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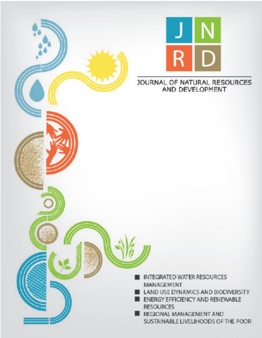

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Factors influencing adoption of farm management practices in three agrobiodiversity hotspots in India: an analysis using the count data model

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Abstract

Sustainable agricultural practices require, among other factors, adoption of improved nutrient management techniques, pest mitigation technology and soil conservation measures. Such improved management practices can be tools for enhancing crop productivity. Data on micro-level farm management practices from developing countries is either scarce or unavailable, despite the importance of their policy implications with regard to resource allocation. The present study investigates adoption of some farm management practices and factors influencing the adoption behavior of farm households in three agrobiodiversity hotspots in India: Kundra block in the Koraput district of Odisha, Meenangadi panchayat in the Wayanad district of Kerala and Kolli Hills in the Namakkal district of Tamil Nadu. Information on farm management practices was collected from November 2011 to February 2012 from 3845 households, of which the data from 2726 farm households was used for analysis.

The three most popular farm management practices adopted by farmers include: application of chemical fertilizers, farm yard manure and green manure for managing nutrients; application of chemical pesticides, inter-cropping and mixed cropping for mitigating pests; and contour bunds, grass bunds and trenches for soil conservation. A Negative Binomial count data regression model was used to estimate factors influencing decision-making by farmers on farm management practices. The regression results indicate that farmers who received information from agricultural extension are statistically significant and positively related to the adoption of farm management practices. Another key finding shows the negative relationship between cultivation of local varieties and adoption of farm management practices.

Introduction

Crop productivity in the developing world faces several constraints. One of the major crop productivity constraints is the unavailability of crop nutrients in the appropriate amount and form (Hussain et al. 2006). The roles of both macro and micronutrients are crucial in crop nutrition and thus important for achieving higher yields (Arif et al. 2006). However, most soils are deficient in these nutrients (Jahiruddin et al. 1995) and need to be supplemented through proper crop nutrients. Crop loss due to pests is another serious problem that limits or reduces production. The control of pests using chemical methods is predominant, but traditional pest control practices continue, especially in remote areas (Pathak 2002; Sharma et al. 2002). Cultivable land located in mild and steep slopes and shallow soils, risk soil erosion and yield loss at times of high rainfall. In India, large government programs have devoted substantial resources to promote soil conservation, but the results have been disappointing, as adoption and maintenance of introduced conservation technologies has been limited (Kerr and Sanghi 1992). Sustainable agricultural practices require among other factors, adoption of improved nutrient management, pest mitigation and soil conservation measures. Such improved management practices can be tools for enhancing crop productivity.

Farm management practices can be influenced by the crops and varieties cultivated and access to agricultural extension. Indian agriculture is predominantly driven by small holders, with about 83 percent of farmers cultivating an area of 2 hectares or less (Directorate of Economics and Statistics, India, 2011). Crop production and management decisions, especially among small farmers, depend to some extent on extension workers. More than 90 percent of the world's extension personnel are located in developing countries (Umali and Schwartz 1994), where indeed the majority of the world's farmers are located. The goals of extension include the transfer of knowledge from researchers to farmers, advising farmers on their decision-making and educating farmers to make better decisions, enabling farmers to clarify their own goals and possibilities, and stimulating desirable agricultural developments (Van den Ban and Hawkins 1996). The adoption of technology by farmers is inevitably affected by several factors (Feder et al. 1986). Adoption can be influenced by educating farmers about improved varieties, cropping techniques, optimal input use, prices and market conditions, efficient methods of production management, storage and nutrition. Anderson and Feder (2003) mentioned that the low literacy rates among small and marginal farmers implies that they are not able to take advantage of information available in electronic mass media like written materials, radio, television, internet, which could potentially be used as intervention to motivate farmers to adopt new technologies and production practices.

Several scholars have studied technology adoption in agriculture and the factors influencing adoption behavior among farming households (Abdulai and Huffman 2005; Akinola and Owombo 2012; Deressa et al. 2009; Howley et al. 2012; Mariano et al. 2012). Literature on technology adoption shows that binary logit and probit models have been extensively used to analyze technology and best practice adoption by farm households. Ramierez and Shultz (2000) used a poisson count model to analyze adoption of integrated pest management in selected Central American countries. In addition to studies related to a single technology adoption, there are several studies that look at multiple technology adoption (Chaves and Riley 2001; Cooper 2003; Isgin et al. 2008). Sharma et al. (2011) used parametric and non-parametric models to examine the intensity of technology adoption and integrated pest management strategies employed by farmers in the UK.

Given this background, the present study aims to capture the actual adoption of farm management practices and estimate factors influencing the adoption behavior of farm households using negative binomial count data regression. The study was carried out as part of the research project, "Alleviating Poverty and Malnutrition in Agrobiodiversity Hotspots (APM)", implemented jointly by the M.S.Swaminathan Research Foundation (MSSRF), Chennai, India and the University of Alberta (U of A), Edmonton, Canada. The project is being implemented in three agrobiodiversity hotspots: Kundra block in the Koraput region, Wayanad district in the Malabar region and Kolli Hills block in the Kaveri region. The present study was carried out to address one of the primary objectives of the APM project, related to increasing farm productivity through sustainable farm management practices: nutrient management, pest mitigation and soil conservation and enhancement. Such knowledge can possibly be used to formulate specific policies and target specific groups of producers to promote adoption of sustainable agricultural practices.

In the following section, we describe the methodological framework including study area, data collection, the negative binomial model and descriptive figures of variables used in the regression. Section 3 discusses the results and major findings regarding the general characteristics of farm households, actual adoption of farm management practices, technology count of adoption and estimation of factors influencing adoption behavior. Concluding remarks are provided in the final section.

Methodology

Study area

India is one of twelve mega-diverse countries in the world and is considered as a major center of domestication of crop plants. Farming communities from time immemorial have grown and developed a rich cornucopia of crop plants through selection and adaptation. It is reported that at least 166 crop plants and about 320 species of wild relatives of cultivated plants originated in India (Nayar et al. 2009a). In 2007, the Protection of Plant Varieties & Farmers' Rights Authority (PPV&FRA) of the Government of India (GoI) constituted a task force to characterize, demarcate and list the agrobiodiversity hotspots in India. The task force identified 22 hotspots across India, based on listing the species of botanical and agricultural importance, endemic and endangered species and socio-cultural aspects of the areas (Nayar et al. 2009b). The current research is being implemented in three of the agrobiodiversity hotspots identified by the task force – the Kundra block in the Koraput region, Wayanad district in the Malabar region and Kolli Hills block in the Kaveri region.

Koraput is a center of biodiversity for many food crops and forest species. It is considered as the secondary center of origin of Asian cultivated rice *Oryza sativa L* (Mishra et al. 2012). The district covers an area of about 8379 km^2 (Arunachalam et al. 2008). The mean elevation is 2900 feet above sea level. It is also well known for its rich human cultural diversity. Sixty-two tribal communities constituting 54.45% of its population live in the district (Mohanti et al. 2006). For generations, they have played a major role in identifying, conserving, improving and utilizing local plant genetic resources as well as in sustaining them. Their tireless efforts have conserved and improved the quality of many food crops. Besides rice, a variety of millets, pulses, oilseeds and vegetables (Mishra and Chaudhury 2012) have also been conserved. Even today they possess a high level of traditional knowledge regarding the various fields that governs their livelihood. Low literacy rates and poor financial condition of farmers limit improvements in crop productivity (Mishra and Taraputia 2013).

Wayanad district, situated in the Western Ghats in the north-eastern part of Kerala, India, is considered one of the world's most important biodiversity hotspots. It is spread over an area of 2136 km^2, where 37% of the land area is covered by forests and 55% is cultivated (Kumar et al. 2003). Wayanad is a plateau with an altitude varying from 700 to 2100 m above sea level. The difference in altitude of each locality within the district leads to variations in climatic conditions. The small hills have many plantations such as tea, coffee, pepper and cardamom, while the valleys see a predominance of paddy fields (Siljal et al. 2008). Tribal population represents 17% of the total population of the district, and is the largest tribal population in the state of Kerala (Josephat 1997). The district is characterized by high ethnic diversity, with five dominant tribal groups – Kurichiya, Kuruma, Paniya, Adiya and Kattunaikka - and seven minor communities (Kumar et al. 2003).

Kolli Hills is a mountainous area with a temperate climate located on the eastern border of the Namakkal district in Tamil Nadu. Forests occupy 44 per cent of the total area of 28,293 ha, while agricultural activities take place on 52 per cent of the total area, leaving 4 per cent for other activities (Kumaran 2004). Agricultural land-use in the Kolli Hills can be classified into three types: (i) spring-fed valley lands, mainly under paddy, (ii) rain-fed lands, allocated for millets and cassava, and (iii) land on the valley fringes, under pineapple, coffee, pepper and other crops (Gruere et al. 2009; Kumaran 2004). The Kolli Hills region is characterized by significant in-situ crop genetic diversity of minor millets (Jayakumar et al. 2002; King et al. 2008). More than 95 per cent of the inhabitants are tribal people belonging to the Malayali tribal community (MSSRF 2002).

Data collection

The present study area was selected mainly because of its low socio-economic level with low human indices, contrasted by its rich genetic diversity. The major livelihood of the communities in the study area is agriculture. The project is being implemented with the objective of enhancing the livelihood of the communities based on genetic resources and agricultural development. The data for this study was collected using a structured questionnaire. The questionnaire was pre-tested and modified before the actual initiation of the survey process. The actual survey was conducted during November 2011 to February 2012, and the information collected pertains to the reference year of 2010-2011. The enumerators involved in the data collection were familiar with the local, social and cultural norms, and were trained using mock-interviews, and were consistently monitored. The collected data were periodically examined in order to identify and correct errors.

The primary data collection was carried out by employing the census method, which covered the entire households from three study areas; resulting in 3845 households: 2004 households in 32 villages of Kundra block, 1000 households in 31 villages of Meenangadi panchayat and 841 households in 31 villages of Kolli Hills. The results presented in this study are restricted to those households engaged in crop production: 1307 farm households in Kundra block, 675 farm households in Meenangadi panchayat and 744 farm households in Kolli Hills; making a total sample of 2726 farm households. Data pertaining to general household socio-economic information such as age, gender, education, primary occupation, information on seeded area, cropping pattern, input use, adoption of farm management practices including nutrient management, pest mitigation and soil conservation, information on livestock, status of savings and credit, and access to information were elicited.

The negative binomial model

Following Greene (2008), the negative binomial model is employed as a functional form that relaxes the equidispersion restriction of the Poisson model. A useful way to motivate the model is through the introduction of latent heterogeneity in the conditional mean of the Poisson model. Thus:

$$E[y_i/X_i,\varepsilon_i]=\exp(\alpha+X_i'\beta+\varepsilon_i)=h_i\lambda_i, \quad (2.1)$$

where $h_i = \exp(\varepsilon_i)$ is assumed to have a one parameter gamma distribution, $G(\theta,\theta)$ with mean 1 and variance $1/\theta = \kappa$;

$$f(h_i)=\frac{\theta^{\theta}\exp(-\theta h_i)h_i^{\theta-1}}{\Gamma(\theta)}, h_i \geq 0, \theta > 0. \quad (2.2)$$

After integrating h_i out of the joint distribution, we obtain the marginal negative binomial (NB) distribution,

$$\text{Prob}[Y=y_i|X_i]=\frac{\Gamma(\theta+y_i)r_i^{\theta}(1-r_i)^{y_i}}{\Gamma(1+y_i)\Gamma(\theta)}, \quad (2.3)$$

$$y_i=0,1,\ldots,\theta>0, \quad r_i=\frac{\theta}{\theta+\lambda_i}.$$

The latent heterogeneity induces overdispersion while preserving the conditional mean;

$E[y_i/X_i] = \lambda_i,$ (2.4)

$Var[y_i/X_i] = \lambda_i[1+(1/\theta)\lambda_i] = \lambda_i\ [1+k\lambda_i]$ (2.5)

Where k = Var[h_i]

Maximum likelihood estimation of the parameters of the NB model (α,β,θ) is straightforward, as documented in Greene (2007), for example. Inference proceeds along similar lines. Inference regarding the specification, specifically the presence of overdispersion, is the subject of a lengthy literature, as documented in Cameron and Trivedi (1990, 1998, 2005) and Hilbe (2007).

Variables used in the regression

The dependent variable (y_i) used in the regression analysis is a count model. The dependent variable used in the study is a count of technologies adopted by each farm household. A maximum of five technologies each in nutrient management and pest mitigation, and six technologies in soil conservation was adopted by surveyed households ***Table 1***. Independent variables (X_i) used to explain adoption behavior of farmers fall under three categories: characteristics of household head, such as gender, age, primary occupation, farm related variables notably farm size, access to agricultural extension and variety cultivated and location factors.

Table 1: Description of variables used in the regression

Variable name	Mean	Std. dev.	Description of variable
Dependent Variable			
Nutrient_management (Model 1)	1.9	0.92	values from 0 to 5
Pest_mitigation (Model 2)	0.79	0.66	values from 0 to 5
Soil_conservation (Model 3)	0.97	0.87	values from 0 to 6
Independent Variables			
1. Household head characteristics			
Gender_household head	0.91	0.28	1=male, 0=female
Age_household head	45.26	13.15	in years
Primary occupation_household head	0.73	0.45	1=farming, 0=others
2. Farm Characteristics			
Farm_size	0.94	1.53	in hectare
Agriculture_extension	0.15	0.36	1=yes, 0=no
Local_variety	0.24	0.42	1=yes, 0=no
3. Location dummies			
Dummy_Kundra	0.48	0.5	1=yes, 0=no
Dummy_Meenangadi	0.25	0.43	1=yes, 0=no
Dummy_Kolli Hills	0.27	0.45	1=yes, 0=no

Results and discussion

General characteristics of farm households

This section provides the general characteristics of the farm households ***Table 2***. The average household size in all three study locations is approximately 4.5. The majority of the households are male headed households: 94 percent in Kundra, 85 percent in Meenangadi and 93 percent in the Kolli Hills. The average age of household heads across the study area ranges from 43 to 52 years. The number of years of education of the household head is highest in Meenangadi with 3.4 years and lowest in Kundra with 1.7 years. Crop production is the primary occupation of the majority of households: 87 percent in Kundra, 86 percent in Meenangadi and 91 percent in Kolli Hills. The remaining households used in the analysis are also engaged in crop production, but the primary occupation is non-farm work, such as salary, business or non-agricultural wage income. The average farm size is 1.12 hectares in Kundra, 0.67 hectares in Meenangadi and 0.88 hectares in Kolli Hills. The major crops cultivated in Kundra are Paddy [*Kharif* (rainy), *Rabi* (winter) and summer], small millets, maize, sugarcane, niger, green gram, black gram and horse gram. In Meenangadi, paddy (*kharif* and summer), banana, tapioca, coffee, areca nut, coconut, elephant foot yam, green gram and ginger are cultivated. The major crops cultivated in Kolli Hills are paddy (*kharif* and summer), small millets, tapioca, banana, coffee and pepper, pineapple and green gram. About 99.2 percent of households in Kolli Hills, 42.1 percent in Kundra and 20.3 percent in Meenangadi comprise of Scheduled Tribes.

Table 2: General characteristics of farm households

	Kundra	Meenangadi	Kolli Hills
Sample size (number)	1307	675	744
Average household size (number)	4.6 (1.9)	4.4 (1.5)	4.5 (1.8)
Male headed household (%)	93.9	84.9	92.7
Average age of household head (years)	42.7 (12.5)	52.4 (12.4)	43.3 (12.7)
Average education household head (years)	1.7 (1.0)	3.4 (1.6)	2.4 (1.7)
Farming as primary occupation of household head (%)	86.7	85.6	91.3
Farm size (hectare)	1.12 (1.66)	0.67 (1.77)	0.88 (0.85)
Social category of household (%)			
General/ Forward Caste	8.6	34.4	0
Backward Caste	24.6	41.9	0.7
Most Backward Caste	0	0.7	0.1
Scheduled Caste	25.6	2.7	0
Scheduled Tribe	41.2	20.3	99.2

Note: Figures in the parenthesis is standard deviation

Adoption of farm management practices

Nutrient management: The most adopted nutrient management technologies in the study area is application of chemical fertilizer by 86.7 percent of farm households, followed by the application of farmyard manure (73.4% of households) and the application of green manure (21.9% of households). Approximately 10.2 percent of households do not adopt any nutrient management technologies. The other nutrient management technologies practiced by households in the study area are inter-cropping systems (4.4%), application of organic manure (0.9%), composting/ vermi-composting (0.7%), crop rotation with legumes (0.6%), application of bio-fertilizer (0.5%) and other measures (0.5%).

Pest mitigation: Majority of households (62.9%) apply chemical pesticides for mitigating pests and diseases. Approximately one-third of the households do not adopt any pest mitigation technology. The next most adopted anticipatory pest mitigation technology is inter-cropping and mixed cropping with 4.6 and 4.2 percent of households, respectively. Other pest mitigation technologies adopted by households are agro-forestry/hedgerows (3.9%), application of natural pesticides (0.7%), physical traps (0.4%), mulching (0.4%), trap crops (0.2%), pheromone traps (0.1%) and other measures (1.7%).

Soil conservation: Around one-third of the households adopt contour bunds as a soil conservation measure. Twenty six percent of farmers do not adopt any soil conservation technology. The next most adopted soil conservation technology is grass bunds (22.2 % of households), followed by trenches (9.3% of households). Other soil conservation technologies adopted by the households include mulching (8.7%), terracing (7.5%), hedge rows (5.8%), agro-forestry (4.2%), strip cropping systems (0.8%), application of green manure (0.1%) and other measures (7.0%).

Technology count of adoption

The section above provided the actual data on the adoption of farm management technologies in the study area, and the present section explains the technology adoption counts. Technology count refers to the number of farm management technologies adopted by each farm household for each nutrient management, pest mitigation and soil conservation component ***Table 3***. The technology count of each farmer is used as a dependent variable in the negative binomial regression analysis to estimate the factors influencing adoption of farm management technologies by farm households. The survey results show that 90 percent of farm households adopt at least one of the nutrient management technologies, 69 and 74 percent of households also adopt at least one of the pest mitigation and soil conservation technologies, respectively. A maximum of five nutrient management and pest mitigation technologies, and six soil conservation technologies were adopted by some farm households. The majority of farm households adopt two technologies for nutrient management (56.2%) and one technology each for pest mitigation (63.2%) and soil conservation (59.2%).

Estimation of Negative Binomial regression for technology adoption

The nature of the dependent variable used in the regression analysis corresponds to a count model. In this case, negative binomial regression was used since it was less likely that the unconditional mean of the dependent variable would be equal to its variance. Negative Binomial regression was used to estimate the factors influencing the adoption behavior of farm management practices, specifically nutrient management, pest mitigation and soil conservation measures ***Table 4***. Three independent count data regression models were run, using different sets of independent variables to estimate the adoption behavior of the farm households. For instance, gender of the household head is not included in model 1 and 2, while age of the household head is not included in model 3. In the case of location dummies, (n-1) location is used in all the models.

The regression results indicate that for every unit increase in male headed households, the expected adoption count of soil conservation technologies will decrease by 0.15. The age of the head of the household is statistically significant and positively associated with nutrient management and pest mitigation. When farmers with farming as their primary occupation increases by a unit, the

Table 3: Technology adoption frequency distribution

Technology counts	Nutrient management		Pest mitigation		Soil conservation	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0	277	10.16	832	30.52	710	26.05
1	375	13.76	1723	63.21	1615	59.24
2	1532	56.2	94	3.45	250	9.17
3	440	16.14	67	2.46	86	3.15
4	97	3.56	9	0.33	42	1.54
5	5	0.18	1	0.04	22	0.81
6	0	0	0	0	1	0.04
Total	2726	100	2726	100	2726	100

expected count of technology adoption increases by 0.18 for nutrient management, 0.27 for pest mitigation and 0.37 for soil conservation measures. Since effective agriculture requires a substantial amount of managerial time, technology adoption may be constrained when the farmer works off-farm, because it competes with on-farm managerial time. The impact of adoption and on-farm work as full time is expected to have a positive relationship. This hypothesis is consistent with research reported elsewhere (Kara et al. 2008).

Farm size is positively associated and statistically significant among all three management practices. In explaining adoption decisions, farm size is considered as one of the most consistent variables to exhibit statistical significance. Several theoretical and empirical examples in the literature on technology adoption highlight the importance of farm size (Harper et al. 1990; Pitt and Sumodiningrat 1991; Smale and Heisey 1993). In general, farm size is hypothesized to have a positive impact on adoption decisions (Polson and Spencer 1991; Norris and Batie 1987). As farmers receiving information from agricultural extension increases by one unit, the expected count of technology adoption increases by 0.29 for nutrient management, 0.43 for pest mitigation and 0.60 for soil conservation. Another key finding is the negative relationship between cultivation of local varieties and farm management practices. For every one unit increase in cultivation of local varieties, the results for technology adoption count decrease by 0.45 for nutrient management, 0.35 for pest mitigation and 0.29 for soil conservation.

Table 4: Estimation of negative binomial regression for the technology adoption

Variables	Nutrient management (Model 1)		Pest mitigation (Model 2)		Soil conservation (Model 3)	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Gender_household head	-	-	-	-	-0.1457**	0.067
Age_ household head	0.0023**	0.001	0.0043**	0.002	-	-
Primary occupation_ household head	0.1795***	0.041	0.2662***	0.063	0.3724***	0.058
Farm_size	0.0178**	0.008	0.006	0.012	0.0230**	0.011
Agri_extension	0.2940***	0.039	0.4333***	0.058	0.6031***	0.051
Local_variety	-0.4467***	0.042	-0.3477***	0.063	-0.2890***	0.057
Dummy_Kundra	-0.2571***	0.045	0.6717***	0.061	-	-
Dummy_Meenangadi	-	-	0.6929***	0.082	0.4863***	0.061
Dummy_Kolli Hills	-0.2208***	0.049	-	-	0.4414***	0.046
Constant	0.5982**	0.074	-1.1807***	0.114	-0.5249***	0.085
Number of observations		2726		2726		2726
LR $Chi^2(7)$		339.38		307.23		425.92
Prob> Chi^2		0		0		0
Pseudo R^2		0.04		0.05		0.06

***represent 1% significance level, **represent 5% significance level and *represent 10% significance level

Conclusion

The key findings from the farm household survey on factors influencing adoption of farm management practices are summarized in this section. Only 15 percent of the surveyed households have access to agriculture extension. Farmers who received information from agricultural extension are highly influenced to adopt nutrient management techniques, improved pest mitigation technologies and soil conservation practices. Our results therefore reinforce the importance of expanding agricultural extension, particularly for small and marginal farmers. Considering the fact that new technologies are being introduced rapidly and knowledge transfer in agriculture is generally on the wane, agricultural extension is likely to become an important source of knowledge and information for the younger generation of farmers. Incidentally, small farmers in various countries have indicated a willingness to pay for extension services that meet their needs (Gautam 2000; Holloway and Ehui 2001). Farmers from the surveyed households use chemical fertilizer (87%) and farm yard manure (73%), while the majority of households use a combination of both. This has important implications both for productivity and long term sustainability. A small section of the farmers' surveyed (9%) use inter and mixed cropping practices for dealing with pests and diseases. Promotion of such non-chemical management practices is likely to help farmers and the environment in the long run. The results also indicate that a section of farmers (26%) are yet to adopt soil conservation measures. It is understood that soil conservation measures are critical for sustainable natural resource management in the long run, and hence it would be appropriate to intensify action in this direction.

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