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Farm-level Adaptation to Climate Extremes in India: Do we need a separate Adaptation Policy?

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Abstract

Various studies report that agriculture sector is vulnerable to climate extremes in India on which a majority of households depend for their basic livelihood. Therefore, designing an adaptation policy in order to reduce potential impact is a pertinent issue for the policy makers. But, the farmers are already adopting various options at the farm-level to mitigate impact of past climate extremes on agricultural production, and in fact, the ability of undertaking these options differs from farmer to farmer. A better understanding of current adaptation decision-making process is imperative to design policies aimed at promoting successful adaptation strategies for farmers in the disaster prone regions of India. Using data from a survey of 285 farm households in cyclone and flood prone regions of Odisha, India, the present study identify the determinants of adaptation options. For the sake of brevity, this study has selected seven mostly practiced farm-level adaptation options: salt and flood tolerant indigenous/ traditional paddy seeds, soil conservation techniques, mixed paddy cropping, crop diversification, land holiday, more time seedling and re-planting and pest and disease management. With borrowing conceptual framework from the agricultural technology adoption studies, a multivariate probit model was used to examine factors influencing farm households' decision to adopt these options. In doing so, this study identified cyclone and/ or flood sensitive adaptation measures which should be promoted in the disaster prone regions of India. Further, household size, per capita income, agricultural extension, access to MGNREGA, received crop loss compensation and informal credit are some of the important determinants. Since some of these could be addressed as part of the ongoing rural development programme, this study asserts the non-necessity of formulating a separate climate change specific adaptation policy. However, it is imperative to restructure the existing development programme with including climate specific response measures.

Key Words: Cyclone and Flood, Adaptation Policy, Farm-Level Adaptation Options, Determinants, India

JEL Classifications: Q54, Q12, Q58

1. Introduction

The frequency and severity of climate extremes have gone up over the years and are expected to enhance in the foreseeable future due to climate change (Solomon et al., 2007; IPCC, 2012). The damages associated with these events have also increased, especially in the developing nations like India (Botzen and van den Bergh, 2009; IPCC, 2012). The amount of loss, for example, is about 1 percent of GDP (Gross Domestic Product) for middle income nations during 2001-06, whereas it is around 0.3 percent for low income nations and less than 0.1 percent for high income nations (IPCC, 2012). With regard to India, Padmanabhan (2012) finds that the total economic damage due to climatic extremes was US$ 4806.4 billion during 1980-2010, which converts into an average of US$ 155.1 billion per annum during the same period. Another study conducted by the World Bank in 2001 estimates that the total economic loss due to extreme events was US$ 138 billion during 1996-2001, and the direct losses are up to 2 percent of the India's GDP (Nanda Kumar, 2012).

It is observed that the impact of these events is relatively higher for households living in the disaster prone regions of India, particularly the farm households (Bhattacharya and Das, 2007; Rao, 2010). A large number of households in India depend on agriculture for their livelihood (54.6 percent as of 2011 Census), and adaptation measures regarding agriculture are imperative to mitigate potential impacts of foreseeable climate extremes. Meanwhile, the Indian farmers have been adopting different adaptation mechanisms to mitigate impacts of past extreme events (Jodha, 1991; Mwinjaka et al., 2010; Jodha et al., 2012). But, the ability of taking up different adaptation options differs from farmer to farmer. In view of this, prior to formulating an adaptation policy to buffer climate extremes, knowledge of the present adaptation practices and factors affecting farmers' choices will have policy suggestions in the context of successful implementation of adaptation options - mainly in the disaster prone regions of India.

Some recent studies have attempted to look into farmers' adaptive behaviour in the context of Africa, Latin America, China and India (e.g. Maddison, 2007; Kurukulasuriya and Mendelsohn, 2007; Nhemachena and Hassan, 2007; Seo and Mendelsohn, 2008; Hassan and Nhemachena, 2008; Gbetibouo, 2009; Deressa et al., 2009 and 2011; Bryan et al., 2009; Deressa, 2010; Wang et al., 2010; Di Falco et al., 2011 and 2012; Panda et al., 2013). Among these studies, Maddison (2007), Bryan et al. (2009), Deressa (2010), Deressa et al. (2011) and Di Falco et al. (2011 and 2012) investigate factors influencing famers' decision to adapt or not to adapt. However, farmers are taking up various adaptation options which are either mutually exclusive or vice-versa. Considering such aspects, Panda et al. (2013) examine determinants of various adaptation options to drought in Odisha while treating them as independent; but, the options are not mutually exclusive. Taking such limitations into account, Nhemachena and Hassan (2007) identify factors influencing different adaptation options in Africa while allowing complementarities and substitutabilities relationship among different measures. Rest of the studies find factors influencing the choice of crops (Kurukulasuriya and Mendelsohn, 2007; Seo and Mendelsohn, 2008; Wang et al., 2010) and farm management adaptation practices (Hassan and Nhemachena, 2008; Gbetibouo, 2009; Deressa et al., 2009) over no adaptation; here options are mutually exclusive. To the best of our knowledge, no studies have so far examined this in the context of India (Panda et al., 2013 is a noteworthy exception), particularly with reference to climate extremes.

Therefore, this study aims to identify determinants of farm-level adaptation options to climate extremes. For empirical assessment, the state of Odisha, India is taken as a case study – a state prone to both cyclone and flood (Government of Odisha, hereafter GoO, 2004). Such analysis could help the policy makers to influence farmers to undertake farm-level adaptation mechanisms in the disaster prone regions of Odisha. The significance of the study is that it tries to address the larger policy question about the need for a separate adaptation policy to deal with the impacts of climate extremes.

2. Perceived Farm-level Adaptation Strategies of Farmers in Odisha

Based on the cross-sectional survey data collected from 285 farm households during 2010/2011 production season in the Odisha, this section briefly summarises the farm-level adaptation measures which they consider appropriate to cope with cyclone and flood. Detailed description on the sampling technique is given in section 4.

The farm-level adaptation measures are salt and flood tolerant indigenous/ traditional paddy seeds, soil conservation techniques, mixed paddy cropping, crop-diversification, land holiday, more time seedling and re-planting[1] and pest and disease management[2] (Table 1). These options are not mutually exclusive. Among them, five measures are chosen by more than half of the farmers, e.g. more time seedling and replanting (77.89 percent), land holiday (71.23 percent), pest and disease management (71.23 percent), salt and flood tolerant indigenous paddy seeds (64.91 percent) and mixed paddy cropping (56.84 percent). While 42.46 percent of farmers practice crop diversification, soil conservation techniques are adopted by 31.58 percent of farmers.

Table 1: Farm-level adaptation measures undertaken by farm households

Farm-level adaptation measures	No. of farm households
Salt and flood tolerant indigenous paddy seeds	185 (64.91)
Soil conservation techniques	90 (31.58)
Mixed paddy cropping	162 (56.84)
Crop-diversification	121 (42.46)
Land holiday	203 (71.23)
More time seedling & re-planting	222 (77.89)
Pest and disease management	203 (71.23)

Source: Computed from the primary data
Note: Figures in the parentheses indicate percentages.

3. Empirical Approach

To examine the determinants of farm-level adaptation measures, this study has followed the theory of agriculture technology adoption (see Feder et al., 1985). This sheds light on the

[1] While paddy crop damaged due to cyclone and flood, the farmers are again doing seedling and re-planting based on the stages of crop growth. In the earlier stage, farmers are going for again seedling, and they are purchasing seedling from farmers in the neighbourhood villages for re-panting in the case of middle stage. In the case of matured stage, the farmers leave their agricultural land barren.

[2] The level of salinity in soil has increased due to salt water intrusion. As a result, there is high possibility of occurrence of insects and pests like stem borer, gall midge and leaf folder, and diseases like sheath rot and bacterial leaf blight, and weeds like wild rice, *Echinocloa spp.*, *Cyperus spp.*, and *Schemoplectus spp.* (Singh and Sasmal, 2004). In addition, the wet period also increases the possibility of fungal and bacterial diseases (Padgham, 2009). Farmers are therefore following pest and disease management to counteract.

adaptive behaviour of farm household assuming that a farm household selects a combination of adaptation measures to maximise expected utility at the end of production period. The probability that a farm household may select an adaptation measure depends on how profitable that choice is. The choice of adaptation measure is determined by a host of factors related to socio-economic characteristics of household, access to formal and informal institutions and nature of the climatic extreme events. Assuming that the utility function is state independent, solving this problem would give an optimal mix of adaptation measures undertaken by the farm household, as given by (Di Falco et al., 2012)

$$A_h = A\left(S_h, HH_h, FIN_h, INFIN_h; \beta\right) + e_h \cdots\cdots(1)$$

Where, A_h represents adaptation strategies that farm household h adopted to withstand against the cyclone and flood. A households' preference for adaptation measures depends on vector of household characteristics (HH_h), access to formal (FIN_h) and informal institutions ($INFIN_h$) and intensity of crop damage due to past cyclones and floods (S_h). β is the vector of parameters to be estimated, and e_h is the household specific random error term.

As observed in the literature (Kurukulasuriya and Mendelsohn, 2007; Seo and Mendelsohn, 2008; Di Falco et al., 2012), the farm household would choose a set of adaptation measures $'j'$, over all other set k if,

$$\mathrm{E}\left[\mathrm{U}\left(A_{\mathrm{j}}\right)\right] > \mathrm{E}\left[\mathrm{U}\left(A_{\mathrm{k}}\right)\right] \text{for} \quad \forall\, \mathrm{k} \neq \mathrm{j} \cdots\cdots(2)$$

The adaptation measures considered for empirical estimation are not mutually exclusive and therefore a '*multivariate probit model*' is found to be appropriate (Nhemachena and Hassan, 2007). The advantage is that it simultaneously models the influence of the set of explanatory variables on each of the different adaptation mechanisms while allowing the unobserved and unmeasured factors (error term) to be freely correlated (Lin et al., 2005). Complementarities (positive correlation) and substitutabilities (negative correlation) among different options may be the source of the correlations between error terms. The correlations are taken into account in the multivariate probit model. Following Lin et al. (2005) and Nhemachena and Hassan (2007), the multivariate probit model used in the present analysis is characterised by a set of n binary dependent variables y_h, such that,

$$\begin{aligned} y_h &= 1 \ \ if \ \ \mathrm{x}\beta_h + e_h > 0 \\ &= 0 \ \ if \ \ \mathrm{x}\beta_h + e_h \leq 0, h = 1, 2, \ldots, n \cdots\cdots (3) \end{aligned}$$

Where x is a vector of explanatory variables, β_h is a vector of parameters to be estimated, e_h is a random error term which is distributed as multivariate normal distribution with zero mean and unitary variance and $n \times n$ contemporaneous correlation matrix $R = \left[\rho_{hj}\right]$ with density $\phi\left(e_1, e_2, \ldots\ldots, e_n; R\right)$. The likelihood contribution for an observation is the n-variate standard normal probability

$$\Pr\left(y_1, \ldots, y_n \mid x\right) = \int_{-\infty}^{(2y_1-1)x'\beta_1} \int_{-\infty}^{(2y_2-1)x'\beta_2} \ldots \times \int^{(2y_n-1)x'\beta_n} \phi\left(e_1, e_2, \ldots, e_n; Z'RZ\right) de_1 \ldots de_2 de_1 \cdots\cdots (4)$$

Where, $Z = \mathrm{diag}\left[2\mathrm{y}_1 - 1, \ldots, 2y_n - 1\right]$. Maximum-likelihood estimation is carried out by maximising the sample likelihood function, which is the product of probabilities (equation 4) across sample observations. The analysis undertaken in this study utilised estimation process outlined by Cappellari and Jenkins (2003) in order to implement the multivariate probit model using the method of simulated maximum likelihood – also known as the Geweke-Hajivassiliou-Keane (GHK) stimulator[3]. The cross sectional econometric analysis is associated with the

[3] It expresses the multivariate normal distribution function as the product of sequentially conditional univariate normal distribution functions that can be easily and accurately evaluated. In the case of multivariate normal limited

problem of multicollinearity and heteroskedasticity. A variance inflation factor[4] (VIF) for each of the explanatory variable was estimated to check multi-collinearity, and a robust standard error was calculated to address the possibility of heteroskedasticity. The information was gathered at the household-level and not at plot-level, and the results of this estimation should be interpreted under this caveat.

4. Study Area, Data and Empirical Specification of Model Variables

The state of Odisha consisting of thirty districts and is geographically situated at the head of the Bay of Bengal has a coastal stretch of around 480 km (Figure 1). In addition, a number of perennial rivers, e.g. *Mahanadi*, *Brahmani*, *Baitarani*, *Rushikulya*, *Birupa*, *Budhabalanga* and *Subarnarekha* etc and their tributaries pass through Odisha, making the state prone to flooding. During 1804-2010, both cyclones and floods have occurred for 126 years in Odisha (Bhatta, 1997; Chittibabu et al., 2004; GoO, 2004 and 2011). In particular, outbreak of floods has been reported for nine consecutive years during 2001-2010 (GoO, 2011). While Mohanty et al. (2008) and Pasupalak (2010) highlight that the frequency and intensity of cyclonic storms are increased in the recent years, Guhathakurta et al. (2012) find an increasing trend in the intensity of extreme rainfall events during the last century in Odisha. Within the state, three cyclone and flood prone districts were purposively selected, namely as Balasore, Kendrapada and Jajpur, for conducting a farm-household level survey. For instance, these three districts have been affected by at least 20 cyclones and floods during 1994-2008, and among them, the Balasore district has experienced a higher number of these events, i.e. 29 times (data collected from Special Relief Commissioner, Government of Odisha, District Emergency Offices and GoO, 2011).

Balasore is one of the northeastern coastal districts of Odisha (Figure 1), which accounts for 2.44 percent (i.e. 3806 Km^2) of the total geographical area and 5.53 percent of the total population (i.e. 2.32 million) of Odisha as per 2011 census. It is geographically located between

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dependent variables models, the simulated probabilities of the GHK simulator are unbiased and bound within (0,1) interval and also more efficient in terms of variance of the estimator of probabilities than other simulators like acceptance-rejection and Stern (Cappellari and Jenkins, 2003).

[4] The VIFs range of explanatory variables is from 1.12 to 4.7, which is less than the threshold value as 10.

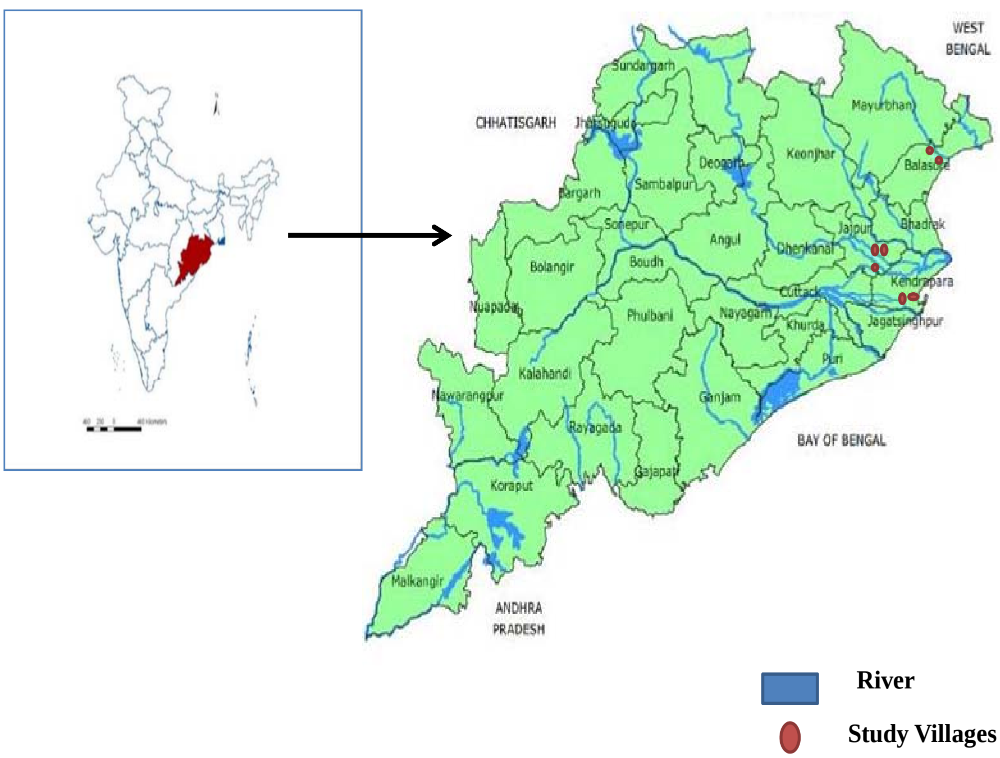
$21^0$03’ and $21^0$59’ north latitude and between $86^0$20’ and $87^0$29’ east latitude. It has a coastal stretch of around 26 km, and this could be a reason for its exposure to cyclone. As per Building Materials and Technology Promotion Council (BMTPC) vulnerability atlas, the total area of Balasore (i.e. 100 percent) is prone to cyclonic storms (BMTPC, 2006). Further, Mohapatra et al. (2012) assert that Balasore in one of the cyclone prone districts in India as it experienced 28 cyclonic storms, including 5 severe cyclonic storms, during 1891-2008. In addition, there are three major rivers, e.g. *Budhabalanga*, *Subarnarekha* and *Kansabansa*, that flow through the state making 46.3 percent of the total area flood prone (BMTPC, 2006).

Kendrapada is one of the central coastal districts of Odisha (Figure 1), which accounts for 1.7 percent (i.e. 2644 Km^2) of the total geographical area and 3.43 percent of the total population (i.e. 1.44 million) of Odisha as per 2011 census. It is geographically located between $20^0$21’ and $20^0$47’ north latitude and between $86^0$14’ and $87^0$83’ east latitude. It has a coastline of 48 km, stretching from *Dhamara* delta to *Batighar*. Most of the coastal regions are situated on the river delta formed by the *Brahmani*, the *Baitarani* and branch rivers of the *Mahanadi* (Behuria, 1996). This is one of the causes of vulnerability of the Kendrapada to cyclone and flood. BMTPC (2006) finds that 100 percent and 35.5 percent of the total area of the district are cyclone and flood prone respectively. Further, Kendrapada is cited as one of the cyclone prone districts in India as it comes across 17 cyclonic storms, including 6 severe cyclonic storms, during 1891-2008 (Mohapatra et al., 2012).

Jajpur is geographically situated next to the coastal districts of Odisha like Kendrapada and Bhadrak (Figure 1), which accounts for 1.8 percent (i.e. 2807.08 Km^2) of the total geographical area and 4.35 percent of the total population (1.83 million) of the state as per 2011 census. It is geographically located between $20^0$30’ and $21^0$10’ north latitude and between $85^0$40’ and $86^0$44’ east latitude. Jajpur is found as one of the cyclone prone districts among the non-coastal districts in India (Mohapatra et al., 2012). It is webbed by a network of rivers, e.g. *Mahanadi* and *Baitarani*; this is the major reason for the susceptibility of the district to flood.

The farm household-level survey was conducted in the randomly selected seven disaster prone villages in these three districts (Figure 1) during November 2010 to March 2011. The study villages were selected based on distance from sea and/ or river. A stratified random sampling method was used to select sample farm households with an aim to cover households representing different categories of land ownership. In doing so, a two step sampling procedure was followed. In the first step, all the households at village-level were stratified into five categories on the basis of land ownership: landless (0 hectare), marginal (< 1 hectares), small (1-2 hectares), medium (2-10 hectares) and large (> 10 hectares). It should be noted that there were no large farmers in the study villages. In the second step, with following a simple random sampling method 10 percent of the farm households has been drawn in proportion to the total households within each 'strata'. Following this, a total of 285 farm households were interviewed.

Figure 1. Map of the Study Region



The dependent variables in the empirical estimation are the choice of adaptation options from the set of measures listed in Table 1. The choice of explanatory variables was based on the review of previous studies (Howden et al., 2007; Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Below et al., 2010; Di Falco et al., 2011 and 2012) and field experience. The explanatory variables include intensity of crop damage due to past cyclones and floods such as high, moderate and low affected; household characteristics such as size of household, years of education of household head (HH), years of farming experience of HH, agriculture as major source of income and per capita income; factors related formal institution such as access to agricultural extension, formal credit, access to MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) and received crop loss compensation, and informal institution such as access to informal credit and received remittances. Table 2 presents the description of the independent variables. Moreover, hypothesis on how the explanatory variables influence adaptation to cyclone and flood are presented below.

In order to capture the influence of cyclone and flood on farmers' adaptive behaviour, the present analysis included variables like intensity of crop damaged due to past cyclones and floods, i.e. high, moderate and low. This helps to explore the adaptation options which are cyclone and/or flood sensitive.

The influence of size of household on adoption behaviour is viewed from two perspectives: (i) the adult members of a large household size could opt off-farm activities in an attempt to earn low risky income to smoothen income and consumption, and (ii) the availability of labour endowment due to large household size can motivate farmers to undertake labour intensive adaptation measures (Deressa, 2010). A positive relationship is expected between size of household and labour intensive adaptation measures, which is also supported by various studies (e.g. Hassan and Nhemachena, 2008; Bryan et al., 2009; Gbetibouo, 2009; Di Falco et al., 2011). Education facilitates access to information on improved technology as well as assimilating the information on agronomic and agro-climatic aspects which could help farmers to undertake suitable adaptation measures. The existing empirical evidence shows a positive correlation between the level of education of HH and adaptation to climate change (Maddison, 2007; Deressa et al., 2009). This study posits a positive relationship between years of education by HH and various adaptation mechanisms.

Maddison (2007) reports that farmers with greater experience in farming are likely to notice impacts of climate change. Since adaptation process involves two steps (i.e. first realising the impacts of climate change and then making an attempt to counteract; Deressa et al., 2009), it is expected that an experienced farmer is likely to notice the impact of cyclone and flood, and undertakes various adaptation measures to counteract such impacts. Climate change studies such as Hassan and Nhemachena (2008), Bryan et al., (2009), Gbetibouo, (2009) and Panda et al., (2013) find a positive relationship between farming experience of HH and climate change adaptation. Based on the field experience, it is anticipated that a farm household with higher level of dependence on agriculture is likely to adopt different adaptation options, because major source of livelihood is at risk due to cyclone and flood. Since adaptation requires sufficient financial wealth, the rich farm households are expected to undertake different adaptation measures. Franzel (1999), Hassan and Nhemachena (2008), and Panda et al. (2013) find a positive correlation between income and adoption potential of farmers.

Table 2: Description of the independent variables

Explanatory Variables	Mean	SD	Description
High affected by cyclones	0.48	0.50	Binary (Yes, no)
Moderate affected by cyclones	0.17	0.37	Binary (Yes, no)
Low affected by cyclones	0.20	0.40	Binary (Yes, no)
High affected by floods	0.26	0.44	Binary (Yes, no)
Moderate affected by floods	0.02	0.13	Binary (Yes, no)
Low affected by floods	0.09	0.29	Binary (Yes, no)
Size of household	5.89	2.52	Numerical
Years of education of HH	1.57	2.70	Numerical
Years of farming experience of HH	24.04	13.16	Numerical
Log (Per capita income)	3.74	0.18	Continuous
Agriculture as major source of income	0.71	0.46	Binary (Yes, no)
Formal agricultural extension	0.17	0.38	Binary (Yes, no)
Formal credit	0.38	0.49	Binary (Yes, no)
Access to MGNREGA	0.48	0.50	Binary (Yes, no)
Received crop loss compensation	0.60	0.49	Binary (Yes, no)
Informal credit	0.84	0.37	Binary (Yes, no)
Remittances received	0.67	0.47	Binary (Yes, no)

Source: computed from primary data

Agricultural extension is expected to be a better source to provide agronomic information in rural Odisha. A few climate change studies find that farmers are getting information on climate change through extension which governs their adaptive behaviour (Deressa et al., 2009; Di Falco et al., 2012). Through extension, the sample farmers are expected to get information about soil conservation techniques, crop diversification, mixed paddy cropping and pest and disease management strategies. This study hypothesises that access to extension increases adoption of different adaptation measures. In addition, a number of studies underline the fact that access to formal credit positively influenced adoption behaviour of the farmer (Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Deressa et al., 2009; Bryan et al., 2009). In this context, Jodha (1981) reports three ways through which formal credit helps farmers to reduce risk: (i) pooling resources into agricultural system to make it less vulnerable (i.e. direct resource transfer to vulnerable regions for irrigation, cyclone and flood resistant crops, soil and moisture conservation devices and improve agronomic practices), (ii) risk/ loss minimising credit, and (iii) loss management credit (i.e. actual payment in cash or kind received by the cyclone and/ or flood affected farmers). While the first and second directly motivate farmers' adaptation decisions, the third has an indirect bearing on their adaptive behaviour.

Quintessentially, the MGNREGA could work as a safety net for the farm households. This could influence farmers' decision on adaptation in two ways: (i) increase overall income of the household that could have a positive impact on adaptation decision, and (ii) construction of rural development projects (e.g. watersheds, flood embankment and sea dyke) to increase the probability of adopting various adaptation measures (see Tiwari et al., 2011). Similarly, receiving compensation for the crop loss is also expected to positively influence farmers' adaptive behavior. For instance, farmers could invest more on adaptation if there is an option to get compensation when the crop is damaged due to the cyclone and flood, which could partially help them to smooth consumption. Previous studies also suggest that the informal institution plays a major role in smoothing both income and consumption through adaptation (Bryan et al., 2009), particularly in the rural areas of developing nations where there is imperfect formal insurance (Morduch, 1999; Dercon, 2002). The variables capture the role of informal institution, such as access to informal credit and received remittance, are likely to have a positive impact on farmers' adaptive behaviour.

5. Results and Discussion

The result of multivariate probit model is presented in Table 3. The results of correlation coefficients of the error terms are significant (based on the t-test statistics) for any pairs of equations. It indicates that there are complementarities (positive correlation) in different adaptation options suggesting interdependence among adaptation measures. Another important point to note is that there are substantial differences in the estimated coefficients across equations that support the appropriateness of differentiating the adaptation options. Based on the joint probability estimation, it is found that probability of taking up all the adaptation measures is 3.9 percent, whereas undertaking none of the option is 1.1 percent. The following summarises results from Table 3.

5.1. Intensity of Cyclones and Floods

The cyclone affected farmers are likely to adopt salt and flood tolerant indigenous paddy seeds, mixed paddy cropping, land holiday, more time seedling and re-planting and pest and disease management. Though other options are available to increase yield (e.g. salt tolerant high yielding variety – HYV – paddy seeds like '*Lunishree*'), farmers are still growing salt tolerant traditional variety of paddy due to lack of awareness about availability (discovery-stage lag) as well as use (evaluation-stage lag). This is mainly because of poor functioning of agricultural extension, e.g. 17 percent of farmers have access to it (Table 2). In addition, farmers prefer to cultivate low investment, less productive crops in order to minimise potential loss due to cyclone; Morduch (1995) calls it an 'income skewing activity'. In a similar tradition, Morduch (1990) finds that poor farmers in India devoted a larger share of land to safer traditional variety of rice than the riskier and high value crops. Dercon (1996) also reports that households with limited liquid asset grow more of low-return, low risk crops such as, sweet potatoes in Tanzania.

In order to minimise risk involved in agriculture, farmers are cultivating different varieties of paddy (i.e. mixed paddy cropping) and also keeping the highly susceptible land as barren (i.e. land holiday). Due to soil salinity and seepage of salt water, there is a high possibility of pests and diseases attacks (Singh and Sasmal, 2004). This affects agricultural crops, and therefore, farmers have to undertake integrated pest and disease management. A negative relationship is found between intensity of cyclone and crop-diversification. Based on the field survey, it is observed that most of the cyclone affected farmers are cultivating only paddy crops due to soil salinity and lack of availability of fresh water. In addition, they are ignorant about crops that can be cultivated in the saline soil with less water requirement. This could be attributed to the poor functioning of extension in the rural Odisha.

The flood affected farm households are likely to adopt salt and flood tolerant indigenous paddy seeds, soil conservation techniques, mixed paddy cropping and crop-diversification. Like cyclone affected farmers, the flood affected farmers also cultivate flood tolerant indigenous paddy to minimise expected crop loss. The agricultural land in the delta region is submerged by saline water (regularly) and by flood water (occasionally). Due to this, there is a high probability of adopting soil conservation techniques in order to protect agricultural land from both soil erosion and salt water intrusion. Further, the flood affected farmers grow different varieties of not only paddy crops (i.e. mixed paddy cropping) but also other crops (i.e. crop-diversification) in order to minimise risks involved in agriculture due to the flood. The farmers, for example, cultivate paddy and jute crops in the *Kharif* season (May to November), and groundnut and cereals in the *Rabi* season (December to March). In addition, high flood affected farmers are likely to adopt more time seedling and re-planting. It is observed that farmers have to repeat the process of seedling or re-planting of paddy crop once the crop is damaged due to the flood, but is dependent on the stage of crop growth. A flood affected farmer is expected to keep his/ her land as barren during the *Kharif* season in order to minimise potential crop loss due to the flood. However, a negative relationship is found in the case of high flood affected and moderate flood affected; because, the cost of making a barren land ready for *Rabi* crop cultivation (e.g. removing grass from the land) is higher than the cultivated land where they practice low investment less productivity crops, e.g. traditional varieties paddy crops. Similarly, the flood affected intensity variables are negatively associated with the options like pest and disease management.

In between cyclone or flood affected farmers, a different adoption behaviour is observed in the context of four adaptation measures, namely, soil conservation techniques, crop-diversification, land holiday and pest and disease management. While soil conservation techniques and crop-diversification are flood sensitive, land holiday and pest and disease management are cyclone sensitive adaptation mechanisms. It means the remaining three adaptation measures, namely, salt and flood tolerant indigenous paddy seeds, mixed paddy cropping and more time seedling and re-planting, are common among cyclone and/ or flood affected farm households.

5.2. Household Characteristics

Increase in the size of household enhances the probability of adopting soil conservation techniques, more time seedling and re-planting and pest and disease management. As soil conservation techniques and more time seedling and re-planting are labour intensive, farm households with larger members are likely to adopt these options. Due to lack of liquidity and high labour cost especially during the cultivation period, it is difficult for the farm households to adopt particularly more time seedling and re-planting strategies without the support of household members. In addition, these mechanisms need financial support, and therefore, large farm households can adopt these measures as the adult members can opt for off-farm employment in order to provide financial support. It can be inferred that the larger the size of the household, better the chance of adopting these measures.

Table 3 Determinants of farm-level adaptation measures

	Salt and flood tolerant indigenous seeds	Soil conservation techniques	Mixed paddy cropping	Crop diversification	Land holiday	More time seedling and re-planting	Pest and disease management
High affected by cyclones	2.251***	0.259	1.479***	-1.581***	1.786***	2.092***	1.752***
	(0.389)	(0.380)	(0.378)	(0.454)	(0.387)	(0.420)	(0.368)
Moderate affected by cyclones	1.393***	-0.474	1.130***	0.222	0.219	1.536***	0.635*
	(0.365)	(0.366)	(0.346)	(0.423)	(0.331)	(0.401)	(0.366)
Low affected by cyclones	1.123***	-0.554	0.887**	0.300	-0.298	0.874**	0.511
	(0.366)	(0.368)	(0.358)	(0.404)	(0.312)	(0.368)	(0.319)
High affected by floods	1.392***	0.396	1.238***	1.666***	-0.404	1.007***	-0.205
	(0.325)	(0.331)	(0.304)	(0.309)	(0.293)	(0.334)	(0.301)
Moderate affected by floods	1.457**	0.241	0.691	0.471	-0.257	-1.067	-2.38***
	(0.697)	(0.619)	(0.838)	(0.685)	(0.699)	(0.675)	(0.532)
Low affected by floods	0.805**	0.542*	-0.094	0.216	1.809***	-0.157	-1.309***
	(0.361)	(0.308)	(0.280)	(0.354)	(0.426)	(0.350)	(0.310)
Size of Household	0.008	0.077**	-0.027	0.077	0.026	0.158***	0.127**
	(0.038)	(0.039)	(0.041)	(0.050)	(0.036)	(0.053)	(0.052)
Years of education of HH	-0.058*	0.026	0.048	0.051	-0.054	-0.036	-0.005
	(0.034)	(0.034)	(0.038)	(0.039)	(0.033)	(0.034)	(0.036)
Farming experience years of HH	0.004	0.005	0.008	0.031***	0.001	0.001	-0.008
	(0.007)	(0.007)	(0.007)	(0.011)	(0.008)	(0.009)	(0.008)
Log(Per capita income)	0.198	1.771***	-0.158	1.531**	-0.820	2.893***	2.054***
	(0.509)	(0.546)	(0.543)	(0.687)	(0.564)	(0.701)	(0.648)
Agriculture as major source of income	-0.313*	0.216	0.002	0.814***	-0.069	0.291	0.041
	(0.19)	(0.192)	(0.186)	(0.312)	(0.248)	(0.207)	(0.223)
Formal agricultural extension	-0.021	-0.567**	0.188	0.287	-0.444*	0.529*	-0.182
	(0.249)	(0.234)	(0.225)	(0.356)	(0.240)	(0.295)	(0.272)

Formal credit	-0.037	0.040	0.202	-0.015	0.221	0.045	0.267
	(0.193)	(0.208)	(0.201)	(0.242)	(0.228)	(0.262)	(0.215)
Access to MGNREGA	0.321*	0.295	0.310*	-0.514**	-0.268	0.044	0.440**
	(0.181)	(0.182)	(0.179)	(0.234)	(0.213)	(0.206)	(0.211)
Received crop loss compensation	-0.035	0.050	0.747***	1.964***	-0.072	0.264	0.135
	(0.208)	(0.203)	(0.206)	(0.362)	(0.259)	(0.271)	(0.217)
Informal credit	0.579**	-0.105	0.130	-0.477*	-0.246	0.459*	-0.097
	(0.254)	(0.246)	(0.248)	(0.271)	(0.260)	(0.246)	(0.256)
Received remittances	0.129	0.229	-0.292	-0.529**	0.576***	-0.094	0.076
	(0.190)	(0.196)	(0.189)	(0.250)	(0.220)	(0.208)	(0.201)
Constant	-2.774	-8.192***	-1.335	-8.379***	3.131	-13.130***	-8.615***
	(1.963)	(2.156)	(2.126)	(2.573)	(2.134)	(2.781)	(2.529)
	Rho1	Rho2	Rho3	Rho4	Rho5	Rho6	
Rho2	0.330***						
Rho3	-0.244***	0.244**					
Rho4	-0.365***	-0.227	0.302**				
Rho5	0.483***	0.352***	0.106	-0.693***			
Rho6	-0.085	0.145	0.471***	0.168	0.196*		
Rho7	-0.093	0.254**	0.226*	0.024	0.141	0.536***	
No. of observations				285			
Log likelihood				-793.802			
$\Pr\left(y_h = 1, \text{for all } h = 1, \ldots, 7\right)$				0.039			
$\Pr\left(y_h = 0, \text{for all } h = 1, \ldots, 7\right)$				0.011			

Source: Computed from primary data

Note: i) Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = rho54 = rho64 = rho74 = rho84 = rho65 = rho75 = rho85 = rho76 = rho86 = rho87 = 0: $chi^2(28)$ = 118.286, Prob. > chi^2 = 0.0000

ii) Figures in the parentheses are robust standard error

iii) *** p<0.01, ** p<0.05 and * p<0.1 respectively

With respect to farming experience, it is observed that experience increases the possibility of taking up crop-diversification. As experienced farmers have more knowledge, avenues for knowledge sharing and farmer-to-farmer interactions can lead to the increase in the use of various adaptation measures as also found by Nhemachena and Hassan (2007) for Africa. Since adaptation requires financial resources, richer farm households have a higher probability of undertaking adaptation measures. The influence of log per capita income is positive and also statistically significant on soil conservation techniques, crop diversification, more time seedling and re-planting and pest and disease management. In tune with this, Deressa et al. (2009) find that farm income increases the probability of farmers adopting soil conservation, using different crop varieties and changing planting dates, in Africa. Panda et al. (2013) report that total income enhances the possibility of adopting early maturing rice varieties and shift from rice to cotton among the drought prone farmers in Odisha. The farm households whose major share of income is derived from agriculture have a higher chance of adopting crop-diversification to counteract flood loss. When the main source of income is from farming and the amount of land for farming is limited, farmers tend to invest on crop-diversification in order to increase farm income.

5.3. Access to Formal and Informal Institutions

Access to agricultural extension increases the likelihood of taking up more-time seedling and replanting, and reduces the probability of adopting land holiday. Farmers who have extension contacts are more aware about various agricultural production and management practices which they can use to adapt to cyclone and/ or flood. In particular, they get information about different varieties of HYV paddy seeds, which can sustain salinity and water logging, by giving higher yields. Such information helps farmers to reduce the possibility of keeping land barren. These farmers have also easy access to jute, paddy and groundnut seeds, which help them to practice more time seedling and re-planting. In view of this, improving access to extension services has the potential to increase awareness among the farmers about different farm-level adaptation practices.

Access to MGNREGA in rural areas has significant potential for promoting options like salt and flood tolerant indigenous paddy seeds, mixed paddy cropping and pest and disease management. Employed in MGNREGA during off season increases income of the farm households, and particularly assists the poor farmers to diversify their income. Different development based activities (e.g. fresh water dam, sea dyke, and flood embankment) are constructed through MGNREGA, which reduces seepage of salt and water logging in the agricultural land. Therefore, farmers are able to cultivate different varieties of paddy crops instead of depending on a single variety. This underlines the fact that the government should promote various development based activities, especially related to agriculture, in the rural villages in order to increase farm-level adaptation measures (Tiwari et al., 2011). The coefficients of received crop loss compensation are positively associated with two options namely, mixed paddy cropping and crop-diversification.

Better access to informal credit increases the likelihood of undertaking salt and flood tolerant indigenous paddy seeds and more time seedling and re-planting. Bryan et al. (2009) find that informal institutions and social relationship facilitate adaptation to climate change. In order to undertake re-seedling and re-planting of paddy crops, farmers require immediate financial resources which necessitate the role of informal credit. The coefficient of received remittances is statistically significant in the case of crop-diversification and land holiday. While this is negatively associated with crop-diversification, a positive relationship is observed in the case of land holiday. The receipt of remittances has allowed the farm households to divert their resources for non-farm activities and harvesting only for self consumption.

6. Conclusions and Policy Implications

This study analysed the factors affecting choice of farm-level adaptation options to cyclone and flood based on a cross-sectional survey data collected during 2010/2011 production season in the cyclone and flood prone region of Odisha. The adaptation measures undertaken by the sampled farmers are salt and flood tolerant indigenous/ traditional paddy seeds, soil conservation techniques, mixed paddy cropping, crop-diversification, land holiday, more time seedling and re-planting and pest and disease management. A multivariate probit model was employed to explore the determinants of adaptation measures.

From the econometric analysis, the following salient points emerge. The cyclone experienced farmers are likely to adopt salt and flood tolerant indigenous paddy seeds, mixed paddy cropping, land holiday, more time seedling and re-planting and pest and disease management. The flood affected farmers prefer to adopt salt and flood tolerant indigenous paddy seeds, soil conservation techniques, mixed paddy cropping and crop diversification. Between the cyclone and flood affected farmers, differential adoption behaviour is observed in the case of four adaptation options. While soil conservation techniques and crop diversification are flood sensitive, land holiday and pest and disease management are cyclone sensitive adaptation options. The remaining three adaptation measures are both cyclone and flood sensitive. Factors like size of household, per capita income, access to agricultural extension, access to MGNREGA, received crop loss compensation and informal credit are some of the other major determinants of farm-level adaptation options. Households with more access to the above factors are likely to take up more number of adaptation measures.

The focus of policy makers should be to design policies that facilitate adoption of different adaptation measures by the farm households. In fact, some of the determinants of adaptation measures, namely, access to MGNREGA, formal credit, agronomic and agro-climatic information can be addressed as part of rural development programme. This asserts the non-necessity of formulating a separate climate change specific adaptation policy different from other rural development and poverty alleviation programme to buffer against the impacts of climatic risks. It is, therefore, imperative to restructure the existing development programme with including climate specific response measures, e.g. distribution of flood and salt tolerant seeds and raise awareness among the farmers regarding climatic risks so that farmers can buffer a wide range of risk and shocks. In addition, more resources need to be deployed to promote agricultural research, develop salt tolerant crops, and more importantly to strengthen the existing farm extension management to disseminate such information among farmers in the cyclone and flood prone regions of Odisha.

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