livestock and assets). This stress is likely to increase based on projected climate change impacts which could lead to ecosystem degradation and loss of goods and services from natural resources on which they are highly reliant.
(ii) The current adaptation strategies undertaken in the two study villages were found to be inadequate.

With projected increase, in frequency and intensity of droughts and high temperature events, it is likely that the adaptive capacity of both communities will progressively be weakened. The resources they draw upon to build their resilience will be eroded and the impacts of climate change may be progressively damaging in the near future. Patnaik (2011) indicates that traditional adaptation mechanisms that are aimed at loss-minimisation and land utilization to deal with drought, in tune with survival instincts, adversely affects asset creation of poorer households and pushes them into deeper poverty.

There is a strong need to incorporate a robust and planned adaptation strategy to help rural communities to cope with the impacts and vulnerabilities due to climate risks. This will inadvertently help them adapt to long-term climate change. The potential adaptation strategies to enhance climate resilience in rural communities residing in semi-arid regions are listed as follows:

1. ***Build on existing land-management and agronomic practices***: Research in many sectors and regions indicates humans have an inherent capacity to adapt to long-term mean climate conditions but less success in adapting to extremes and year-to-year variations in climatic conditions. Adaptation strategies to weather conditions have evolved through many years of knowledge, interest and innovativeness of local actors. Whilst indigenous knowledge is important to cope with immediate risks, these mechanisms are not adequate to cope with

severe risks posed by predicted potential climate variability. Land and agriculture will continue to be critical for current as well as long-term adaptation. Thus there is a need to build on existing land management strategies through soil and water conservation and soil fertility improvement measures. It is also essential to develop scientific methodologies and communicate and train farmers with agronomic practices (crop selection, planting, sowing, etc.) adequate to tackle current and future changes in rainfall and soil moisture patterns, specific to semi-arid regions.

2. ***Enhancing opportunities through agroforestry***: Diversifying productivity to include trees that enhance economic potential and capability would provide buffer against income risks due to climate variability. Findings of this study and others suggest farmers adopt agroforestry as it is more profitable and less risky relative to other agricultural options because of the variety of produce (Kebebew and Urgessa, 2011). The development of homesteads and farm forestry areas would be an easily implementable intervention in the immediate future. Better agroforestry management is key to building resilience among dry land rural communities.
3. ***Livestock management and grass production improvement***: In both villages, only a small percentage of ownership of cattle/sheep/goats was observed due to scarcity of fodder and grazing land. Thus attempts should be made to enhance diversity and ownership of livestock along with programmes to improve access to fodder and grass in the study villages as well as other villages in the region.
4. ***Access to knowledge on weather trends and projections:*** Based on available metrological information it is necessary to provide regular knowledge on short-term (daily and weekly) and long-term (monthly and seasonal) weather to inform farmers and enable them for planned adaptation to climate vulnerabilities, particularly in semi-arid regions.
5. ***Improved access to institutions, crop insurance and finance:*** Investments to reduce their vulnerability, for example in agroforestry were made by only a few. Furthermore, crop insurance was found to be minimal. Although there is a desire to invest in such measures, small and marginal farmers do not have the capital to do so and thus there is a need to provide institutional and financial support to help them in their endeavours to adapt to current climate risks as well as future climate change. Further, there is a need to enhance knowledge, implementation and accessibility to existing government programmes to support farmers as evidenced by the under-utilisation of programmes such as MGNREGA in the study villages.
6. ***Active co-ordination between agencies:*** There is a need for government, non-government agencies, private sector partners and farmers to work jointly together to enhance implementation of existing programmes, which support sustainability for farmers. The opportunities available for effective implementation of these programmes, which have the potential to enhance climate resilience, depends on the introduction of new technologies and support from agencies that have the potential to get involved in the region and enable improvements in the performance of existing local institutions.
7. ***Enhance opportunities for young people in the region:*** The development of planned adaptation strategies to enhance sustainable life in these rural areas is crucial to enable and enhance opportunities for young people growing up and wishing to continue to live and work in these regions (Kattumuri, 2013).

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