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## **Accounting for Impact of Environmental Degradation in Agriculture of Indian Punjab**

**Joginder Singh<sup>1</sup> and R.S. Sidhu<sup>2</sup>**

### **Abstract**

Having witnessed a fast growth, the agriculture in Punjab has reached a plateau. To sustain even the existing level, the costs are increasing and natural resources are being depleted due to overuse. This study has examined the use of certain resources and its impact on the cost of production. The data have been collected from different primary and secondary sources. The fast increase in area under rice and wheat appears to be unsustainable due to the fast decline in water table. Therefore, the cost of pumping out water with electricity has been going up, shortage of electric power has resulted in increase in the number of electric and diesel tubewells, further escalating the cost of production. The replenishment of soil health due to depleting macro and micronutrients and increased pesticide-use have also been observed to increase the cost. Thus, the cost on account of these factors together has gone up by Rs 63/t in wheat and Rs 189/t in rice. The varietal diversity of wheat has decreased and that of rice crop has increased during the past two and a half decades. The policy measures to minimize excessive use of natural resources requires suitable input pricing, particularly for water resource, improving input-use efficiency and revamping market forces to encourage diversification of state agriculture from rice to alternative crops.

### **Introduction**

The state of Punjab in India, covering only 1.5 per cent geographical area of the nation, has attained rapid rate of growth in the agricultural sector. As a result of increase in the cultivated area, cropping intensity and productivity per hectare, the agricultural production index rose from 100 in 1960-61 to 340.8 in 2001-02, but of late, it has started showing some decline

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<sup>1</sup> Professor and Head (Retd.); <sup>2</sup>Professor, Department of Economics, Punjab Agricultural University, Ludhiana – 141 004, Punjab; E.mail: ravibaba@satyam.net.in (Joginder Singh)

(to 334.1 in 2003-04). The cereals, particularly rice and wheat crops, showed a remarkable growth in production due to increase in area and productivity per hectare. Their effective price support and developed market infrastructure were further responsible for the monoculture of rice-wheat system, which covered 62 per cent of cultivated area during summer and 82 per cent during the winter season of 2003-04. The enhanced production of wheat and rice was helpful in not only solving the food problem and eradicating poverty but also generating exportable surpluses in the country. Such an intensive agricultural production in the state has caused environmental degradation such as fall in water table, deterioration in soil health, perpetuating pest problem and eroding bio-diversity, apart from imbalanced use of farm resources and associated social problems, etc. (Singh *et al.*, 1997). Consequently, growth in the agricultural sector has slowed down. The compound growth rates (CGR) in average yield of rice and wheat, which were 5.29 per cent and 2.31 per cent during 1970s, depicted a fast decline to 1.48 per cent and -3.23 per cent during 2000-01 to 2003-04, respectively (Table 1).

Evidently, the state agriculture has reached at a stage of stagnation whereas the social cost is increasing due to environmental degradation (Singh and Hossain, 2002). Though the economic evaluation of social cost is a cumbersome process, this paper has assessed it in terms of increase in cost of production and extent of degradation in natural resources of the state. Some policy measures have also been suggested to reduce the adverse impacts of environmental degradation.

## Methodology

Since wheat and rice are the major crops accounting for three-fourths of the total cropped area of the state, the analysis was focussed only on

**Table 1. Compound growth rates of area and average yield of rice and wheat crops in Punjab: 1970-71 to 2003-04**

Period	Wheat		Rice	
	Area	Yield	Area	Yield
1970-71 to 1979-80	2.32	2.31	12.69	5.29
1980-81 to 1989-90	1.20	3.00	5.39	1.29
1990-91 to 1999-00	0.04	1.97	2.52	0.02
2000-01 to 2003-04	0.27	-3.23	1.67	1.48
Absolute value, 2003-04*	3444(82.0)	4207	2614(62.2)	3694

*Note:* Absolute values of area are in thousand ha and yield in kg/ha  
Figures within the parentheses indicate percentages of total cultivated area

these crops. To capture the extent of degradation of environmental factors, data from different sources were collected.

### Field Survey

The data on water table at two points of time, viz. June (pre-rainy season) and October (post-rainy season) available for 12 erstwhile districts of the state were taken from the Department of Agriculture, Punjab, for the period of 1981-2001. Trend values were worked out to estimate rise/fall in water table in different agro-climatic regions of the state. A field survey was also carried out by taking a random sample of 10-11 farmers from different farm-size groups in 19 villages, representing different agro-climatic conditions of the state. Thus, in all, 193 farmers were interviewed and the data on farmers' perceptions about the use of water and soil resources, pest problems, bio-diversity, use of by-products, etc. were recorded. To substantiate the results, the over time data on the cost of cultivation of wheat and rice crops were also taken (Govt. of India, CACP reports).

The cost of environmental change for fall in water table, soil fertility and pesticide-use was worked out at constant (2002-03) prices.

### Varietal Diversity

The Department of Economics, Punjab Agricultural University, has also been collecting data on the area under different varieties of wheat and rice every year since 1981-82 for the Punjab state by taking a large sample of 700-900 farmers (Singh, 2003). On the basis of these data, Theil's Entropy Index for measuring varietal diversification was worked out as under:

$$E = \sum_{i=1}^n P_i \log (1/P_i)$$

where,

E is the entropy index,  $P_i$  is the proportion of area under  $i$ th variety to total area under the crop;  $n$  is the number of varieties raised by the farmers; and E varies from 0 to  $\log n$ .

### Determinants of Crop Yield

The annual data collected under the cost of cultivation scheme from 1970-71 to 2001-02 were analyzed. The yield of wheat and rice was regressed separately against the parameters given below to quantify their possible effect:

Y = Yield of crop in kg/ha

$X_1$  = Fertilizer-use in nutrients (kg/ha)

$X_2$  = Cost of pesticides used on the crop (Rs/ha) deflated by input price index, and

$X_3$  = Theil's Entropy Index, indicating varietal diversification.

The irrigation water could not be taken as a possible determinant due to state policy of free electricity for irrigation and free canal water and physical data on water-use was not available.

It was expected that the use of fertilizers and pesticides had increased much faster and the farmers were expected to be using excess of such agro-chemicals. The varietal diversity was believed to have a negative effect on the crop yield, as farmers had started growing highest-yielding varieties of wheat at the cost of diversification in order to maximize profit, while in the case of rice, the duration of the variety and its suitability in different farming systems, resistance to pests and diseases, export possibilities played dominant role in maintaining the varietal diversity.

## Results and Discussion

### Depletion of Water Resource

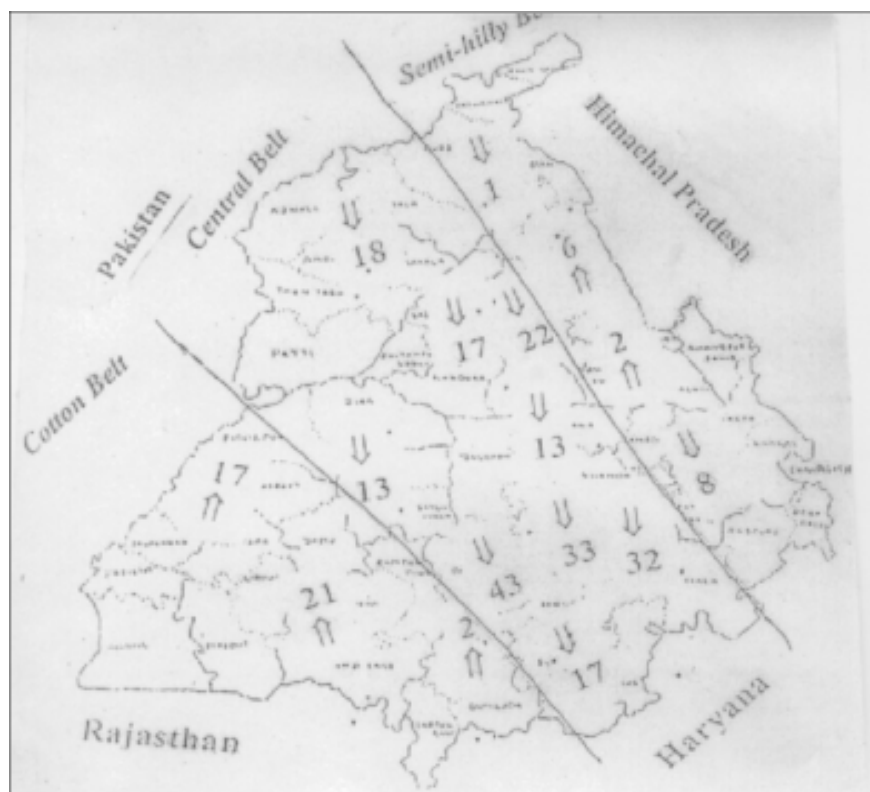
The water table depth was measured from a sample of wells in different blocks of 12 districts for the past two decades. The three agro-climatic regions of Punjab presented a varied picture in this regard (Table 2 and Map 1). In the semi-hilly belt, the water table showed an insignificant rise/fall over the past two decades. Since water table was deep and soil was rocky, pumping out water was relatively un-economical and the problem of declining water table depth was not serious in this belt of Punjab. In the central belt, which mainly had the rice-wheat cropping system, water table was declining at an average rate of 24-25 cm per annum. This is a high

**Table 2. Linear trend of rise/fall in water table: 1981-2001**

(in metres)				
District/ Zone	Month	Intercept	Regression coefficient	R <sup>2</sup>
Semi-hilly area	June	18.3690	-0.0443	0.0367
	October	14.2030	-0.0667	0.0880
Central belt	June	5.5940	0.2467	0.9156**
	October	5.0852	0.2401	0.8372**
South-western belt	June	6.4118	-0.1806	0.6598**
	October	6.0410	-0.1645	0.9359**

*Source:* Based on the data collected by Department of Agriculture, Punjab.

\*\* Significant at 0.01 probability levels



**Map 1.** Rise (+) or fall (-) in water table in Punjab (cm/year)

potential agricultural production belt but due to fast depletion of water resource, it is facing the problem of sustainability of the existing cropping system (Prihar *et al.*, 1993). The cotton belt comprising almost one-fourth of the cultivated area of the state, has deep and brackish water and water table is estimated to be showing a rise of 16-18 cm per year, forcing the farmers to shift from cotton to rice cultivation.

The fall in water table in the state, in general, can be attributed mainly to increase in rice area from 1180 thousand hectares in 1980-81 to 2614 thousand hectares in 2003-04. The rainfall as exogenous variable did help to improve the position of underground water resource, which was exploited faster than its rejuvenation. The situation is clear from the following function fitted in the state data for the 1980-81 through 2003-04:

$$Wt = -0.9393 AP_{t-1}^{0.6518**} RF_{t-1}^{-0.1821**} \quad (R^2 = 0.9118**)$$

\*\* Indicates the significance at 0.01 levels.

The level of water table in June (in metres) (Wt) was determined by one year lagged paddy area ( $AP_{t-1}$ ) and rainfall ( $RF_{t-1}$ ) to the tune of 91 per

cent. The rainfall helped improve the situation significantly but rice area alone depleted it more than that, resulting in deterioration of overall water balance situation. The fall in water table, particularly in the central belt, had the following impacts;

- a) The cost of pumping out water has increased. The power required for lifting water from deeper surface is much higher than that from the shallow one. The quality of water is also getting poorer (Hira and Khaira, 2000).
- b) Submersible pumps are replacing the centrifugal pumps. The increase in HP of motors has worked out to be 10 per cent during the past one decade.
- c) More number of tubewells is being installed. The electricity is getting in short supply and diesel pumps as supplementary source of power are being increasingly used, accelerating the cost of production further. For example, the number of electric- and diesel-operated tubewells in the state has gone up from 600 thousand and 200 thousand in 1990-91 to 856 thousand and 288 thousand in 2003-04, respectively, showing an increase of 3 per cent per year.

On the basis of field survey of 193 farmers, it was estimated that the additional cost for deepening of a tubewell amounted to Rs 7612. An average tubewell commands two hectares of rice crop and almost double the area under wheat crop. The additional depth of 7 metres per tubewell was added to the original average depth of 32 metres. The electricity required to pump out water from the deeper surface also went up from 5.03 HP to 5.64 HP per tubewell, showing an increase of 12 per cent over a period of 12 years (Singh, 2004a).

To split the cost of deepening of tubewells and additional use of electricity between paddy and wheat, the area under these crops, number of irrigations and intensity of irrigation were considered (Singh, 2004b). The cost of deepening of tubewells (in terms of labour, higher HP and connection fee, etc.) worked out to be Rs 317/ha, that was split into Rs 206 (65% of water-use) for rice and Rs 63 (20% of water-use) for wheat crop per year (Table 3). The additional annual cost of electricity was estimated to be Rs 35 and Rs 4 per hectare for paddy and wheat, respectively. But due to increasing shortage of electricity and subsequent use of diesel engines, the annual diesel cost for irrigation has increased by Rs 72/ha for rice and Rs 14/ha for wheat. Further, an increase in the number of electric and supplementary diesel tubewells, without increase in the coverage of irrigated area, escalated the annual cost in terms of depreciation and interest on such investment by Rs 80/ha in the case of wheat and Rs 260/ha in paddy. Therefore, on account

**Table 3. Additional cost of irrigation for wheat and rice crops in Punjab at 2002-03 prices**

Items of cost	(Rs/ha)	
	Wheat	Rice
Deepening of tubewells	63	206
Depreciation & interest on additional number of diesel & electric tubewells	80	260
Running cost of higher HP motors		
(a) Electricity	4	35
(b) Diesel	14	72
Total	161	573

**Table 4. Use of micro-nutrient for paddy crop in Punjab**

Year	Zinc sulphate (kg/ha)	Ferrous sulphate (kg/ha)	Manganese sulphate (kg/ha)	Total cost (Rs/ha)	Annual increase (Rs/ha)
1992-93	4.18	0.13	0.00	90.28	
2002-03	12.57	1.34	0.12	330.43	22

*Source:* Directorate of Agriculture, Punjab.

of water-use, an increase in cost by Rs 161/ha for wheat and Rs 573/ha for rice crop was estimated.

### Deteriorating Soil Health

The use of major soil nutrients such as nitrogen, phosphorus and potash had almost stagnated during the past decade, but the deficiency of micronutrients like zinc, iron, and manganese was commonly observed. The use of FYM per hectare declined due to its less availability resulting from expansion in the crop area. The use of micronutrients, particularly of zinc, iron and manganese had gone up in case of paddy crop (Table 4). Such deficiency symptoms were not observed in the wheat crop as the impact of nutrient application sustains for about 3 years. All these changes in the soil nutrition resulted an additional expenditure of Rs 26/ha/annum on rice and Rs 33/ha/annum on wheat (at 2002-03 prices) during the past one decade (Table 5). Therefore, farmers were using higher levels of major and micronutrients to sustain the crop yields.

### Developing Pest Resistance

The monoculture of rice and wheat had resulted into the resistance to some of the weeds, insect-pests and diseases, overtime. The incidence of



**Table 5. Cost of agro-chemicals at 2002-03 prices**

(in Rs/ha)

Particulars	Wheat crop			Rice crop		
	1992-93	2002-03	Annual increase	1992-93	2002-03	Annual increase
<b>1. Fertilizers</b>						
Major nutrients, kg/ha	194.6	222.1		183.2	177.4	
Cost at 2002-03 prices	2339	2670	33	2124	2140	2
<b>2. Micro-nutrients</b>						
Cost	0	0	0	90	330	24
<b>3. Pesticides</b>						
Cost at 2002-03 prices	399	1086	69	218	1211	99
Cost due to agro-chemicals	2738	3756	102	2432	3681	125

*Source:* CACP Report

attack of pest and diseases had also gone up manifolds. Consequently, the area covered under herbicide spray which was about 68 per cent and 72 per cent in paddy and wheat during 1991, increased to 95 per cent and 93 per cent, respectively during 2001 (Singh, 2003). Besides, the dose of herbicide application had also increased. Similarly, the cost on other pesticides also went up and new types of herbicides and pesticides were introduced which put together raised the annual cost of production by Rs 99/ha in paddy and Rs 69/ha in wheat.

The fall in water table, deficiency of micronutrients, and resistance to herbs, pests and diseases together had increased the cost of production by Rs 263/ha and Rs 698/ha or Rs 62.51/t and Rs 188.96/t of wheat and rice, respectively.

### **Varietal Diversity**

The decline in fauna and flora was evident from the emerging monoculture of rice-wheat system. A number of crops like sun hemp, tobacco, cluster beans, sorghum, etc. had been replaced by the rice and wheat crops, which got further squeezed in terms of fall in varietal diversification. More serious weeds have replaced their common weeds. This was more true in the case of wheat, where a single variety was dominating the scene. In the case of rice, the situation was more comfortable due to the fact that price support by the government took care of some quality aspects, necessitating certain varieties with different traits to be grown. Further, cultivation of basmati rice, was found increasing in specific

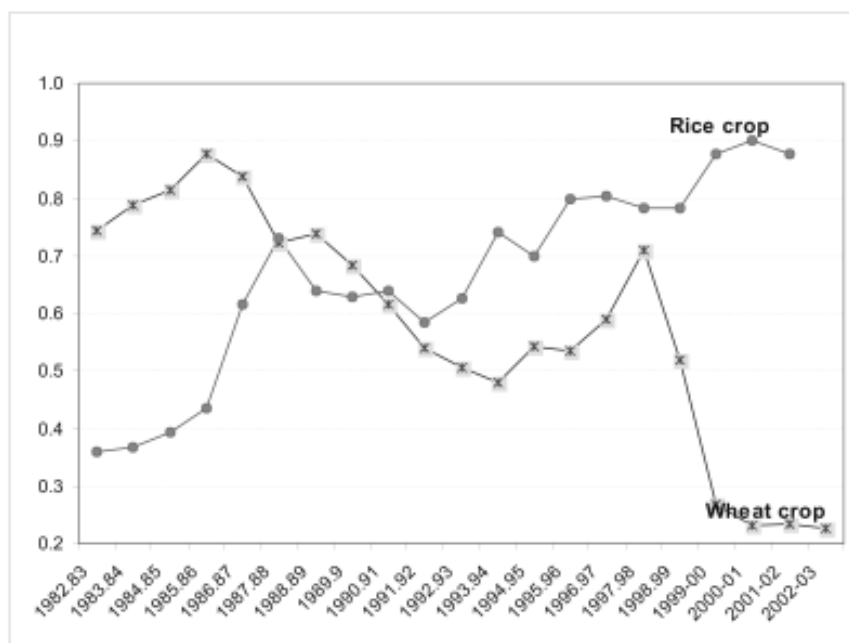


Figure 1. Varietal diversification index

areas of the state. The Theil Entropy Index of varietal diversification has shown a decline over time while that of rice crop has been increasing (Fig. 1).

### Crop Yield and Environmental Degradation

The decade of 1990s saw stagnation in the productivity of rice, whereas the productivity of wheat slowed down. The trend appears to have been reversed in recent years. The growth in productivity of wheat has turned negative, while in rice, is showing a positive growth. In the quest for higher and higher productivity, the farmers are resorting to excessive use of inputs like fertilizers, pesticides and irrigation and very high varietal concentration in favour of few varieties, eroding biodiversity. Regression analysis was conducted to examine the relationship between yield of wheat and rice and higher use of inputs and fall in varietal diversity.

Different forms of regression functions were tried to bring out the impact of such factors on crop yield. Since the electricity for irrigation and canal water supply were totally free for agriculture in the state, fall in water table was used as the proxy for higher use of irrigation water for sustaining crop yields and leading to environmental degradation. Linear quadratic function was used to bring out the impact of higher use of these inputs for sustaining

**Table 6. Regression coefficients of linear function**

Variables	Wheat crop	Rice crop
Intercept	4204.9451*	-4101.3529
X <sub>1</sub>	-13.1335	111.4866**
X <sub>1</sub> <sup>2</sup>	0.0572	-0.2930**
X <sub>2</sub>	11.1344**	-12.9123
X <sub>2</sub> <sup>2</sup>	-0.0344**	0.0361
X <sub>3</sub>	-1376.8641*	-199.5827*
R <sup>2</sup>	0.8962**	0.6667**

\* Significant at 0.05 probability levels

\*\* Significant at 0.01 probability levels

crop yields and consequently causing ecological problems. The results (as presented in Table 6) indicate that the use of pesticides in wheat crop and of fertilizer in rice exerted significant positive effect on crop yield, while their respective quadratic coefficients showed a negative significant effect. It is a clear indication that to maintain the crop yield level, higher use of agro-chemicals is to be curtailed. The negative significant effect of varietal diversity on both the crops was also observed, indicating that more number of choices rather than exploiting the yield potential better of different agro-ecological situations, command same minimum support price, thus the market ignoring the quality premium. The negative coefficient of this factor both for wheat and rice crops, suggests that increasing diversity of rice has been helping the upkeep of crop yield and decreasing diversity of wheat has caused a decline in yield.

### Some Policy Issues

In the context of stagnating agriculture productivity and prices, and thus squeezing profitability (Sidhu and Johl, 2002), it is essential to provide economic support to resource-poor farmers, who are in majority in the Punjab state. However, the policy prescriptions should be viewed seriously not only from the angle of achieving economic rationale of input-use but also about its implications for degradation of natural resources. The state government policy of supplying free electricity and water for irrigation needs to be re-looked and revamped and simultaneously the farmers should be advised to avoid indiscriminate and irrational use of water and other inputs by following appropriate agronomic practices (Singh, 2004). The emerging heavy direct and indirect financial costs can largely be minimized through suitable pricing of inputs. Some area, particularly with low productivity of rice, has to be shifted to suitable alternative crops through market incentives.

The existing market system provides almost the same price irrespective of the quality of the produce. The market mechanism must provide quality incentive in wheat and rice crops to encourage farmers to grow diverse genetic material with different usages. Further, the research and technology development should focus on curtailing excessive use of agro-chemicals through genetic and bioengineering methods.

### Conclusions

To sustain the existing plateau of Punjab agriculture, the costs are increasing and natural resources are being depleted at a fast rate. The fast increase in area under rice and wheat appears to be unsustainable due to fast decline in water table. Therefore, the cost of pumping out the water for the existing crops is increasing. The replenishment of soil health due to depleting macro- and micro-nutrients and increased use of pesticides were observed to enhance the cost of production. On account of these factors together, cost went up by Rs 63/t in wheat and Rs 189/t in rice. The varietal diversity of wheat decreased and that of rice crop showed an increasing trend. The policy measures to minimize the excessive use of natural resources require suitable water pricing, improving input-use efficiency, and revamping market forces to encourage diversification of the state agriculture from rice to alternative crops.

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