

## **LAND DEGRADATION AND AGRICULTURAL PRODUCTIVITY: A DISTRICT LEVEL ANALYSIS, INDIA**

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### **ABSTRACT**

*Increase in agricultural productivity contributes to overall economic development and by providing capital, employment, and increased purchasing power of the rural people it also helps in reducing poverty. Environmental degradation is emerging as a major constraint in increasing productivity in agriculture. Land degradation is among the most crucial environmental problems affecting agricultural development. This paper tries to evaluate the implication of land degradation, by examining input use in agriculture in the severely degraded districts of India. Although land degradation directly affects agricultural productivity, the use of fertilisers and rainfall also influences productivity. In turn, productivity is also influenced by other inputs like irrigation, conventional inputs, credit, extension services and adoption of mechanical and chemical technologies.*

### **Introduction**

Degradation takes place all over the Earth in different ways and diverse degradations are very challenging, disputant and significant too. The upper most surface of the Earth is always in the influence of atmospheric activity, geological process, and energy radiated or transmitted by the Sun. Also, the amount of degradation has also been stepped up by many other components,

for instance, climatic factors- coldest, driest, etc.; organic factors; but most importantly the uncontrolled human activities highly contributed because of competition in achieving more and more development. This problem seems to be a matter of environment, but notably related to social and economic aspects throughout the world. When land from its own original condition has failed to keep or to maintain the capacity of

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The authors are thankful to Professor Deepak Mishra, Centre for the Study of Regional Development, School of Social Sciences, Jawaharlal Nehru University, for his valuable suggestions during conceptualisation of the paper.

productivity and other qualities to sustain the vegetation, then the concept of land degradation has emerged.

Agriculture contributes significantly to the growth process of the country not only in economic ways but also in providing livelihoods to human beings. Increase in agricultural productivity helps in the growth process in three ways- provides capital for economic growth, creates employment and increases the purchasing power of the rural people (Christensen and Yee, 1964; Braun and Gerber, 2012). In India, rice and wheat are the major foodgrains (Easter et al., 1977). Therefore, the study has focused on these two crops. The introduction of new varieties, along with increased availability of fertilisers and irrigation highly raise the production potential in agriculture. Dobbies and Foster (1972) have summarised that these inputs- high-yielding seeds, fertilisers, tube wells, etc., are adopted successfully by the large farmers leaving the small farmers technologically behind. The contribution of green revolution in minimising the world's food security problem is widely recognised. However, the adverse environmental impacts of the green revolution technology have also emerged as a global problem (Paddock, 1970).

India's green revolution has been confined to few regions and few crops. Ranade (1986) stated that it was technology, which brought changes in wheat and rice production, which also helped in tapping the comparative advantage of the States like Punjab and Haryana (Adams and Bumb, 1979; Chakravarti, 1973). The new varieties

of grains are highly responsive to fertilisers (Posgate, 1974; Ranade, 1986). The green revolution was expanded to new areas in the 1980s, but 1990s was a period of stagnation in agricultural productivity growth. More importantly, the ecological constraints started to slow down productivity growth in the 'traditional green revolution belt in India'. There are so many studies relating to land degradation process and the declining productivity of the farms, separately. But it is evident that an attempt to find the association of both has not been done through statistical studies. This paper has tried to attempt the same.

### **Objective**

Thus, it is important to understand the association of land degradation with agricultural productivity in India. In the backdrop of all the developmental processes, this study has attempted to examine whether land degradation, quantified through a Land Degradation Index, has a significant impact on agricultural productivity at the district level, particularly in the context of rice and wheat.

### **Methodology**

To examine the impact of land degradation on agricultural productivity a regression model has been fitted (Kumar and Pani, 2013). Firstly, in this study value output per hectare of 32 crops has been taken as a measure for agricultural productivity for 281 districts of India. Land degradation and wasteland data have been taken from NRSC and land degradation indices value has been taken from the Priya (2014) and Priya and Pani (2015) calculation by

using Principal Component Analysis. Agricultural data have been collected from Bhalla and Singh (2012) study. Other farm related data have been taken from Agricultural Census. The data for the Year 2008 have been taken for all the variables in the context of analysis. Though the data have been taken from different sources for regression analysis of independent variables, the data for productivity and the land degradation are of the same year (2008) to get a synchronised analysis.

Factor analysis comes into perform when all variables are correlated to some extent. It reduces mass number of variables and high or low correlation coefficients indicate high inter-correlations as independent factors (Ho, 2006; Giodano et al., 2011). This analyses observations in three steps- computation of correlation matrix, extraction of initial factors and run finally rotation of the extracted factor to final solution as instructed in the works of Ho (2006). First principal component analysis is carried out on each dataset, which is then normalised through dividing all datasets by square root of the first Eigen value obtained from each PCA (Giodano et al., 2011). Then linear function has been accounted and land degradation index is computed.

$$LDI = a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + \dots + a_6X_6.$$

Where, a = Coefficient vector,

X = Selected variables of land degradation types.

Land Degradation Index (LDI) (Priya, 2014; Priya and Pani, 2015), Workers (Number of agricultural workers per GCA ha), Fertilisers (N+P+K per ha), Tractors (Number of tractors

per ha), Tube wells (Number of Tube wells per ha), Irrigation (Percentage of GCA under irrigation) have been taken as independent variables in the regression analysis. In order to probe the impact of land degradation status on the gross value of output per hectare, the following linear regression model has been used.

$$Y = \hat{\alpha}_0 + \hat{\alpha}_1 X_1 + \hat{\alpha}_2 X_2 + \hat{\alpha}_3 X_3 + \hat{\alpha}_4 X_4 + \hat{\alpha}_5 X_5 + \hat{\alpha}_6 X_6 + u$$

Here Y is Gross Value Output per hectare of 35 crops.

X1 is Workers (Number of agricultural workers per GCA ha), X2 Fertilisers (N+P+K per ha), X3 Tractors (Number of tractors per ha), X4 Tube wells (Number of tube wells per ha), X5 Irrigation (Percentage of GCA under irrigation in the district) and X6 is the Land Degradation Index as an independent variable.

To examine the implications of land degradation on agricultural productivity in highly degraded districts of India, linear regression model has been run at a more disaggregated level. Firstly, 231 districts have been selected on the basis of land degradation index value, out of which seven have been taken from the highest degraded districts, 20 districts have been taken from highly degraded, 66 from moderately degraded, 134 from low degraded and finally four districts have been taken from no degraded districts (Priya, 2014; Priya and Pani, 2015). The districts have been selected in proportionate to their population which has been under rice producing districts. The equation used for linear regression model is given below.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + u$$

Here Y is rice production (yield in tonnes per hectare).

X1 is the value of land degradation index for each district, X2 is fertilisers (NPK in metric tonnes/hectare) and X3 is the percentage of gross cropped area under irrigation as independent variable.

For assessment of implication on wheat productivity a total of 220 districts, which come under wheat cultivating districts in India, have been selected, out of which eight districts have been taken from highest degraded districts, 24 from highly degraded, 65 from moderately degraded, 118 from the low degraded and five districts have been taken from no degraded districts. The following equation is used to run the linear regression model.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + u$$

Here Y is wheat production (yield tonnes per hectare).

X1 is the value of land degradation index for each district, X2 is fertilisers (NPK in metric tonnes/hectare) and X3 is the percentage of gross cropped area under irrigation as independent variable.

### **Land Degradation in India: A District Level Analysis**

All districts of India have been selected for the study, but as value output of 35 crops is calculated for those districts where these crops

are mainly produced. Therefore, the same number of districts has been selected for this study. To assess the first objective of the study, 281 districts are selected for measuring the impact of land degradation on agriculture productivity aggregately.

### **Analysis of Relation between Land Degradation and Agricultural Productivity**

To evaluate the impact of land degradation on agricultural productivity, a linear regression model has been fitted. Agricultural productivity is likely to be affected by other factors as well. So the other variables related to agricultural inputs have also been incorporated in the model. The value of R square= 0.297 which suggests that about 30 per cent of the total variations in the dependent variable are explained by the model and correlation has explained that the association of agricultural productivity with land degradation and other agricultural inputs has been very significant reaching to the correlation up to 60 per cent. The F value (18.55) has provided the evidence of the overall significance of the model (Table1). The t-test has been undertaken for testing the significance of each independent variable. The t-value for each independent variable is highly significant (Table1). It is important to note that land degradation index has a negative and significant impact on agricultural productivity, even after controlling for other factors. Though coefficient value explains that land degradation is not a major factor for the decline of productivity (B= -0.002) because the other factors of production have controlled productivity, e.g., fertilisers (B=10.188), tube wells

(B= 15.54) and irrigation (B= 0.036). It is very interesting to observe that the increase in labour has not impacted positively. But it is fertilisers and irrigation which have become the drivers of agricultural productivity (Table 1).

**Table 1: Determinants of Agricultural Productivity: Coefficients <sup>a</sup> (India)**

	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	7.228	0.623		11.597	0.000
LDI	-0.002	0.001	-0.117	-2.223	0.027
No. of agricultural workers per GCA ha	-1.126	0.285	-0.213	-3.956	0.000
N+P+K per ha	10.188	1.904	0.301	5.352	0.000
No. of tractors per ha	-59.373	17.624	-0.213	-3.369	0.001
No. of tube wells per ha	15.543	2.970	0.286	5.233	0.000
Irrigation percentage of GCA under irrigation in the district	0.036	0.011	0.220	3.233	0.001
R = 0.54, R square = 0.292, Adjusted R Square= 0.276, Std. Error of the Estimate = 4.080, F = 18.55*, N = 281. a. Predictors: (Constant), LDI, No. of agriculture workers, N+K+P, No. of tractors, No. of tube wells, Irrigation. b. Dependent Variable: Value Output of 35 Crops. *Significant at the level of < 0.001.					

Source: Authors' own calculation based on different data sources.

Several studies have highlighted the specific problems caused by land degradation for specific crops at the regional level. In Rajasthan, for example, the degradation has taken place due to moderate water erosion, wind erosion and gypsum query (Adams and Bumb, 1979). Another study has tried to correlate the satellite data with physical and chemical characteristics and it has revealed that in western Rajasthan, the mean organic carbon is 31 per cent less in slightly, 62.7 per cent in moderately and

68 per cent less in severely degraded soil than non-degraded soil. The impact of types of land degradation such as wind erosion, water erosion, and salinisation on fertility status of soil has revealed the loss of potassium, phosphorus and organic carbon (Raina et al., 2009). Due to high salinity and alkalinity, gullied and ravines, lack of proper irrigation system and non-adoption of suitable agricultural techniques, land productivity is found to be low (Easter et al., 1977; Adams and Bumb, 1979; Drost et al., 1999). Thus, there is an

urgent need to examine the inter-relationship between land degradation and agricultural development at a more disaggregated level.

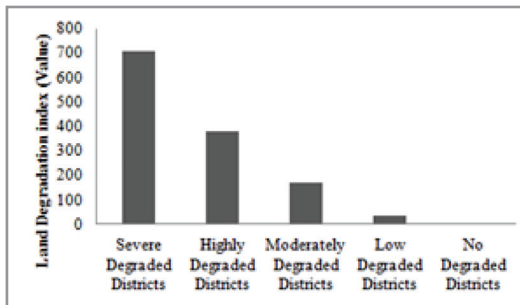
The form of agriculture practices in India is mostly of subsistence type. The high population pressure has increased the stress on land (Kangalawe and Lyimo, 2010; Sadanandan, 2014; Priya and Pani, 2015). Yet, the agricultural sector is providing 59 per cent employment out of the total employment provided by all sectors of the economy. Due to increase in population and marginal agricultural productivity, migration from rural areas is taking place rapidly. But the process is not so easy and is not smooth (Sadanandan, 2014). Lending to the farmers in rural areas is yet another problem. Small farmers are not capable of investing in farm inputs (Storm, 2006). Integrated land resources management policy is needed to meet the projected phytomass/biomass demand. Some new methodologies should be developed at various scales using modern tools and procedures. The integrated farming system should be evaluated in different agro-ecological regions. Scientific planning of land resources is required for utilisation of waste/

degraded land. Soil health cards with modern soil testing tools or test kits are needed to know the fertility status of agricultural land for balanced use of fertilisers. Salinity and alkalinity have to be managed by leaching of excess salts, improving drainage system, applying gypsum and growing green manures and mulches (Sharda, 2011).

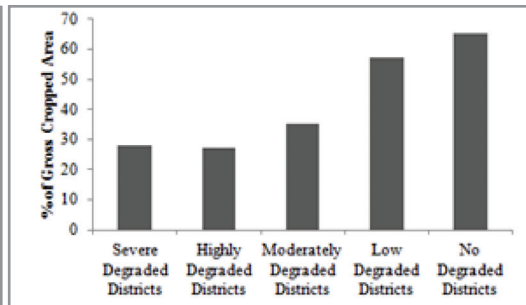
### **Agricultural Productivity in the Land Degraded Districts**

The general description shows that the districts having severely degraded land of their total geographical area are having best rice production at some level [Figure 1 (d)]. It is significantly evident that the same districts are availing of the facility of fertiliser consumption [Figure 1 (c)] and the irrigation facilities [Figure 1 (b)]. However, besides having a good quality of land [Figure 1 (a)], irrigation facility [Figure 1 (b)] and use of fertilisers [Figure 1 (c)], the moderately, low and no degraded districts have, on an average, recorded less rice productivity. As rice is dependent on rainfall, it might be one of the factors which control the productivity of rice (Grepperud, 1997).

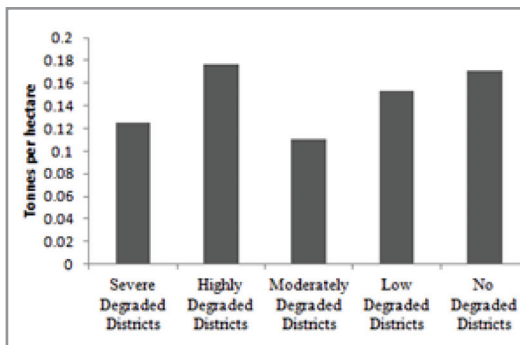
**Figure 1 (a): Average Value of Land Degradation Indices**



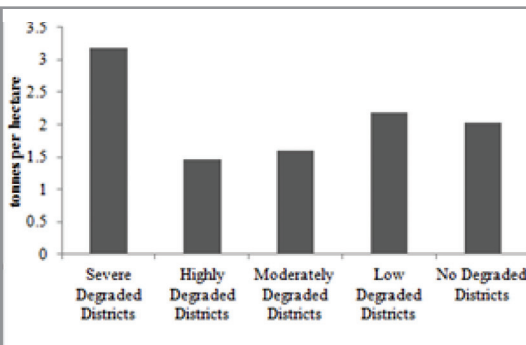
**Figure 1 (b): Average Percentage of the GCA Under Irrigation**



**Figure 1 (c): Average Use of Fertilisers (NPK) Per Hectare**



**Figure 1 (d): Average Rice Production (Tonnes Per Hectare)**



**Rice:** As explained above, this section has dealt with five types of degraded districts, namely severe, high, moderate, low and non-degraded districts, which come under the rice production (all the selected districts are spread over major States covering 2,27,54,463 hectare area under rice cultivation). Regression result has suggested that the relation of land degradation, fertilisers and irrigation with rice production is significantly strong ( $r = 0.50$ ) having  $R^2 = 0.25$ , if not too

strong. The whole regression is significant at the level of  $< 0.001$  (Table 2). The t-value for each variable of land degradation, fertilisers and irrigation are 0.144, 3.602 and 5.265 and they are significant at the level of  $< 0.886$  (not significant),  $< 0.001$  and  $< 0.001$ , respectively (Table 2). The association of land degradation with the rice field is not strong because it is more or less controlled by the rainfall conditions in the region (Grepperud, 1997).

**Table 2: Determinants of Agricultural Productivity: Coefficients <sup>a</sup> (India)**

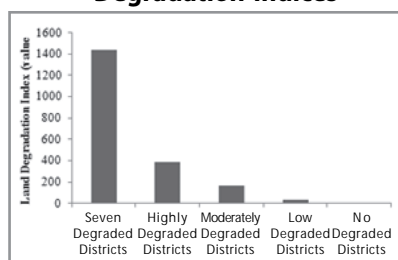
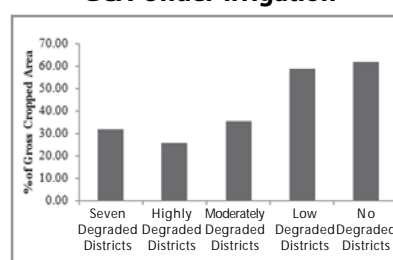
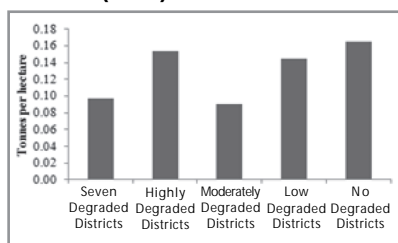
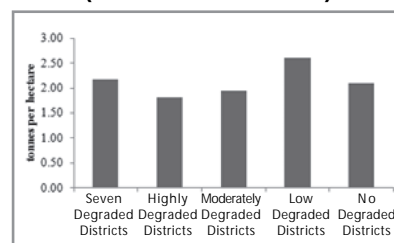
	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.090	0.148		7.343	0.000
LDI	6.098	0.000	0.009	0.144	0.886
N+P+K per ha	1.763	0.489	0.231	3.602	0.000
Percentage of GCA under irrigation	0.013	0.001	0.358	5.265	0.000

R = 0.496,  
R square = 0.246,  
Adjusted R square= 0.236,  
Std. Error of the Estimate = 0.946,  
F = 24.72\*,  
N = 231.  
a. Predictors: (Constant), LDI, Fertilisers (N+K+P), Irrigated Area of Gross Cropped Area.  
b. Dependent Variable: Rice Productivity (Yield, tonnes per hectare).  
\*Significant at the level of < 0.001.

Source: Authors' own calculation based on different data sources.

**Wheat:** The selected districts for the analysis are covering almost 1,84,61,432 hectare area spread over different important wheat producing States with an average wheat productivity of 2.29 tonnes per hectare. Contrary to rice producing districts, the scenario in the wheat producing

districts is very different. The low degraded districts, despite availability of irrigation and fertilisers [Figure 2 (b) and (c)], are having average productivity like other categories of districts which are comparatively more degraded [Figure 1 (a)].

**Figure 2 (a): Average Value of Land Degradation Indices****Figure 2 (b): Average Percentage of the GCA Under Irrigation****Figure 2 (c): Average Use of Fertilisers (NPK) Per Hectare****Figure 2 (d): Average Wheat Production (Tonnes Per Hectare)**



For the analysis of implications of land degradation, fertilisers and irrigation on wheat productivity, 220 districts have been taken from different categories of districts which are affected by several levels of degradation. The

correlation of land degradation, fertilisers and irrigation with wheat productivity is significantly high ( $r = 0.71$ ). Adjusted R-square is 0.50, explaining 71 per cent of variability of the independent variable (Table 3).

**Table 3: Determinants of Agricultural Productivity: Coefficients<sup>a</sup> (India)**

	Unstandardised Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.164	0.100	–	11.691	0.000
LDI	-5.154	0.000	-0.019	-0.384	0.701
N+P+K per ha	-0.027	0.383	-0.004	-0.070	0.945
Percentage of GCA under irrigation	0.024	0.002	0.706	13.102	0.000

R = 0.71,  
R square = 0.50,  
Adjusted R Square= 0.495,  
Std. Error of the Estimate = 0.73,  
F = 72.43\*,  
N = 220.  
a. Predictors: (Constant), LDI, Fertilisers (N+K+P), Irrigated area of Gross Cropped Area.  
b. Dependent Variable: Wheat Productivity (Yield tonnes per hectare).  
\*Significant at the level of < 0.001.

Source: Authors' own calculation based on different data sources.

The model is significant at the level of <0.001. The probability value for f-test is 72.43 (Table 3). The t-value for land degradation is -0.384, -0.070 for fertilisers and 13.102 for irrigation. The t-value for land degradation and fertilisers is not significant, while it is significant for irrigation at the level of < 0.001 (Table 3), suggesting a much higher level of impact of irrigation on wheat productivity compared to other variables.

Even in high degraded districts, the productivity has been recorded high for both the crops of rice (Figure 1 and Table 2) and wheat (Figure 2 and Table 3). It is evident in the

analysis that the land degradation, though high, is having influence on the production of crops. It is irrigation and fertilisers (Tables 2 and 3), which are enabling the soil to support the crop. Irrigation facilities have been a major input for agriculture (Ayars et al., 1990). When the same is supported by fertilisers, it is revealed, the plot would get higher yield compared to those which have only irrigation facilities (Bame et al., 2014).

### Policy Implication

The study has found that though degradation is affecting the quality of soil, its impact on productivity is not visible directly. It is

due to more use of fertilisers and increase in irrigation facilities, which is a good sign for agricultural growth. Most important to note here is use of fertilisers in a judicious manner, if not taken care of can be hazardous for the land itself (Bell, 2002). Similarly, the sign of negative impact of fertilisers on rice production has been ascertained (Table 3). The research has suggested that in the short-run, the impact of land degradation is not visible so drastically because of new innovational developments in agriculture either by mechanisation or other methods and the same has been found in other studies (Haigh, 1984; Bell, 2002; Bowman, et al., 2002). Therefore, the policies related to farming and farmers should incorporate the compulsory provision of awareness about land degradation and judicious use of fertilisers and irrigation facilities, which are the most significant parts of the agricultural procedure in the farming activities (Haigh, 1984; Bell, 2002; Bowman, et al., 2002; Gabriel et al., 2012; Kwon et al., 2016). Thus, the process of development should have one aspect of the sustainable mechanism to conserve land as well as increase food security for the ever-increasing population. Inclusion of the aspect of conservation of land in the initial stage would have a multiplier effect on sustainable growth in the economy.

### **Conclusion**

Finally, it can be concluded that with other type of factors of production like fertilisers, irrigation, rainfall and other inputs, land degradation is also one of the most significant components which plays a key role in the determination of agricultural productivity. Other aspects of agriculture like minimum and maximum temperature and rainfall are not dealt in this research work. This is the limitation which requires further research. But the man-made environment affects productivity very high, due to which the real impact of degradation of land is not seen significantly. The introduction of new varieties and development of canal system have come with an opportunity to improve the productivity of land. Other than that change in market structure, improvement in connectivity, development efforts, new crop technology, use of supporting inputs and improvement in social and private irrigation in eastern India are capable of increasing rice production besides lagging in high land quality. The study has a limitation to include the aspect of technological enhancement in agricultural development, though some of the variables like mechanisation have been tried to include. More data availability for the technological extension in agriculture would be more helpful to understand the Indian agriculture.

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