International Journal of Economic Research

ISSN : 0972-9380

available at http: www.serialsjournal.com

Volume 14 • Number 8 • 2017

Farmers' Sensitivity to Crop Loss: Evidence From India

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Abstract: This study analyses farmer's sensitivity to crop yield loss in India. The four prominent reasons identified are: drought; disease; natural causes and others, among which drought appears to be the major issue. The farmers who had small landholdings and lacked irrigation facilities, assets, credit and technical guidance were more at loss. The crop loss severity and its region at agro-ecosystem level has also been analysed and it was found that across all ecosystems, arid area experiences more crop loss followed by rainfed, costal, irrigated and hills & mountain. Arid and rainfed agro-ecosystems are worse hit by inadequate rainfall and while coastal and hills & mountain are more risky due to insect/disease/animal. In case of irrigated ecosystem both inadequate rainfall and insect/disease/animal come out as credible threat and emerge as major reasons for crop loss. Insurance could be one possible ways to mitigate the impact of climate change on agriculture.

Keywords: Agriculture, Risk, Crop insurance, India

1. INTRODUCTION

The produce of agricultural system is complex and prone to many a risks owing to various biotic and abiotic factors as well as climatic changes. Other factors are the quality and quantity of inputs, agronomic features of farmed parcels, pest pressure, intrinsic or acquired skills of farmers, and the policy environment (Hardaker, Huirne and Anderson, 1997, Gautam 2016). Indian agriculture is prone to four risks namely: production, market price, government policy and climatic (Joshi 2015). However, the production and climate risks are more uncertain. Crops can be affected by weather, pests and disease. Yields can be low due to inadequate rainfall. Crops can be destroyed due to hail and heavy rains. While the other two; market and price risk and government policies are beyond the control of farmers. These two are generally influenced by demand/supply and also production costs.

In India, agricultural sector consists of fifty percent of the country's workforce and majority of them have marginal and small landholdings. Hence any confluence of biotic and abiotic risks will make farmers life more risky and vulnerable. Therefore understanding the risks associated with agriculture becomes very crucial. Climatic factors are one of the reasons for risks in agriculture. Risks in agriculture definitely has to do with climatic factors. It impacts Indian agriculture directly or indirectly depending upon temperature variation, shifting precipitation patterns, extreme weather events and water resources availability. Indian agriculture is prone to a variety of climatic factors like floods, cyclones, storms and hot/cold waves and droughts (Khan *et al.,* 2016).

The effects of climatic change on agriculture is being found all over the world, but for a country like India where eighty percent of the farmers are small and marginal, the effect of climatic changes is more harsh owing to poor coping mechanism. These farmers are further susceptible due to their over dependence on agriculture and natural resources (Mendelsohn *et al.*, 2006; Stern, 2006; Nelson *et al.*, 2009) and their technological and financial capability to mitigate and adapt to climatic change is low (Kavi Kumar 2011). Recently, climatic changes have been noticed with increased occurrence of natural tragedies such as droughts, floods, cyclones and heat waves and made significant negative impact on agriculture (Kalra *et. al.* 2010, Birthal, *et. al.* 2014, Gautam, 2016). Drought is a recurring thing in India with over two-thirds of the nation vulnerable to droughts. India has suffered thirteen major droughts since 1966. The probability of areas in India experiencing a drought in any given year varies from about 20 percent in dry-humid areas to 40 percent or more in the arid regions (Birthal *et al.* 2015). Extreme and extended droughts can cause severe harm to agriculture and increase food insecurity as well as also exacerbate poverty. Studies have shown that on average, a drought decreases rural incomes by 25–60 percent and head-count poverty ratio rises by 12–33 percent (Pandey *et al.* 2007). There were recurrent floods and droughts, which lead to disparities in agricultural output. However agriculture is now significantly less sensitive to rainfall variation than it was in the early 1980s (reducing variability in agricultural growth by more than half), but monsoons continue to drive large annual fluctuations in agricultural growth, affecting rain-fed areas (about 55% of total cultivated area) Chand, Saxena and Rana 2015).

In this paper, data from the 70th round of National Sample Survey Office (2012-13) is used to study the crop loss and its reasons and to assess what factors make agriculture more risky and their relative importance. Determining just how different biotic and abiotic risk reduces crop yield is important for the design and implementation of insurance scheme, a micro-level risk management strategy. We also have analysed crop loss and its reasons at different agro-ecological zones as India has numerous agro ecological systems, with diversity in crops and cropping systems, climate, agronomic and resource management inputs and socioeconomic aspects. This facilitates in understanding crop response to varying biotic and abiotic stresses, which subsequently can be used to design and implement of effective insurance scheme.

To the surprise of the authors, these observations on crop loss and the reasons thereof have not been rigorously analysed. Most of the studies dealt with climate change and extremes. In this paper, an attempt has been made to fill this gap in the literature by studying the factors accompanying the reasons for crop loss. The exact research question that this paper addresses is: what are the factors that are correlated with crop loss? A typology of farmers experiencing crop loss is developed and the reasons for it are studied. Consequently, an attempt is made to understand the differences in characteristics of these farmers which those who do not suffer crop loss. This analysis can offer significant opinion for planning remedial measures and improve upon the agricultural output.

The research is structured as follows. Section II deals with data and the methodology used to study the causes of crop loss and its correlates. A typology of the farmers who suffered crop loss is done in Section III by agro-ecological zone wise. Section IV discusses the correlates of the identified causes of crop loss. Section V summarizes the key findings and its implications.

2. DATA AND ESTIMATION

2.1. Data

Household data of agricultural households in the 70th round NSSO of Government of India in 2012-13 (GoI, 2015) is used. This national representative survey contains data on various characteristics of agriculture from a sample of 32,500 households. A question in the survey dealt with farmers' experiencing crop loss in both Kharif and Rabi season. The farmers who voiced their crop loss were then questioned about the chief cause of it. This survey further collected data on household level features on various aspects of socio-economics and crop economics besides information on farmers' use of credit, insurance, and information in agriculture which leads to find the correlates of crop loss reason. Lastly, after summing up all the data points we have a operational sample of 32,071 households.

2.2. Empirical Strategy

This research examines farmers' stated experience on crop loss and its correlates. For this, a random utility framework is applied wherein the net utility of an alternative (experience crop loss) is a linear function of the individuals' observed characteristics plus an additive error term (Greene 2008). This net utility is latent i.e. it is not observed. What is observed is the stated preference for crop loss in terms of yes and no. Given resources and other factor endowments, a farmer will maximise his/her utility or minimise his/her crop loss from given resources, and based on this the crop loss can be expressed as CL_i, $CL_i = 1$ if a farmer experiences crop loss and $CL_i = 0$ otherwise. CL_i will be correlated with resource endowment W_i, farm profits r_i and a vector of other observable characteristics X_i such as biotic and abiotic stress. Then, the function of a farmer who experienced crop loss is: $U_{0i} = U(0, W_i, r_i, X_i)$; and of the one who states otherwise is: $U_{1i} = U(1, W_i, r_i, X_i)$. Assuming linear and additively separable utility functions, U_{0i} and U_{1i} can be written as a sum of the deterministic part and the error term.

$$U_{0i} = U(0, W_i, r_i, X_i) = V(0, W_i, r_i, X_i) + \epsilon_{0i} \quad (1)$$

$$U_{1i} = U(1, W_i, r_i, X_i) = V(1, W_i, r_i, X_i) + \epsilon_{1i} \quad (2)$$

Given this resource endowments and other observable factors a farmer will experience of crop loss if $U_{1i}(\cdot) \geq U_{0i}$ or either he/she faces some shock in terms of biotic and abiotic stress. Thus we estimate the crop loss correlates using linear probability model.

As farmers have stated different reasons for crop loss, and each household growing more than one crop that makes a total of 102418 household crop combination from 32071 households in both the agricultural season, such as kharif and rabi. *To* establish a statistical relationship between crop loss reasons (CLR) and observable variables, we used panel data fixed effect approach (Greene 2008). Our panel consisted of household data for India's two main crop seasons viz. kharif (June to September) and rabi (October to March). The fixed effect panel model for climate impacts is specified as:

$$\ln CLR_{it} = D_i + T_t + \beta X_{it} + \gamma Z_{it} + \varepsilon_{it} \tag{3}$$

The subscripts *i* and *t* in Equation (1) denote crop and time, respectively. The dependent variable CLR represents crop loss reasons, and *D* is household fixed effects. It is assumed that household fixed effects absorb all the unobserved household-specific time-invariant factors; for example, soil and water quality, which influence crop loss, and reduces bias owing to omitted variables. *T* is time fixed effects controlling technological changes, infrastructure, human capital, etc.; *X* is a vector of variables such as irrigated area awareness about minimum support price, fertilizer use, Value of crop loss per hectare, etc. and ε is the error term.

3. FARMERS' EXPERIENCE FOR CROP LOSS

As many as 30% of households crops in India have experienced crop loss (Table 1). The experience of crop loss is more in kharif season and the loss is relatively low in rabi season. The prominent causes for crop loss were inadequate rainfall/drought, disease/insect/animal, other natural causes like storm, cyclone, flood, earthquake etc., and others. About 45% farmers suffered loss of crops owing to insufficient rainfall, 32 % due to disease/insect/animal, 17% due to natural causes and the remaining 6% to other causes. Regrettably, only 4 % of farmers had crop insurance. The major reasons for crop loss were inadequate rainfall and drought in kharif season and insect/disease and animal in rabi season.

Table 1
Crop loss and its reason (%)

	Rabi	*Kharif*	*Total*
Inadequate rainfall/drought	32.15	52.97	44.28
Insect/disease/animal	38.67	26.89	31.81
other natural calamities	20.61	15.37	17.56
Others	8.57	4.77	6.36
Total	26.30	32.22	29.45

Source: Author's estimate

We also analysed the loss and its reason across different agro-ecosystems, and we found that inadequate rainfall/drought is a major reason for crop loss in arid and rainfed ecosystem. In case of costal ecosystem inadequate, rainfall/drought and insect/disease/animal are equally important reasons for crop loss, however in hills & mountain ecosystem insect/disease/animal emerges as a major reason for crop loss, and in case of irrigated ecosystem inadequate, rainfall/drought and insect/disease/animal are key reasons for crop loss. This priority setting of different reasons for crop loss across all agro-ecosystems help us in preparing a suitable policy for sustainable agriculture systems.

Table 3 presents the frequency distribution of crop loss and its severity across different agro-ecosystems. Agriculture works in an ecosystem where many a things like geographical area, climate, resource endowments, and even socio economic conditions are homogeneous. Most of the farmers have same production

Table 2
Crop loss and its reason across agro-ecosystems

	Arid	*Coastal*	*Hills & Mountain*	*Irrigated*	*Rainfed*	*Overall*
Inadequate rainfall/drought	77.29	32.72	17.77	32.83	57.21	44.28
Insect/disease/animal	12.08	36.49	67.35	35.11	20.17	31.81
other natural calamities	4.54	25.40	9.16	23.00	17.09	17.56
Others	6.08	5.39	5.71	9.06	5.52	6.35

Source: Author's estimate

constraints and research needs, which can be very well identified using agro-ecosystem approach. Across all ecosystems, arid areas experience more crop loss followed by rainfed, costal, irrigated and hills & mountain. We also found similar trends for both kharif and rabi season.

Table 3
Crop loss and its severity across agro-ecosystems

		Arid	*Coastal*	*Hills & Mountain*	*Irrigated*	*Rainfed*	*Overall*
Overall	Exp. Crop loss (%)	65.97	25.10	22.97	23.48	36.47	29.45
	Loss (INR/Ha)	18604.19	104198.00	21650.53	14206.00	41484.00	37108.00
	Overall Loss (INR/Ha)	10690.69	22155.00	4358.41	3165.18	14369.00	10114.59
Kharif	Exp. Crop loss (%)	79.70	24.22	24.08	26.57	38.17	32.22
	Loss (Rs/Ha)	18688.45	30636.38	28334.01	16805.00	40492.00	32015.00
	Overall Loss (INR/Ha)	12955.88	6398.11	5931.00	4251.24	14661.08	9551.41
Rabi	Exp. Crop loss (%)	27.35	25.96	21.64	20.98	34.04	26.30
	Loss (Rs/Ha)	17921.52	174255.80	12894.50	11508.35	43067.82	44223.06
	Overall Loss (INR/Ha)	4315.79	8778.20	2471.74	2281.17	6421.18	10755.91

Source: Author's estimate

We have estimated the loss (INR/ha) after dividing total loss (INR) experienced by farmers by its cropped area (hectare). Overall loss (INR/Ha) shows the scale adjustment for all households. It reflects the overall loss faced by average household in the region. Rainfed and arid systems are worse hit followed by coastal and hill & mountain ecosystems. The loss was minimum in case of irrigated system. Similarly in both kharif and rabi season irrigated ecosystems experienced less loss per hectare as this could be due farmers' adaptive capacity such as expansion of irrigation facilities.

4. CORRELATES OF THE STATED REASONS FOR CROP LOSS

An attempt was made to identify the factors leading to loss of crops. We have used the ordinary least square regression results after controlling for district, crop code and agricultural season. We also reported the standard error clustered at agro ecosystem level. The results indicate that farmers experiencing loss of crops had landholdings which were small, irrigation facilities were poor and fewer productive assets were fewer. It is interesting to note that access to irrigation comes out as a good adaption practice in offsetting the crop loss. However, the coefficients for access to credit and information of technical advice does not have any significant influence on crop loss. It also indicates that females and elderly women and aged farmers are more likely to experience crop loss. Less education has positive associates with crop loss this clearly confirms that lower level of education will face more loss. Batte and Arnholt (2003) and Birthal, *et. al.* (2015) also observe similar results and they have found that households belonging to the upper caste have bigger resource endowments and had greater access to services and technologies. That is the reason that there is a lesser amount of crop loss among upper castes and with farmers having higher education.

Table 4
Crop loss experience and its correlates

	(1)	*(2)*	*(3)*
Irrigation, Credit and technology			
Households having access to irrigated area (%)	-0.0381**	-0.0383**	-0.0381**
	(0.0117)	(0.0117)	(0.0121)
Use of information on modern technology	0.0226	0.0226	0.0240
	(0.0218)	(0.0217)	(0.0211)
Household having access to credit for farm	0.0193	0.0185	0.0177
	(0.0096)	(0.0092)	(0.0092)
Personal and household characteristics:			
Households growing high value crops (%)		-0.0970**	-0.0954**
		(0.0320)	(0.0318)
Awareness about the minimum support prices (%)		-0.0035	-0.0004
		(0.0067)	(0.0062)
Whether insured any crop I this season?		0.0260	0.0291
		(0.0178)	(0.0188)
Gender (Male=1 , else==0)			-0.0063
			(0.0091)
Average age of the household head (years)			0.0001
			(0.0001)
Family size (number of persons)			-0.0005
			(0.0004)
Whether attended any formal training in agriculture?			-0.0107
			(0.0112)
Farming by Landholding Size			
Marginal			0.0075
			(0.0063)
Small			0.0193*
			(0.0071)
Medium			0.0133
			(0.0085)

cond. table 4

	(1)	*(2)*	*(3)*
Education level of the household head:			
Illiterate (%)			0.0223***
			(0.0027)
Primary school (%)			0.0162
			(0.0088)
Middle school (%)			0.0156*
			(0.0065)
Secondary and higher secondary (%)			0.0097
			(0.0097)
Caste of the household:			
Scheduled tribe (%)			-0.0313
			(0.0148)
Scheduled caste (%)			0.0252
			(0.0124)
Other backward caste (%)			-0.0063
			(0.0116)
Constant	0.8374***	0.8312***	0.8095***
	(0.0103)	(0.0107)	(0.0107)
No. of Observation	102233	101858	101434
Source: Author's estimate			

Note: ***, ** and * denotes significance at 1%, 5% and 10% respectively, Agro ecosystem clustered standard error are in parenthesis. In education and caste of the household, the base category was graduation and above and general (higher caste) respectively.

Table 7
Fixed effect regression for crop loss reason and its covariates

	Inadequate rainfall/ drought	*Insect/ disease/ animal*	*other natural calamities*	*Others*
Cropped area (ha)	0.0003*	-0.0009***	0.0002**	0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Households having access to irrigated area (%)	-0.0128*	-0.0041	0.0004	-0.0091**
	(0.0051)	(0.0169)	(0.0147)	(0.0028)
Use of information on modern technology	-0.0107	-0.0106	0.0052	0.0161*
	(0.0143)	(0.0131)	(0.0078)	(0.0074)
Agriculture Season (Kharif=1, else=0)	0.1154***	-0.0593**	-0.0200	-0.0362***
	(0.0124)	(0.0168)	(0.0238)	(0.0067)
Household insured any crop	0.0203	-0.0439	0.0402	-0.0167
	(0.0159)	(0.0356)	(0.0273)	(0.0135)

contd. table 7

	Inadequate rainfall/ drought	*Insect/ disease/ animal*	*other natural calamities*	*Others*
Households growing high value crops (%)	-0.1012***	0.0650*	0.0202	0.0161
	(0.0197)	(0.0262)	(0.0193)	(0.0134)
Constant	0.3830***	0.3571***	0.1794***	0.0805***
	(0.0151)	(0.0071)	(0.0176)	(0.0096)
No. of Observation	30110	30110	30110	30110
Log lik.	4042.8324	1938.9998	9727.0986	19481.6145

Source: Author's estimate

Note: ***, ** and * denotes significance at 1%, 5% and 10% respectively

Agro ecosystem clustered standard error are in parenthesis

The above table presents the fixed effect regression of household crop across both kharif and rabi season. In this regression, we are interested to see the possible correlates of crop loss reason after controlling the household crop fixed effect. The earlier results confirm through linear probability model that access to irrigation reduces the likelihood to experience crop loss however after controlling the household and crop fixed effect we do not find a similar trend. However the magnitude of coefficients are relatively less. The coefficients for access to use of information and modern technology is not significant. It is interesting to note that kharif season will be hard hit by inadequate rainfall/drought while it shows that kharif season will experience less insect/disease/animal than rabi season. Household who grows high value crops (fruits and vegetables) are less likely to experience crop loss due to inadequate rainfall however, they certainly face more stress due to insect/disease/animal. Crop insurance does not have any significant relation and this could be due to lower uptake of crop insurance by farmers.

5. CONCLUSION

Based on the data from India's agricultural household's survey, sensitivity of 35200 Indian farmers' to crop yield loss is analysed to crop yield loss. The four prominent reasons identified for crop loss are inadequate rainfall/drought, disease/insect/animal, other natural causes like storm, cyclone, flood, earthquake etc., and others. Amongst all, most of the farmers cited inadequate rainfall/drought as a major cause of crop loss. Using regression, the study points out that crop loss is experienced by farmers whose landholdings is small, whose irrigation facilities are poor, and whose productive assets are fewer. These farmers also had poor access to credit and technical assistance. Across all ecosystems, arid areas experience more crop loss followed by rainfed, costal, irrigated and hills & mountain. Arid and rainfed agro-ecosystems are worse hit by inadequate rainfall and while coastal and hills & mountain are more risky due to insect/disease/animal. In case of irrigated ecosystem both inadequate rainfall and insect/disease/animal comes out as credible threat and emerges as a major reasons for crop loss.

As most of the farmers stated inadequate rainfall/drought as the prime reason for crop loss and results from the priority setting exercise of different reason for crop loss across all agro-ecosystems helps us in preparing a suitable policy for sustainable agriculture systems. Nevertheless ample of the damage can be evaded and farmers' suffering lowered, by tactically filling gaps by making available precise weather predictions on time and by providing irrigation facilities.

Also, once a farmer faces crop loss, he has very few options available to him. He may go for a sale of his assets, take loan or wait for assistance from government. All of these have their own limitations. Like crop loss when it happens it generally happens for the entire area and when all farmers are selling their assets, they don't get good prices; loans from banks are not that easy and rates of informal loans is bound to go high when demand for loans is high; and state compensation can't be that quick. Active promotion of crop insurance would provide much respite.

However, crop insurance is marred with the issue of high premium rates. Therefore, crop insurance needs lots of subsidies. Without subsidies, crop insurance does not work, because private players find it is too risky to invest. Most of the agricultural insurances are heavily subsidised by the government. Combining crop insurance with microfinance and other social protection schemes like house, vehicles etc., would make the private sector to invest in it. We also need to innovate and evolve a mechanism for crop insurance. Besides, there is a need to create an institution for implementing and monitoring crop insurance.

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