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Quantification of Risk Associated with Technology Adoption in Dryland Systems of South Asia

A Household Level Analysis in Andhra Pradesh, Karnataka and Rajasthan States of India

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INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IWMI
International Water Management Institute

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Executive Summary

Climate change increasingly becomes a challenge for smallholder farmers. Strategies that will help farmers to cope with vulnerability are important. These strategies comprise a variety of interventions ranging from technical, institutional to policy. This study is an in-depth analysis of household level climate change shocks, farmers' perception of vulnerability, adaptation strategies they followed and risk in technology adoption. A baseline survey was conducted in the dryland system action sites in three states of India: Andhra Pradesh (Kurnool and Anantapur districts); Karnataka (Bijapur district) and Rajasthan (Jaisalmer, Barmer and Jodhpur districts) in 2012-13 for 2011-12 production season. A total of 1019 farmers were surveyed.

Socioeconomic profile

In Andhra Pradesh, out of 513 farmers surveyed, 28 (5.45%) farmers were landless and relied only on livestock related income even though off-farm activities were also observed in few cases. The average net income of the study farm households was ₹ 19,676 ha^{-1} (US$ 328 ha^{-1}). The average farm size was 2.3 ha, family size was 4.4 members and 96% of the household heads were males. About 31% of the farmers had encountered drought, hailstorm and irregular weather, while 21% had encountered drought alone. On an average, they invested ₹ 24,765 (US$ 413) on buying farm machinery and spent ₹ 15,582 (US$ 260) on other infrastructure including digging wells and ponds.

In Karnataka, out of 250 farmers surveyed, 9 (3.6%) farmers were landless and they mainly depended on livestock for their livelihood. The average net income was ₹ 70,538 ha^{-1} (US$ 1175 ha^{-1}). The average farm holding size was 3.8 ha. Average family size was 5.6 members and 93% of the household heads were males. About 34% of the farmers encountered shocks, drought, hailstorm and irregular weather while 17% had encountered drought, animal disease, untimely rain and irregular weather alone. Further, 15% of the farmers encountered drought and untimely rain alone. The average investment in farm machinery was ₹ 14,000 (US$ 233) while an average of ₹ 100,893 (US$ 1681) was spent on other farm infrastructure, e.g., digging wells, farm ponds, etc.

In Rajasthan, the average net income was ₹ 38,713 ha^{-1} (US$ 645 ha^{-1}). Average farm and family size were 3.03 ha and 5.7 persons respectively and 90% of the household heads were males. About 24% of the farmers encountered all the shocks except flood. Unlike farms in Karnataka and Andhra Pradesh almost 99.6% of the farmers owned livestock indicating the importance of livestock in their farm income. The average investment in farm machinery was ₹ 47,500 (US$ 791) and they spent about ₹ 48,257 (US$ 804) towards farm infrastructure: digging wells, fitting electric motors, construction of farm ponds, etc. Thus in all the regions, the household income is comparatively low in Andhra Pradesh due to lesser income from dryland crops and from other sources indicating the need to enhance the household income through the adoption of several adaptation strategies.

Farm technologies adopted

Farmers in the study regions adopted several strategies such as possessing livestock, small farm mechanization, supplemental irrigation, change in cropping pattern (including late planting) and developing skills for adoption of new technology. Focus group discussions with the farmers indicated that farmers were facing problems in the adoption of small farm mechanization and providing supplemental irrigation is less due to their high capital cost and less frequency of their use in crop production. As farmers did not face any challenge in adopting livestock and change in cropping pattern, only small farm mechanization and supplemental irrigation strategies which face challenges in the adoption were considered in the analysis of risk associated with the technology adoption.

Quantification of risk and determinants of technology adoption

The flexible moment-based approach for the estimation of the stochastic production function allowed for estimation of relative risk premium that each sample farmer will be willing to pay while adopting the technologies in order to avoid the crop production risk.

For Andhra Pradesh, the average relative risk premium was about 22% for supplemental irrigation and 23% for farm mechanization. This means, given the average profit of ₹ 20,385 ha^{-1} (US$ 340 ha^{-1}) under farm mechanization, the farmers will be willing to pay ₹ 4,689 ha^{-1} (US$ 78 ha^{-1}) for adoption of farm mechanization. For supplemental irrigation with a profit of ₹ 41,249 ha^{-1} (US$ 687 ha^{-1}), the relative risk premium which the farmers could pay will be ₹ 6,600 ha^{-1} (US$ 110 ha^{-1}). Relative risk premium had a significant positive contribution to adaptation of small farm mechanization particularly in soil and moisture conservation practices. Other significant variables that influenced more adoption of the technologies were climatic shocks drought, untimely rain and irregular weather encountered, investment in farm machineries and farm ponds and location of the farm (access to infrastructure facilities). For supplemental irrigation, in addition to relative risk premium, farm size, household gender (male), education, married life (years), investment in farm infrastructure and location of the farm close to cities were important determinants of adoption of supplemental irrigation technology.

For Karnataka, the average relative risk premium was 6% for supplemental irrigation and 9% for farm mechanization. This means, given the average profit of ₹ 79,003 ha^{-1} (US$ 1317 ha^{-1}) under farm mechanization, the farmers could pay ₹ 7,110 ha^{-1} (US$ 118 ha^{-1}) for farm mechanization. For supplemental irrigation, the relative risk premium which the farmers could pay will be ₹ 6,037 ha^{-1} (US$ 100 ha^{-1}). Relative risk premium has a significant positive contribution to adaptation of farm mechanization. Other significant variables were farm size, household size, distance to output market, household head's health status, experience in farming, climatic shocks drought and untimely rain and using improved crop production practices. Expected profit, livestock ownership and relative risk premium had positive significant marginal effects on the probability of adoption of supplemental irrigation technology by farmers in Karnataka.

In Rajasthan, the average relative risk premium for supplemental irrigation and farm mechanization were comparable with Karnataka mentioned earlier. This means, given the average profit of ₹ 57,356 ha^{-1} (US$ 956 ha^{-1}) under farm mechanization, the farmers will be willing to pay ₹ 9,177 ha^{-1} (US$ 153 ha^{-1}) in the process of implementing the farm mechanization. In the case of supplemental irrigation, the relative risk premium which the farmers could pay will be ₹ 2,906 ha^{-1} (US$ 48 ha^{-1}). Expected profit, and maintaining poultry were the key determinants of adoption of supplemental irrigation technology by Rajasthan farmers.

In all the cases, it was observed that the risk premium was higher for farm mechanization compared to supplemental irrigation except in Andhra Pradesh (₹ 6,600 ha^{-1}) (US$ 110 ha^{-1}). The higher risk premium might be due to the high investment needed to build infrastructure required for mechanization and supplemental irrigation in the regions.

Average farm level investment was ₹ 15,582, ₹ 100,893 and ₹ 48,257 (US$ 260, 1,681 and 804) respectively in Andhra Pradesh, Karnataka and Rajasthan states. The ratio of risk premium to the profit margin for farm mechanization was about 1.12, 0.59 and 0.26 for Andhra Pradesh, Karnataka and Rajasthan respectively. For supplemental irrigation, the ratios were estimated at 0.27, 0.16 and 0.08 respectively. This generally suggests that investment in technology adoption is sound, except in the case of farm mechanization in Andhra Pradesh, where we found a higher risk premium than the profit margin.

Policy suggestions

Given the scarcity of water, households felt the importance of supplemental irrigation to minimize the crop losses and hence were willing to invest in infrastructure such as farm ponds, sprinkler irrigation and similarly for farm mechanization mainly due to increasing scarcity of farm labor.

The present study showed that risk preferences of the households influenced the probability of technology adoption in dryland systems. Higher the level of adoption of the technologies, higher will be the risk premium the households should pay. Even with risk premium accounted for by the households with technology adoption, their net income is still higher than the households without technology adoption. The results had more inferences for policy making and for promoting the adoption of the new technologies. The following key policy measures are suggested:

- Account for or quantify the risk associated with each technology identified for adoption by the farmers and the list of technologies and their relative risk premium should be discussed with the implementing partners.
- Enhance the rate of adoption; create more awareness about the technologies through appropriate and affordable training programs. Expected benefits that the households could derive from the reduction in their production risk due to technology adoption (cost and benefits of adaptation technologies) should be worked out and included in the technology promotion programs.
- Comparison of the risk premium for technology adoption with the premium for the weather-based insurance products (for different crops) can help to analyze the link between the two as technology adoption may help in reducing the risk associated with crop yield.
- Examine the possibilities for converging the government or private sector programs that address the same issues; for example, most of the farmers are facing the risk of rainfall variability and investment in farm ponds for providing supplemental irrigation is needed. As many government departments are already concentrating their programs on these areas, convergence of different government programs that facilitate construction of farm ponds and other water harvesting structures will minimize the transaction cost of farmers as well as government departments. Piloting some of the technology options in selected locations will be helpful in scaling out and scaling up the technologies.

1. Introduction

1.1. Problem setting

Agriculture in general is very much affected by climate change. Climate change projections for India up to 2100 indicate that there will be an overall increase of 2-4°C temperature with no substantial change in precipitation (Kavikumar 2010). Climate change affects not only mean yield of the crops but also induces variability in yield (Palanisami et al. 2014). These research findings strengthen the hypothesis that rainfed farming will be severely affected by climate change. Though rainfed crops can tolerate high temperatures, crops grown in these regions during post rainy (*rabi*) season are vulnerable to changes in minimum temperature (Venkateswarlu and Rama Rao 2010). This has also strong implication for livestock feed quality and quantity and thus to their productivity as crop residues generally constitute major feed components in South Asia.

Strategies that can help farmers to cope with these uncertainties and vulnerability will, therefore, be important to be in place. These strategies can involve variety of interventions ranging from technical, institutional to policy. In this context, a household level vulnerability analysis could provide a basis on which interventions can be identified and targeted to respective households. More generally vulnerability analysis will be a key component of the theory of change as it provides a basis on which interventions can be targeted and assessed on households and communities in the context of overall livelihood strategies and the biophysical characteristics of the production system.

The CGIAR-Consortium Research Program (CRP) on Dryland Production Systems focuses on dryland agricultural and livelihood systems at action sites and more generally in dryland production systems that comprise a mosaic of households and communities with varying degrees of vulnerability and risk, and capacity to increase production and improve livelihoods. The extent to which households or communities are able to manage vulnerability and risk, and exploit opportunities offered by favorable environments or institutional innovations, is a measure of their resilience. All households, whether rich or poor, or in high or low potential agroecological zones, have to cope with risk. Indeed, households and communities will move between different vulnerability levels temporally and in any landscape there will be spatial variability and this study contributes towards better explanation of these arguments (Palanisami et al. 2014). Hence, it is important to see how the household livelihoods could be enhanced through increased agricultural production.

Agricultural production can be increased by either expanding crop area or increasing crop productivity or both. Unlike intensification option, which has already reached threshold point, productivity increase by technology use is seemingly possible due to the availability of different crop production technologies. However, the current level of technology adoption is comparatively low and pushing the technology uptake will be a major task ahead as it involves interaction of both farm and policy level interfaces. This might be due to: technology may be costly or not suitable to the situation or risk involved. As we are dealing with adaptation of only selected technologies, identifying risks and determinants of technology adoption will contribute to productivity enhancement efforts.

This study makes an in-depth analysis of household level climate change shocks, farmers' perception of vulnerability, adaptation strategies they followed and risk they face in technology adoption. It is based on data collected from a baseline survey conducted in the dryland system action sites in three states of India: Andhra Pradesh (Kurnool and Anantapur districts), Karnataka (Bijapur district) and Rajasthan (Jaisalmer, Barmer and Jodhpur districts) in 2012-13 for 2011-12 production season. A total of 1019 farmers were surveyed.

1.2. Objectives

The main objective is to examine the factors and risk associated with technology adoption. More specifically, the study focuses on:

- Identification of various crop and water management technologies in the selected regions.
- Quantification of risk in technology adoption by the households by developing a theoretical framework that conceptualizes the technology adoption process by the households.
- Assessment of important social, economic and institutional factors that either enhance or deter adoption.

This research will also focus on decision-making processes at the household and community levels. The following hypotheses will be tested in the course of the research study:

- The higher the level of risk premium associated with the technology, the higher will be the rate of adoption of the technology.
- Risk premium will be higher with the technologies that have higher investment.
- Household level diversity in livelihood endowments (asset) and socioeconomic characteristics determine the level of risk associated with technology adoption.

2. Methods

2.1. Description of study regions

A long list of target regions in South Asia was discussed and proposed during the dryland system workshop in Dubai in 2012[1]. Using the criteria such as aridity index, length of growing period (<90 days, <180 days), land use (rainfed + forest/rangeland) and resource degradation (water and wind erosion), three regions, viz., Andhra Pradesh, Karnataka and Rajasthan were selected and grouped under the Strategic Research Themes (SRT2 and SRT3) where SRT2 aims at reducing vulnerability, and SRT3 aims at sustainable intensification. Among the selected regions, SRT2 is represented by Rajasthan, while SRT2 and SRT3 are represented both by Karnataka and Andhra Pradesh. Accordingly the Intermediate Development Outcomes (IDOs) are framed to address the livelihood vulnerability and sustainable intensification respectively[2]. The selected regions are shown in Figure 1.

In terms of production systems, SRT2 type environments purposely include low rainfall rangelands where pastoral and agro-pastoral systems predominate. Elsewhere in India, SRT3 type environments are dominant, except for a large SRT2 area in peninsular India centered in parts of Maharashtra, Andhra Pradesh and Karnataka. In all SRT2 and SRT3 type environments in India outside of western Rajasthan, mixed crop–livestock systems predominate. In these mixed systems a major determinant of agricultural systems is soil type, with two major tropical soil types; red soil (Alfisols, Acrisols and Entisols) and black clayey soil (Vertisols) based systems. Red soils make up 60-65% of the cropping belt in South India followed by black soils, where Anantapur and Kurnool districts of Andhra Pradesh represent the red soil areas and Bijapur the black soil areas (Table 1).

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1. CRP1.1 Dryland Systems Framework Development Workshop on Integrated Agricultural Systems for Food Security and Improved Livelihoods in Dry Areas (Dryland Systems), 30 January–1 February 2012, Dubai.

2. The Intermediate Development Outcome (IDO) 1 refers to the more resilient livelihoods for vulnerable households in marginal areas whereas IDO 2 refers to the more sustainable and higher income per capita for intensifiable households.

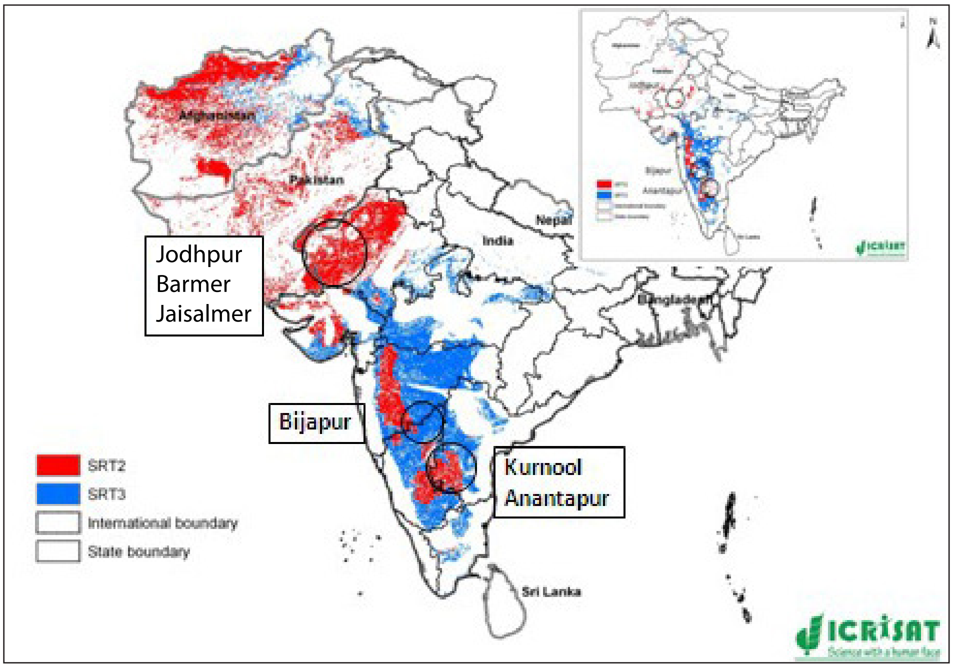

Figure 1. Location of action sites in India.

Table 1. Action sites and the production systems in India.

Action site	Subdistrict (Mandal, Tehsil, Taluk, Block)	SRT[3]	System
Jodhpur, Barmer and Jaisalmer (Rajasthan)	Osian, Chohtan, Jaisalmer	2	Rangeland, agro-pastoral
Bijapur (Karnataka)	Bijapur	3	Mixed crop–livestock, black soils
Anantapur and Kurnool (Andhra Pradesh)	Kalyandurg, Dhone	2, 3	Mixed crop–livestock, red (and black) soils

3. SRT = Strategic Research Theme; SRT2 (Reducing vulnerability): Threats to and vulnerability of dryland agricultural production systems can be reduced with a better systems integration and diversification; SRT3 (Sustainable intensification): It is possible to maintain/increase productivity whilst making dryland systems more resilient/sustainable.

2.2. Technology adoption and risk – an overview

There are a number of works on production risk and farm technology adoption. Stochastic production models are used to estimate the effect of input choice on risk. For example, Just and Pope (1978) provided a general stochastic specification of the production function. This model includes two general functions, one for the mean output and the other for the variance in production. The two functions can be used to study the effects of inputs/technologies on the mean and variance in production. This model allows inputs/technologies to be either risk increasing or risk decreasing. If the marginal contribution of an input to variance is positive, then the input is risk increasing; otherwise it is risk decreasing. Though Just and Pope's model is a good generalization of stochastic specification models, it does not restrict the effects of inputs on the variance to be related to the mean. To alleviate this difficulty, Antle (1983, 1987) proposed moment-based approach. He has shown that the mean input restricts the effects of inputs across the second and higher moments. His moment-based approach allows more flexible representation of input distribution and the identification of risk parameters.

Many authors have used Antle's approach to quantify risk in production. Espinoza (2012) studied the potato production risk and irrigation technology adoption among farmers in Chile. The results indicated that education level, proportion of land under secure tenure arrangements, credit access and knowledge from extension activities are determinants of irrigation technology adoption. Yesuf and Bluffstone (2009) used Antle's moment-based approach to investigate impact of use of chemical fertilizer and adoption of soil and water conservation technology on production risks. They found that fertilizer use reduces yield variability, but increases the risk of crop failure and adoption of soil and water conservation technology has no impact on yield variability, but reduces the downside risk of crop failure. Maurice et al. (2010) explored the production risk and farm technology adoption in rainfed, semi-arid lands of Kenya. Their study showed that yield variability and the risk of crop failures affect technology adoption decisions. Kassie et al. (2008) examined the role of production risk in sustainable land management technology adoption in Ethiopia. The study identified that impact of production risk varied by technology type. Production risks which were measured by the second and third moments had significant impact on fertilizer adoption and extent of adoption. Koundouri et al. (2003) derived the conditions under which a risk-averse farmer with incomplete information adopted an efficient irrigation technology to hedge again production technology. They found that the higher the expected profit, the greater the probability of adopting a new irrigation technology. Similarly, greater the variance of profit, greater will be the probability to adopt new irrigation technologies to save water and reduce production risk. Shajari and Bakhshoodeh (2006) studied the link between new seed varieties and wheat production risk in Iran using a moment-based approach and showed that use of new seed varieties is risk-increasing with higher cost of risk. They concluded that the more the farmer is risk averse, the less likely he will adopt new seed varieties to decrease the production risk.

2.3. Framework to quantify risk in technology adoption

Even though several approaches are available to address the technology adoption and risk assessment, this paper follows the flexible moment-based method outlined by Antle (1983, 1987). The methodology has two stages and has been followed by many authors (for example, Shajari and Bakhshoodeh 2006, Groom et al. 2008, Espinoza 2012). The advantage of this method is that it takes into account both variability and skewness in the yield. Brief description of these methods is given below:

Let us assume that farmers in a region grow a single crop (with output denoted by q), say groundnut using many inputs, $X = (x_1, x_2 \ldots x_n)$. Also assume that the farmers are risk averse. The output production function is given by $f(X;S;\beta)$ where *S* is a vector of extra shifters including farmer specific characteristics (such as age, experience, household size engaged in farming, etc.) and farm specific characteristics (such as plot size, technology followed, etc.) and β is a vector of parameters to be estimated assumed to satisfy the regularity conditions: continuous with respect to all variables and twice differentiable. The output unit price is denoted by p and the input prices are given by the vector $r = (r_1, r_2, \ldots r_n)$. We assume that the prices of output and inputs are deterministic while the output q is a random variable depending on factors over which the farmer has no control. This risk in the crop output, denoted by ε is assumed to have a distribution denoted by $G(.)$. Also the function f is assumed to be continuous and twice differentiable.

Farmers in rainfed areas face uncertainty over the availability of inputs like timely labor and supplemental irrigation. They depend on machine labor and supplemental irrigation sources whose supplies are uncertain. Hence, the output is also uncertain. The profit function of the farmer is given by:

$$\Pi = pf(X;S;\beta) - r'X \tag{1}$$

Since the output is a random variable, equation (1) implies that the profit, Π is also a random variable and we assume that its expected value is finite. If farmer is risk neutral, then his/her objective will be to maximize the expected profit. He/she will be indifferent to the variance, that is risk, in profit. But if the farmer is risk averse, which we assume, he/she would want to maximize the expected utility of profit. So the farmer's problem can be stated mathematically as:

$$\max_X E(U(\Pi)) = \max_X \int E\left(U\left(pf - r'X\right)\right) dG(\varepsilon) \tag{2}$$

where $U(.)$ is the Von Neuman-Morgenstern utility function that represents the risk preferences of the farmer, who will prefer to maximize $E(U(\Pi))$ with respect to the input, X_w supplemental water. The first order condition for optimal use of input, say supplemental irrigation water, X_w, is given by:

$$E\left[r_w U'\right] = E\left[p\frac{\partial f}{\partial x_w} \times U'\right] \Rightarrow \frac{r_w}{p} = E\left[\frac{\partial f}{\partial x_w}\right] + \operatorname{cov}\left[\frac{U', \partial f/\partial x_w}{E(U')}\right] \tag{3}$$

where $U' = \partial U(\Pi)/\partial \Pi$, derivative of utility with respect to income. For risk neutral farmers, who will maximize the expected profit, the ratio of input price over output price, that is, (r_w/p) will be equal to expected marginal contribution of input x_w to profit function $f(X;S;\beta)$ and so for the second term in the right hand side of equation 3 will be zero and for risk- averse farmers it will be nonzero.

In principle, we can solve equation 3 to obtain the optimum level of X_w. The optimal solution would depend on prices of supplemental irrigation, inputs, output and on the shape of functions $U(.)$, $f(.)$, and $G(.)$ which are usually unknown. Hence, this problem is empirically difficult. In addition to the choice of technology specification, the distribution of ε needs to be known and the farmer's preferences need to be specified. For this reason, Antle (1983, 1987) proposed a flexible estimation approach that has the advantage of requiring only cross-sectional information on prices and input quantities. The important feature of this approach is that the solution to the producer problem can be written as a function of input levels alone. According to this approach and without loss of generality, maximizing the expected utility of profit with respect to any input is equivalent to maximizing a function of moments of the distribution of ε, those moments having themselves the input vector X as an argument. This is given by:

$$\max_X E(U(\Pi)) = \max_X F[\mu_1(X), \mu_2(X), \ldots \mu_m(X)] \tag{4}$$

where μ_j is the j^{th} moment of the farm profit and $F(.)$ is the cumulative distribution function completely unspecified. Using the first order condition, it can be shown that the marginal impact of k^{th} input on the first moment is given by:

$$\frac{\partial \mu_1(X)}{\partial x_k} = (-1/2!)\left(\frac{\partial \mu_2(X)}{\partial x_k}\right) \times \alpha_{2k} + (-1/3!)\left(\frac{\partial \mu_3(X)}{\partial x_k}\right) \times \alpha_{3k} + ... + (-1/m!)\left(\frac{\partial \mu_m(X)}{\partial x_k}\right) \times \alpha_{mk} \tag{5}$$

where

$$\alpha_{jk} = \frac{\partial F(X)/\partial \mu_j(X)}{\partial F(X)/\partial \mu_1(X)}, j = 2,3,...m \tag{6}$$

represents the "weight" attributed by the farmer to the j^{th} moment of the profit distribution. The analysis is done technology by technology because each technology contributes in a different manner to the moments of the profit distribution. So for each technology, the following model will be estimated:

$$\frac{\partial \mu_1(X)}{\partial x_k} = \theta_{1k} + \theta_{2k}\frac{\partial \mu_2(X)}{\partial x_k} + \theta_{3w}\frac{\partial \mu_3(X)}{\partial x_k} + ...\theta_{mk}\frac{\partial \mu_m}{\partial x_k} + u, k = 1,2,...n \tag{7}$$

where

$$\theta_{jk} = -\alpha_{jk}(1/j!), j = 2,3,...m \tag{8}$$

Model 7 has two important features. The first is that it shows that the marginal contribution of an input (technology) to the first moment is a linear function of marginal contribution of the input to second, i.e., variance: $\frac{\partial \mu_2(X)}{\partial x_k}$, third, i.e., skewness: $\frac{\partial \mu_3(X)}{\partial x_k}$ and other higher moments. A negative sign on the marginal contribution of an input (that is, the variance) to second moment indicates that the input is risk reducing while positive sign indicates risk increasing. Similarly, a negative sign on the marginal contribution of an input to the third moment implies that the input is downside risk increasing function and positive sign means that the input is downside risk decreasing. We usually take up to third moment, that is, $m = 3$, because the second moment represents variance, that is, risk and third moment represents skewness and usually higher moments have less influence on the profit. The Arrow-Pratt absolute risk aversion coefficient is defined by:

$$AP = -\frac{E(U''(\pi))}{E(U'(\pi))} \approx -\frac{\partial F(X)/\partial \mu_2(X)}{\partial F(X)/\partial \mu_1(X)} \tag{9}$$

Using equations 6 and 8 in 9, we see that $AP_k = 2\theta_{2k}$. Similarly the downside risk aversion measure is:

$$DS = -\frac{E\left(U'''(\pi)\right)}{E\left(U'(\pi)\right)} \approx -\frac{\partial F(X)/\partial \mu_3(X)}{\partial F(X)/\partial \mu_1(X)} \tag{10}$$

So using equations 6 and 8 in 10, we get $DS_k = -6\theta_{3k}$. Thus the parameters θ_{2k} and θ_{3k} can be directly interpreted as Arrow-Pratt and downside risk coefficients respectively. They can be interpreted as marginal contribution of each moment to risk premium (Groom et al. 2008), which is defined as the difference between a guaranteed or certain income and a risky income that generate the same level of utility. Risk premium is the amount of income that a risk-averse farmer is willing to pay to avoid the risk associated with technology adoption. Assuming that the farmer is concerned with the first three moments of profit distribution only, the risk premium is given by:

$$RP_k = \mu_2 \frac{AP_k}{2} - \mu_3 \frac{DS_k}{6} \tag{11}$$

where μ_2 and μ_3 are the measures for second and third moments of the profit for individual farmer. A positive value for Arrow-Pratt coefficient means that the farmer is risk averse. This means that they are willing to forego a proportion of their expected profit in order to avoid the risk associated with the adopted technology. Similarly, a positive value for downside risk means that the farmer is averse to downside risk. This means that they are risk averse to a negatively skewed profit distribution. A positive value for risk premium, that is, >0 means that the farmer has positive willingness to pay to be insured against risk. The constant term θ_{1k} should be nonsignificant. If it is positive and significant, it implies that the particular input is overused and if negative and significant, it implies that the particular input is underused. The framework of the analysis is given in Figure 2.

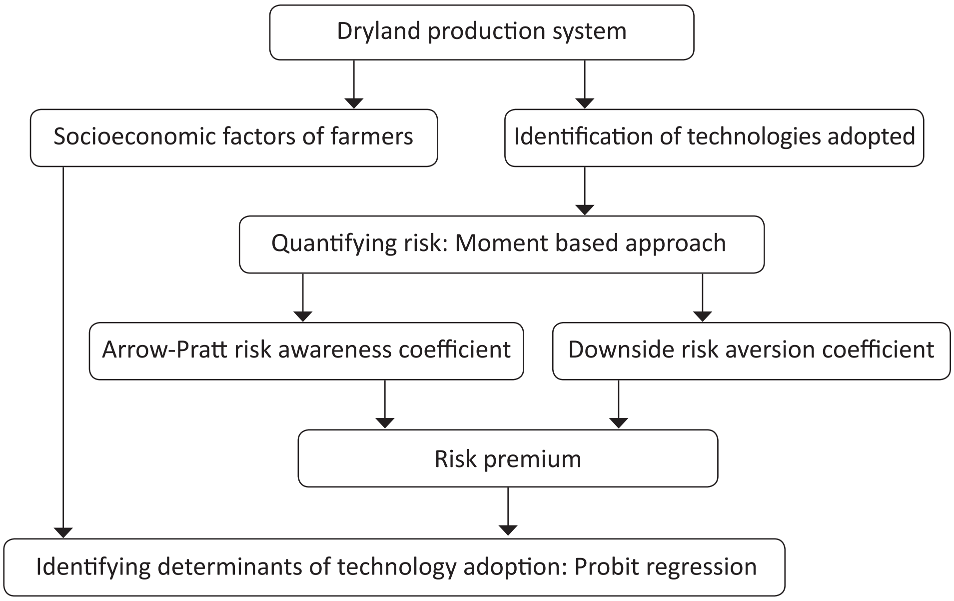

Figure 2. Flowchart showing the links between the technology adoption and the risk premium calculations.

2.4. Empirical model

2.4.1. First stage

Empirically the first three moments of the profit and the risk aversion coefficients and the risk premium are computed as follows:

Total observed profit per hectare is regressed on all levels, squared and cross-products of all inputs; that is, we choose linear quadratic form because it is a good second order approximation of the profit function (Kumbhakar and Tveterås 2003). The residuals of the fitted regression are then used to compute conditional higher moments (variance and skewness) and are regressed at all levels, squared and cross-products of inputs. This approach has been used in many studies (Antle 1983, Kim and Chavas 2003, Koundouri et al. 2003). Mathematical expressions for derivatives of these moments with respect to each input are then computed. Finally, using these derivatives for individual farmers, the above stated equation 7 was estimated through two-stage least squares regression analysis. The instrumental variables used for this purpose are: (i) distance of the farm from the market for the outputs disposal; (ii) investment in farm machineries; (iii) investment in new infrastructure; and (iv) awareness of technologies (dummy variable). After estimating equation 7, Arrow-Pratt risk aversion coefficient and downside risk coefficient are computed and they are substituted in equation 11 to estimate the risk premiums. Then the relative risk premium is computed by dividing the risk premium by the expected profit.

2.4.2. Second stage

In order to identify the determinants of adoption of a technology by the farmers, the socioeconomic characteristics of the farmer along with the relative risk premium are then used in a probit regression model (with dependent variable being a binary variable taking the value 1 for those farmers who adopted a particular farming technology and 0 for those who have not adopted it).

2.5. Data and variables

The data for the present study were collected during 2013 from households in CGIAR-CRP dryland production and livelihood systems action sites in Anantapur and Kurnool districts of Andhra Pradesh, Bijapur district of Karnataka and Jodhpur, Jaisalmer and Balmer districts of Rajasthan. A total of 1019 farmers were surveyed (Table 2).

Table 2. Surveyed states and sample size.

State	Number of farmers
Andhra Pradesh (Anantapur and Kurnool districts)	513
Karnataka (Bijapur district)	250
Rajasthan (Jodhpur, Jaisalmer and Barmer districts)	256
Total	1019

The collected data set included household characteristics like age, education, experience in farming, profile of household members, training, etc., crops grown in each season (*rabi* and *kharif*), quantities and costs of inputs (like seed, fertilizer, labor, bullock and machine power, fuel and electricity), main and sub-product outputs, etc. Type of adaptation technologies followed by the farmers and the costs and benefits related to these technologies were also recorded. Since technology adoption and input use largely depend on locations, the analysis was done separately for Andhra Pradesh, Karnataka and Rajasthan action sites.

3. Results and Discussion

3.1. Socioeconomic profile of the households

The descriptive statistics of variables used in the study for the three locations are provided in Table 3. In Andhra Pradesh, of 513 farmers surveyed, 28 farmers are landless and dependent mainly on livestock even though some off-farm labor employment was also observed. Excluding these farmers, the study was confined to data related to 485 farmers. The average net income was ₹ 19,676 ha^{-1} with a standard deviation of ₹ 37,435 (with a coefficient of variation of 190%). This means that there is substantial variation in the farm income across the farmers in the region. The average farm size is 2.3 ha. The standard deviation is 2.5 ha and so there is wide variability in the cultivated area among the farmers. On an average, there are about 4.4 members in the farm family and 96% of the household heads are males. They walk about an average distance of 6.8 km to buy inputs as well as sell their agricultural outputs. Education of the farmer was measured in 7-point scale with a score of 1 for no formal education and a score of 7 for postgraduation. The farmers are not much educated as their average score for education is only 1.6. Further, the average age of the household is 48 years with a farming experience of about 25 years. About 97% of the households are married with married life spanning to about 28 years. The health status of the household is fairly good with an average score of 1.5 (it was measured in 6-point scale with 1 for good and 6 for bad). About 31% of the farmers have encountered drought, hailstorm and irregular weather, while 21% have encountered drought alone. About 54% of the farmers possess livestock. On an average, they invest ₹ 24,765 on buying farm machinery and spent ₹ 15,582 on other infrastructure. About 87% of the farmers borrow money from their friends and relatives for farming and 37% rely on government assistance.

Table 3. Descriptive statistics of variables used in farm technology adoption modelling.

	Andhra Pradesh		Karnataka		Rajasthan		
Dependent variable	Mean	SD	Mean	SD	Mean	SD	Description
Profit (₹ ha^{-1})	19,676	37,435	70,538	68,398	38,713	50,403	Continuous
Explanatory variables							
Farm size (ha)	2.34	2.51	3.80	4.85	3.03	3.11	Continuous
Household size (no.)	4.39	2.01	5.58	2.63	5.71	2.48	Continuous
Distance to market (km)	6.80	31.64	31.98	16.32	14.05	9.29	Continuous
Household gender	0.95	0.19	0.93	0.24	0.90	0.29	Dummy variable = 1 for male and 0 for female
Household education	1.56	1.01	1.71	1.09	1.44	0.71	Discrete with 7 point scale; 1 for no formal education and 7 for postgraduation
Household age (years)	47.99	13.56	51.86	12.97	51.77	13.05	Continuous
Household marital status (no.)	0.97	0.16	0.96	0.19	0.86	0.34	Dummy variable = 1 if married and 0 otherwise

continued

Table 3. continued

	Andhra Pradesh		Karnataka		Rajasthan		
Dependent variable	Mean	SD	Mean	SD	Mean	SD	Description
Household married life (years)	27.63	14.64	29.78	13.85	31.42	15.48	Continuous
Male earning members	1.87	1.11	1.57	0.70	1.78	1.12	Continuous
Household health status	1.52	0.95	1.41	0.66	1.76	1.25	Discrete with 6 point scale; 1 for good (can perform agricultural activities) and 6 for bad
Farming experience (years)	24.74	12.23	22.54	11.85	33.56	14.45	Continuous
Investment in farm machinery (₹)	24,765	18,421	14,004	24,551	47,517	138,323	Continuous
Investment in infrastructure (₹)	15,582	42,103	100,893	63,651	48,257	160,547	Continuous
No. of visits of farmers to extension officials	2.19	1.16	2.26	0.58	-[1]	-	Discrete
No. of visits of extension officials to farmers	2.52	1.34	0.84	0.73	-[2]	-	Discrete

1. In Rajasthan 219 farmers did not visit any extension official.
2. In Rajasthan extension officials did not visit 226 farmers.

In Karnataka, out of 250 farmers surveyed, 9 farmers were landless and they depend on livestock for their livelihood. The average net income per ha was ₹ 70,538 with a standard deviation of ₹ 68,398 (CV 97%). The net income was very much higher than that of Andhra Pradesh farmers. The average farm holding size is 3.8 ha with a standard deviation of 4.85 ha which again shows that, as in the case of Andhra Pradesh, there is much variation in farm holdings. On average there are about 5.6 members in the farm family and 93% of the household heads are males. They walk about an average distance of 32 km to buy inputs as well as sell their agricultural outputs. The farmers are not much educated as their average score for education is only 1.7. Further the average age of the household is 52 years with a farming experience of about 23 years, which is slightly higher than Andhra Pradesh households. About 96% of the households are married with married life spanning about 30 years. The health status of the household is fairly good with an average score of 1.4. About 34% of the farmers have encountered shocks drought, hailstorm and irregular weather while 17% have encountered drought, animal disease, untimely rain and irregular weather alone or drought alone. Further, 15% of the farmers have encountered drought and untimely rain alone. Also about 40% of the farmers possess livestock: a figure which is lower than Andhra Pradesh sites by 14%. The average investment in farm machinery was ₹ 14,000 while an average of ₹ 100,893 was spent by them on other farm infrastructure like digging wells, farm ponds, etc. About 82% of the farmers had undergone capacity-building training which have good technology awareness, 59% of them go for change in cropping pattern and 44% go for change in planting date. Improved crop production practices are followed by 25% of the farmers while 19% of the farmers have provided supplemental irrigation. As in the case of Andhra Pradesh farmers, 87% of the farmers borrow money for farming operations and 77% relied on government assistance for loans and subsidies.

In Rajasthan, the results indicated that on average, farmers earned ₹ 38,713 ha^{-1} as net farm revenue. The standard deviation is ₹ 50,403 and so there is wide variation in net revenue across sampled farmers (CV 130%). Each farmer holds on an average 3.03 ha of land and the standard deviation is 3.1 ha. Thus there is more than 100% variation in land holdings. The average household size is about 5.7 persons and 90% of the household heads are males. The average walking distance to market to buy inputs and sell their agricultural output is about 14 km. The average household education score is only 1.44 which indicates the poor educational status of the farmers. The average age of the farmers is about 52 years and their farming experience is about 33.5 years. About 86% of the households are married with married life spanning about 31 years. Also the number of members of both sex are almost equal in households with 1.9 males and 1.7 females. The health status of the household is fairly good with an average score of 1.8. About 24% of the farmers have encountered all the shocks except flood. Almost 99.6% of the farmers own livestock, indicating the importance of livestock in their farm income. This is the highest percentage as compared to other two states. Farm mechanization is practiced by about 40% of the farmers. Selling livestock for farming and livelihood is highest (with about 50% of the farmers doing it). This is what is unique about western Rajasthan farmers. Similarly, borrowing money from friends and relatives and depending on government for assistance are common practices as reported by 75% and 46% of the farmers respectively. The average investment in farm machinery was ₹ 47,500 and they spent about ₹ 48,257 towards farm infrastructure (digging wells, fitting electric motors, construction of farm ponds, etc.). Shifting to nonfarm employment and leaving land fallow are done by about 66% and 58% of the households respectively.

3.2. Farm technologies adopted

Farmers in the study regions adopted several adaptation strategies such as possessing livestock, small farm mechanization, providing supplemental irrigation, change in crop pattern including planting dates and developing skills in technology adoption through training (Appendix 1). Focus group discussions with the farmers had indicated that they were facing problem in the adoption of small farm mechanization and providing supplemental irrigation due to their high cost as well as frequency of their use in crop production. In the case of possession of livestock and change in cropping pattern they did not face any challenges. Hence, in the analysis of technology adoption and risk, only small farm mechanization and supplemental irrigation strategies were included.

Among the different adaptation strategies, farm mechanization is commonly followed in all the three regions even though it is costly. Similarly, providing supplemental irrigation is another technology used by rainfed farmers of Andhra Pradesh and Karnataka. As these two technologies are mostly adopted in all the regions, it is assumed the constraints in the overall technology adoption will be captured when analyzing the adoption of these two technologies (Fig. 3).

Given the high income under the technology adoption, still adoption of these technologies is comparatively low and this may be due to inherent risk associated with the adoption of new practices that derives mainly from uncertainty on future income flows. Hence, it is important to see how the cost of this risk or uncertainty otherwise called premium varies across different technology adoption. Several studies dealing with rainfed agriculture also indicated that risk is

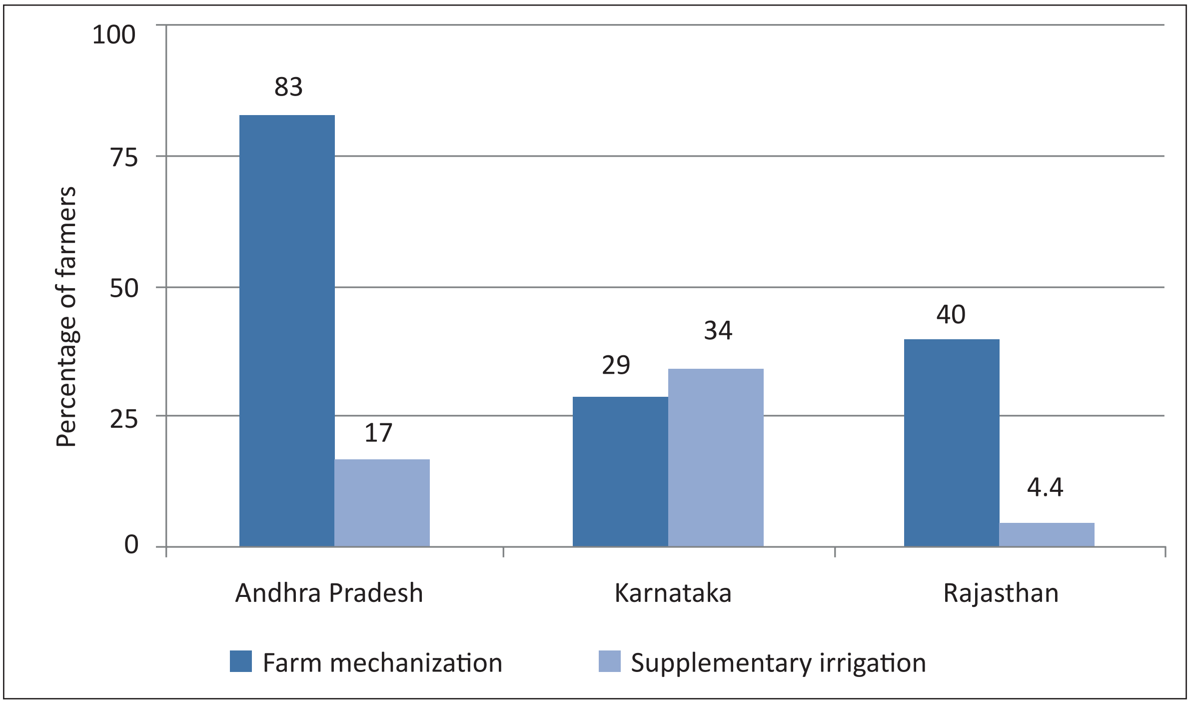

Figure 3. Prominent technologies/adaptation strategies followed by farmers in the study region.

an important determinant of technology adoption. For example, Maurice et al. (2010) identified that factors such as yield variability and risk of crop failure affect technology adoption decisions in the rainfed semi-arid lands of Kenya. As stated by Maurice et al. (2010), only economically secure farmers who have sufficient defence against downside risk will undertake profitable investments and innovations, while most of the poor remain caught, in a risk-induced poverty trap (Eswaran and Kotwal 1990, Rosenzweig and Binswanger 1993, Mosley and Verschoor 2005, Dercon and Christiaensen 2007, Yesuf and Bluffstone 2009).

3.3. Estimation of risk in technology adoption in Andhra Pradesh

3.3.1. Estimation of the moment functions

As stated in the methodology section, a quadratic form of functional relationship between net revenue per ha and the five inputs, viz., seed, fertilizer, labor, use of machine labor (small farm mechanization) and irrigation water (supplemental irrigation) was fitted. The moment functions were estimated as per the methodology stated in section 2. The estimated coefficients of the quadratic form of the first three moments are presented in Table 4. Many linear, quadratic and interaction coefficients of the three moments are strongly significant implying the suitability of the corresponding inputs in the model. The coefficients of fertilizer and supplemental irrigation were strongly significant for the first moment. Interaction of fertilizer with other inputs are also strongly significant. For the second moment of the profit function, except fertilizer all other inputs are strongly significant. A positive sign of the coefficients imply that they induce higher variance of profit. So seed, human and bullock labor and supplemental irrigation are risk increasing inputs because of the uncertainty inbuilt in the rainfed situations which influenced use of these inputs. The third moment represents skewness of the profit distribution and except supplemental irrigation all the other four variables have statistically significant coefficients implying that the profit distribution is skewed with respect to the respective inputs and adaption technologies.

Table 4. Estimates of parameters of three moments of profit function – Andhra Pradesh.

Variable[1]	First moment		Second moment		Third moment	
	Coefficient[2]	t-value	Coefficient[2]	t-value	Coefficient[2]	t-value
Constant	0.2788**	2.0792	-0.4496	-1.5259	-2.0756*	-1.7168
Seed	0.1393	1.4030	0.7023***	3.2192	3.4935***	3.9030
Fert	-0.3097***	-3.0295	-0.3001	-1.3359	-1.9205**	-2.0833
HBLB	0.0638	0.6854	0.5925***	2.8943	2.4376***	2.9023
MCLB	-0.1154	-1.3267	-0.3964**	-2.0743	-1.4561*	-1.8569
Water	0.5800***	4.0614	0.8671***	2.7624	2.0762	1.6122
Seed2	0.2587***	6.9485	0.1677**	2.0491	0.1939	0.5774
Seed*Fert	-0.1307***	-2.3637	-0.1225	-1.0076	-0.6524	-1.3082
Seed*HBLB	-0.0969***	-2.3758	-0.2855***	-3.1833	-1.2143***	-3.3005
Seed*MCLB	-0.0004	-0.0074	-0.0963	-0.9190	-0.1612	-0.3750
Seed*Water	-0.2173***	-4.1520	-0.0161	-0.1404	0.5427	1.1500
Fert2	0.0051	0.2234	0.0365	0.7327	0.3137	1.5333
Fert*HBLB	0.1354***	2.9392	0.0036	0.0358	0.1693	0.4076
Fert*MCLB	0.0829	1.5301	0.1298	1.0902	0.4886	0.9998
Fert*Water	0.0907**	2.2873	-0.0199	-0.2281	-0.3726	-1.0422
HBLB2	-0.0145	-0.7021	-0.1074***	-2.3707	-0.4444***	-2.3916
HBLB*MCLB	-0.0140	-0.4388	0.1461**	2.0856	0.4824*	1.6790
HBLB*Water	0.0624	1.4673	0.2473***	2.6465	1.1269***	2.9394
MCLB2	-0.0019	-0.1557	0.0167	0.6412	0.0298	0.2780
MCLB*Water	-0.0042	-0.0913	-0.2593***	-2.5428	-0.8951**	-2.1391
Water2	-0.0732***	-3.7183	-0.1302***	-3.0112	-0.4440***	-2.5020

1. Fert = Fertilizer; HBLB = Human and bullock labor; MCLB = Machine labor.
2. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

From the regression outputs, the risk parameters were estimated for the selected adaptation strategies, viz., small farm mechanization and supplemental irrigation. Estimated sample average risk parameters, viz., θ_1, θ_2 and θ_3 for each technology, the Arrow-Pratt and downside risk coefficients and relative risk premium for each technology are presented in Table 5. R^2 ranges from 0.1326 (machine labor) to 0.8118 (supplemental irrigation). The parameter θ_{2k} is associated with the variance of profit. It is positive and significant for farm mechanization and supplemental irrigation and consequently the corresponding Arrow-Pratt coefficients are positive and significant implying that farmers are risk averse with respect to the adoption of these technologies. This means that farmers are willing to forego a portion of their expected profit in order to avoid the risk associated with adoption of these technologies. Further, the downside risk coefficients for these technologies are negative and significant implying that they are downside risk averse with respect to these technologies, i.e., they are risk averse to a profit distribution that is skewed towards negative values. The flexible estimation of the stochastic production function also allows the estimation of relative risk premium that each farmer in the sample is willing to pay in order to avoid the risk associated with the technology adoption. The average relative risk premium ranges from 22% (supplemental irrigation water) to 23% (mechanization).

This means, given the average profit of ₹ 20,385 ha^{-1} under farm mechanization, the farmers are willing to pay ₹ 4,689 in the process of implementing farm mechanization. In the case of supplemental irrigation, which gives a profit of ₹ 41,249 ha^{-1} the relative risk premium which the farmers will be willing to pay will be ₹ 9,075 ha^{-1}. The relative risk premium is then used in the estimation of choice model in order to examine whether risk attitude of the farmers affect the decisions to adopt the new technologies.

Table 5. Estimation of risk aversion measures of various adaptation technologies – Andhra Pradesh.

	Farm mechanization		Supplemental irrigation	
Parameter	Coefficient[1]	SE	Coefficient[1]	SE
θ_{1k}	-0.0800***	0.0127	0.0647	0.0602
θ_{2k}	0.5543***	0.1357	1.5594***	0.1030
θ_{3k}	-0.1035	0.0319	-0.3225***	0.0378
R^2	0.1326		0.8118	
Arrow-Pratt	1.1086***	0.2714	3.1188***	0.2060
Downside risk	0.6208***	0.1914	1.9349***	0.2270
Relative risk Premium (%)	23	0	22	0

1. *** = Significant at 1% level.

3.3.2. Identifying determinants of technology adoption in Andhra Pradesh: farm mechanization

In this section, we investigate the determinants of adaptation of two technologies: (i) farm mechanization, and (ii) supplemental irrigation by rainfed farmers. The relative risk premiums of farm mechanization and supplemental irrigation water were used in the respective choice models to elucidate the determinants of risk attitude. For this purpose, separate Probit regression models were run for the two technologies. The results for farm mechanization are presented in Table 6. The first three moments of the profit function are included in the Probit models as independent variables. Table 6 reveals that the first moment of profit (mean) has a positive and significant effect on farm mechanization technology by farmers. Relative risk premium has a significant positive contribution to adoption. Other significant variables are climatic shocks, drought, untimely rain and irregular weather encountered, magnitude of investment in farm machineries and location of the farm (access to infrastructure facilities).

Table 6. Estimates of the Probit model for farm mechanization – Andhra Pradesh.

Variable	Coefficient[1]	SE
Constant	1.5104*	0.8053
First moment	0.1140**	0.0527
Second moment	1.0393	0.7471
Third moment	-0.1914	0.1842
Farm size (ha)	-0.0218	0.0379
Household size (no.)	-0.0432	0.0697
Distance to market for sales	0.0034	0.0046

continued

Table 6. continued

Variable	Coefficient[1]	SE
Gender (M/F)	-0.8469	0.6348
Education (1-7 scale)	0.1126	0.0965
Age (years)	0.0163	0.0142
Marital status (no.)	1.0046	0.6992
Married (years)	-0.0032	0.0122
Earning male members	0.0259	0.1101
Earning female members	0.0031	0.1130
Health status (1-6 scale)	0.0314	0.0836
Experience in farming (years)	-0.0131	0.0090
sc1 (Dummy variable = 1 if drought, hailstorm and irregular weather are encountered and 0 otherwise)	0.4069*	0.2236
sc2 (Dummy variable = 1 if drought alone encountered and 0 otherwise)	-0.9175*	0.5059
sc3 (Dummy variable = 1 if drought, untimely rain and irregular weather encountered and 0 otherwise)	0.4111	0.3946
sc4 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather encountered and 0 otherwise)	0.5807	0.5996
Livestock ownership	-0.0515	0.1869
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.3993	0.3039
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	-0.1598	0.2847
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	0.0035	0.2879
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	0.1699	0.3483
Cpsi (Dummy variable = 1 if supplemental irrigation is provided, 0 otherwise)	0.2243	0.2813
Cfsls (Dummy variable = 1 if sold livestock, 0 otherwise)	0.4188	0.2647
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.3595	0.2675
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	0.2993	0.2049
Investment in farm machinery	0.0005***	0.0002
Investment in infrastructure	0.0000	0.0000
No. of visits of farmers to extension officials	0.0062	0.0751
No. of visits of extension officials to farmers	0.0506	0.0867
Location (Dummy variable = 1 for Anantapur and 0 otherwise)	-2.8341***	0.4938
Relative risk premium	0.5145***	0.1830

1. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

Given the factors influencing adaptation of the technologies, it is important to see the actual influence by calculating the value of the derivatives at the mean values of all independent variables. These derivatives given in Table 7 represent the marginal effects of each regressor which approximates the change in the probability of adoption of the given technology for a unit change in the corresponding independent variables. The values of the derivatives were calculated at the mean values of all the independent variables. The coefficient for relative risk premium is strongly significant indicating that relative risk premium has a significant and positive effect on the adoption decision of the farmer. This implies that the higher the risk premium, more will be the probability to adopt the technology. For example, the relative risk premium is 23%, or ₹ 4,689 ha^{-1} which means that farmers will be able to forego this amount of the profit in their production process for adopting farm mechanization under rainfed situations compared to non-adoption which normally results in comparatively low income (see section 3.6). The risk premium will be increasing when the technology is so scarce but become inevitable in the production process. This is true in the case of farm mechanization and supplemental irrigation where labor scarcity and rainfall variations make the farmers to decide for mechanization and supplemental irrigation. When compared to the profit level without these technologies, the profit level after allowing for risk premium is still high; hence farmers are tempted to adopt these technologies. Therefore, higher risk premium means higher level of use of these technologies in order to sustain the production process. Similarly, investment in farm machinery and infrastructure have positive marginal effects on the adoption of the technology. Further, encountering climatic shocks, getting liquid cash through selling livestock will increase the probability of adopting farm mechanization. Finally, female households have higher probability of using the farm mechanization technology, as the gender coefficient is negative but significant. The dummy variable on gender takes values 1 for male and 0 for female.

Table 7. Marginal effects of inputs on the probability of adoption of farm mechanization – Andhra Pradesh.

Variable	Coefficient[1]	SE
First moment	0.0153	0.0261
Second moment	0.1396	0.1006
Third moment	-0.0257	0.0247
Farm size (ha)	-0.0029	0.0051
Household size (no.)	-0.0058	0.0095
Distance to market for sales (km)	0.0005	0.0006
Gender (M/F)	-0.0637**	0.0262
Education (1-7 scale)	0.0151	0.0130
Age (years)	0.0022	0.0019
Marital status (no.)	0.2427	0.2431
Married (years)	-0.0004	0.0016
Earning male members	0.0035	0.0148
Earning female members	0.0004	0.0152
Health status (1-6 scale)	0.0042	0.0113
Experience in farming (years)	-0.0018	0.0013

continued

Table 7. continued

Variable	Coefficient[1]	SE
sc1 (Dummy variable = 1 if drought, hailstorm and irregular weather are encountered and 0 otherwise)	0.0492*	0.0263
sc2 (Dummy variable = 1 if drought alone encountered and 0 otherwise)	-0.1775	0.1161
sc3 (Dummy variable = 1 if drought, untimely rain and irregular weather encountered and 0 otherwise)	0.0416	0.0296
sc4 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather encountered and 0 otherwise)	0.0531	0.0351
Livestock ownership	-0.0069	0.0249
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.0642	0.0562
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	-0.0230	0.0442
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	0.0005	0.0385
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	0.0206	0.0380
Cpsi (Dummy variable = 1 if supplemental irrigation is provided, 0 otherwise)	0.0264	0.0294
Cfsls (Dummy variable = 1 if sold livestock, 0 otherwise)	0.0464*	0.0252
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.0585	0.0514
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	0.0379	0.0252
Investment in farm machinery	0.0000**	0.0000
Investment in infrastructure	0.0000*	0.0000
No. of visits of farmers to extension officials	0.0008	0.0101
No. of visits of extension officials to farmers	0.0068	0.0115
Location (Dummy variable = 1 for Anantapur and 0 otherwise)	-0.4667***	0.0694
Relative risk premium	0.0691***	0.0260

1. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

3.3.3. Identifying determinants of technology adoption in Andhra Pradesh: supplemental irrigation

Table 8 presents the results of choice model for using supplemental irrigation in dryland system of Andhra Pradesh. Important farm related determinants of adoption are all the three moments of profit function and farm size. Socioeconomic variables which have strong effect on adaptation are farmer education, age and married years as married life offered scope for joint decision-making. Other determinants are: improved crop production practices, incidence of droughts, untimely rain and irregular weather, availability of cash through selling livestock and investment in infrastructure.

Table 8. Estimates of the Probit model for supplemental irrigation – Andhra Pradesh.

Variable	Coefficient[1]	SE
Constant	-5.7944***	1.2862
First moment	1.2935**	0.5785
Second moment	3.7172***	1.2153
Third moment	-0.8152***	0.2819
Farm size (ha)	0.2385***	0.0781
Household size (no.)	0.0605	0.1018
Distance to market for sales (km)	0.0029	0.0052
Gender (M/F)	1.3060	1.8109
Education (1-7 scale)	0.3486***	0.1115
Age (years)	-0.0361*	0.0208
Marital status (no.)	-1.4681	1.8227
Married (years)	0.0428**	0.0172
Earning male members	0.0521	0.1481
Earning female members	-0.0838	0.1842
Health status (1-6 scale)	-0.1250	0.1214
Experience in farming (years)	0.0085	0.0135
sc1 (Dummy variable = 1 if drought, hailstorm and irregular weather are encountered and 0 otherwise)	0.2474	0.3130
sc2 (Dummy variable = 1 if drought alone encountered and 0 otherwise)	-0.3150	0.8987
sc3 (Dummy variable = 1 if drought, untimely rain and irregular weather encountered and 0 otherwise)	0.9064*	0.5255
sc4 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather encountered and 0 otherwise)	-0.8601	0.8441
Livestock ownership	-0.0511	0.2846
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.0780	0.4419
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	0.2591	0.3887
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	0.3849	0.4280
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	1.0339**	0.4049
Cfsls (Dummy variable = 1 if sold livestock, 0 otherwise)	0.6808**	0.3176
Cnfbm (Dummy variable =1 if borrowed money, 0 otherwise)	0.0311	0.4373
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	-0.3216	0.2896
Investment in farm machinery	0.0000	0.0000

continued

Table 8. continued

Variable	Coefficient[1]	SE
Investment in infrastructure	0.0000	0.0000
No. of visits of farmers to extension officials	-0.0732	0.1257
No. of visits of extension officials to farmers	0.3203**	0.1335
Location (Dummy variable = 1 if location is Anantapur, 0 otherwise)	1.8235***	0.5980
Relative risk premium	0.1721	0.1518
McFadden R-squared	0.6623	

1. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

The marginal effects of these influencing variables on the use of supplemental irrigation are presented in Table 9. The marginal effect of variance in profit is 0.309 and it is significant at 10% level. This means the probability of adoption increases by 0.309 approximately when the variance increases by one unit. Similarly, the marginal effect of skewness (third moment) is -0.0678 and it is also significant at 10% level. This implies that when skewness increases by one unit the probability of adoption decreases approximately by 0.0678. Farm size, household gender (male), education, married years, investment in farm infrastructure and location of the farm close to cities are other determinants which increase the likelihood of adoption.

Table 9. Marginal effects of inputs on the probability of adoption of supplemental irrigation – Andhra Pradesh.

Variable	Coefficient[1]	SE	p-value
First moment	0.1075	0.0719	0.135
Second moment	0.3090*	0.1691	0.068
Third moment	-0.0678*	0.0390	0.082
Farm size (ha)	0.0198**	0.0098	0.044
Household size (no.)	0.0050	0.0087	0.562
Distance to market for sales (km)	0.0002	0.0004	0.572
Gender (M/F)	0.0417*	0.0247	0.091
Education (1-7 scale)	0.0290**	0.0140	0.038
Age (years)	-0.0030	0.0021	0.144
Marital status (no.)	-0.3309	0.6665	0.62
Married (years)	0.0036*	0.0019	0.065
Earning male members	0.0043	0.0123	0.724
Earning female members	-0.0070	0.0151	0.645
Health status (1-6 scale)	-0.0104	0.0109	0.34
Experience in farming	0.0007	0.0011	0.535
sc1 (Dummy variable = 1 if the drought, hailstorm and irregular weather are encountered and 0 otherwise)	0.0224	0.0321	0.486
sc2 (Dummy variable = 1 if drought alone encountered and 0 otherwise)	-0.0225	0.0522	0.667

continued

Table 9. continued

Variable	Coefficient[1]	SE	p-value
sc3 (Dummy variable = 1 if drought,, untimely rain and irregular weather encountered and 0 otherwise)	0.1482	0.1361	0.276
sc4 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather encountered and 0 otherwise)	-0.0377	0.0232	0.105
Livestock ownership	-0.0043	0.0242	0.86
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.0062	0.0339	0.855
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	0.0247	0.0426	0.563
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	0.0411	0.0588	0.484
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	0.1701	0.1144	0.137
Cfsls (Dummy variable = 1 if sold livestock, 0 otherwise)	0.0832	0.0595	0.162
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.0025	0.0348	0.942
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	-0.0249	0.0238	0.294
Investment in farm machinery	0.0000	0.0000	0.251
Investment in infrastructure	0.0000	0.0000	0.291
No. of visits of farmers to extension officials	-0.0061	0.0108	0.572
No. of visits of extension officials to farmers	0.0266**	0.0135	0.049
Location (Dummy variable = 1 if location is Anantapur, 0 otherwise)	0.1880**	0.0770	0.015
Relative risk premium	0.0143	0.0140	0.307

1. * and ** = Significant at 10% and 5% levels respectively.

3.4. Estimation of risk in technology adoption in Karnataka

The estimated coefficients of the first three moment functions are presented in Table 10. Many linear, quadratic and interaction terms have significant coefficients in all the three moment functions. Irrigation water is strongly related to the mean function. Its linear and quadratic terms are strongly and positively significant. The quadratic term of mechanical labor and the term corresponding to its interaction with water are all significant. The quadratic term corresponding to seed is negative and significant. For the second moment, the coefficient of the linear term corresponding to seed was positive and significant and all the interaction terms that involved seed were also significant. Similarly many other interaction terms like machine labor and supplemental irrigation (water), human labor and machine labor, seed and human labor are also significant. Overall, this means suitability of the quadratic functional form. Similar inferences can be obtained by examining the coefficients of the third moment function.

Estimated sample average risk parameters, viz., θ_1, θ_2 and θ_3 for each input, the Arrow-Pratt and downside risk coefficients and relative risk premium for each input are presented in Table 11.

The R^2 ranges from 0.367 (seed) to 0.923 (machine labor). The parameter θ_{2k} is associated with the variance of profit. It is positive for machine labor and supplemental irrigation water and consequently the corresponding Arrow-Pratt coefficients are positive: implying that farmers are risk averse with respect to these adaptation strategies. This means that farmers are willing to forego a portion of their profit in order to avoid the risk associated with these strategies. Further the downside risk coefficients for machine and labor were positive implying that farmers are downside risk averse with respect to these strategies. The average relative risk premium ranges from 6% (supplemental irrigation) to 9% (farm mechanization). This means, given the average profit of ₹ 79,003 ha^{-1}, the farmers will be willing to pay ₹ 7,110 ha^{-1} in the process of implementing farm mechanization. In the case of supplemental irrigation, the relative risk premium which the farmers will be willing to pay will be ₹ 6,037 ha^{-1}.

Table 10. Estimates of parameters of three moments of profit function – Karnataka.

	First moment		Second moment		Third moment	
Variable^1	Coefficient^2	t-value	Coefficient^2	t-value	Coefficient^2	t-value
Constant	0.2791***	2.0532	-0.0312	-0.2239	0.1907	0.5076
Seed	0.2315	1.1711	0.4316***	2.1276	1.6048***	2.9359
Fert	0.0910	0.6325	0.0337	0.2280	0.6421	1.6144
HBLB	-0.1449	-0.7003	-0.2444	-1.1516	-1.4665***	-2.5641
MCLB	0.1783	0.9668	0.2603	1.3762	0.3993	0.7832
Water	0.6600***	4.1745	0.1509	0.9302	-0.0122	-0.0280
Seed2	-0.0488***	-2.6975	-0.0294	-1.5849	-0.0132	-0.2633
Seed*Fert	0.1125	1.4049	0.4178***	5.0867	0.2084	0.9416
Seed*HBLB	-0.0004	-0.0029	-0.4335***	-2.9409	-0.9376***	-2.3606
Seed*MCLB	-0.0528	-0.4672	0.3051***	2.6320	0.3514	1.1248
Seed*Water	0.0748	1.1274	-0.2601***	-3.8234	-0.2206	-1.2033
Fert2	-0.0647	-1.0606	-0.0672	-1.0729	-0.1872	-1.1092
Fert*HBLB	0.0584	0.5369	-0.1985**	-1.7793	0.1472	0.4897
Fert*MCLB	-0.0480	-0.6472	0.1961***	2.5770	-0.0988	-0.4819
Fert*Water	0.0120	0.2054	-0.0056	-0.0942	-0.1579	-0.9791
HBLB2	0.0114	0.1282	0.3142***	3.4297	0.3250	1.3164
HBLB*MCLB	0.2036**	1.7048	-0.4632***	-3.7792	0.0951	0.2880
HBLB*Water	-0.0549	-0.6723	0.0387	0.4616	0.4026**	1.7837
MCLB2	-0.0946**	-1.9549	0.1052**	2.1192	-0.1265	-0.9455
MCLB*Water	-0.3282***	-3.5895	0.1887**	2.0121	-0.6508***	-2.5745
Water2	0.1237***	3.0661	-0.1128***	-2.7255	0.3122***	2.7985

1. Fert = Fertilizer; HBLB = Human labor; MCLB = Machine labor.
2. ** and *** = Significant at 5% and 1% levels.

Table 11. Estimation of risk-aversion measures of various adaptation technologies – Karnataka.

	Farm mechanization		Supplemental irrigation	
Parameter	Coefficient[1]	SE	Coefficient[1]	SE
θ_{1k}	0.0537	0.0410	0.4264***	0.0468
θ_{2k}	0.2603***	0.1073	0.1847	0.4174
θ_{3k}	-0.4919***	0.0926	0.5051***	0.1964
R^2	0.9232		0.5220	
Arrow-Pratt	0.5207***	0.2146	0.3695	0.8348
Downside risk	2.9514***	0.5554	-3.0308***	1.1785
Relative risk premium (%)	9		6	

1. *** = Significant at 1% level.

3.4.1. Identifying determinants of technology adoption in Karnataka: farm mechanization

In this section, we investigate the determinants of the two technologies: (i) farm mechanization, and (ii) supplemental irrigation by rainfed farmers. The relative risk premiums for farm mechanization and supplemental irrigation water are used in the respective choice models to elucidate the determinants of risk attitude. For this purpose, separate Probit regression models were run for the two technologies. The results for farm mechanization are presented in Table 12. The first three moments of the profit function are included in the Probit models. Table 12 reveals that the first moment of profit had a positive and significant effect on farm mechanization technology by farmers. Relative risk premium had a significant positive contribution to adaptation. Other significant variables were farm size, household size, distance to output market, household head's health status, experience in farming, climatic shocks drought and untimely rain and using improved crop production practices.

Table 12. Estimates of the Probit model for farm mechanization – Karnataka.

Variable	Coefficient[1]	SE
Constant	-1.935**	0.969
First moment	0.122***	0.013
Second moment	-0.267	0.280
Third moment	-0.203	0.175
Farm size (ha)	0.041*	0.024
Household size (no.)	-0.106**	0.052
Distance to market for sales (km)	0.015**	0.006
Gender (M/F)	0.004	0.421
Education (1-7 scale)	0.076	0.100

continued

Table 12. continued

Variable	Coefficient[1]	SE
Age (years)	0.027	0.020
Marital status (no.)	-0.100	0.553
Married (years)	-0.001	0.019
Earning male members	0.151	0.185
Earning female members	-0.098	0.197
Health status (1-6 scale)	0.291**	0.146
Experience in farming (years)	0.020*	0.011
sc1 (Dummy variable = 1 if the shocks drought, untimely rain and irregular weather are encountered and 0 otherwise)	-0.364	0.246
sc2 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather alone are encountered and 0 otherwise)	0.033	0.309
sc3 (Dummy variable = 1 if the shocks drought and untimely rain are encountered and 0 otherwise)	-0.507*	0.302
Livestock ownership	0.245	0.212
Investment in farm machinery	0.000	0.000
Investment in infrastructure	0.000	0.000
No. of visits of extension officials to farmers	-0.005	0.134
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.373	0.263
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	-0.324	0.204
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	0.113	0.216
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	0.375	0.221
Cpsi (Dummy variable = 1 if supplemental irrigation is provided, 0 otherwise)	-0.312	0.307
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	-0.036	0.302
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	0.199	0.263
Cnfomc (Dummy variable = 1 if out-migration to cities is used as coping strategy and 0 otherwise	0.062	0.215
Relative risk premium	0.358**	0.178
McFadden R-square	0.766	

1. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

Table 13 presents the marginal effects of each regressor and approximate changes in the probability of adoption of farm mechanization. The values of the derivatives were calculated at the mean values of all the independent variables. The coefficient for relative risk premium was strongly significant. It means that relative risk premium has a significant and positive effect on the adoption decision of the farmer. This implies that higher the risk premium, more will be the probability to adopt the technology.

Table 13. Marginal effects of inputs on the probability of adoption of farm mechanization – Karnataka.

Variable	Coefficient[1]	SE
First moment	0.039**	0.020
Second moment	-0.086	0.090
Third moment	-0.065	0.057
Farm size (ha)	0.013**	0.006
Household size (no.)	-0.034**	0.017
Distance to market for sales (km)	0.005***	0.002
Gender (M/F)	0.001	0.137
Education (1-7 scale)	0.024	0.032
Age (years)	0.009	0.006
Marital status	-0.033	0.190
Married (years)	0.000	0.006
Earning male members	0.049	0.060
Earning female members	-0.031	0.064
Health status	0.094***	0.047
Experience in farming (years)	-0.007	0.004
sc1 (Dummy variable = 1 if the shocks drought, untimely rain and irregular weather are encountered and 0 otherwise)	-0.112	0.072
sc2 (Dummy variable = 1 if the drought, animal disease, untimely rain and irregular weather alone encountered and 0 otherwise)	0.011	0.100
sc3 (Dummy variable = 1 if the shocks drought and untimely rain are encountered and 0 otherwise)	-0.142**	0.072
Livestock ownership	0.080	0.071
Investment in farm machinery	0.000	0.000
Investment in infrastructures	0.000	0.000

continued

Table 13. continued

Variable	Coefficient[1]	SE
No. of visits of extension officials to farmers	-0.001	0.041
Cfaig (Dummy variable =1 if possess skill development activities, 0 otherwise)	0.128***	0.043
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	-0.106	0.096
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	0.036	0.067
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	0.127	0.070
Cpsi (Dummy variable = 1 if supplemental irrigation is provided, 0 otherwise)	-0.094	0.078
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	-0.012	0.084
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	0.061	0.098
Cnfomc (Dummy variable = 1 if out-migration to cities is used as coping strategy and 0 otherwise	0.020	0.079
Relative risk premium	0.115**	0.055

1. ** and *** Significant at 5% and 1% levels respectively.

Similarly, the first moment (that is, expected profit), farm size, distance to output market, health status of the household and awareness of technology have positive marginal effects on the adoption of the technology. So probability of using farm mechanization will increase with increase in the values of these variables. Further, household size, encountering drought and untimely rain have negative marginal effects on adoption meaning that increase in these variables will decrease the probability of adoption (Tafesse et al. 2013).

3.4.2. Identifying determinants of technology adoption in Karnataka: supplemental irrigation

Table 14 presents the results of Probit model for adoption of irrigation technology by farmers in Karnataka. It shows that the first moment of profit, livestock ownership, relative risk premium and farming experience are important determinants of adoption of supplemental irrigation technology by Karnataka farmers. The marginal effects of variables computed at the mean values of the independent variables are provided in Table 15. It shows that expected profit, livestock ownership and relative risk premium have positive significant marginal effects on the probability of adoption of irrigation technology by Karnataka farmers.

Table 14. Estimates of the Probit model for supplemental irrigation – Karnataka.

Variable	Coefficient[1]	SE
Constant	-3.3514	1.2737
First moment	0.9561***	0.2320
Second moment	0.5413	0.4328
Third moment	0.0405	0.2310
Farm size (ha)	0.0044	0.0300
Household size (no.)	0.0321	0.0641
Distance to market for sales (km)	0.0018	0.0077
Gender (M/F)	0.5303	0.5629
Education (1-7 scale)	0.1100	0.1216
Age (years)	0.0049	0.0252
Marital status (no.)	0.2806	0.6908
Married (years)	0.0126	0.0228
Earning male members	-0.1442	0.2419
Earning female members	0.0590	0.2501
Health status (1-6 scale)	0.1811	0.1914
Experience in farming (years)	0.0206**	0.0148
sc1 (Dummy variable = 1 if the shocks drought, untimely rain and irregular weather encountered and 0 otherwise	0.0748	0.2985
sc2 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather alone encountered and 0 otherwise)	0.4669	0.3821
sc3 (Dummy variable = 1 if the shocks drought and untimely rain encountered and 0 otherwise)	-0.2493	0.4026
Livestock ownership	0.4983***	0.2203
Investment in farm machinery	0.0000**	0.0000
Investment in infrastructure	0.0000	0.0000
No. of visits of extension officials to farmers	-0.0075	0.1411
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.0107	0.1566
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	-0.2005	0.3374
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	-0.1502	0.2565
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	-0.5826	0.2633
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.0039	0.3772
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	0.3161	0.3281
Cnfomc (Dummy variable = 1 if out-migration to cities is used as coping strategy and 0 otherwise)	-0.0998	0.2609
Relative risk premium	0.3919***	0.1653
McFadden R-square	0.6897	

1. ** and *** = Significant at 5% and 1% levels respectively.

Table 15. Marginal effects of inputs on the probability of adoption of supplemental irrigation – Karnataka.

Variable	Coefficient[1]	SE
First moment	0.3504***	0.0873
Second moment	0.1984	0.1589
Third moment	0.0149	0.0846
Farm size (ha)	0.0016	0.0110
Household size (no.)	0.0118	0.0235
Distance to market for sales (km)	0.0007	0.0028
Gender (M/F)	0.1710	0.1525
Education (1-7 scale)	0.0403	0.0445
Age (years)	0.0018	0.0092
Marital status (no.)	0.0964	0.2197
Married (years)	0.0046	0.0084
Earning male members	-0.0529	0.0886
Earning female members	0.0216	0.0916
Health status (1-6 scale)	0.0664	0.0701
Experience in farming (years)	-0.0076	0.0054
sc1 (Dummy variable = 1 if the shocks drought, untimely rain and irregular weather are encountered and 0 otherwise	0.0275	0.1104
sc2 (Dummy variable = 1 if drought, animal disease, untimely rain and irregular weather alone are encountered and 0 otherwise)	0.1787	0.1492
sc3 (Dummy variable = 1 if the shocks drought and untimely rain are encountered and 0 otherwise)	-0.0877	0.1348
Livestock ownership	0.2622**	0.1005
Investment in farm machinery	0.0000	0.0000
Investment in infrastructure	0.0000	0.0000
No. of visits of extension officials to farmers	-0.0028	0.0517
Cfaig (Dummy variable = 1 if possess skill development activities, 0 otherwise)	-0.0039	0.0574
Cfccp (Dummy variable = 1 if change in cropping pattern is followed, 0 otherwise)	-0.0752	0.1286
Cfcpd (Dummy variable = 1 if change in planting date is followed, 0 otherwise)	-0.0553	0.0948
Cfic (Dummy variable = 1 if improved crop production practices are followed, 0 otherwise)	-0.2080	0.0898
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.0014	0.1381
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	0.1111	0.1100
Cnfomc (Dummy variable = 1 if out-migration to cities is used as coping strategy and 0 otherwise)	-0.0368	0.0967
Relative risk premium	0.2038**	0.0912

1. ** and *** = Significant at 5% and 1% levels respectively.

3.5. Estimation of risk in technology adoption in Rajasthan

The moment functions were estimated as per the methodology already stated. The estimated coefficients of the quadratic form of the first three moments are presented in Table 16. Seed, human labor and square of machine power had positive and significant effect on the first moment, which is expected profit. The first two variables had positive and significant effect on the second moment, variance of profit. Machine power and interaction of seed and machine labor, square of human labor all have significant negative impacts on first moment. The two variables human labor and interaction of seed and water have significant positive effect on the third moment (i.e., skewness) whereas, machine labor has significant negative effect implying that at higher levels of skewness, farmers will have less interest to adopt the small farm mechanization.

Table 16. Estimates of parameters of three moments of profit function – Rajasthan.

	First moment		Second moment		Third moment	
Variable[1]	Coefficient[2]	t-value	Coefficient[2]	t-value	Coefficient[2]	t-value
Constant	-0.0005	-0.0029	-0.7137	-1.3181	-2.7967	-0.9344
Seed	2.4313***	3.0899	4.3883*	1.8177	7.7495	0.5488
Fert	0.1627	0.6746	-0.8306	-1.0605	-3.0003	-0.6930
HBLB	0.4431**	1.8597	1.4350**	1.9548	6.6227**	1.9487
MCLB	-0.4661*	-1.7690	-0.8859	-1.0356	-3.3852***	-2.4160
Water	-0.0807	-0.0639	-0.8966	-0.2186	-8.4660	-0.3735
Seed2	0.0057	0.0172	0.0072	0.0068	-0.6577	-0.1113
Seed*Fert	0.4835	0.5277	0.4666	0.1569	1.2808	0.0779
Seed*HBLB	-0.1319	-0.4391	-1.4097	-1.4458	-3.0870	-0.5728
Seed*MCLB	-0.7839**	-1.9034	-1.4398	-0.8506	-1.2269	-0.1311
Seed*Water	-1.2746	-0.3662	7.0139	0.6208	10.9936***	2.1760
Fert2	-0.1000	-0.9812	-0.0526	-0.1590	0.4563	0.2494
Fert*HBLB	0.0203	0.0641	0.1204	0.1172	-0.6266	-0.1104
Fert*MCLB	0.0820	0.3379	0.1200	0.1522	0.6099	0.1400
Fert*Water	0.0270	0.0181	-0.1776	-0.0367	-0.2375	-0.0089
HBLB2	-0.1580**	-1.9763	-0.2130	-0.8206	-0.5854	-0.4081
HBLB*MCLB	0.2813	1.2869	0.4859	0.6848	-0.1464	-0.0373
HBLB*Water	1.0988	0.8055	0.7186***	0.1622	6.2858	0.2567
MCLB2	0.0635***	1.9989	0.1431	0.7626	0.6428	0.6198
MCLB*Water	-1.7846	-1.1129	-3.9057***	-0.7502	-5.7717	-0.2006
Water2	0.0095	0.0633	0.1106	0.2276	0.1871	0.0696

1. Fert = Fertilizer; HBLB = Human labor; MCLB = Machine labor.
2. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

Estimated sample average risk parameters, viz., θ_1, θ_2 and θ_3 for each input, the Arrow-Pratt and downside risk coefficients and relative risk premium for each input are presented in Table 17.

R^2 ranges from 0.3317 (seed) to 0.916 (machine power). The parameter θ_{2k} is associated with the variance of profit. It is positive and significant for fertilizer and machine power and positive only for supplemental irrigation and consequently the corresponding Arrow-Pratt coefficients are positive and significant for the two inputs fertilizer and machine power implying that farmers are risk averse with respect to these inputs. This means that farmers are willing to forego a portion of their profit in order to avoid the risk associated with investing in these inputs. Further, the downside risk coefficients for water is positive implying that farmers are downside risk averse with respect to water. The coefficients of θ_{2k} are negative and not significant for seed and human labor cost. The average relative risk premium ranges from 4% (supplemental irrigation water) to 16% (machine power). This means, given the average profit of ₹ 57,356 ha^{-1} under farm mechanization, the farmers are willing to pay ₹ 9,177 in the process of implementing farm mechanization. In the case of supplemental irrigation, the relative risk premium which the farmers will be willing to pay will be ₹ 2,906 ha^{-1} while adopting the supplemental irrigation technology.

Table 17. Estimation of risk-aversion measures of various adaptation technologies – Rajasthan.

	Farm mechanization		Supplemental irrigation	
Parameter	Coefficient[1]	SE	Coefficient[1]	SE
θ_{1k}	-0.0131	0.0896	-0.7634***	0.2203
θ_{2k}	0.4499***	0.0594	0.2641	0.3277
θ_{3k}	0.0067	0.0410	-0.2083**	0.0828
R^2	0.9964		0.1699	
Arrow-Pratt	0.8998***	0.1188	0.5282	0.6553
Downside risk	-0.0402	0.2461	1.2499***	0.4967
Relative risk premium (%)	16	0	4	0

1. ** and *** = Significant at 5% and 1% levels respectively.

The risk premium for farm mechanization was higher for Rajasthan and Karnataka states when compared to Andhra Pradesh indicating the possible high investments and uncertain nature of rainfed cultivation. In Andhra Pradesh, risk premium for supplemental irrigation was higher illustrating that there is a need to develop farm ponds, wells, mechanization, etc. Farmers who are more risk averse with respect to their water use are more likely to adopt the new technologies that allow them to reduce water use and the production risk (Koundouri et al. 2003, Torkamani and Shajari 2008).

3.5.1. Identifying determinants of technology adoption in Rajasthan: farm mechanization

In this section, we investigate the determinants of farm mechanization by rainfed farmers of Rajasthan. The relative risk premiums of machine power and fertilizer use were used in the respective choice models to elucidate the determinants of risk attitude. For this purpose, separate Probit regression models were run for the two technologies. The results for farm mechanization are presented in Table 18. The first three moments of the profit function are included in the Probit models. Table 18 reveals that the first two moments of profit and maintaining poultry have a positive and significant effect on farm mechanization technology. The third moment of profit, earning female members and selling livestock, has significant negative effect. The relative risk premium is negative but not significant implying that the level of risk premium might be too high to encourage the farmers to go for technology adoption.

Table 18. Estimates of the Probit model for farm mechanization – Rajasthan.

Variable	Coefficient[1]	SE
Constant	-2.6439	0.8915
First moment	0.5680*	0.2469
Second moment	2.7818***	0.5599
Third moment	-0.5850***	0.1414
Farm size (ha)	-0.0020	0.0348
Household size (no.)	-0.0281	0.0616
Distance to market for sales (km)	0.0149	0.0131
Gender (M/F)	-0.0395	0.4806
Education (1-7 scale)	0.0531	0.1628
Age (years)	0.0297	0.0177
Marital status (no.)	0.4742	0.3912
Married (years)	-0.0067	0.0115
Earning male members	0.0623	0.1314
Earning female members	-0.2375*	0.1273
Health status (1-6 scale)	0.0235	0.0977
Experience in farming (years)	-0.0206	0.0133
sc1 (Dummy variable = 1 if all the shocks except flood are encountered and 0 otherwise)	-0.1723	0.3083
sc2 (Dummy variable = 1 if all the shocks except flood and temperature (low) fluctuation are encountered and 0 otherwise)	0.0498	0.3045
sc3 (Dummy variable = 1 if the shocks drought, hailstorm, animal disease and untimely rain are encountered and 0 otherwise)	0.4685	0.3897
Cflf (Dummy variable = 1 if left land fallow and 0 otherwise)	0.0081	0.2472
Cfsls (Dummy variable = 1 if selling livestock is used as a coping strategy and 0 otherwise)	-0.6210**	0.2661
Cfmpoultry (Dummy variable = 1 if maintaining poultry and goats is used as a farm-based coping strategy and 0 otherwise)	0.5185*	0.3231
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.3006	0.2916
Cnfsnfe (Dummy variable = 1 if shifting to nonfarm employment is used as a nonfarm-based coping strategy and 0 otherwise)	-0.0513	0.2758
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	-0.2931	0.2470
Cnflfc (Dummy variable = 1 if less food consumption or changed food habits is used as a coping strategy and 0 otherwise)	0.1104	0.2831
Investment in farm machinery	0.0000	0.0000
Investment in infrastructure	0.0000	0.0000
Relative risk premium	-0.5458	0.4172
McFadden R-square	0.3677	

1. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

Table 19. Marginal effects of inputs on the probability of adoption of farm mechanization – Rajasthan.

Variable	Coefficient[1]	SE
First moment	0.2213**	0.0955
Second moment	1.0838***	0.2268
Third moment	-0.2279***	0.0567
Farm size (ha)	-0.0008	0.0136
Household size (no.)	-0.0109	0.0240
Distance to market for sales (km)	0.0058	0.0051
Gender (M/F)	-0.0154	0.1884
Education (1-7 scale)	0.0207	0.0634
Age (years)	0.0116*	0.0069
Marital status (no.)	0.1740	0.1323
Married (years)	-0.0026	0.0045
Earning male members	0.0243	0.0512
Earning female members	-0.0925*	0.0495
Health status (1-6 scale)	0.0092	0.0381
Experience in farming (years)	-0.0080	0.0052
sc1 (Dummy variable = 1 if all the shocks except flood are encountered and 0 otherwise)	-0.0663	0.1169
sc2 (Dummy variable = 1 if all the shocks except flood and temperature (low) fluctuation are encountered and 0 otherwise)	0.0194	0.1194
sc3 (Dummy variable = 1 if the shocks drought, hailstorm, animal disease and untimely rain are encountered and 0 otherwise)	0.1851	0.1520
Cflf (Dummy variable = 1 if left land fallow and 0 otherwise)	0.0032	0.0963
Cfsls (Dummy variable = 1 if selling livestock is used as a coping strategy and 0 otherwise)	-0.2379**	0.0987
Cfmpoultry (Dummy variable = 1 if maintaining poultry and goats is used as a farm-based coping strategy and 0 otherwise)	0.2044*	0.1055
Cnfbm (Dummy variable = 1 if borrowed money, 0 otherwise)	0.1144	0.1081
Cnfsnfe (Dummy variable = 1 if shifting to nonfarm employment is used as a nonfarm-based coping strategy and 0 otherwise)	-0.0200	0.1078
Cnfrag (Dummy variable = 1 if relying on assistance from government, 0 otherwise)	-0.1137	0.0954
Cnflfc (Dummy variable = 1 if less food consumption or changed food habits is used as a coping strategy and 0 otherwise)	0.0431	0.1108
Investment in farm machinery	0.0000	0.0000
Investment in infrastructure	0.0000	0.0000
Relative risk premium	-0.2126	0.1641

1. *, ** and *** = Significant at 10%, 5% and 1% levels respectively.

Table 19 presents the marginal effects of each regressor which represented approximate changes in the probability of adoption of farm mechanization. The values of the derivatives were calculated at the mean values of all the independent variables. The coefficients for the first two moments are positive and significant. It means that the mean and variance of profit have significant and positive effect on the adoption decision of the farmer. This implies that the higher the mean and variance of profit, the more will be the probability to adopt the technology. Similar conclusion can be arrived at with respect to the variable maintaining poultry whose coefficient is positive and significant. Further, the variables third moment of profit, number of earning female members and selling livestock all have significant negative coefficients meaning that increase in these variables will decrease the probability of adoption of the technology as possession of more livestock will sustain the livelihoods of the households in terms of increased household income.

3.6. Risk premium and technologies

Table 20 and Figure 4 present the main results of the present study. In all the states, it is seen that the risk premium is higher for farm mechanization compared to supplemental irrigation and this might be due to the high investment made to overcome the scarcity of labor and to do timely farm operations (Table 20). This was the same case in Andhra Pradesh for supplemental irrigation which has higher risk premium.

Table 20. Technology adoption and risk premium.

State	Technology	Farm investment on infrastructure (₹/farm)	Profit with adoption (₹ ha^{-1})	Risk premium (₹ ha^{-1})	Profit without adoption (₹ ha^{-1})	Profit margin (₹ ha^{-1})	Ratio of risk premium to profit margin[1]
Andhra Pradesh	Farm mechanization	15,582	20,385	4,689	16,194	4,191	1.12
	Supplemental irrigation	41,207	41,249	6,600	17,030	24,219	0.27
Karnataka	Farm mechanization	1,00,893	79,003	7,110	67,052	11,951	0.59
	Supplemental irrigation	88,217	1,00,620	6,037	63,423	37,197	0.16
Rajasthan	Farm mechanization	48257	57,356	9,177	21,994	35,362	0.26
	Supplemental irrigation	79,045	72,641	2,906	34,378	38,263	0.08

1. Expressed as the ratio of risk premium to the difference in profits between adaptation and non-adoption of technology.

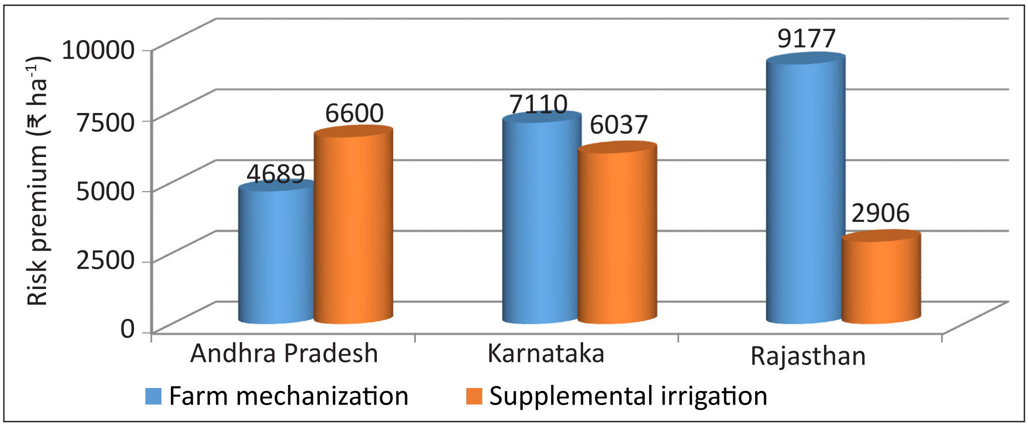

Figure 4. Farm technologies and risk premium.

4. Conclusions and Recommendations

This study makes an in-depth analysis of household level climate change shocks, farmers' adaptation strategies and risk they face in technology adoption. A disaggregated analysis was done on technology adoption and risk premium for cluster of action sites across the three states (Andhra Pradesh, Karnataka and Rajasthan). Farm mechanization and supplemental irrigation were considered for assessing the risk premium in the respective states. The risk premium ranged from 22% to 23% for supplemental irrigation and farm mechanization. It was found that the risk premium was higher for farm mechanization in Karnataka and Rajasthan, while in Andhra Pradesh, risk premium was higher for supplemental irrigation.

The relative risk premium had a significant positive contribution to adaptation of farm mechanization in action sites in all the three states as most of the farmers are risk averse and prefer to adopt technologies to minimize the risk in crop production. Other significant variables were climatic shocks, drought, untimely rain and irregular weather encountered, investment in farm machineries and location of the farm (access to infrastructure facilities). Relative risk premium, farm size, household gender (male), education, married life (years), investment in farm infrastructure and location of the farm close to cities were the other determinants of adoption of supplemental irrigation technology.

Relative risk premium has a significant positive contribution to adaptation of farm mechanization and supplemental irrigation. The significant variables contributed for adaptation in Andhra Pradesh were farm size, household size, distance to output market, household head's health status, experience in farming, climatic shocks drought and untimely rain and using improved crop production practices. Expected profit, livestock ownership and relative risk premium had positive significant marginal effects on the probability of adoption of supplemental irrigation technology by Karnataka farmers. Expected profit, and maintaining poultry were the key determinants of adoption of supplemental irrigation technology by Rajasthan farmers.

The ratio of risk premium to the profit margin for farm mechanization will be 1.12, 0.59 and 0.26 for Andhra Pradesh, Karnataka and Rajasthan respectively whereas the ratio for supplemental irrigation will be 0.27, 0.16 and 0.08 respectively for the above three states indicating that it is worth to invest in technology adoption except in the case of farm mechanization in Andhra Pradesh where the risk premium is higher than the profit margin which needs further investigation on the type and magnitude of farm mechanization used.

The results had shown that risk preferences of the households influenced the probability of technology adoption in dryland systems and the higher the level of risk premium the households should pay, the higher will be the adoption of the technologies. The results had more inferences for policy making when promoting the adoption of the new technologies and therefore, the following policy related measures are suggested:

- It is crucial to account for or quantify the risk associated with each technology identified for adoption by the farmers. The list of technologies and their relative risk premium should be discussed with the implementing partners.
- Creation of more awareness through appropriate and affordable training programs, about the technologies and help farmers to adopt faster. Expected benefits that the households could derive from the reduction in their production risk due to technology adoption (cost and benefits of adaptation technologies) should be worked out and included in the technology transfer programs.

- Existing weather-based crop insurance products should be examined about their applicability to dryland systems. In that case, comparison of the premium for the weather-based insurance products (for different crops) with the risk premium derived for different technologies will help judge the premium levels that farmers can pay for their crops. The weather-based insurance product can be adjusted according to the quantum of risk premium that farmers will be willing to pay. Thus, a match of crop and technology-based premium can be worked out. A hybrid insurance product can be suggested.
- Examining the possibilities for converging the government or private sector programs that focus on technology related issues should be sought. For example, most of the farmers are facing the risk of rainfall variability and investment in farm ponds for providing supplemental irrigation is needed. As many government departments are already concentrating their programs on these areas, convergence of different government programs that facilitate construction of farm ponds and other water harvesting structures and use of micro-irrigation will minimize the transaction cost of farmers as well as government departments. Piloting some of the technology options in selected locations will be helpful in scaling out and scaling up the technologies.

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Appendix 1

1. Major adaptation strategies followed in Andhra Pradesh.	
No.	Adaptation strategy
1	Livestock + Farm mechanization
2	Livestock + Change in cropping pattern + Farm mechanization
3	Livestock + Following improved crop production practices + Farm mechanization
4	Livestock + Providing supplemental irrigation + Farm mechanization
5	Livestock + Awareness of technology + Change in cropping pattern + Farm mechanization
6	Livestock + Awareness of technology + Change in cropping pattern + Change in planting date + Farm mechanization
7	Livestock + Awareness of technology + Change in cropping pattern + Change in planting date + Providing supplemental irrigation + Farm mechanization
8	Livestock + Awareness of technology + Change in cropping pattern + Change in planting date + Following improved crop production practices + Providing supplemental irrigation + Farm mechanization

2. Major adaptation strategies followed in Karnataka	
No.	Adaptation strategy
1	Awareness of Technology
2	Awareness of Technology + Following improved crop production practices
3	Livestock + Awareness of technology
4	Livestock + Change in cropping pattern
5	Livestock + Awareness of technology + Change in cropping pattern
6	Livestock + Awareness of technology + Following improved crop production practices
7	Livestock + Awareness of technology + Change in planting date
8	Livestock + Awareness on technology + Change in cropping pattern + Following improved crop production practices
9	Livestock + Awareness of technology + Change in cropping pattern + Change in planting date
10	Livestock + Awareness of technology + Change in cropping pattern + Farm mechanization

3. Major adaptation strategies followed in Rajasthan	
No.	Adaptation strategy
1	Livestock only
2	Livestock + Farm mechanization
3	Livestock + Poultry and goats
4	Livestock + Poultry and goats + Farm mechanization
5	Livestock + Providing supplemental irrigation + Farm mechanization
6	Livestock + Invested in farm ponds + Farm mechanization

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