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Sustainability of Water Resources during the Post-Green Revolution Period in Punjab

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Even since the introduction and large scale adoption of high-yielding fertiliser responsive varieties of wheat and paddy, the role of irrigation water has gained a great importance in the overall development of Punjab's agricultural economy. In the Punjab, out of the total of 4.197 million hectares of annual cropped area, 3.717 million ha are irrigated. Of the total irrigated area, nearly 40 per cent depends on surface canal water source and the rest on the groundwater resource. The canal water contains negligible amounts of dissolved salts and is of excellent quality for irrigation purpose. The groundwater in all the areas of the state is, however, not sweet and suitable for irrigation. It has been estimated by the scientists of Punjab Agricultural University (PAU), Ludhiana, that the problem with regard to the underground water is severe in the south-western parts and to some extent in the central parts of the state, where the major source of irrigation is canal water and the same is being intensively exploited.

Though the well-developed irrigation infrastructure (both canal and underground water) in the Punjab has saved the state's economy from the vagaries of weather over time, yet the intensive exploitation of the water resources in the state is becoming increasingly a matter of serious concern. Keeping in view the pace of these fast changes in the Punjab's agricultural sector, a natural question which arises in one's mind is whether the existing water availability will sustain the pressure of these changes or not. The present study was undertaken to probe into this aspect. Efforts have been made to estimate the irrigation water requirements and its available supply in different agro-climatic zones of the Punjab so as to arrive at the water balance estimates. In addition, the groundwater development has also been studied over time in different zones of the state.

METHODOLOGY

The State of Punjab has been divided into six agro-climatic homogeneous zones by the Experts Committee of PAU scientists. This classification was slightly modified by merging the area of zone VI (representing the 'bet' area of the state) into the appropriate zones so as to have spatially contiguous zones in this study. The following are the zonewise details of the number of blocks:

Zones I	Sub-Mountain Undulating Zone	12+8*
Zone II	Undulating Plain Zone	12+10*
Zone III	Central Plain Zone	48+4*
Zone IV	Western Plain Zone	18+2*
Zone V	South-Western Zone	16

* means half block.

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Data

The block level data regarding area under different crops for the years 1980-81 to 1989-90 were obtained from the Directorate of Agriculture, Punjab. The information regarding the groundwater balances, as estimated by using Groundwater Estimation Committee (Anonymous, 1984)[1] methodology for the years 1984 and 1989 were obtained from the Directorate of Ground Water Resources, Punjab. Finally, the experimental data on evapotranspiration (ET) demand for the normative growth of different crops were collected from the Department of Soils, PAU, Ludhiana.

Various blocks have been classified into white, gray and dark on groundwater development basis depending upon whether the annual net draft (withdrawal) is less than 65 per cent, between 65 and 85 per cent, or more than 85 per cent of the annual net recharge in the groundwater.

Estimation of Availability and Requirements of Water

The annual normative demand for water for irrigation purpose has been estimated by using the following formula:

$$AND = \sum_{i=1}^{n} ET_i \cdot A_i$$

where AND = annual normative demand for irrigation purposes in hundred hectare metre (ham),

ET = evapotranspiration demand for ith crop in ham.

A_i = area under the ith crop in 00 ha.

The figure of AND so obtained was raised by 25 per cent to take care of water requirements of fodders, vegetables and other crops plus water requirements for drinking and industrial purposes.

The zonewise estimates of supply of water were computed from the data given in Prihar *et al.* (1990).

The differences between water requirements and available supply were worked out to arrive at the water balance estimates for each zone. Although the estimates of supply figures as arrived at by Prihar *et al.* (1990), and used in this study are based on 11 years' rainfall data, yet these estimates are likely to increase over time with installation of more tubewells. However, due to non-availability of blockwise data on the number of tubewells, this aspect could not be empirically verified and hence we were compelled to consider only the static water supply level.

TABLE I. CROPPING PATTERN IN DIFFERENT ZONES AND ET COEFFICIENTS FOR THE CROPS IN PUNJAB

(area in hundred hectares)

Zone	Year	Area under									Total area
		Paddy	Maize	Sugarcane	Groundnut	Cotton	Wheat	Gram	Rapeseed and mustard	Other crops	
	(ET coefficient)	(0.72)	(0.60)	(1.80)	(0.50)	(0.65)	(0.50)	(0.40)	(0.35)	(Not available)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
I	1980-81	536.00(14.82)	849.00(23.47)	98.50(2.72)	51.50(1.42)	33.00(0.91)	1,746.00(48.26)	238.50(6.59)	31.00(0.86)	34.50(0.95)	3,618.00
	1989-90	708.00(17.52)	876.00(21.68)	204.00(5.05)	17.00(0.42)	6.00(0.15)	1,958.50(48.47)	54.00(1.34)	42.50(1.05)	174.50(4.32)	4,040.50
II	1980-81	1,619.50(27.56)	780.00(13.27)	191.50(3.26)	74.50(1.27)	42.50(0.72)	2,949.50(50.19)	106.00(1.80)	61.50(1.05)	51.50(0.88)	5,876.50
	1989-90	2,312.00(33.79)	613.50(8.97)	362.50(5.30)	15.00(0.22)	5.00(0.07)	3,361.00(49.13)	15.00(0.22)	38.00(0.55)	119.50(1.75)	6,841.50
III	1980-81	6.486.00(28.67)	1,658.50(7.33)	317.50(1.40)	597.00(2.64)	1,016.00(4.49)	11,870.00(52.47)	197.50(0.87)	232.50(1.03)	250.00(1.10)	22,625.00
	1989-90	10,623.00(41.09)	562.75(2.18)	400.75(1.55)	81.00(0.31)	456.00(1.76)	13,092.00(50.65)	10.00(0.04)	224.00(0.87)	400.25(1.55)	25,849.75
IV	1980-81	1,981.50(18.23)	350.30(3.22)	56.50(0.52)	21.50(0.20)	1,473.50(13.56)	5,666.00(52.13)	489.50(4.50)	328.30(3.02)	502.15(4.62)	10,869.25
	1989-90	3,563.10(27.68)	60.15(0.47)	66.95(0.52)	12.15(0.09)	1,890.00(14.69)	6,713.00(52.16)	85.20(0.66)	89.00(0.69)	391.45(3.04)	12,871.00
V	1980-81	722.60(6.16)	42.20(0.36)	13.60(0.11)	1.60(0.01)	3,697.20(31.51)	4,704.00(40.09)	1,434.40(12.22)	681.20(5.81)	437.40(3.73)	11,734.20
	1989-90	1,130.40(8.30)	9.60(0.07)	32.50(0.24)	6.60(0.05)	4,811.40(35.34)	6,410.00(47.09)	375.80(2.76)	509.00(3.74)	327.80(2.41)	13,613.10

N.A. Not available.

Figures in parentheses are percentages to the total area.

RESULTS AND DISCUSSION

This section presents the zonewise details regarding the balance between the total water requirements at the normative level of crop production and available water supply. Besides, the overall groundwater scenario of the Punjab State is also discussed.

Shifts in Cropping Pattern vis-a-vis Water Requirements

The zonewise cropping pattern along with evapotranspiration (ET) coefficients for different crops are presented in Table I. It may be seen from the table that the area under paddy has increased in all the zones during the period of study, *i.e.*, from 1980-81 to 1989-90. These changes were particularly sharp in zones III and IV, where the area under paddy increased from 6,486 and 1,981.50 hundred hectares during 1980-81 to 10,623 and 3,563.10 hundred hectares during 1989-90 respectively. The area under paddy as per cent of the total cropped area of the zone also increased from 28.67 and 18.23 per cent to 41.09 and 27.68 per cent in the respective zones during this period. Further, these two zones continued to account for about 62 per cent of the total cropped area of the state over the study period, highlighting their relative importance in the overall economy of the state (Table II).

TABLE II. SHARE OF DIFFERENT ZONES IN THE GROSS CROPPED AREA IN PUNJAB
(per cent)

	Zone					
Year	I	II	III	IV	V	Total
1984	5.91	10.37	42.33	20.14	21.53	100.00
1989	6.07	10.53	41.40	21.48	20.52	100.00

The area under sugarcane too is observed to have increased in absolute terms and as per cent of the total cropped area of the zone. The area under maize and groundnut each showed a consistent decline in all the zones during this period. It may be observed that the area under cotton also witnessed an increase during this period in zones IV and V.

During the *rabi* season, wheat continued to occupy a most important position in all the zones. The area under wheat has shown an increase mainly at the cost of its competing crops like gram and rapeaseed and mustard in all the zones.

A critical evaluation of these changes during the last decade shows that the cropping pattern in the Punjab has been shifting towards paddy, sugarcane, cotton (in zones IV and V) and wheat. Since all these crops required significantly large quantities of water for their proper growth as evident from their respective ET coefficients (Table I), hence the total water requirements in all the zones have shown a considerable increase during this period (Table III).

Estimates of Water Balance

The differences in the total utilisable water available (excluding unfit and marginally fit water) and the total water requirements constituted the estimated water balance (Table III). The estimates of water balance is observed to be positive only in zone I in the state. Since this zone is located at a relatively higher altitude, hence the surplus groundwater moves to

the contiguous zones at lower levels by surface flow permitted by existing hydraulic gradient. Suitable collection of surface run-off in this zone may, therefore, greatly help in minimising the water stresses experienced by the crops grown here.

TABLE III. ZONEWISE WATER BALANCE ESTIMATES IN PUNJAB

(00 ham)

Zone	Year	Total water requirements (quantity demanded)	Utilisable resource excluding unfit and marginally fit waters	Marginally fit groundwater resource	Difference between demand and supply for water
(1)	(2)	(3)	(4)	(5)	(6)
I	1980-81	1,178.94	3,544.18	44.71	+2,365.24
	1989-90	1,916.36	3,544.18	44.71	+1,627.82
II	1980-81	3,552.47	3,640.93	93.63	+88.46
	1989-90	4,926.36	3,640.93	93.63	-1,285.43
III	1980-81	16,081.30	12,667.42	1,062.60	-3,413.88
	1989-90	19,632.14	12,667.42	1,062.60	-6,964.72
IV	1980-81	6,906.91	4,506.35	765.86	-2,400.56
	1989-90	9,214.91	4,506.35	765.86	-4,708.56
V	1980-81	6,842.21	5,095.46	505.63	-1,746.75
	1989-90	9,201.98	5,095.46	505.63	-4,106.52

The situation for the other zones, unfortunately, is not very encouraging. Not only the water balance estimates in all these zones are negative but they also showed a declining trend over time. This meant that the total water availability was not enough to meet the normative requirements. Hence, lesser water would be available over time for crop growth in the future. If the present trend continues the situation will become still worse. To tackle this problem, there should be an increasing tendency to supplement the water supply by installing more tubewells, as the surface water and effective rainfall, the other two components of water availability, still continue to be beyond one's control. Though this may help in improving the situation in the short run, yet it may have far-reaching consequences in the long run in terms of sustainability of the water resources in the Punjab.

Overview of Groundwater Scenario

The discussion in the preceding section highlighted the deficiency of water availability in the Punjab except in zone I. It was also suggested that the underground water may have to be exploited more in order to meet this deficiency. Hence, it was considered important to discuss in detail the underground water resource development in the Punjab.

In zone I, where the water availability is more than water requirements, the number of blocks falling under white and gray categories on groundwater development basis increased from 7+4* and 3 during 1984 to 8+4* and 3+4* during 1989 (Table IV). The cropped area as such and as per cent of the gross cropped area of the zone also increased. In most parts of this zone, shallow tubewells are not possible because of its topography. Consequently, pumping out of the groundwater (net draft) is probably less than 65 per cent of the net water recharge in the aquifer.

In zones III and IV, which constituted 62 per cent of the gross cropped area of the state, the net draft of water appears to be increasing rapidly in comparison with the net recharge. This is clearly evident from the increased number of blocks in the dark category in these two zones.

TABLE IV. ZONEWISE DISTRIBUTION OF GROSS CROPPED AREA IN DIFFERENT CATEGORIES ON GROUNDWATER DEVELOPMENT BASIS IN PUNJAB

Zone	1984								1989							
	White		Gray		Dark		Total		White		Gray		Dark		Total	
	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)	No.of blocks	Area (00 ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Zone I																
(Irr.)	7+4*	769.50	3	578.00	2+4*	334.50	12+8*	1,682.00	8+4*	1,026.00	3+4*	849.50	1	82.00	12+8*	1,957.50
		(45.75)		(34.36)		(19.89)		(100.00)		(52.41)		(43.40)		(4.19)		(100.00)
(Total)		1,939.50		847.00		751.50		3,538.00		2,249.00		1,352.00		177.00		3,778.00
		(54.82)		(23.94)		(21.24)		(100.00)		(59.53)		(35.79)		(4.68)		(100.00)
Zone II																
(Irr.)	1-4*	398.50	3	788.00	8+6*	3,861.00	12+10*	5,047.50	1+4*	540.00	4+4*	1,588.50	7+2*	3,451.00	12+10*	5,579.50
		(7.89)		(15.61)		(76.49)		(100.00)		(9.68)		(28.47)		(61.85)		(100.00)
(Total)		846.50		951.00		4,408.50		6,206.00		900.50		2,046.00		3,605.50		6,552.00
		(13.64)		(15.32)		(71.03)		(100.00)		(13.74)		(31.23)		(55.03)		(100.00)
Zone III																
(Irr.)	2	1,143.00	5	1,811.00	41+4*	21,783.50	48+4*	24,737.50	-	-	5	2,667.00	43+4*	22,926.50	48+4*	25,593.50
		(4.62)		(7.32)		(88.00)		(100.00)				(10.42)		(89.58)		(100.00)
(Total)		1,164.00		1,858.00		22,308.00		25,330.00				2,689.00		23,060.50		25,749.50
		(4.59)		(7.34)		(88.07)		(100.00)				(10.44)		(89.56)		(100.00)
Zone IV																
(Irr.)	6	5,316.50	6	3,599.00	6+2*	2,752.50	18+2*	11,668.00	3	2,669.60	4	3,285.00	11+2*	7,262.60	18+2*	13,217.20
		(45.56)		(30.84)		(23.60)		(100.00)		(20.20)		(24.85)		(54.95)		(100.00)
(Total)		5,497.00		3,710.00		2,844.50		12,051.50		2,770.00		3,300.00		7,293.95		13,363.95
		(45.61)		(37.78)		(23.61)		(100.00)		(20.73)		(24.69)		(54.58)		(100.00)
Zone V																
(Irr.)	16	11,771.40	-	-	-	-	16	11,771.40	16	12.186.80	-	-	-	-	16	12,186.80
		(100.00)						(100.00)		(100.00)						(100.00)
(Total)		12,716.40		-		-		12,716.40		12,761.80		-		-		12,761.80
		(100.00)						(100.00)		(100.00)						(100.00)

Note:- (1) White means less than 65 per cent of utilisable groundwater exploited; Gray, 65 to 85 per cent of utilisable groundwater exploited; Dark, above 85 per cent of utilisable groundwater is exploited.

(2) * means number of half blocks. Figures in parentheses are percentages to the total.

The situation in zone V is different from the rest of the zones where in spite of an overall deficiency of utilisable water for irrigation purposes, all the blocks remained in the white category over time. Such a phenomenon may be attributed to the fact that in this zone the underground water is not sweet and fit for irrigation purposes and the major source of irrigation is canal water.

CONCLUSIONS

It may be concluded from the foregoing discussions that the cropping pattern in the Punjab has been shifting towards wheat-paddy and wheat-cotton rotations depending upon the suitability of the area for paddy and cotton. In addition, the area under sugarcane is also showing increasing trends over time. Since the water requirements of these crops are relatively higher, the total water requirements are, therefore, increasing. Further, in the areas where groundwater is the major source of irrigation, the annual net draft of water is increasing over time and in many areas it has even crossed the levels of annual groundwater recharge from various sources. So much so that the water table has started falling almost in the entire sweet water zone of the state. Similar is the case where canal water is the major source of irrigation. The requirements for irrigation water are increasing there also but not the supply and, therefore, shortages are being felt over time.

On the basis of this study, it may be suggested that the research and development efforts should be directed towards the development of the techniques to use the marginally fit and if possible unfit water for various purposes. Besides, the agricultural price policy should be such that it may suitably steer the cropping pattern in the state so as to ensure the sustainability of water resources.

NOTE

1. For details, see Prihar *et al.* (1990, pp. 13-16).

REFERENCE

Prihar, S.S.; S.D. Khepar, Raghbir Singh, S.S. Grewal and S.K. Sondhi (1990). Water Resources of Punjab - A Critical Concern for the Future of Its Agriculture, Punjab Agricultural University, Ludhiana, April.