GIDR WORKING PAPER SERIES
No. 219 : December 2013

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Working Paper No. 219

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Abstracts of all GIDR Working Papers are available on the Institute's website. Working Paper No 121 onwards can be downloaded from the site.

First Published	December 2013
ISBN	81-89023-77-2
Price	Rs. 40.00

Abstract

A large number of rural households in the state of Odisha, India are dependent on agriculture for their basic livelihoods, which is affected by the frequent occurrence of climate externalities like cyclones and floods. In response, the farm households do also undertake adaptation measures to minimise the economic impact of these externalities. It is, imperative to analyse the current adaptation strategies of the farm households so that future adaptation policies aimed at scaling up adaptation strategies can be designed effectively. Using a survey data of 285 farm households in the cyclone and/or flood prone districts of Odisha, the present study identifies the farm-level adaptation measures as well the determinants of these measures: agricultural extension, access to Mahatma Gandhi National Rural Employment Guarantee scheme, received crop loss compensation and informal credit. It is concluded that the government adaptation policies and investment options should take into account these determinants in order to enhance the adaptive capacity of the rural farmers in the cyclone and flood prone regions of the state.

Keywords : Climate Externalities, Farm-Level Adaptation Options, Determinants, Adaptation Policy, Odisha

JEL Classification : Q12, Q15, Q54

Acknowledgements

An earlier version of the paper was presented at the GIDR faculty Seminar and the Indian Society for Ecological Economics (INSEE) conference on 'Global change, Ecosystems, Sustainability', Tezpur, India, December 2013. We are grateful to K.S. Kavi Kumar, Unmesh Patnaik, Patrick S. Ward, Rudra N. Mishra, P. P. Sahu and Sunil Nautiyal for comments on an earlier draft, in addition to participants of the conferences. Usual disclaimers apply.

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Determinants of Farm-level Adaptation Practices to Climate Extremes: A Case Study from Odisha, India

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1. Introduction

A large number of scientific studies assert that the impacts from climate externalities such as cyclones, floods and droughts are increasing over the years, and also expected to rise in the foreseeable future due to climate change, particularly in the developing nations (Intergovernmental Panel on Climate Change, hereafter, IPCC, 2012). The amount of loss due to such events, for instance, was about 1 per cent of the Gross Domestic Product (GDP) for middle income nations during 2001-06, whereas it is around 0.3 per cent for low income nations and less than 0.1 per cent for high income nations (IPCC, 2012). Further, the average direct losses incurred by the developing nations due to natural disasters during the 1990s (i.e., US$ 35 billion) were eight times higher in comparison to the respective figure in the 1960s (Mirza, 2003). With regards to India, Bahinipati *et al.* (2015) report that the total economic damages due to natural disasters were US$ 55.62 billion during the period 1964-2012, which converts into an average of US$ 1.14 billion per annum during the same period; floods inflicted a total damage cost of US$ 36.05 billion, and around US$ 11.43 billion was due to cyclonic storms. It is also estimated that the direct losses from natural disasters are up to 2% of India's GDP (Padmanabhan, 2012). It is observed that the impacts of these events are relatively higher on the agricultural sector, particularly in India (Bhattacharya and Das, 2007; Rao, 2010). For instance, an average of 3.79 million ha crop area was damaged due to floods over a period of time spanning six decades (i.e., 1953-2011) in India, which converts into an economic loss of Rs. 11.19 billion per year[1]. Since a large

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[1] These information have been gathered from 'State-wise Flood Damage Statistics' provided by Central Water Commission, Government of India, New Delhi, Vide Letter No. 3/38/2011-FFM/2200-2291 dated: 27th November 2012.

number of households in the country depend on agriculture for their basic livelihood (54.6% of labour force as of 2011 Census), it is imperative to promote farm-level adaptation options to mitigate expected crop loss due to climate extremes. Moreover, it has been observed that farmers in India are already adapting to past climate extremes (Jodha, 1991; Roy *et al.*, 2002; Mwinjaka *et al.*, 2010; Jodha *et al.*, 2012; Panda *et al.*, 2013; Bahinipati, 2014a), and the ability to adapt differs from farmer to farmer. Hence, knowledge of present adaptation practices and factors influencing farmers' decision to adapt will have policy implications in the context of successful implementation of adaptation mechanisms in the disaster prone regions of India.

A number of studies have investigated farmers' adaptive behaviour to climate change in the context of Africa, Latin America, China and South Asia. Among these studies, Maddison (2007), Bryan *et al.* (2009), Deressa (2010), Deressa *et al.* (2011) and Di Falco *et al.* (2011, 2012) investigate factors influencing famers' decision to adapt or not to adapt. However, farmers have been taking up various adaptation measures, which are either mutually exclusive or inclusive. Taking such factors into account, Panda *et al.* (2013) examine determinants of various adaptation options to drought in India while treating these measures as independent; note, however, that the options undertaken by this study (e.g., water conservation, shift from rice to cotton, change of planting dates, income diversification, etc.) may not be mutually exclusive. Similarly, Wood *et al.* (2014) investigate the influence of three key potential factors on farm households' decision to adapt across Africa and South Asia, e.g., weather information, household and agricultural production related assets, and participation in local social institutions. On the other hand, a few studies also examine the factors determining choosing of options over an option which is kept as a baseline (Hisali *et al.*, 2011; Gebrehiwot and van der Veen, 2013). However, these studies did not take into account the relationship between various not mutually exclusive adaptation mechanisms. Considering the complementarities and substitutability relationship among different not mutually exclusive options, Nhemachena and Hassan (2007) and Piya *et al.* (2013) identify factors influencing different adaptation mechanisms in three countries of Southern Africa (South Africa, Zambia and Zimbabwe) and Chepang, Nepal, respectively. When the choices are mutually exclusive, the studies identify factors influencing choice of an adaptation measure over no adaptation (Kurukulasuriya and Mendelsohn, 2007; Seo and Mendelsohn, 2008; Hassan and Nhemachena, 2008; Gbetibouo, 2009; Deressa *et al.*, 2009; Wang *et al.*, 2010). Further, Bahinipati (2014a) assesses farmers' adaptive behaviour to farm-level adaptation diversity (i.e., number of adaptation options undertaken by the farmers) in eastern India. To the best of our knowledge, no studies have so far examined this in the context of India (studies by Panda *et al.*, 2013 and Bahinipati, 2014a are noteworthy exceptions), particularly with reference to climate extremes.

Therefore, this study aims to identify determinants of farm-level adaptation options to climate extremes. The empirical analysis followed in the present study assumes that the set of adaptation measures undertaken by the farmers are the most effective ones – however, assessment of the benefit of each as well as group of adaptation options is beyond the scope of the present study[2]. For empirical assessment, the state of Odisha, India is taken as a case study – it is a state not only prone to climate extremes like cyclones and floods (Bhatta, 1997; Chittibabu *et al.*, 2004; Government of Odisha, hereafter, GoO, 2004, 2011; Patnaik *et al.*, 2013; Bahinipati, 2014b; Bahinipati and Patnaik, 2015) but also its majority of households depend on agriculture for their basic livelihood (61.48% of labour force as of 2011 Census). The findings of this study could help the policy makers to influence farmers to enhance farm-level adaptation mechanisms in the disaster prone regions of India.

2. Perceived Farm-level Adaptation Strategies to Cyclone and Flood in Odisha

Based on the cross-sectional survey data collected from 285 farm households during the 2010–11 production season in the cyclone and flood prone districts of Odisha, this section briefly summarises the farm-level adaptation measures which the surveyed farmers consider appropriate to cope with cyclones and floods. The detailed description on the sampling technique is given in section 4.

The farmers were particularly asked to report the farm-level adaptation measures which they have been undertaking to mitigate impact from the previous cyclones and floods. The farmers reported various adaptation

[2] For benefits of various adaptation options, see Di Falco *et al.* (2011) and Di Falco and Veronesi (2013, 2014).

options, but the present study has selected seven widely practised farm-level adaptation measures for empirical analysis. These are: salt and flood tolerant indigenous/traditional paddy seeds[3], soil conservation techniques[4], mixed paddy cropping[5], crop-diversification[6], land holiday[7], re-cultivation of seedling and re-planting[8], and pest and disease management[9] (see Figure 1). These options are not mutually exclusive. Among them, five measures are chosen by more than half of the farmers, e.g., re-cultivation of seedling and replanting (78%), land holiday (71%), pest and disease management (71%), salt and flood tolerant indigenous paddy seeds (65%) and mixed paddy cropping (57%). While 42 per cent of the farmers practise crop

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[3] As per the surveyed farmers, traditional paddy seeds, like *Patani*, *Raspanjar*, *Bhaluki*, *Padma*, etc. are salt tolerant, and *Katakal*, *Kakharua*, *Ashu*, *Bhundi*, etc. are flood tolerant; they are cultivating these varieties to reduce expected crop loss (see Roy *et al.*, 2002).

[4] Includes activities like reducing salinity level of soil through using 'gypsum' and more tillage operation, and enhancing height of field bund to protect intrusion of salt water and also to reduce soil.

[5] Farmers are growing different varieties of paddy seeds (high yielding varieties/traditional/mix of both) because some varieties of paddy may survive with cyclones and floods (see Walker and Jodha, 1986).

[6] In the *kharif* season, farmers are diverting a chunk of land, largely in the high flood prone areas, for the cultivation of jute crop, which is not only a low invested crop (income skewing activity – see Morduch, 1995) but also survives water logging due to floods.

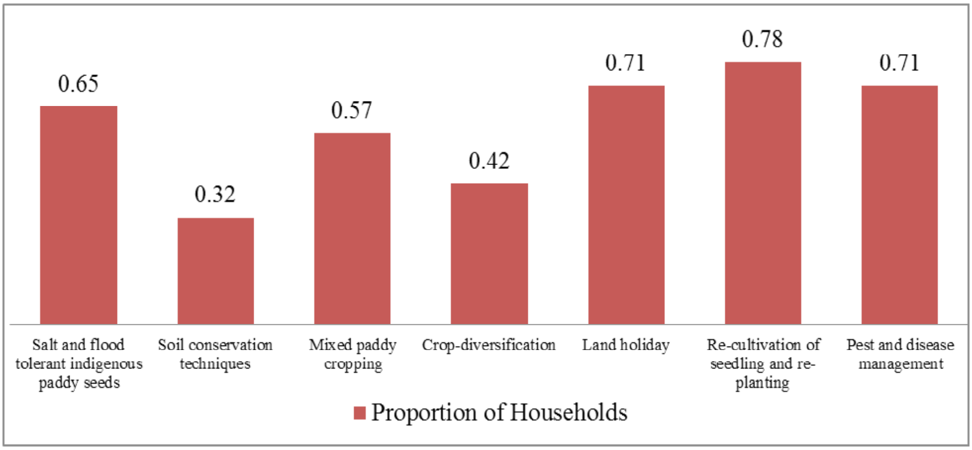
[7] Farmers in general keep their susceptible land as barren to avoid expected crop loss due to cyclones and floods.

[8] While paddy crop gets damaged due to cyclone and flood, the farmers resort to seedling preparation and re-planting based on the stage of crop growth. In the earlier stage (i.e. germination and transplanting), farmers go for re-cultivation of seedling. They purchase seedlings from farmers in the neighbouring villages for re-panting in the case of middle stage (i.e. tillering and panicle stages). They leave their land barren in case the crop has reached maturity stage (i.e. milk stage, dough stage and mature grain stage – harvesting stage).

[9] The level of salinity in soil has increased due to salt water intrusion. As a result, there is a high possibility of the occurrence of insects and pests like stem borer, gall midge and leaf folder; diseases like sheath rot and bacterial leaf blight; and weeds like wild rice, *Echinocloa spp.*, *Cyperus spp.* and *Schemoplectus spp.* (Singh and Sasmal, 2004). On the other hand, the wet period also increases the possibility of fungal and bacterial diseases (Padgham, 2009).

diversification, soil conservation techniques have been adopted by 32 per cent (see Figure 1).

Figure 1: Frequency of Adaptation Options



Source: Based on primary data.

3. Empirical Approach

Following 'agriculture technology adoption' literature (see Feder *et al.*, 1985), a farm household selects a combination of adaptation measures to maximise his/her expected profit at the end of the 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 the 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):

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

Where, A_h represents adaptation strategies that farm household h adopted to withstand against the cyclones and floods. A households' preference for adaptation measures depends on a vector of household/household head 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 present analysis are not mutually exclusive, and hence, a multivariate probit model (MVP) is found to be appropriate (Nhemachena and Hassan, 2007; Piya *et al.*, 2013). 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 (Nhemachena and Hassan, 2007). 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 MVP model. Following Nhemachena and Hassan (2007), the MVP 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 $R = \left[\hat{\rho}_{hj}\right]$ 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

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

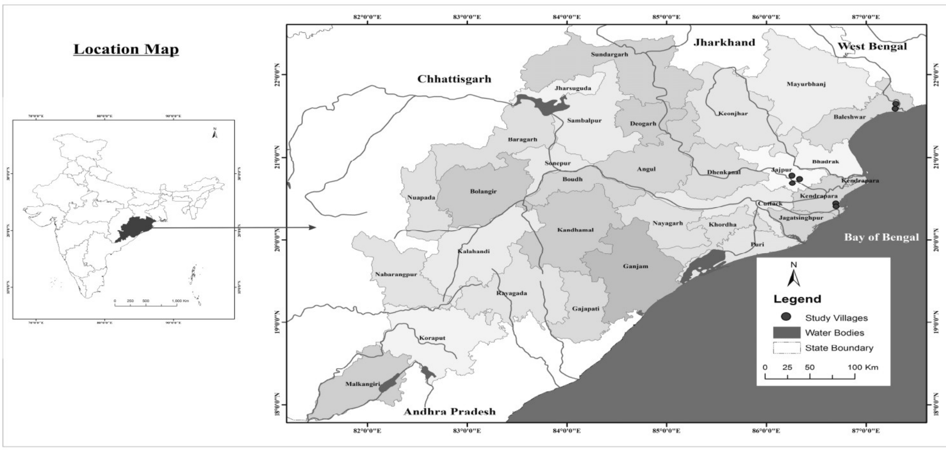
$$de_1 \ldots de_2 de_1 \cdots\cdots (4)$$

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 the estimation process outlined by Cappellari and Jenkins (2003) in order to implement the MVP model using the method of simulated maximum likelihood – also known as the Geweke-Hajivassiliou-Keane (GHK) stimulator. The cross-section econometric analysis is associated with the problem of multicollinearity and heteroskedasticity. A variance inflation factor (VIF) for each of the explanatory variables was estimated to check multicollinearity, and a robust standard error was calculated to address the possibility of heteroskedasticity (Wooldridge, 2002). The VIF value for all the independent variables is below 10 (i.e., in between 1.12 to 4.7), suggesting no problems of multicollinearity. The information was gathered at the household-level and not at the 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 30 districts, is geographically situated at the head of the Bay of Bengal and has a coastal stretch of around 480 km (Figure 2). In addition, a number of perennial rivers, e.g., *Mahanadi*, *Brahmani*, *Baitarani*, *Rushikulya*, *Birupa*, *Budhabalanga*, *Subarnarekha*, etc. and their tributaries pass through Odisha, making the state prone to flooding. The state experiences cyclones and floods for 126 years over the two centuries spanning between 1804 and 2010 (Bhatta, 1997; Chittibabu *et al.*, 2004; GoO, 2004, 2011), and particularly, floods have occurred for nine consecutive years between 2001 and 2010 (GoO, 2011). A majority of cyclones and floods have occurred during the monsoon season, (i.e., June to September: India Meteorological Department, hereafter, IMD, 2008; GoO, 2004, 2011; Bahinipati, 2014b), and therefore, it is the *kharif* crops (May to November) that are mainly affected which comprise 65-70 per cent of the total gross cropped area (GCA). The previous studies report that the frequency and intensity of these events have increased in the recent years in the state (Roy *et al.*, 2002; Mohanty *et al.*, 2008; Pasupalak, 2010; Guhathakurta *et al.*, 2012; Bahinipati and Venkatachalam, 2014; Bahinipati and Patnaik, 2015). Out of the 30 districts in the state, at least 15 districts were affected 10 times by the cyclones and floods during the period 1995-2010 (GoO, 2011). Further, Mohapatra *et al.* (2012) find that 14 districts of Odisha are prone to cyclonic storms. This indicates that not only does the state experience frequent cyclones and floods but also the majority of its districts are regularly affected by these extreme events. An estimate by the GoO reveals that the extreme events (i.e., cyclone, flood and drought) inflicted an economic loss of Rs. 1.05 billion during the 1970s, which increased to Rs. 6.82 billion, Rs. 70.81 billion and Rs. 105.04 billion during the 1980s, 1990s and 2000s, respectively (*c.f.* Bahinipati and Venkatachalam, 2014). A report published by OSDMA (Odisha State Disaster Management Authority) highlights that the average financial loss per annum was to the tune of Rs. 12.42 billion between 1970 and 2007 (Sulagna and Poyyamoli, 2010). Looking at the impact on the agriculture sector, it has been found that an average of 0.33 million ha agricultural land was damaged in the state, which converts into an economic loss of Rs. 0.32 billion due to floods between 1953 and 2011 (see footnote 1).

Figure 2: Map of the Study Region



Within the state, three cyclone and flood prone districts, namely Balasore, Kendrapada and Jajpur, were selected to conduct a household level survey. These districts have witnessed at least 20 cyclones and floods during the period 1994-2010, and among them, the Balasore district especially has experienced a higher number of these events, i.e., 30 (GoO, 2011). Further, a recent study by Bahinipati (2014b) finds that these districts are relatively more vulnerable to cyclones and floods as compared to the other districts of the state. Mohapatra *et al.* (2012) also assert that these districts are prone to cyclonic storms.

Balasore is one of the north-eastern coastal districts of Odisha (Figure 2), which accounts for 2.44 per cent (i.e., 3806 Km^2) of the total geographical area (TGA) and 5.53 per cent of the total population (i.e., 2.32 million) of Odisha as per the 2011 census. It is geographically located between 21^003' and 21°59' north latitude and between 86°20' and 87°29' east latitude. It has a coastal stretch of around 26 km. As per Building Materials and Technology Promotion Council (BMTPC) vulnerability atlas, the total area of this district is prone to cyclonic storms (BMTPC, 2006). Mohapatra *et al.* (2012) report that during the period 1891–2008, the district has experienced 28 cyclonic storms, including 5 severe cyclonic storms. In addition, there are three major rivers, e.g., Budhabalanga, Subarnarekha and Kansabansa, which flow through the district, making 46.3 per cent of the total area flood prone (BMTPC, 2006). During the period 1994-2008, an average of 0.95 million people were affected and 0.07 million ha land was damaged due to cyclones and floods (see Appendix 1).

Kendrapada is one of the central coastal districts of Odisha (Figure 2), which accounts for 1.7 per cent (i.e., 2644 Km^2) of the TGA and 3.43 per cent of the total population (i.e., 1.44 million) of Odisha as per the 2011 census. It is geographically located between 20°21' and 20°47' north latitude and between 86°14' and 87°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). BMTPC (2006) finds that 100 per cent and 35.5 per cent of the district's total area are prone to cyclonic storms and floods, respectively. This district already experienced 17 cyclonic storms, including 6 severe cyclonic storms, during the period 1891-2008 (Mohapatra et al., 2012). Between 1994 and 2008, an average of 0.82 million people were affected and 0.05 million ha land was damaged due to cyclones and floods (see Appendix 2).

Jajpur is geographically situated next to the coastal districts of the state like Kendrapada and Bhadrak (Figure 2), which accounts for 1.8 per cent (i.e., 2807.08 Km^2) of the total geographical area and 4.35 per cent of the state's total population (i.e., 1.83 million) as of the 2011 census. It is geographically located between 20°30' and 21°10' north latitude and between 85°40' and 86°44' east latitude. Jajpur is found to be 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., tributaries of the Mahanadi and Baitarani; this is the major reason for the susceptibility of this district to floods. During the period 1994-2008, an average of 0.63 million people were affected and 0.05 million ha land was damaged due to cyclones and floods (see Appendix 3).

The farm household-level survey was conducted in randomly selected seven disaster prone villages, namely, Dagara, Kudmansingh, Bhateni, Suniti, Rajapur, Fulupur and Bandhapada, in these three vulnerable districts (see Figure 2) between November 2010 and March 2011. Prior to the start of fieldwork, it was assumed that those villages situated nearer to the sea and river, were likely to be more vulnerable than the other villages in these districts. Therefore, the study villages were selected based on the distance from sea and/or river, and on agriculture being a basic source of income for a majority of the households in those villages. A stratified random sampling method was used to select farm households with an aim to cover households representing different categories of land ownership. In doing so, a two-step sampling procedure was followed. Firstly, all the households at village-level were stratified into five categories on the basis of land ownership: landless (0 ha), marginal (< 1 ha), small (1-2 ha), medium (2-10 ha) and large (> 10 ha). Secondly, following a simple random sampling method, 10 per cent of the farm households were selected in proportion to the total households within each stratum. In total, 285 farm households were interviewed (see Appendix 4 for socio-economic characteristics of the sample households). To answer the research question, we developed a structured questionnaire that contained household-level information, module on climate risks and farm-level adaptation strategies used by the farm households to cope with cyclones and floods.

The dependent variables in the empirical estimation are the choice of adaptation options from the set of measures shown in Figure 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, 2012; Panda *et al.*, 2013) and field experience. Table 1 presents the description of the independent variables. The rationale for the hypothesis on how the explanatory variables influence farmers' behaviour to undertake farm-level adaptations to cyclones and floods is 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 and classified them in a three-fold manner, i.e., highly, moderately and less[10]. This helps to explore the adaptation options which are cyclone and/or flood sensitive. The variables representing household and household head (HH) characteristics are: size of the household, years of education of the HH, years of farming experience of the HH, agriculture as major source of income and per capita income. There are two ways in which size of household influences farmers' adoption behaviour-the adult members could opt for off-farm activities to enhance income of the household, and the required amount of labour for adopting labour intensive adaptation measures like re-cultivation of seedling and re-planting could be met through the availability of labour endowment (Deressa, 2010). Hence, a positive relationship is expected between the size of the 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; Bahinipati, 2014a). Education facilitates access to information on improved technology as well as in 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 the HH and adaptation to climate change (Maddison, 2007; Deressa *et al.*, 2009). The present study, therefore, anticipates a positive relationship between years of education of the HH and various farm-level adaptation mechanisms.

[10] Less affected means crop damaged less than half of the times of occurrence of cyclones and floods during the last decade, moderately affected implies crop damaged around half of the times, and highly affected means crop damaged more than half of the times.

Table 1: Description of the Independent Variables

Explanatory Variables	Mean	SD	Description
Highly affected by cyclones	0.48	0.50	Binary (Yes, no)
Moderately affected by cyclones	0.17	0.37	Binary (Yes, no)
Less affected by cyclones	0.20	0.40	Binary (Yes, no)
Highly affected by floods	0.26	0.44	Binary (Yes, no)
Moderately affected by floods	0.02	0.13	Binary (Yes, no)
Less affected by floods	0.09	0.29	Binary (Yes, no)
Size of household	5.89	2.52	Numerical
Years of education of the HH	1.57	2.70	Numerical
Years of farming experience of the 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 MGNREGS	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.

Maddison (2007) reports that farmers with greater experience in farming are likely to notice impacts of climate change. The process of undertaking adaptation involves two steps, i.e., first, realising the impact of climate change and then making an attempt to counteract (Deressa *et al.*, 2009). The present study, therefore, anticipates that an experienced farmer is likely to notice the impacts of cyclones and floods, and then undertake various adaptation measures. Climate change studies such as Hassan and Nhemachena (2008), Bryan *et al.* (2009), Gbetibouo (2009), Panda *et al.* (2013) and Bahinipati (2014a) find a positive relationship between farming experience of the HH and adaptation mechanisms. Based on the field experience, it is observed that a highly agriculture-dependent farm household is likely to adopt different adaptation options to reduce variation in agricultural income and to smooth consumption. It is well known that financial resources are required to adopt various adaptation options, and hence, a rich farm household is expected to undertake a greater number of farm-level adaptation mechanisms, which is also supported by various studies (Franzel, 1999; Hassan and Nhemachena, 2008; Panda *et al.*, 2013; Bahinipati, 2014a).

The factors representing formal and informal institutions are: access to agricultural extension, formal credit, access to MGNREGS (Mahatma Gandhi National Rural Employment Guarantee Scheme), received compensation for crop loss, access to informal credit and received remittances. Agricultural extension is expected to be a better source in providing agronomic information in rural Odisha. A few climate change studies assert that farmers are getting information on climate change through extension which governs their adaptive behaviour (Patt *et al.*, 2005; Deressa *et al.*, 2009; Di Falco *et al.*, 2011, 2012). For instance, Patt *et al* (2005) establish that seasonal climate forecast information improved harvest decision of subsistence farmers in Zimbabwe. This study, henceforth, anticipates that access to extension increases adoption of different farm-level adaptation measures. Based on the previous studies, it is well known that access to formal credit and received compensation on crop loss motivate farmers to adapt (Jodha, 1981; Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Deressa *et al.*, 2009; Bryan *et al.*, 2009; Di Falco *et al.*, 2011; Bahinipati, 2014a). Jodha (1981), for instance, outlines three ways through which credit helps farmers to reduce risk: (i) pooling resources into the agricultural system to make it less vulnerable (i.e., direct resource transfer to vulnerable regions for irrigation, cyclone and flood resistant crops, and soil and moisture conservation devices), (ii) risk/loss minimising credit (i.e., crop insurance), and (iii) loss management credit (i.e., actual payment in cash or kind received by the cyclone and flood affected farmers). While the first and second directly motivate farmers' adaptation decisions, the third has an indirect bearing on their adaptive behaviour.

The access to MGNREGS 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; Esteves *et al.*, 2013). Particularly in the developing nation context, it is found that informal institutions play a major role in smoothening both income and consumption (Bryan *et al.*, 2009) since there is an imperfect formal insurance (Morduch, 1999; Dercon, 2002). The variables capturing 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 MVP model is presented in Table 2. The likelihood ratio test for the null hypothesis of the absence of correlation between the individual equations is strongly rejected (P=0.0000), thus validating the estimation of all equations simultaneously by the MVP instead of individual equations. The correlation coefficients of the error terms are significant (based on the t-test statistics) for any pairs of equations which indicates that there are complementarities (positive correlation) and substitutability (negative correlation) among different adaptation options. 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 3.8 per cent, whereas undertaking none of the options is 1.4 per cent. This underlines the fact that a large number of farmers are taking up at least one option, whereas there is less likelihood for taking up all the adaptation measures.

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, re-cultivation of 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 a lack of awareness about its availability (discovery-stage lag) as well as use (evaluation-stage lag). This is mainly because of poor functioning of agricultural extension, e.g., only 17 per cent of farmers have access to it (see Table 1). In addition, farmers prefer to cultivate low investment, less productive crops in order to minimise potential loss due to cyclones; Morduch (1995) calls it as '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 assets grow more of the 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). However, a negative relationship has been found between intensity of cyclone and crop-diversification. It seems that farmers that are affected by cyclones diversify within paddy but do not diversity away from paddy, towards higher valued crops. It could be that doing so would increase their income uncertainty due to the higher cost of seeds and other inputs that are then exposed to the weather risks. Based on the field survey, it is observed that most of the cyclone affected farmers are cultivating only paddy 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 lesser water requirement. This could be attributed to the poor functioning of extension in the disaster prone regions of Odisha. Further, it is observed that farmers have to repeat the process of seedling or re-planting of paddy once the crop is damaged due to the cyclone, but it is dependent on the stage of crop growth (see footnote 8). Due to soil salinity and seepage of salt water, there is a high possibility of pests and diseases attacks (Singh and Sasmal, 2004). Therefore, farmers practise integrated pest and disease management.

The flood affected farmers 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 reduce the variance of expected crop yields. The agricultural land in the delta region is submerged by saline water (regularly) and flood water (occasionally). Due to this, there is a high probability of adopting soil conservation techniques (i.e., increasing frequency of tillage operation and enhancing the height of the field bund) 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 (i.e., mixed paddy cropping), but also other crops (i.e., crop-diversification) in order to minimise risks in agriculture due to floods. The farmers, for example, cultivate paddy and jute crops in the kharif season, and groundnut and cereals in the rabi season (December to March). The highly flood affected farmers are also likely to adopt re-cultivation of seedling and re-planting. A flood affected farmer is expected to keep his/her land barren during the kharif season in order to minimise potential crop loss due to floods. But, a negative relationship is found in the case of highly and moderately flood affected. It is observed through field survey that the cost involved in keeping a piece of land barren during kharif season for rabi crop cultivation (e.g., removing grass from the land) is higher than the land cultivated during kharif season, where the farmers mostly practise low investment less productivity crops, i.e., traditional varieties of paddy, as an income skewing activity (Morduch, 1995). Similarly, the flood affected intensity variables are negatively associated with options like pest and disease management. The wet period increases the possibility of fungal and bacterial diseases (Padgham, 2009); and it seems that the flood affected farmers are ignorant about the pesticides to counteract.

In between cyclones or floods, one observes a range of different adoption behaviour among the affected farmers 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 re-cultivation of seedling and re-planting, are common among cyclone and/or flood affected farmers.

5.2 Household Characteristics

Increase in the size of the household enhances the probability of adopting soil conservation techniques, re-cultivation of seedling and re-planting, and pest and disease management. As soil conservation techniques, and increasing frequency of seedling preparation and re-planting are labour intensive, farm households with larger number of members are likely to undertake these measures. Due to lack of liquidity and high labour cost, especially, during the cultivation period, it is difficult for the farm households to adopt these strategies without the support of household members. In addition, the adoption of these mechanisms needs financial support, and therefore, large farm households can undertake these options 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, the better the chance of adopting these measures. Further, it is found that education of the head of the household decreases the probability of taking up salt and flood tolerant indigenous paddy seeds. Because, there is a higher probability that an educated farmer has knowledge about salinity and water-logging tolerant HYV paddy varieties.

With respect to the farming experience, it has been observed that experience increases the possibility of taking up mixed paddy cropping and crop-diversification. As the 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 Southern African countries. Since undertaking adaptation measures requires financial resources, richer farm households have a higher probability of taking up various adaptation measures. The influence of log per capita income is positive and also statistically significant for soil conservation techniques, crop diversification, re-cultivation of 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 the Nile Basin of Ethiopia. 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 India. The farm households whose major share of income is derived from agriculture have a higher chance of adopting crop-diversification, and increasing frequency of seedling preparation and replanting to counteract losses due to floods. When the main source of income is from farming and the amount of land for farming is limited, farmers tend to invest in crop-diversification in order to increase as well as reduce variance of farm income.

Table 2: Determinants of Farm-level Adaptation Measures

	Salt and flood tolerant indigenous paddy seeds	Soil conservation techniques	Mixed paddy cropping	Crop diversification	Land holiday	Re-cultivation of seedling and re-planting	Pest and disease management
Highly affected by cyclones	2.303*** (0.388)	0.180 (0.368)	1.510*** (0.354)	-1.274*** (0.458)	1.547*** (0.412)	2.406*** (0.500)	1.875*** (0.387)
Moderately affected by cyclones	1.417*** (0.368)	-0.494 (0.368)	1.163*** (0.328)	0.488 (0.430)	0.214 (0.366)	1.806*** (0.441)	0.715** (0.363)
Less affected by cyclones	1.159*** (0.365)	-0.606* (0.370)	0.974*** (0.328)	0.611 (0.409)	-0.392 (0.337)	1.144** (0.476)	0.601* (0.360)
Highly affected by floods	1.427*** (0.325)	0.288 (0.318)	1.281*** (0.293)	1.818*** (0.338)	-0.466 (0.301)	1.310*** (0.390)	-0.159 (0.314)
Moderately affected by floods	1.471** (0.704)	0.061 (0.622)	0.577 (0.780)	0.598 (0.760)	-0.435 (0.814)	-1.269* (0.735)	-2.729*** (0.584)
Less affected by floods	0.841** (0.362)	0.516* (0.305)	-0.078 (0.285)	0.131 (0.365)	1.753*** (0.455)	-0.050 (0.354)	-1.276*** (0.329)
Size of Household	0.009 (0.037)	0.074** (0.039)	-0.032 (0.041)	0.086 (0.055)	0.054 (0.047)	0.131** (0.052)	0.109** (0.050)
Years of education of the HH	-0.060* (0.033)	0.035 (0.033)	0.049 (0.039)	0.063 (0.043)	-0.046 (0.033)	-0.035 (0.038)	-0.017 (0.037)
Farming experience years of the HH	0.003 (0.007)	0.007 (0.007)	0.011* (0.007)	0.030*** (0.011)	0.001 (0.008)	-0.001 (0.009)	-0.010 (0.009)
Log (Per capita income)	0.251 (0.513)	1.852*** (0.550)	-0.270 (0.534)	1.540** (0.765)	-0.747 (0.627)	2.778*** (0.806)	2.094*** (0.683)
Agriculture as major source of income	-0.342* (0.192)	0.196 (0.191)	0.010 (0.188)	0.977*** (0.316)	-0.210 (0.224)	0.370* (0.211)	0.167 (0.220)
Formal agricultural extension	-0.005 (0.248)	-0.525** (0.232)	0.200 (0.231)	0.217 (0.339)	-0.304 (0.276)	0.646** (0.318)	-0.047 (0.287)
Formal credit	-0.060 (0.192)	0.060 (0.206)	0.144 (0.197)	-0.021 (0.246)	0.296 (0.227)	0.040 (0.305)	0.254 (0.237)
Access to MGNREGS	0.294* (0.183)	0.329* (0.180)	0.232 (0.176)	-0.551** (0.263)	-0.067 (0.209)	0.021 (0.209)	0.318 (0.208)

	Salt and flood tolerant indigenous paddy seeds	Soil conservation techniques	Mixed paddy cropping	Crop diversification	Land holiday	Re-cultivation of seedling and re-planting	Pest and disease management
Received crop loss compensation	-0.061 (0.206)	0.013 (0.204)	0.710*** (0.200)	1.961*** (0.370)	-0.158 (0.251)	0.261 (0.293)	0.188 (0.242)
Informal credit	0.609** (0.254)	-0.100 (0.244)	0.104 (0.254)	-0.428 (0.294)	-0.253 (0.283)	0.348 (0.280)	-0.148 (0.230)
Received remittances	0.123 (0.190)	0.255 (0.195)	-0.284 (0.186)	-0.430* (0.246)	0.625*** (0.211)	-0.014 (0.217)	0.171 (0.213)
Constant	-2.977 (1.963)	-8.474*** (2.161)	-0.883 (2.111)	-8.828*** (2.881)	2.973 (2.468)	-12.886*** (3.201)	-8.823*** (2.638)
	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\hat{\rho}_4$	$\hat{\rho}_5$	$\hat{\rho}_6$	
$\hat{\rho}_2$	0.418***						
$\hat{\rho}_3$	-0.296***	0.262**					
$\hat{\rho}_4$	-0.466***	-0.087	0.148				
$\hat{\rho}_5$	0.571***	0.212*	0.100	-0.731***			
$\hat{\rho}_6$	-0.029	0.196	0.474**	0.330	0.269*		
$\hat{\rho}_7$	-0.042	0.193	0.333**	0.263	0.194	0.603***	
Draws				17			
No. of observations				285			
Log pseudo likelihood				-796.005			
$\Pr(y_h = 1, \text{for all} h = 1,\ldots,7)$				0.038			
$\Pr(y_h = 0, \text{for all} h = 1,\ldots,7)$				0.014			

Source: Computed from primary data

Note: Likelihood ratio test $H_0: \hat{\rho}_{21} = \hat{\rho}_{31} = \hat{\rho}_{41} = \hat{\rho}_{51} = \hat{\rho}_{61} = \hat{\rho}_{71} = \hat{\rho}_{32} = \hat{\rho}_{42} = \hat{\rho}_{52} = \hat{\rho}_{61} = \hat{\rho}_{72} = \hat{\rho}_{43} = \hat{\rho}_{53} = \hat{\rho}_{63} = \hat{\rho}_{73} = \hat{\rho}_{54} = \hat{\rho}_{64} = \hat{\rho}_{74} = \hat{\rho}_{65} = \hat{\rho}_{75} = \hat{\rho}_{76} = 0$, $\chi^2(21) = 113.88$, P Value = 0.0000; Figures in the parentheses are robust standard error; *** p<0.01, ** p<0.05 and * p<0.1 respectively

5.3 Access to Formal and Informal Institutions

Access to agricultural extension increases the likelihood of taking up re-cultivation of seedling and replanting, and reduces the probability of adopting an option like land holiday. Farmers who have extension contacts are more aware about various agricultural production and management practices, which they can use to adapt to cyclones and/or floods. In particular, they get information about different varieties of HYV paddy seeds, which can sustain in salinity and water logging, by giving higher yields. Such information helps farmers to reduce the possibility of keeping land barren. These farmers are now accessing jute, paddy and groundnut seeds, which help them to increase frequency of seedling preparation and re-planting. Further, these farmers are able to network with farmers living in the neighbouring villages who regularly visit extension, which facilitates them to access seedling in the aftermath of a cyclone and/or flood as most of the farmers in their village are likely to be similarly affected and won't, therefore, be able to offer such help. Similarly, Piya *et al.* (2013) find that extension services enhance the possibility of adopting options like 'varietal selection'. Further, Patt *et al.* (2005) and Wood *et al.* (2014) observe that access to weather information positively influenced the probability of adopting various options across different regions of Africa and South Asia. In view of this, improving access to extension services has the potential to increase awareness among the farmers about different farm-level adaptation practices. Surprisingly, it has been observed that a negative relationship exists between access to extension and soil conservation techniques. In addition, we have not found a significant relationship between formal credit and the adaptation options.

Access to MGNREGS in rural areas has significant potential in promoting options like salt and flood tolerant indigenous paddy seeds, soil conservation techniques, mixed paddy cropping, and pest and disease management. Employment in MGNREGS during the 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 MGNREGS (see Tiwari *et al.*, 2011; Esteves *et al.*, 2013), which reduce seepage of salt and water logging in the agricultural land. For instance, around 1483 projects on flood control and protection from cyclonic storms were completed in Odisha during the period 2006-13[11]. Therefore, farmers are able to adopt soil

[11] These information were collected from MGNREGS's webpage.

conservation techniques and also cultivate different varieties of paddy crops instead of depending on a single variety. Again, surprisingly, access to MGNREGS has a negative relationship with crop-diversification. This underlines the fact that the government should promote various development based activities in the rural areas, especially related to agriculture, in order to increase farm-level adaptation measures. 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 using salt and flood tolerant indigenous paddy seeds and increasing frequency of seedling preparation and re-planting. Bryan *et al.* (2009) find that informal institutions and social relationships facilitate adaptation measures to climate change. In order to undertake re-cultivation of 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 could have allowed the farm households to divert their resources for non-farm activities and harvesting only for self-consumption.

The estimated correlation coefficients ($\hat{\rho}_{kj}$) among the various adaptation options are significant for eleven out of twenty-one combinations (see Table 2). The option like salt and flood tolerant indigenous paddy seeds is positively correlated with soil conservation techniques and land holiday, but negatively correlated with mixed paddy cropping and crop-diversification. The option of soil conservation techniques is complemented by mixed paddy cropping and land holiday. Mixed paddy cropping is positively correlated with re-cultivation of seedling and re-planting, and pest and disease management. While, crop-diversification is negatively correlated with land holiday, re-cultivation of seedling and re-planting option is positively correlated with pest and disease management. Surprisingly, land holiday is positively correlated with re-cultivation of seedling and re-planting.

6. Conclusions and Policy Implications

This study analysed the factors affecting choice of farm-level adaptation options to cyclones and floods based on a cross-sectional survey data collected during the 2010-11 production season in selected disaster prone regions of Odisha. The adaptation measures undertaken by the farmers are salt and flood tolerant indigenous/traditional paddy seeds, soil conservation techniques, mixed paddy cropping, crop-diversification, land holiday, re-cultivation of seedling and re-planting, and pest and disease management.

A MVP model was employed to explore the determinants of adaptation measures, and the following salient points emerged. The cyclone-experienced farmers are likely to adopt salt and flood tolerant indigenous paddy seeds, mixed paddy cropping, land holiday, re-cultivation of seedling and re-planting, and pest and disease management. The flood-affected farmers preferred 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 sensitive to floods, 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 the household, per capita income, access to agricultural extension, access to MGNREGS, 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. Government policies and investments must promote these determinants in order to enhance the adaptive capacity of the rural farmers in the disaster prone regions of the state.

In fact, some of the determinants of adaptation measures, namely, access to MGNREGS, formal credit and agronomic information can be addressed as part of the rural development programme. This asserts the non-necessity of formulating a separate climate change and climate induced extreme event specific adaptation policy different from other rural development and poverty alleviation programmes to buffer against the impact of climatic risks. It is, therefore, imperative to restructure the existing development programme by including climate specific response measures, e.g., distribution of flood and salt tolerant seeds and raising awareness among the farmers regarding climatic risks so that farmers can cushion against a wide range of risk and shocks. In addition, more resources need to be deployed to promote agricultural research, develop salt tolerant crops, promote village-level seed bank, construct development based activities through MGNREGS, and more importantly, strengthen the existing farm extension management to disseminate such information among farmers in the cyclone and flood prone regions of Odisha.

Our results do need to be interpreted with caution in three respects. The first limitation is undertaking various assumptions due to cross-section data, e.g., the adaptation measures considered in the present study are efficient in ways that increase yields, and farmers are choosing efficient options that maximise their profit at the end of the production period. The second has to do with the empirical design. In comparison to other studies, the sample size of the present study was smaller and that makes it difficult to generalise the findings in the context of the disaster prone regions of India. Because of the small sample size, we might have missed other relevant farm-level effective adaptation measures which are otherwise adopted by the farmers. Household is taken as the unit of the present analysis, which is the third limitation. Because of this, we have not been able to consider geographical and physical characteristics of land as other determinants. Each farm household has more than one plot, and therefore, we are not able to generalize this information at the household level. The result could be more robust if the analysis is undertaken at the plot-level.

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Appendix 1: Impact of Cyclones and Floods in Balasore District, 1994–2008

Year	Cyclone/ Flood	Frequency	No. of villages affected (Nos.)	Total people affected (in millions)	Human casualties (Nos.)	Total houses damaged (Nos.)	Crop lands damaged (in thousand hectares)
1994	Flood	5	647	0.60	3	227	162.13
1995	Flood	1	2819	1.48	2	6464	127.12
1996	Flood	2	217	0.14	0	25	13.74
1997	Flood	4	2497	1.73	0	24910	46.34
1998	Flood	1	1227	0.86	1	4996	-
1999	Flood	1	830	0.49	2	1274	75.89
1999	Cyclone	2	1812	1.72	99	91690	141.00
2001	Flood	2	204	0.11	0	6	18.67
2003	Flood	1	1340	0.67	6	15797	24.02
2004	Flood	1	140	0.07	0	3	19.73
2005	Flood	2	1263	0.08	2	10910	-
2006	Flood	3	1405	0.90	1	1043	58.18
2007	Flood	3	3632	3.50	36	16036	128.00
2008	Flood	1	1114	0.94	10	38077	49.85
Total (1994–2008)		29	19147	13.28	162	211458	864.67

Source: GoO (1999a, b and 2011), Special Relief Commissioner, Government of Odisha, Bhubaneswar and District Emergency Office, Balasore

Note: Blank entries in the table denote ‘not available’

Appendix 2: Impact of Cyclones and Floods in Kendrapada District, 1994–2008

Year	Cyclone/ Flood	Frequency	No. of villages affected (Nos.)	Population affected (in millions)	Human casualties (Nos.)	Total houses damaged (Nos.)	Crop Lands damaged (in thousand hectares)
1994	Flood	1	435	0.39	10	-	30.42
1995	Flood	2	1506	1.17	4	3017	-
1999	Flood	1	359	0.25	4	80	14.65
1999	Cyclone	2	1567	1.65	473	308733	123.75
2001	Flood	1	821	0.82	0	31926	64.29
2003	Flood	2	585	0.62	14	7744	22.65
2005	Flood	3	378	0.41	3	-	-
2006	Flood	4	1021	0.94	2	5444	69.94
2007	Flood	4	1918	1.23	5	2214	29.27
2008	Flood	2	684	0.76	16	58429	64.99
Total (1994–2008)		22	9274	8.24	531	417587	419.96

Source: GoO (1999a, b and 2011), Special Relief Commissioner, Government of Odisha, Bhubaneswar and District Emergency Office, Kendrapada.

Note: Blank entries in the Table denote 'not available'

Appendix 3: Impact of Cyclones and Floods in Jajpur District, 1994–2008

Year	Cyclone/ Flood	Frequency	No. of villages affected (Nos.)	Population affected (in millions)	Human casualties (Nos.)	Total houses damaged (Nos.)	Crop lands damaged (in thousand hectares)
1994	Flood	2	585	0.53	7	-	49.05
1995	Flood	2	3620	1.09	0	7107	-
1996	Flood	1	354	0.25	0	548	19.43
1997	Flood	1	478	0.46	3	2253	100.51
1998	Flood	1	537	0.04	1	67	29.55
1999	Flood	1	422	0.42	3	234	23.78
1999	Cyclone	2	1781	2.08	270	257319	188.00
2001	Flood	3	817	0.84	-	20703	185.54
2003	Flood	2	429	0.44	6	14518	8.80
2004	Flood	1	11	0.01	-	0	4.03
2005	Flood	3	711	0.67	5	1543	6.12
2006	Flood	4	754	0.46	1	1587	38.58
2007	Flood	4	639	0.80	0	783	21.70
2008	Flood	1	694	0.73	10	6991	29.52
Total (1994–2008)		28	11832	8.82	306	313653	704.61

Source: GoO (1999a, b and 2011), Special Relief Commissioner, Government of Odisha, Bhubaneswar and District Emergency Office, Jajpur.

Note: Blank entries in the Table denote 'not available'

Appendix 4: Socio-Economic Characteristics of Sample Farm Households

Socio-economic Characteristics	Combined	Cyclone	Cyclone & Flood
Details of Farm Household Head			
Average age	49.23	46.91	51.04
Average farming experience	24.04	21.5	26.03
Illiterate (%)	64.56	64	65
Literate (%)	35.44	36	35
Demographic and Educational Indicators			
Average family size	5.88	5.37	6.29
Illiterate (%)	40.27	42.91	38.59
Literate (%)	59.73	57.09	61.41
Assets and Amenities			
Pucca (%)	9.82	4	14.38
Semi-Pucca (%)	16.84	3.2	27.5
Thatched (%)	73.34	92.8	58.12
Availability of Water within the premises (< 100 meters) (%)	55.44	27.2	77.5
Electricity (%)	34.74	15.2	50
Toilet (%)	22.81	17.6	26.88
Total productive asset (Rs in million)	0.137	0.042	0.212
Net wealth[a] (Rs in million)	0.111 (-0.19)	0.023 (-0.44)	0.180 (-0.15)
Land-holding details			
Percentage of landless farmers	40.35	64.8	21.25
Percentage of small and marginal farmers	57.19	35.2	74.38
Gini-coefficient of land holding	0.596	0.689	0.501
Intensity of dependency on agriculture			
> 50 percent of income (%)	70.88	58.40	80.63
< 50 percent of income (%)	29.12	41.60	19.37
Income and consumption expenditure (month wise)			
Per capita income (in Rs)	501.99	487.59	513.31
Per capita consumption expenditure (in Rs)	466.67	438.68	488.5
Sources of borrowing			
% of households have outstanding loan	89.47	91.2	88.13
Collateralized (%)	90.2	79.82	98.58
Un-collateralized (%)	9.8	20.18	1.42
Access to formal sources (%)	37.89	20.8	51.25
Access to informal sources (%)	83.51	87.2	80.63
Per capita loan amount (in Rs)	4547.5	3502.82	5363.66

Source: Computed from primary data.

Note: Figures in parentheses indicate proportionate decline in comparison to the total productive asset; a- Net wealth is calculated as total value of productive assets minus total borrowing amount.

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