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Perspective and Prospects of Sustainable Agriculture in Haryana

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I

INTRODUCTION

Haryana, being one of the states which experienced green revolution in the first instance of its introduction, has witnessed impressive increase in foodgrains production from about 26 lakh tonnes in 1966-67 to 114.48 lakh tonnes in 1996-97. Moreover, it has improved its relative position in terms of per capita income from fifth position in 1966-67 to third position during the year 1996-97. Haryana is the second state after Punjab contributing to the national foodgrains pool. In addition, it produces a large quantity of cotton, oilseeds, sugar, vegetables and animal products such as milk, eggs and broilers.

Available evidence suggests that those gains from the green revolution are being eroded. The expansion of area under paddy and wheat has nearly halted, the growth in their productivity is thought by many to have slowed down and the historical sources of productivity growth appear to be exhausting their potential. Declining soil fertility, organic matter loss, water induced land degradation, declining/rising water table, increasing nitrate content in groundwater, hazardous residual contents in food and fodder chain, a threat to beneficial flora and fauna, all appear to be important factors. Therefore, the need is for a new approach, equally revolutionary but different in its ideas and strategies on three fronts, viz., ecological, economic and equity. It is not necessary that every planned/visualised development will bring a positive impact in isolation but may yield negative diversions too. The main threat to agriculture is diminishing resource base. Resources are threatened in two ways, by depletion and by contamination such that the resource becomes unusable. Both the problems have an impact far beyond agriculture, in that the resulting loss of food production and environmental damage threaten and diminish the quality of life.

Objectives

With these and associated considerations, all along with their repercussions in view, the following objectives were framed for the present study: (i) to study the

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utilisation pattern of land, water and agro-chemicals in perspective, (ii) to reschedule the resource use pattern for sustainable production and (iii) to suggest suitable policy measures for sustainable agriculture.

Methodology

The study is based primarily on secondary data scanned from various sources. The data on land use pattern, cropping pattern, irrigation, irrigated area of important crops, consumption of fertilisers, pesticides, productivity of important crops, cereal output per capita, population density, female literacy, people below poverty line, etc., were collected from the various issues of the *Statistical Abstract of Haryana* covering the period 1980-81 to 1996-97. The data on per capita utilisable groundwater and current groundwater use as percentage of its ultimate potential were taken from the publication of Groundwater Cell, Department of Agriculture, Government of Haryana (1994). The data on irrigation water requirements and the fertiliser requirements at recommended level were collected from the 'Package of Practices' published by Directorate of Extension Education, CCS Haryana Agri-cultural University, Hisar (1992). The cropwise pesticides consumption on per cent basis of the total consumption was ascertained from the entomologists through personal interviews. The gross returns from the different crops were calculated by taking average productivity of a particular crop for the triennium ending 1996-97 and multiplying by post-harvest price for the year 1996-97. The cropwise detailed information is presented in Table 1.

TABLE 1. WATER, FERTILISER REQUIREMENTS (RECOMMENDED), PESTICIDES CONSUMPTION AND GROSS RETURNS

Crop	Recommended water requirement (ha-metre)	Recommended fertiliser requirement (kg/ha)			Pesticide consumption (per cent)	Gross Returns (Rs./ha)
		Nitrogen	Phosphorous	Potash		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Paddy	1.300	150	75	60	14.00	7,230
Jowar	0.225	40	20	-	-	-
Bajra	0.225	40	20	-	2.50	2,275
Maize	0.350	150	60	60	1.00	4,697
Wheat	0.325	150	60	60	5.50	10,903
Barley	0.225	112	60	30	1.00	5,710
Gram	0.115	15	40	-	1.50	4,855
Groundnut	0.275	15	50	25	-	7,276
Rapeseed	0.175	40	20	-	4.50	9,896
Cotton	0.450	150	60	60	22.50	13,555
Sugarcane	1.450	150	-	-	7.00	20,141
Potato	0.350	150	50	100	1.50	22,896
Redgram	0.200	15	40	-	1.00	6,525
Greengram	0.200	15	40	-	1.00	4,121
Soybean	0.200	-	25	80	-	7,500
Lentil	0.200	-	15	40	-	4,188

Note: The gross returns are rounded to the nearest figure.

The average input prices considered for water (Rs./hectare-metre), fertilisers (nitrogen, phosphorous and potash in Rs./kg of nutrient) and pesticides (Rs./kg or Rs./litre) were Rs. 1,580, Rs. 6.65, Rs. 7.75, Rs. 2.80 and Rs. 195 respectively.

In order to study the first objective, viz., land use pattern, cropping pattern, utilisation pattern of irrigation water, fertilisers, pesticides, etc., tabular analysis using averages, percentages, ratios, and indices, were employed. To make gradual switchover with systematic replacement and to imbibe the possible gamut in its entirety covering the underlined objectives of sustainable agriculture, linear programming technique was employed, so as to make the rescheduling of resources on sustainable lines. The crops which required more of water and agro-chemicals, were substituted with those requiring less of it with 10, 15, and 20 per cent area reduction (Table 2). On the basis of average area under different crops during the years 1994-95, 1995-96 and 1996-97 as well as targets fixed by the Department of Agriculture, Government of Haryana, it was presumed that the share of soybean, redgram and greengram in the area released from paddy cultivation will be 40, 30 and 30 per cent respectively. Similarly, gram, rapeseed and mustard, potato and lentil will equally share acreage released from wheat cultivation. Groundnut (40 per cent), maize (30 per cent) and redgram (30 per cent) will share acreage substituted from cotton. The crops were substituted having importance in maintaining and improving soil status.

TABLE 2. AREA REPLACEMENT AND SUBSTITUTION OF CROPS

Sr. No. (1)	Area reduction (10, 15 and 20 per cent) Crop (2)	Area substitution (Per cent distribution) Crop (3)
1.	Paddy	Soybean + Redgram + Greengram (40) (30) (30)
2.	Wheat	Gram + Rapeseed + Potato + Lentil (25) (25) (25) (25)
3.	Cotton	Groundnut + Maize + Redgram (40) (30) (30)

Note: Figures in parentheses indicate per cent share of different crops in the area substituted from paddy, wheat and cotton crops.

Symbolically the linear programming model used can be expressed as:

$$\text{Max. } Z = \sum_{j=1}^{n} c_j X_j$$

Subject to,

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \; ; \quad i = 1,2,\ldots\ldots n$$

where $b_i \geq 0$, $a_{ij} \geq 0$, $x_j \geq 0$

Z = Gross returns,

c_j = Gross returns from one unit of j-th activity (j = 1, 2 ...n),

x_j = Real activities,

a_{ij} = Input coefficients or amount of i-th input required by j-th activity, and

b_i = Resource supply level of i-th resource.

The existing area of a crop considered here is the average area of the crop during the years 1994-95 to 1996-97. For pesticides consumption, the average consumption of 1994-95 to 1996-97 was taken into account and then based on the opinion survey of the entomologist, the cropwise consumption was worked out. To estimate the optimum crop combinations at various levels as outlined, the linear programming technique was employed.

Crop acreage, water and fertiliser availabilities were used as restrictions to work out the possible alternative optimum crop plans at various levels of switchover. The water and fertiliser availability was worked out based on their requirements at the existing cropping pattern. The input-output prices as well as productivity levels were assumed to remain the same in all the plans. The optimal plan over existing and optimal plans at 10 per cent (optimal plan I), 15 per cent (optimal plan II) and 20 per cent (optimal plan III) area adjustment in the existing cropping pattern were worked out all along with changes in water, fertiliser requirement and gross returns. The pesticides consumption was worked out based on the crop acreages under alternative optimal plans.

Agricultural sustainability status is a pre-requisite for identifying the strong and weak linked aspects of sustainable development of agriculture for a particular area. This also focuses on priority hint for policy attention and orientation of programmes towards sustainable development of a region. Based on these considerations, for ascertaining the agricultural sustainability status, Sustainable Livelihood Security Index (SLSI) approach was employed (see Swaminathan, 1991; Saleth, 1993). The concept of SLSI is a livelihood option, which is ecologically secure, economically efficient and socially equitable. In an operational context, the Sustainable Development of Agriculture (SDA) requires the SLSI to be a composite of three indices, viz., Ecological Security Index (ESI), Economic Efficiency Index (EEI) and Social Equity Index (SEI), so that it can take stock of both the conflicts and synergy between ecology, economic and equity aspects of SDA.

Let x_{ijk} and $SLSI_{ijk}$ denote respectively the value and index of the i-th variable representing j-th component of the SLSI of k-th region. Then,

$$SLSI_{ijk} = \frac{X_{ijk} - \underset{j}{\min.}\, x_{ijk}}{\underset{j}{\text{Max.}}\, x_{ijk} - \underset{j}{\min.}\, x_{ijk}} \quad \ldots. (1a)$$

$$SLSI_{ijk} = \frac{\underset{j}{\text{Max.}}\, x_{ijk} - x_{ijk}}{\underset{j}{\text{Max.}}\, x_{ijk} - \underset{j}{\min.}\, x_{ijk}} \quad \ldots. (1b)$$

where $i = 1, 2, \ldots\ldots I, j = 1, 2, \ldots\ldots J$, and $k = 1, 2, \ldots\ldots K$.

The numerators in the equation (1a) and (1b) measure the extent by which the k-th region did better in the i-th variable representing j-th component of its SLSI as compared to the region(s) showing the worst performance. The denominator is actually the range, i.e., the difference between the maximum and minimum values of a given variable across regions which are simple statistical measures of variation present in that variable and serves as a scale or measuring rod by which the performance of each region is evaluated in a given variable.

Having calculated the $SLSI_{ijk}$ for all the variables, the indices for the various components of SLSI are calculated as a simple mean of the indices of their respective representative variables, i.e.,

$$SLSI_{jk} = \frac{\sum_{j=1}^{n} SLSI_{ijk}}{I} \qquad \begin{matrix} j = 1,2,\ldots\ldots\ldots J \\ k = 1,2.,\ldots\ldots\ldots K \end{matrix} \quad \ldots. (2)$$

The composite indicator for each region is calculated as a weighted mean of the indices obtained from equation (2), i.e.,

$$SLSI_{k} = \frac{\sum_{j=1}^{n} W_{jk}{}^{SLSI}{}_{jk}}{J} \qquad k = 1,2,\ldots\ldots\ldots\ldots,k \quad \ldots. (3)$$

The W_{jk} in equation (3) denotes the weight assigned to the i-th component of the SLSI of the k-th region and has a property that $W_{ik} + \ldots. + W_{jk} = 1$. If the weights are identical and sum to unity, then SLSI is calculated as simple mean. But when weights are different across all j and k, SLSI is calculated as weighted mean. For distinction the former is denoted simply as SLSI and the latter as SLSI*. Obviously, all the indices and hence, both the SLSI and SLSI*, will be bounded by 0 and 1 (Saleth, 1993, pp.544-545).

In the present investigation, ecological security is reflected by three variables, viz, the proportion of geographical area under forest, per capita utilisable groundwater potential in ha-metres and population density per square kilometre. The economic efficiency is represented by land productivity in Rs./ha, labour productivity in Rs./ha and cereal output per capita in kg. The social equity is reflected by people below poverty line in per cent, female literacy in per cent and current groundwater use as percentage of its ultimate potential.

While developing the individual indices, equation (1a) was applied for four variables (i.e., forest cover, land and labour productivities and female literacy) having positive effect on SDA and equation (1b) was applied for all the remaining variables having an inverse effect on SDA. Whenever the values of the variables exceeded their respective norms, then the indices for these variables were assigned the values of one, else their indices will be based on equation (1). For developing weights, the inverse of the proportional contribution of ESI, EEI and SEI to the SLSI was obtained and the weight to be assigned to each component was calculated as the ratio of its inverse contribution to the sum of all the three inverse proportions. This is due to the fact that as one has more (less) of something he/she will value it less (more).

II

RESULTS AND DISCUSSION

Land Use Pattern

The various facets of land use pattern during the period 1980-81 to 1996-97 are presented in Table 3. As is evident from the table, the area under forest which showed a rising trend upto 1991-92 failed to maintain its pace and declined to the ever lowest figure of 115 thousand hectares in 1996-97, accounting for a decline of about 15 per cent over 1980-81. On an average, the forest area in Haryana accounted for less than 4 per cent of the geographical area. Barring 1987-88 and 1992-93, more than 80 per cent of the area have been put under crops. This is a much higher figure compared to many states. More than half of the net sown area (except few years) has been double cropped. The cropping intensity recorded as high as 168.69 per cent during the year 1988-89.

Cropping Pattern

The shares of different crops in the total cropped area of Haryana State are presented in Table 4 during the period 1980-81 to 1996-97. In the order of share in

TABLE 3. LAND USE PATTERN IN HARYANA

(*000 ha*)

Year (1)	Total area (2)	Forest area (3)	Land not available for cultivation (4)	Permanent pastures and other grazing land (5)	Culturable waste (6)	Current fallow (7)	Net area sown (8)	Area sown more than once (9)	Total cropped area (10)	Cropping intensity (per cent) (11)
1980-81	4,405	132	434	30	30	177	3,602 (81.77)	1,860	5,462	151.64
1985-86	4,391	166	392	28	23	168	3,613 (82.28)	1,988	5,601	155.02
1988-89	4,391	166	398	26	25	209	3,564 (81.16)	2,448	6,012	168.69
1990-91	4,378	169	417	23	21	169	3,575 (81.66)	2,344	5,919	165.57
1996-97	4,399	115	480	24	23	137	3,615 (82.18)	2,459	6,074	168.02

Figures in parentheses are percentages to the total area.

TABLE 4. CROPPING PATTERN IN HARYANA

(*per cent to total cropped area*)

Year (1)	Paddy (2)	Jowar (3)	Bajra (4)	Maize (5)	Wheat (6)	Barley (7)	Gram (8)	Other pulses (9)	Ground-nut (10)	Rape-seed and mustard (11)	Cotton (12)	Sugar-cane (13)	Veget-ables (14)	Total cropped area (000' ha) (15)
1980-81	8.86	2.51	15.93	1.30	27.08	2.28	13.22	1.33	0.11	5.48	5.79	2.07	0.71	5,462
1985-86	10.43	2.06	11.59	0.98	30.37	1.56	13.58	1.52	0.18	6.48	6.14	1.86	0.81	5,601
1988-89	10.01	2.57	13.07	0.72	30.39	1.06	10.73	1.38	0.05	6.37	7.20	2.17	0.71	6,012
1990-91	11.17	2.19	10.28	0.59	31.26	0.85	10.97	1.57	0.04	8.00	8.29	2.50	0.73	5,919
1996-97	13.67	2.12	9.39	0.42	33.21	0.56	5.68	0.82	0.03	10.09	10.74	2.67	0.66	6,074

the gross cropped area, the first four crops were wheat, bajra, gram and paddy during the year 1980-81. In 1996-97, while wheat increased its share in the gross cropped area, retaining the first place in the cropping pattern, paddy moved to the second place, followed by cotton and rapeseed and mustard. The cropping pattern that emerged and continued since the eighties, highlighted more of acreage concentration of foodgrain crops than diversification. Cereal based cropping pattern, accounting for a share of more than 50 per cent acreage in the gross cropped area, does pose overall risk of crop specialisation in the long-run on a few crops instead of many crops, thus the farmers are prone themselves to disaster, thereby setting the stage for potential widespread crop losses. In addition to increasing danger of widespread losses, paddy, cotton and wheat being resource exhaustive crops put a severe drain on natural resources like water and soil micronutrients, thus posing a big question mark on long-term sustainability of the existing resource use pattern.

Utilisation Pattern of Irrigation Water

Assured supply of irrigation water in most of the areas has remained the mainstay of agricultural development. The details of percentage of area irrigated to net area sown are presented in Table 5. It is evident from the table that over the years, there has been an increase in the area under irrigation. The area irrigated increased from 59.20 per cent in 1980-81 to as high as 79.80 per cent in 1987-88. The year 1987-88 was a drought year, and it might have resulted in a decrease in net sown area and in an increase in the percentage area under irrigation to net area sown during this year. Keeping surface and groundwater resource potentials into consideration, the area coverage under irrigation have reached a high peak.

Area Irrigated of Important Crops

The details of area irrigated of important crops are presented in Table 5. The area under irrigation in bajra crop which was 11.84 per cent in 1980-81 increased to 15.59 per cent in 1996-97, with an all time high of 27.33 per cent in 1987-88. In the case of gram also the area irrigated fluctuated over the years with a downward trend; it reached a high of 65.43 per cent in 1987-88. This might be on account of shifting of bajra and gram acreage to the more assured crops of paddy and wheat with increased availability of irrigation water. With little bit aberrations and a little less than cent per cent coverage, the trend of area under irrigation under paddy, wheat, cotton and sugarcane follows the path of sustenance. This might be due to stability, responsiveness to modern technology/inputs and high returns from these crops. With increased irrigation coverage, major share of irrigation water was shared amongst paddy, wheat, cotton, sugarcane and like crops while crops like bajra and gram got reduced area under irrigation.

TABLE 5. IRRIGATED AREA OF IMPORTANT CROPS

(*per cent*)

Year	Irrigated area of important crops						Total area irrigated to net area sown
	Paddy	Bajra	Wheat	Gram	Cotton	Sugarcane	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1980-81	97.13	11.84	93.10	43.08	98.29	91.07	59.20
1985-86	98.80	12.93	95.40	25.10	99.97	95.01	62.20
1987-88	99.50	27.33	97.98	65.43	98.94	94.87	79.80
1990-91	99.02	15.45	97.56	21.72	99.47	96.08	72.90
1991-92	99.51	19.04	98.13	28.69	99.64	96.36	76.00
1993-94	99.60	19.68	98.19	20.49	99.64	96.43	75.80
1996-97	99.63	15.59	98.31	18.84	99.24	98.15	76.50

Use of Agro-Chemicals

With the advent of green revolution, the use of modern inputs especially of agro-chemicals have increased manifold, owing to the responsiveness of high-yielding strains to irrigation, chemicals, etc. The consumption pattern of major plant nutrients, viz., nitrogen(N), phosphorous(P) and potash(K) as well as pesticides is shown in Table 6. It is evident that the consumption patterns of major nutrients have not been proportionate. The total consumption of N, P and K showed an increasing trend during the period (barring potash). It increased from 64 kg/ha in 1980-81 and reached a high of 212.34 kg/ha in 1996-97 with the contribution of N, P and K being 172.66, 38.81 and 0.86 kg/ha respectively.

TABLE 6. CONSUMPTION OF FARM CHEMICALS

Year	Consumption of fertilisers (nutrients kg/ha)			Total	Consumption of pesticides (kg/litre/ha)
	Nitrogen	Phosphorous	Potash		
(1)	(2)	(3)	(4)	(5)	(6)
1980-81	52.02	8.70	3.36	64.08	0.060
1985-86	82.04	19.27	1.70	103.01	0.100
1987-88	93.01	27.32	1.51	121.84	0.114
1990-91	125.32	39.02	1.42	165.76	0.147
1991-92	132.47	40.31	0.72	173.50	0.150
1993-94	149.93	42.51	0.11	192.35	0.148
1996-97	172.66	38.81	0.86	212.34	0.139

The consumption of pesticides has increased upto 1991-92. Thereafter, the pesticides consumption exhibited a declining trend. The increasing trend in pesticides consumption which has put a question mark on the sustainability of the present system has shown some relief after 1991-92, indicating a declining trend, since indiscriminate use of pesticides destroys the natural enemies of pests and encourages the development of pest resistant strains.

Groundwater Quality, Change in Water Table and Extent of Problematic Areas

The details of groundwater quality, change in water table and extent of problematic areas are presented in Table 7. The overall repercussions associated with farm activities have changed the scenario of water quality and water table, resulting in an increase in problematic areas. The groundwater quality limits the scope of crop choice. Nearly 55 per cent of water (sodic 18 per cent, saline 11 per cent, saline sodic 26 per cent) seems to be unfit for crop production. The problems are further accentuated with increasing acreages under problematic areas as is evident from the table, mainly due to non-judicious use of water.

TABLE 7. GROUNDWATER QUALITY, CHANGE IN WATER TABLE AND EXTENT OF PROBLEMATIC AREA

Particulars (1)	Haryana (2)
Ground water quality (per cent)	
Good	37
Normal	8
Sodic	18
Saline	11
Saline sodic	26
Average annual water table change (cm)	±26
Saline/alkaline area (000 ha)	526

The foregoing discussion discerns the fact that the acreage under the plough has reached its peak, further addition to area under the plough appears to be remote. Even it is likely to decrease with increased urbanisation. The cropping pattern, despite the emphasis on diversification, has tilted towards resource exhaustive paying crops. There has been irrational use of crucial farm inputs, viz., irrigation, fertilisers, pesticides, etc., with intensive agriculture. Creation of intensive irrigation facilities and excessive use of canal water have resulted in problems of waterlogging, soil salinity, soil sodicity, etc. The problems of wind/water erosion, flood deposition are no more uncommon. The changing quality of groundwater, with rise and fall in the water table has already sounded alarm. The negative impacts of agro-chemicals especially fertilisers, pesticides, etc., have been well documented. The nitrate poisoning, the toxic residues in food and fodder chain, the threat to beneficial soil micro fauna and flora by adverse alteration in physio-chemical structures of the soil have all come to the fore. Thus the strain and adverse impact of the existing order of agricultural production environment and natural resources has already reached an alarming situation. All in all, this has resulted in an increase in direct and indirect costs associated with farming.

III

RESCHEDULING OF RESOURCE USE PATTERN FOR SUSTAINABLE PRODUCTION

Changing Crop Patterns in Existing and Optimal Plans

The most important criterion for the farmers, considering a change in farming practices is the likely economic outcome. Wider adoption of sustainable farming methods requires that they should be at least as profitable as the existing methods along with non-monetary advantages, such as preservation of rapidly deteriorating soil and water resources. Although sustainable agriculture encompasses the multifaceted activities, here the major stress is laid on crop component, its diversification, crop-mix and their visual impact on land and water use and on the consumption of agro-chemicals. Based on these considerations (Table 2) and priority approaches, the linear programming technique was employed to work out the alternate optimal crop plans, in a way to make the switchover smooth and sweeping towards sustenance.

In the order of acreage, the major crops in the existing crop plan were wheat, paddy, bajra, rapeseed and mustard, gram, cotton and followed in that order was the sugarcane crop (Table 8). In the existing optimal plan, there were no changes in gram, cotton, sugarcane and potato acreages whereas paddy, maize, rapeseed and mustard acreages increased and barley disappeared from the plan. The changing crop acreages under different suggested optimal plans give simultaneously vivid picture of constant acreage under bajra, cotton and sugarcane. Barley escapes its inclusion. The area under gram, potato, redgram, greengram, soybean and lentil got substantially increased in the subsequent plans, while there was up-down trend for wheat, paddy, maize and rapeseed and mustard in the three optimal plans.

TABLE 8. EXISTING AND SUGGESTED CROP PLANS

(000 ha)

Crop	Existing plan	Existing optimal plan	Suggested optimal plans		
			I	II	III
(1)	(2)	(3)	(4)	(5)	(6)
Wheat	1,837.70	1,761.22	1,733.37	1,719.43	1,705.51
Paddy	646.70	648.02	655.27	658.90	625.79
Bajra	597.50	494.68	494.68	494.68	494.68
Rapeseed/mustard	516.37	645.52	535.55	480.57	425.56
Gram	493.93	493.93	539.86	562.84	585.82
Cotton	489.33	489.33	489.33	489.33	489.33
Sugarcane	148.87	148.87	148.87	148.87	148.87
Maize	34.97	136.47	49.86	6.50	-
Barley	52.67	-	-	-	-
Potato	12.17	12.17	58.11	81.09	104.06
Redgram	-	-	34.08	51.12	68.16
Greengram	-	-	19.40	29.10	38.80
Soybean	-	-	25.87	38.80	51.74
Lentil	-	-	45.94	68.91	91.89

Note: Jowa - pre-determined crop with acreage of 700 ha in each plan.

The increased acreage under pulses, oilseeds and other leguminous crops with decreased acreage under paddy and wheat in the optimal plans made a better change for crop rotation and the crop-mix. Finally, it will help in attaining the ultimate objective of lessening the use of irrigation water and agro-chemicals, thereby paving the path for sustainable agriculture.

Changing Patterns of Input Use

Resource use pattern in the existing crop plan being followed and the changing scenario of resource use pattern emerging from existing optimal plan as well as suggested optimal plans are discussed in this section. Table 9 reveals that except in the suggested optimal plan III, in all other plans, the water requirement has remained the same, as in the existing plan (2,183.97 thousand ha-metres). It came down to 2,149.07 thousand ha-metres in the optimal plan III. Usual precedence of gradual reduction in fertiliser requirement in the subsequent plans seems to be a virtual possibility with a maximum reduction of 2.56 per cent in the optimal plan III, compared to the existing plan. Barring potash consumption in the subsequent optimal plans, nitrogen and phosphorous consumption got reduced by 4.46 per cent and 0.24 per cent respectively in the suggested optimal plan III over the existing plan. The pesticides consumption pattern exhibited up-down-up trend, indicating thereby an increase of 4.31 per cent in the suggested optimal plan III over the existing plan. Although there is some increase in the pesticides use, on account of increasing potato acreage and status quo situation in the case of cotton and sugarcane acreages, yet these increases are far below the prescribed threshold limits.

TABLE 9. CHANGING PATTERN OF INPUT USE

Particulars	Existing plan	Existing optimal plan	Suggested optimal plans		
			I	II	III
(1)	(2)	(3)	(4)	(5)	(6)
Water use ('000 ha-metres)	2,183.97	2,183.97	2,183.97	2,183.97	2,149.97
	(100.00)	(100.00)	(100.00)	(100.00)	(98.40)
Fertiliser use ('000 kg)	9,52,668.69	9,50,739.63	9,39,800.78	9,34,330.05	9,28,308.26
	(100.00)	(99.80)	(98.65)	(98.07)	(97.44)
Nitrogen	5,33,323.79	5,32,428.36	5,20,979.34	5,15,254.18	5,09,528.21
	(100.00)	(99.83)	(97.69)	(96.61)	(95.54)
Phosphorous	2,36,025.80	2,34,992.17	2,35,502.34	2,35,756.77	2,35,460.95
	(100.00)	(99.56)	(99.78)	(99.89)	(99.76)
Potash	1,83,319.10	1,83,319.10	1,83,319.10	1,83,319.10	1,83,319.10
	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
Pesticides ('000 kg)	3,014.72	3,135.55	3,133.73	3,132.86	3,144.81
	(100.00)	(104.01)	(103.95)	(103.92)	(104.31)

Figures in parentheses show the changes over the existing plan.

Consequent upon the changed crop acreages in the optimal crop plans, the pattern of use of farm inputs, viz., water and agro-chemicals, reveals a picture of reducing phenomenon. This will in turn reduce the dependency in the subsequent plans on crucial farm inputs and will enhance biotic activity and arrest the adverse hydrological changes (Table 7). Consequently, it will be a signpost for better environment.

Savings Benefits Accrued

The changed pattern of accruable savings benefits due to savings in water and agro-chemicals is shown in Table 10. The accrued savings benefits for Haryana tread a varied path. Only the optimal plan III shows the savings in water requirement to the tune of Rs. 55.14 million. In the subsequent optimal plans, the fertiliser savings got increased and peaked to a high of Rs. 162.62 million in the optimal plan III, of which nitrogen and phosphorous savings accounted for Rs. 158.24 million and Rs. 4.38 million respectively. The pesticides savings pattern exposes the negative trend in all the optimal plans, with a little bit difference. The maximum additional burden of Rs. 25.37 million towards pesticides was observed for optimal plan III. As a result, the total savings benefits accrued in the existing optimal plan turned out to be a negative sum of Rs. 9.6 million. Benefits in the subsequent plans do show an increasing trend with a peak figure of Rs. 192.4 million in the suggested optimal plan III.

TABLE 10. SAVINGS BENEFITS ACCRUED

(*Rs. 000*)

Particulars	Existing optimal plan	Suggested optimal plans		
		I	II	III
(1)	(2)	(3)	(4)	(5)
Water	-	-	-	55,142.00
	(-)	(-)	(-)	(34.90)
Fertiliser	13,965.24	86,147.40	1,22,247.89	1,62,618.20
	(1,929.06)	(12,867.91)	(18,338.64)	(24,360.43)
Nitrogen	5,954.61	82,090.59	1,20,162.91	1,58,240.61
	(895.43)	(12,344.45)	(18,069.61)	(23,795.58)
Phosphorous	8,010.63	4,056.81	2,084.98	4,377.59
	(1,033.63)	(523.46)	(269.03)	(564.85)
Potash	-	-	-	-
	(-)	(-)	(-)	(-)
Pesticides	-23,561.85	-23,206.95	-23,037.30	-25,367.55
	(-120.83)	(-119.01)	(-118.14)	(-130.09)
Total benefits	-9,596.61	62,940.45	99,210.59	1,92,392.65

Figures in parentheses show the quantities saved in thousand ha-metres in the case of water and thousand kg in the case of fertiliser use over the existing plan.

The reduced use of crucial farm inputs, viz., water and agro-chemicals will open a new window for economic, social and for ecological considerations. Thus in a way, it will add to economic (savings) benefits with reduced use of purchased inputs. The harmful and hazardous effects would be curtailed. Further it will help in building soil structure and texture.

Changing Patterns of Returns

With changes in acreage under different optimal plans, the input use pattern as well as returns pattern underwent a change. The emerging patterns of gross returns, savings, gross returns plus savings benefits in the optimal plans over the existing plans are presented in Table 11. It is revealed that the gross returns from the crop production activity in the subsequent suggested optimal plans decreased marginally by 0.56 per cent in the optimal plan III over the existing plan. On per hectare basis, gross returns decreased to Rs. 9,049.37 from Rs. 9,100.27, showing a negligible decline of Rs. 50.90 per hectare which further reduced to Rs. 11.07 when savings benefits were taken into account. The savings benefits accrued over the existing plan turned out to be a negative sum of Rs. 9.6 million in the existing optimal plan. Thereafter, it showed an upward trend through successive optimal plans with a maximum savings benefits of Rs. 192.4 million in the optimal plan III. The resulting positive changes in savings benefits helped in arresting the downward trend in gross returns plus savings benefits in successive optimal plans. The least reduction of 0.12 per cent was observed in the optimal plan III, wherein the gross returns plus savings benefits were reduced to Rs. 43,900.8 million.

TABLE 11. CHANGING PATTERN OF RETURNS

(*Rs. 000*)

Particulars	Existing plan	Existing optimal plan	Suggested optimal plans		
			I	II	III
(1)	(2)	(3)	(4)	(5)	(6)
Gross returns (crops)	4,39,54,327.20 (100.00)	4,33,19,608.68 (98.56)	4,35,60,559.64 (99.10)	4,36,81,131.28 (99.38)	4,37,08,456.18 (99.44)
Gross returns/hectare (Rs.)	9,100.27	8,968.86	9,018.75	9,043.71	9,049.37
Savings benefits (water, fertilisers, pesticides)		-9,596.61	62,940.45	99,210.59	1,92,392.65
Gross returns + savings benefits	4,39,54,327.20 (100.00)	4,33,10,012.07 (98.53)	4,36,23,500.09 (99.25)	4,37,80,341.87 (99.60)	4,39,00,848.83 (99.88)
Gross returns + saving benefits (Rs./ha)	9,100.27	8,966.88	9,031.78	9,064.25	9,089.20

Figures in parentheses show the changes over the existing plan.

The findings of Table 11 revealed that with an initial minor setback, gross returns and savings benefits picked up in the successive optimal plans indicating more or less a status quo situation. Moreover, the changed pattern of returns will have to be viewed not only from economic consideration but also from quantification, qualitativeness on food front, ecological dimensions and sustainable growth parameters.

Agricultural Sustainability Status

The relative agricultural sustainability status for Haryana indicated by the value and ranks of their SLSI and SLSI* as well as ESI, EEI and SEI is presented in Table 12. The values of ESI, EEI and SEI ranged from 0.33 to 0.73. This indicates that the agricultural systems of Haryana show wider variation in their ecological and social aspects than in economic aspects. The SLSI and SLSI* ranged from 0.480 to 0.503 and from 0.500 to 0.507 respectively. The slight upward movement of SLSI* is due to the effect of weighting procedure. The relatively narrower range of SLSI and SLSI* as compared to their component indices indicates that the performance is not consistent across the three aspects of sustainable development of agriculture. Based on the component sub-indices, the state was better placed in ecological aspects, and it was poor in economic and social aspects. As such, there does not appear to be appreciable significant deviations in the values of sub-indices as well as those of SLSI and SLSI* in different plans. In terms of results obtained, there is need for policy focus and orientation of programmes on economic as well as social aspects. Thus the priority areas have been identified from policy and action point of view.

TABLE 12. RELATIVE AGRICULTURAL SUSTAINABILITY STATUs

Particulars	Existing optimal plan	Suggested optimal plans		
		I	II	III
(1)	(2)	(3)	(4)	(5)
Ecological security index (ESI)	0.73	0.73	0.73	0.72
Rank	1	1	1	1
Economic efficiency index (EEI)	0.33	0.35	0.36	0.38
Rank	2	2	2	2
Social equity index (SEI)	0.38	0.40	0.40	0.41
Rank	2	2	2	2
SLSI	0.480	0.493	0.496	0.503
Rank	1	1	1	1
SLSI*	0.500	0.501	0.501	0.507
Rank	1	1	1	1

Note: SLSI = Sustainable Livelihood Security Index.
SLSI* = Weighted Sustainable Livelihood Security Index.

CONCLUSIONS

Based on the results, the study concludes that the area under forests does not show any appreciable increase over the years. The intensity of cropping has increased over the years. The cropping pattern vividly exhibits acreage concentration of the resource exhaustive crops like paddy, wheat, cotton and sugarcane which accounted for a major share of irrigation water. Fertiliser consumption pattern showed an increasing trend at disproportionate rate over the years. Consumption of nitrogenous fertilisers increased at a much faster rate than that of phosphatic and potashic fertilisers. All in all, the continuing crop and input use patterns have resulted in accentuating the area under problematic soils and in disturbing the hydrological balance. However, the input use pattern of water and agro-chemicals showed a declining trend under successive optimal plans. The savings benefits brought about by savings in water and agro-chemicals are likely to open a new window for economic, social ecological frontiers. On the economic front, the optimal plans promise a bright outlook for gross returns as well as for accruable savings benefits. In a way, the optimal plans make sure to accommodate the economic, ecological as well as social aspects, paving the path for sustainable ways and means. The successive optimal plans are marked by slow but upbeat trend of sustainable livelihood security index. This stamps the eco-econ and social footing of the envisaged optimal plans.

In order to respond dynamically to current challenges and the new and unfamiliar needs for promoting sustainable agricultural development, the following policy measures have emerged:

1. Intensification of extension education programmes especially complete farm and village adoption programmes to create awareness among the farmers about the benefits of increasing the area under less input intensive crops in general and that of leguminous crops in particular.
2. Incentives and regulatory policies to compensate for externalities related to natural resources, e.g., water pricing, watershed management and problem soils.
3. Adjustments/changes, e.g., diversification, crop rotations in crop plans must be facilitated in order to achieve a balanced crop-mix to make progress towards profitable and environmentally sustainable production systems.
4. Information about sustainable agricultural practices and new policies to encourage wider adoption must be disseminated to the farmers to strengthen the cause of sustainable agriculture.

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