MANAGEMENT OF LAND AND WATER RESOURCES FOR SUSTAINABLE CROP PRODUCTION

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ABSTRACT

Over exploitation and degradation of natural resources under green revolution has become a major threat in region of India which experienced green revolution in very first stage of its introduction. The adoption of monoculture, specialized and high chemical input use agriculture has led to severe environmental damage and resource degradation. The shrinking of natural resources coupled with technology and public policy related problems have caused increase in cost of production over the years. Considering various factors like optimization of agriculture productivity and profitability, employment generation, natural resource conservation and reduction in agro- chemical use, the objectives framed were i) to study utilization pattern of land, water and agro-chemicals ii) to reschedule the crop enterprise combination and resource use pattern to formulate suitable sustainable farm plans .

The study was carried out in Haryana being one of the states of Indian Union which experienced green revolution in the first instance of its introduction has witnessed impressive increase in food grains production from 25.92 to 14.76 million tones during the period 1966-2007. Moreover, it improves its relative position in terms of per capita income and second in position for contributing to national food grain pool. The data with regards to land use pattern, irrigation water, cropping pattern etc. were scanned from various published sources. The gross returns for different crop enterprises were calculated by taking average productivity of a particular crop for triennium ending 2007 and post harvest prices of current year. Simple percentage, average and ratio statistical tools were applied for analysing the utilization pattern of resources. General Algebric Modelling System (GAMS) was employed to make rescheduling of resources on sustainable lines.

The results of the study reveal that area under forests does not indicate any appreciable increase over the years. The cropping pattern exhibited the acreage concentration of resource exhaustive and less risky crops like cotton, wheat and rice and most of irrigation water were used amongst these crops. Increased consumption of nitrogenous fertilizers and pesticides, continuation of same cropping pattern over the time period resulted into accentuating the area under problematic soils, depletion of underground water, infestation of weeds, insect-pests and diseases. The optimal sustainable production plans showed increase in gross returns as well as accrued benefits through saving the water and agro-chemicals. The optimal plans in incorporated the crop enterprises like green gram, black gram, soybean, cluster bean etc. not only improved the soil health but also reduction in use of natural resources and agro-chemicals. The optimal plans further make sure to accommodate the economic, ecological and social aspects paving the path for sustainable development in agriculture. The agro-climatic zone wise planning of agriculture is also essential for sustainability of crop production.

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INTRODUCTION

The cultivators rapidly adopted high yielding varieties of crops particularly wheat and rice in seventies in North India, which produced high yields by greatly responding to purchased inputs, generation of suitable crop production technologies and favourable Govt. policies. No doubt, India has emerged from a food deficit to self-sufficient. But over exploitation and degradation of natural resources under green revolution has become a major threat in region of India which experienced green revolution in very first stage of its introduction during seventies. The adoption of monoculture, specialized and high chemical input use in agriculture has led to severe environmental damage and resource degradation. With the increase in crop yields from recent farming techniques, reaching plateau and the creating environmental problems, the need for sustainable agriculture is increasing being felt. But continuation of same cropping patterns over the last four decades with inefficient and indiscriminate use of agro-chemicals inputs as well as natural resources have resulted into mounting environmental problems. The shrinking of natural resources coupled with latest technology has caused manifold increase in cost of production over the years. As agricultural pests become more resistant to chemicals used to control them, farmers can become trapped in a vicious circle of unsustainable debt through increased of pesticides applications with the accompanying risks to health. Contamination of underground water, from excessive use of agro-chemicals in agriculture caused domestic water pollution.

Haryana being one of the states of India experienced Green Revolution in the first instance of its introduction has exhibited impressive increase in food grain production from about 25.92 to 147.63 lakh tonnes during the period 1966-2007. More, it ranks second next to Punjab state in productivity of all most crops and second largest contributor to national food grain pool. In addition, it also produces a large quantity of cotton, oilseeds, sugar, vegetables and flowers. About 84 percent of net sown area is irrigated using various irrigation sources like canal water, tubewell, sprinkler and drip irrigation water saving technologies in the year 2006-07.

The expansion of wheat and paddy area has nearly halted, growth in their productivity is observed from information recorded has been slowed and productivity growth appear to be achieved highest potential. Declining soil fertility, organic matter loss and water induced land degradation, declining /rising water table, increasing nitrate content in groundwater and soil, hazardous residual contents in food and fodder chain need attention. The land under cultivation of crops is declining as result of urbanization due to close proximity to National Capital of Country and industrial growth. The main threat to agriculture is diminishing resource base in two ways, by depletion and contamination. With these and associated considerations, the following objectives were framed for the present study: i) to study utilization pattern of land, water and agro-chemicals.

ii) to reschedule the crop enterprise combination and resource use pattern to formulate suitable sustainable farm plans

METHODS AND MATERIALS

The study is based primarily on secondary data scanned from published sources for the period 1981-2003 The gross returns of different crops were calculated by taking average productivity of crop* in year 2008-09 and multiplying by the post- harvest price for the year 2008-09. The crop wise detailed information has been presented in table 1. The average input prices considered for the water (Rs./metre ha.) fertilizers i.e. Nitrogen, Phosphorous and Potash (Rs./ kg in nutrient) and pesticides (Rs./ kg/ litre) were calculated were Rs 2280, Rs.10.43, Rs.16.22, Rs.5.28 and Rs.278, respectively.

Table 1: Water, fertilizer requirement (recommended), pesticides consumption and gross returns of various crops in Haryana state.

Sr.No.	Crop	Recommended water requirement (metre ha.)	Recommended fertilizer requirement (kg/ha.)			Pesticides consumption (%)	Gross return (Rs./ha.)
			Nitrogen	Phosphorous	Potash		
1.	Paddy	1.300	150	75	60	11.00	21532
2.	Pearl millet	0.225	40	20	-	2.20	6216
3.	Maize	0.350	150	60	60	1.00	13780
4.	Wheat	0.325	150	60	60	5.50	22908
5.	Barley	0.225	112	60	30	1.00	15010
6.	Sunflower	0.450	80	60	-		17640
7.	Chickpea	0.115	15	40	-	1.50	7924
8.	Rapeseed	0.175	40	20	-	4.50	16388
9.	Cotton	0.450	150	60	60	22.50	19832
10.	Sugarcane	1.450	150	60	-	7.00	47179
11.	Potato	0.350	150	50	100	1.50	32560
12.	Red gram	0.200	15	40	-	1.00	8451
13.	Green gram	0.200	15	40	-	1.00	14000
14.	Soybean	0.200	25	80	-	-	13530
15.	Lentil	0.200	15	40	-	-	14680

General Algebric Modelling System (GAMS) technique was employed to make the rescheduling of resources on sustain lines.

Format of model.

$$\text{Maximise } Z = \sum_{j=1}^{n} c_j x_j \quad \text{.... (1)}$$

$$\text{Subject to } \sum_{j=1}^{n} a_{ij} x_j < b_i \ (i = 1,2,3....m) \quad \text{.... (II)}$$

$$x_j > o \ (j = 1,2,3...n) \quad \text{.... (III)}$$

Z = Total returns over operating expenses in rupees

* data collected BY DES(FM) in CCS Haryana Agricultural University, Hisar, India

x_j = Level of jth activity

c_j = Return over variable cost per unit of jth activity

a_{ij} = Requirement of ith resource per unit of jth activity

b_i = Quantity of the ith resource.

The crops having more requirements of water and agro-chemicals were substituted with requiring less of it with 10, 15 and 20 percent area reduction (Table 2).

After long discussion with crop scientists, crops were substituted having importance in maintaining and improving soil health. The existing area of a crop considered as an average area of the crop during the preceding three years. For the pesticides consumption, the average consumption of period 2008-09 was taken. Besides crop acreage, water and chemical fertilizers availabilities were used as restrictions to formulate the possible alternative crop plans at various levels of area substitution. The input-output prices as well as productivity levels were remain constant in all the plans.

RESULTS AND DISCUSSION

Land use pattern

It is evident from the table 3 that there has not been any substantial change in area under forest during the period 1980-2003. The forest area showed the sign of rising trend upto 1991-92 failed to maintain and declined to ever lowest figure of 39 thousand hectares as result of widening of roads, urbanisation and industrialization in 2006-07. Presently, the forest area in the state accounted for 0.89 percent of total geographical area. Barring the years 1987-88 and 1992-93 more than 80 percent of the total reported area in the state has been utilized for crops. More than half of the net sown area (except few years) has been double cropped and the cropping intensity was touched to 180.17 percent.

Table 3. Land use pattern in Haryana State.

(000,ha.)

Year	Total area	Forest area	Land not available for cultivation	Permanent pastures and other grazing land	Culturable waste	Current fallow	Net sown area	Area sown more once	Total cropped area	Cropping intensity
1980-81	4405	132	434	30	30	177	3602(81.77)	1860	5462	151.64
1981-82	4405	134	425	25	41	120	3660(83.09)	2166	5826	159.18
1982-83	4405	136	417	27	48	170	3596(81.84)	1710	5306	147.55
1983-84	4394	130	405	27	47	185	3600(81.93)	2088	5688	158.00
1984-85	4391	132	402	27	46	168	3616(82.35)	1896	5512	152.43
1985-86	4391	166	392	28	23	168	3613(82.28)	1988	5601	155.02
1986-87	4391	169	390	28	23	158	3622(82.49)	2040	5662	156.32
1987-88	4391	166	405	30	23	528	3233(73.63)	1453	4686	144.94
1988-89	4391	166	398	26	25	209	3564(81.16)	2448	6012	168.69
1989-90	4380	168	391	21	29	175	3593(82.02)	2058	5651	157.28
1990-91	4378	169	417	23	21	169	3575(81.66)	2344	5919	165.57
1991-92	4385	170	379	25	43	256	3508(80.00)	2062	5570	158.78
1992-93	4376	171	405	31	33	240	3492(79.78)	2361	5883	167.61
1993-94	4374	167	413	29	38	209	3513(80.31)	2302	5815	165.53
1994-95	4369	110	498	27	14	156	3559(81.46)	2430	5989	168.28
1995-96	4398	110	494	24	23	156	3586(81.54)	2388	5974	166.59
1996-97	4399	115	480	24	23	137	3615(82.18)	2459	6074	168.02
1997-98	4402	115	441	25	37	149	3635(82.58)	2508	6143	168.99

1998-99	4394	115	440	24	37	144	3628(82.57)	2692	6320	174.20
1999-00	4400	115	464	22	23	219	3552(80.72)	2477	6029	169.73
2000-01	4402	115	470	34	18	232	3526(80.10)	2589	6115	173.42
2001-02	4372	115	425	25	30	173	3566(81.56)	2752	6318	177.17
2002-03	4374	115	470	25	35	232	3458(79.05)	2577	6035	174.52
2003-04	4374	45	532	25	36	196	3534 (80.79)	2854	6388	180.75
2004-05	4374	44	525	25	35	212	3528(80.65)	2897	6425	182.11
2005-06	4372	44	519	25	31	169	3556(81.33)	2943	6409	180.23
2006-07	4372	39	524	27	65	141	3556(81.33)	2851	6407	180.17

Note: Figures in parentheses indicate the percentage of the total area

Cropping pattern

The cropping pattern for the state as whole is presented in table 4.The first four crops in percentage viz; wheat, pearl millet, chickpea and paddy accounted for the highest share of total cropped area during the year 1980-81. But the order changed to wheat, paddy, cotton, rapeseed and pearl millet in the year 2006-07. The area from coarse cereals and pulses diverted towards crops like wheat, paddy, rapeseed and cotton as result of improved production technology, easy disposal and higher returns. The cereal based cropping pattern sharing more than 50 percent acreage indicate overall risk of crop concentration in the long run on a few crops instead of diversification, thus cultivators prone themselves to land degradation. Paddy, cotton and wheat being resource exhaustive crops put a severe drain on resources like water and soil micro- nutrients, thus posing threat on the long-term sustainable production with existing l resource availability.

Table 4: Cropping pattern in Haryana State

Year	Area under crops (in percentage)												Total cropped area (000,ha.)
	Paddy	Jowar	Maize	Pearl-millet	Wheat	Barley	Chickpea	Other pulses	Rapeseed &mustard	Cotton	Sugarcane	Vegetables	
1980-81	8.86	2.51	1.30	15.93	27.08	2.28	13.22	1.33	5.48	5.79	2.07	0.71	5462
1981-82	8.66	2.02	1.20	14.62	26.81	2.06	17.97	1.52	3.48	5.66	2.50	0.71	5826
1982-83	9.22	2.18	1.06	14.67	32.48	1.55	9.59	0.98	3.06	7.48	2.77	0.68	5306
1983-84	9.85	2.67	0.95	14.76	31.52	1.32	11.39	1.27	3.44	7.12	2.33	0.60	5688
1984-85	10.11	2.78	1.12	13.58	32.93	1.22	11.28	1.28	5.82	5.34	2.10	0.78	5512
1985-86	10.43	2.06	0.98	11.59	30.37	1.56	13.58	1.52	6.48	6.14	1.86	0.81	5601
1986-87	11.09	2.67	0.96	13.67	31.48	1.22	10.79	1.20	5.01	6.72	2.21	0.67	5662
1987-88	9.91	2.86	0.87	10.34	36.94	1.33	4.27	1.39	6.97	8.88	3.04	1.01	4686
1988-89	10.01	2.57	0.72	13.07	30.39	1.06	10.73	1.38	6.37	7.20	2.17	0.71	6012
1989-90	11.35	1.82	0.73	11.10	32.86	0.91	9.30	1.38	7.74	8.34	2.42	0.82	5651
1990-91	11.17	2.19	0.59	10.28	31.26	0.85	10.97	1.57	8.00	8.29	2.50	0.73	5919
1991-92	11.44	1.84	0.52	9.98	32.42	1.01	5.51	1.08	11.45	9.08	2.91	0.86	5570
1992-93	12.09	2.02	0.53	10.87	33.54	0.90	6.63	0.94	9.60	9.10	2.36	0.66	5883
1993-94	12.98	1.55	0.51	8.74	34.28	0.66	6.97	0.91	9.91	9.68	1.92	0.77	5815
1994-95	13.29	1.84	0.45	9.50	33.15	0.83	6.71	0.94	9.67	9.29	1.98	0.66	5989
1995-96	13.89	2.11	0.43	9.63	33.01	0.68	6.31	0.89	9.62	10.91	2.40	0.67	5974
1996-97	13.67	2.12	0.42	9.39	33.21	0.56	5.68	0.82	10.09	10.74	2.67	0.66	6074
1997-98	14.75	2.11	0.42	9.43	33.21	0.68	5.71	0.79	8.97	10.20	2.28	0.68	6143
1998-99	17.18	2.05	0.31	9.69	34.62	0.57	5.64	0.28	7.88	9.22	2.02	0.71	6320
1999-00	17.96	1.85	0.33	9.73	38.42	0.58	1.66	0.23	7.46	9.01	2.26	0.65	6029
2000-01	17.24	1.79	0.25	9.94	38.50	0.72	2.03	0.31	6.68	9.08	2.33	0.69	6115
2001-02	16.26	1.64	0.28	9.27	36.40	0.47	2.25	0.73	8.49	9.96	2.55	0.70	6318
2002-03	15.01	1.87	0.26	8.51	37.56	0.50	0.91	1.27	10.06	8.59	3.13	0.72	6035
2003-04	15.89	1.58	0.26	9.78	36.40	0.42	1.92	1.18	9.69	8.23	2.51	0.75	6388
2004-05	15.94	1.51	0.25	8.80	37.57	0.35	1.68	1.06	10.89	9.67	2.07	0.75	6425
2005-06	16.08	1.37	0.27	9.71	36.25	0.43	1.99	28.01	10.87	8.97	1.98	0.93	6509
2006-07	16.26	1.39	0.21	9.66	36.06	0.59	1.68	0.96	9.34	8.24	2.19	0.20	6407

Note: crops with negligible share in the total cropped area were excluded

Area irrigated of important crops

The assured supply of irrigation water in most of the area in the state caused development in agriculture. The area under pearl millet increased continuously. In case of chickpea also, area irrigated fluctuated over the years with a downward trend, it reached a high of 65.45 percent in 1987-88 (Table 5) and declined to 17.60 percent of total cultivated area under the crop in year 2004-05. This might be on account of shifting of chickpea acreage to the more remunerative crops like wheat and rapeseed-mustard with increased availability of irrigation water. This trend of percentage area under irrigation under paddy, wheat, cotton and sugarcane follow 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, most of irrigation water was shared amongst paddy, wheat, cotton, sugarcane, pearl millet and chickpea got reduced area under irrigation. The area under irrigation got reduced in case of oilseeds, pulses and coarse cereals in the state.

Table 5: Irrigated area of important crops in Haryana state

Year	Irrigated area of major crops(in percentage)						Total area irrigated to net sown area(%)	Net sown area (000.ha.)
	Paddy	Pearl millet	Wheat	Chickpea	Cotton	Sugarcane		
1980-81	97.13	11.84	93.10	43.08	98.29	91.07	59.20	3602
1981-82	95.72	13.50	92.96	32.10	98.03	89.59	61.40	3660
1982-83	98.26	15.93	94.02	41.27	97.38	92.39	65.50	3596
1983-84	90.79	14.42	95.62	26.25	96.47	91.18	60.80	3600
1984-85	98.33	11.63	95.40	20.11	97.76	92.24	60.50	3616
1985-86	98.80	12.93	96.33	25.10	99.97	95.01	62.20	3613
1986-87	98.73	15.36	97.98	33.88	99.29	95.62	64.80	3622
1987-88	99.50	27.33	97.54	65.43	98.94	94.87	79.80	3233
1988-89	98.89	13.87	97.83	21.07	99.28	95.64	71.00	3564
1989-90	99.30	21.20	97.56	29.86	99.45	96.42	73.90	3593
1990-91	99.02	15.45	97.87	21.72	99.47	96.08	72.90	3575
1991-92	99.51	19.04	98.13	28.69	99.64	96.36	76.00	3508
1992-93	99.57	17.45	97.91	22.94	99.62	96.34	75.30	3492
1993-94	99.60	19.68	98.19	20.49	99.64	96.43	75.80	3513
1994-95	99.62	15.29	98.39	20.00	99.64	96.43	76.40	3559
1995-96	99.28	17.74	98.33	18.57	99.34	97.22	77.30	3586
1996-97	99.63	15.59	98.31	18.84	99.24	98.15	76.50	3615
1997-98	99.59	17.45	98.29	14.98	98.94	97.59	76.80	3635
1998-99	99.81	18.43	98.18	13.73	99.14	98.43	78.30	3628
1999-00	99.83	19.60	98.77	42.82	99.50	98.02	81.30	3552
2000-01	99.78	24.16	99.11	32.93	99.74	97.90	83.90	3526
2001-02	99.90	22.71	99.13	27.36	99.61	97.71	82.40	3566
2002-03	99.92	34.06	99.24	32.36	98.58	98.94	85.83	3458
2003-04	99.88	26.90	98.98	21.17	99.42	99.18	84.01	3534
2004-05	99.78	31.13	99.10	17.60	99.32	99.25	83.73	3528
2005-06	99.94	30.79	99.01	18.49	99.52	99.07	82.56	3556
2006-07	99.90	37.32	99.11	20.42	99.67	99.57	84.08	3556

Use of agro chemicals

With the advent of the green revolution, the use of modern inputs, especially agro-chemicals, has increased manifold, owing to responsiveness of high yielding varieties to irrigation, chemicals etc. The consumption pattern of major plant nutrients viz; nitrogen, phosphorous and potash as well as pesticides as portrayed in table 6.From use of fertilizers i.e. 64.08 kg/ha .in 1980-81,the

consumption pattern shows an increasing trend (barring potash) has reached a high of 316.34 kg/ha in 2006-07 with contribution of nitrogen, phosphorous and potash being 242.58, 68.64 and 5.12 kg/ha., respectively. The overall emerging issue of the consumption pattern of nitrogen, phosphorous and potash indicates the increasing trend over the years in respect of nitrogen followed by phosphorous and potash. The consumption of pesticides has also increased over the years. The ever increasing trend in chemical fertilizers and pesticides consumption has put a question mark on the sustainability of agriculture. Indiscriminate use of pesticides wipes out the natural enemies of pests, encourages the development of resistant strains of the pests and hazardous effect on human life.

Table 6.Consumption of agro-chemicals in Haryana state

Year	Fertilizers (kg/ha.)				Pesticides (kg/litre/ha.)
	Nitrogen	Phosphorous	Potash	Total	
1980-81	52.02	8.70	3.36	64.08	0.060
1981-82	59.06	8.85	2.95	70.86	0.062
1982-83	60.12	10.38	2.70	73.20	0.073
1983-84	72.09	14.73	3.80	90.62	0.076
1984-85	75.43	15.55	2.11	93.09	0.086
1985-86	82.04	19.27	1.70	103.01	0.100
1986-87	90.29	22.63	1.61	114.53	0.110
1987-88	93.01	27.32	1.51	121.84	0.114
1988-89	107.63	33.56	1.67	142.86	0.125
1989-90	112.05	35.92	1.06	149.03	0.132
1990-91	125.32	39.02	1.42	165.76	0.147
1991-92	132.47	40.31	0.72	173.50	0.150
1992-93	132.47	40.31	0.72	173.50	0.149
1993-94	149.93	42.51	0.70	193.14	0.148
1994-95	159.38	42.24	0.75	202.37	0.143
1995-96	164.94	37.53	0.89	203.36	0.142
1996-97	172.66	38.81	0.86	212.33	0.139
1997-98	182.30	47.25	1.09	230.64	0.138
1998-99	184.78	62.35	1.43	248.56	0.139
1999-00	201.10	58.08	2.72	261.90	0.141
2000-01	202.58	58.51	2.74	263.83	0.142
2001-02	202.04	70.33	3.45	275.82	0.135
2002-03	220.29	66.58	4.94	291.81	0.137
2003-04	216.16	65.34	4.85	286.35	0.138
2004-05	239.66	74.34	4.78	318.78	0.137
2005-06	238.30	71.02	8.06	317.38	0.139
2006-07	242.58	68.64	5.12	316.34	0.137

Ground water quality, change in water table and extent of problematic areas

The overall repercussion associated with farm activities have changed the scenario of ground water quality, water table and increase in problematic area. Nearly 55 percent water seems to be unfit for crop production and water table is declining by 12 to 36 cms each year. The foregoing discussion discerns the fact that the average acreage under cultivation has reached its peak and it is likely to decrease with increased urbanisation. Creation of intensive irrigation facilities, excessive use of canal

water and the irrational use of crucial farm inputs have resulted in the problems of water logging, land degradation etc.

Resource use pattern

Wider adoption of sustainable farming methods requires that they should at least be as profitable as existing methods along with non-monetary advantages without rapidly deteriorating soil and water resources. The major stress is laid on crop component, its diversification, crop mix and their visual impact on land, water use and consumption of agro-chemicals. Based on these considerations and priority approaches, General Algebric Modelling System (GAMS) Technique was used to work out the sustainable crop plans. In order of acreage, the major crops in the existing crop plan were wheat, paddy, pearl millet, rapeseed, chickpea, cotton and sugarcane (Table 7). In the existing optimal plan, there was no change in chickpea, cotton, sugarcane and potato acreages. Barley disappeared from the plan where as area under paddy, maize and rapeseed increased. The changing crop acreages under different suggested optimal plans, give vivid picture of constant acreage under pearl millet, cotton and sugarcane. The acreage under chickpea, potato, red gram, green gram, soybean and lentil got substantially increase in the subsequent plans while there was up declining trend for rapeseed. Wheat and paddy witnessed declining trend in the optimal plan III. Barley escapes its inclusion in all optimal plans while maize excluded in optimal plan III. The increasing acreage under pulses, oilseeds and other leguminous crops with decreased area under paddy, wheat and cotton 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 the sustainable agriculture.

Table 7: Existing and suggested crop plan in Haryana state

(000.,ha.)

Crop	Existing plan	Existing optimal plan	Suggested optimal plans		
			I	II	III
Paddy	1062.26	1062.02	956.83	963.12	918.41
Pearl millet	612.28	509.63	496.35	498.21	498.04
Maize	18.24	123.13	69.86	-	-
Wheat	2278.19	2171.30	2002.57	1943.27	1871.49
Barley	46.34	-	-	-	-
Chickpea	264.18	234.18	302.87	343.42	365.41
Rapeseed	482.08	675.18	662.21	649.12	654.08
Cotton	560.38	560.38	514.71	500.33	498.37
Sugarcane	135.46	127.59	135.46	135.46	135.46
Potato	18.08	14.08	61.08	81.37	98.06
Red gram			72.23	92.07	110.31
Green gram	-	-	62.24	86.78	103.87
Soybean		-	82.94	112.56	126.16
Lentil	-	-	58.14	71.78	97.83

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Input use pattern

The basic aim is to reduce the use of crucial farm resources like water and agro-chemicals without causing any adverse impact on farm income. In all other plans, the water requirement indicated declining trend (Table 8). But it came down to 2613.35 thousand metre hectares in the optimal plan III. The gradual reduction in fertilizer requirement in the subsequent plans seems to be virtual possibly with maximum reduction of 9.89 percent in the optimal plan III. Barring the potash consumption in the subsequent optimal plans, the nitrogen and phosphorous consumption got reduced up to 11.48 and 3.73 percent, respectively in the suggested optimal plan III. The pesticide consumption pattern exhibited increasing down trend. From 3217.68 thousand kg in the existing plan, it reached to 3343.52 thousand kg in the optimal plan and from there to 3342.81 thousand kg in the suggested optimal plan III, indicating thereby an increase of 3.89 percent over the existing optimal plan. Although, there is not much increase on pesticides front, on account of increasing potato acreages. The reducing phenomenon consequent upon the changed crop acreages in the optimal crop plans, will improve soil fertility and productivity, enhance biotic activity and limit the adverse hydrological change.

Table 8: Existing and suggested crop plan in Haryana state

Crop	Existing plan	Existing optimal plan	Suggested optimal plans		
			I	II	III
Water use (metre hectare)	2845.58	2831.25	2686.09	2671.49	2613.35
Fertilizers (kg)	1197506.00	1188462.00	1123469.00	1100450.00	1079106.00
Nitrogen(kg)	663818.70	659680.10	616924.60	601150.50	587668.60
Phosphorous(kg)	295344.50	292363.90	287797.90	286759.50	284335.00
Potash (kg)	238342.40	236417.80	218746.20	212540.20	207102.20
Pesticides(kg/litre)	3217.68	3343.52	3338.36	3336.14	3342.81

Saving benefits accrued

The accrued saving benefits tread a varied path. All the optimal plans showed the saving in water requirement. The fertilizer saving got increased and reached to peak in optimal plan III. Similarly, the nitrogen and phosphorous savings exhibited the trend. The pesticides saving pattern exposed the negative trend in all the optimal plans with little bit difference. As result, total saving benefits accrued in the existing optimal plan turned out to be a sum of Rs. 99361.72 thousands (Table 9). Benefits in subsequent optimal plans show the increasing trend with highest in the suggested optimal plan III. The reduced use of critical farm inputs viz; water and agro–chemicals will open a new window for economic, social and ecological considerations. Thus, in this way, it will add to economic benefits with reduced use of purchased inputs, curtail the harmful and hazardous effects and build up soil structure and texture.

Table 9 : Saving benefit accrued

(000,Rs.)

Crop	Existing optimal plan	Suggested optimal plans		
		I	II	III
Water use	32672.40	363637.20	396925.20	529484.40
Fertilizers	101672.80	714979.30	929113.60	1137767.90
Nitrogen	43165.60	489105.50	653629.30	794245.50
Phosphorous	48345.33	122405.90	139248.70	178574.10
Potash	10161.89	103467.90	136235.60	164948.30
Pesticides	-34983.50	-33549.00	-32931.90	-34786.10
Total	99361.72	1045067.50	1293107.90	1632466.20

Pattern of returns

With changes in acreages under different optimal plans, the input use pattern as well as gross returns under went a change. The emerged out pattern of return has been presented in table 10. The gross returns from the crop production activity in the subsequent suggested optimal plans decreased marginally. The saving benefits accrued over the existing plan turned out to be a positive.

The findings further reveal that with an initial minor set back, it picked up in the successive optimal plans. Moreover, the changed pattern of returns will have to be viewed not only from economic consideration but also taken into consideration viz; said and unsaid quantification, qualitativeness on food front, ecological dimensions and sustainable growth parameters.

The results of the study reveal that area under forests does not indicate any appreciable increase over the years. The cropping pattern exhibited the acreage concentration of resource exhaustive and less risky crops like cotton, wheat, sugarcane and paddy and most of irrigation water were used amongst these crops. Increased consumption of nitrogenous fertilizers and pesticides, continuation of same cropping pattern over the time period resulted into accentuating the area under problematic soils, depletion of underground water, infestation of weeds, insect-pests and diseases. The optimal sustainable production plans showed increase in gross returns as well as accrued benefits through saving the water and agro-chemicals. The optimal plans in corporation the crop enterprises like green gram, black gram, soybean, groundnut etc not only improved the soil health but also reduction in use of natural resources and agro-chemicals. The optimal plans further make sure to accommodate the economic, ecological and social aspects paving the path for sustainable development in agriculture

Table 10: Changing pattern of returns

(000,Rs.)

Crop	Existing plan	Existing optimal plan	Suggested optimal plans		
			I	II	III
Gross returns from crops	101017285.50	99331360.68 (98.33)	105822368.90 (104.75)	105242730.90 (104.18)	104354559.40 (103.30)
Saving benefits (Water+ fertilizers +pesticides)	-	99361.72	1045067.50	1293107.90	1632466.20
Gross return+ saving benefits	101017285.50 (100.00)	99430722.40 (98.42)	106867436.40 (105.79)	106535838.80 (105.46)	105987025.60 (104.91)

Note : Figures in parentheses indicate change over the existing plan

CONCLUSIONS

The results conclude that that area under forests showed declined over the years. However, intensity of cropping has increased. The cropping pattern vividly exhibits the acreage concentration of the resource exhaustive crops like paddy, wheat, rapeseed-mustard cotton and sugarcane. Most of the irrigation water was shared amongst these crops. Consumption of nitrogenous fertilizers increased at much faster rate than that of phosphatic and potashic fertilizers. Continuing adoption of the same cropping pattern has resulted into accentuating the land degradation and distributing hydrological balance. How ever, the input use pattern of water and agro-chemicals exhibits the reducing trend under successive optimal plans. The benefits brought about savings in water and agro–chemicals are likely to open new vistas for economic, social and ecological frontiers. In order to respond dynamically to current challenges, policies like water pricing, water shed management, diversification, change crop-rotations and crop-mix to make progress towards profitable and environmentally sustainable production systems.

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