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Temporal and Spatial Differences in Utilising Degraded Lands in Indo-Gangetic Region

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Unequivocally, the wastelands are to be rehabilitated for sustained agricultural development and to meet the growing demand for foodgrains. The concern is visualised on two counts. First, the man-land ratio is rising resulting in higher demand for land for non-agricultural uses. The per capita availability of land for agricultural purposes in the country has declined from 0.48 hectare in 1951 to about 0.20 hectare in 1981, and it is expected to decline further to around 0.15 hectare by 2000 A.D. (Singh, 1990). Second, the yields of important crops in fertile areas are stagnating with the existing resource endowments, management and technology.

An area of about 40 million hectares is classified as wastelands in the country. Salt affected soils occupy about 7 million hectares (Abrol and Bhumbla, 1971). It is stated that mismanagement of surface irrigation in many parts of arid and semi-arid regions is leading to secondary salinisation. Reports revealed that irrigation benefits in many parts are negated by salt accumulation and rise in watertable. Such a trend of soil degradation and its environment must be arrested and rehabilitated for sustained agricultural development.

Several technological options were developed to utilise and manage problem soils. The Indo-Gangetic plains witnessed impressive technological innovation that provided immense potential for increasing foodgrain production from these soils. Rough estimates revealed that in case the entire area under alkali soils in the Indo-Gangetic region is reclaimed to produce rice and wheat, it is expected to add about 6.5 to 8.8 million tonnes to the national foodgrain production under different scenarios (Singh and Joshi, 1990).

The available evidences revealed marked temporal and spatial differences in the rate of adoption of reclamation technology. It is, therefore, pertinent to understand several dimensions of disseminating the process of technology. This study endeavours to discuss the cross-sectional differences in the pattern of reclamation of alkali soils and the factors responsible for such changes.

METHODOLOGY

Study Area

The study is broadly based on the Indo-Gangetic region, consisting of upper and trans-Gangetic plain and a part of middle Gangetic plains. Punjab, Haryana and part of Uttar Pradesh fall in these agro-climatic zones, with an annual rainfall ranging from 550-1000 mm. The salt affected soils (both alkali and saline) are widely distributed in these three states. These soils occupy approximately 25 lakh hectares of which 14 lakh hectares are alkali soils and accounting for about 56 per cent of the total salt affected area in these states. Roughly, about 12 per cent of the net area sown is alkali in the Punjab. The corresponding

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figures for Haryana and Uttar Pradesh are 7 and 4 per cent respectively. The distribution of alkali soils in different districts is given in Table I. Approximately, 3.32 lakh hectares of alkali affected land has been restored to agricultural production in the Indo-Gangetic plains.

TABLE I. ALKALI AFFECTED AREA IN DIFFERENT DISTRICTS OF INDO-GANGETIC REGION

State/ District	Alkali affected area (000 ha)	Alkali soil to geographical area (per cent)	Area reclaimed by 1987-88	
			(000 ha)	(Per cent)
(1)	(2)	(3)	(4)	(5)
Haryana				
Jind	50.00	15.53	8.70	17.40
Karnal	100.00	28.18	38.42	38.43
Kurukshetra	70.00	19.49	22.04	31.49
Punjab				
Amritsar	270.00	53.36	38.32	14.20
Ferozpur	137.12	23.35	28.50	20.78
Gurdaspur	48.40	13.83	13.75	28.43
Jullandhar	27.55	8.10	11.70	42.50
Kapurthala	49.56	29.68	42.57	85.90
Patiala	45.86	9.91	25.84	56.34
Sangrur	70.31	13.76	65.98	93.85
Uttar Pradesh				
Aligarh	45.05	8.97	5.79	12.86
Azamgarh	32.04	5.59	7.90	24.68
Bareilly	18.58	4.56	1.58	8.52
Etah	56.02	12.60	3.93	7.01
Etawah	42.32	9.69	4.76	11.27
Fatehpur	41.93	9.96	3.29	7.86
Gazipur	14.79	4.44	4.31	29.13
Hardoi	35.53	5.94	3.53	9.95
Kanpur	78.12	12.63	4.05	5.19
Lucknow	25.51	10.10	3.85	15.11
Mainpuri	66.75	15.42	5.49	8.23
Meerut	15.74	4.02	2.54	16.18
Pratapgarh	31.68	8.76	4.55	14.36
Rai Bareilly	59.80	13.05	9.23	15.44
Sultanpur	42.57	9.68	7.60	17.85
Unnao	48.63	10.61	5.71	11.74

Data

All the districts affected by the problem of alkalinity in the Indo-Gangetic region were selected. The data on the extent of problem soil and yearwise progress of reclamation were collected from secondary sources. Other parameters like sourcewise irrigated area, cropping intensity, yields of rice and wheat, size of holding, etc., were collected from published sources. The analysis is based on the data covering a period from 1977-78 to 1987-88. The reason for choosing 1977-78 as the base year was on account of availability of data on the progress of reclaiming alkali soils for crop production in different states.

Analytical Technique

Several forms of trend functions were fitted to the data to explain the cross-sectional differences in terms of the beginning of the technological adoption and its rate. The dependent variable, *i.e.*, area reclaimed, was defined in several ways with different forms of trend functions. Logistic functions turned out to be the best fit and were selected to interpret the results.

The logistic growth curve is written as:

$$A = K / 1 + e^{-(a+bt)}$$

where 'A' is the alkali area reclaimed in percentage, 'K' the ceiling value, 't' the time variable, 'b' the rate of growth coefficient, and 'a' the constant of integration. The parameter 'K' may take values between 0 and 1. In our analysis, the values of 'K' have been determined by developing a frequency distribution of the districts for the ratio between area reclaimed to the total alkali area. The upper limit of class interval, where a district falls, has been used as ceiling value 'K' for that district.

To compare the cross-sectional differences in the 'b' values with separate 'K' values for each district, the approach used by Griliches (1957) and Ballabh and Sharma (1987) was adopted by calculating b′ = bk.

Technological Options for Reclamation

Several technological options are available to ameliorate alkali soils for agro-climatic region of the Indo-Gangetic plains. These options include *(i)* chemical amelioration for crop production and forestry and *(ii)* biological amelioration by growing salt tolerant crop varieties and grasses. Over the past few years, chemical amelioration of alkali soils in the Punjab, Haryana and Uttar Pradesh has been fairly well standardised. It involves land grading and bunding, assured irrigation, soil test based application of amendment (mainly gypsum) and fertilisers, suitable varieties of rice and wheat and judicious water management and agronomic practices. Experimental results and on-farm studies show that proper use of these techniques of land reclamation has produced crop yields comparable to normal soils.

Economic studies on this technology also show that the potential farm level benefits can be higher provided judicious quantity of amendment and inputs are applied and recommended practices are followed. The technology is financially feasible under farmers' resource endowments and its credit worthiness is well recognised (Singh, 1978; Joshi, 1983). Earlier studies in the Operational Research Project in Kapurthala in the Punjab showed the benefit-cost ratio as high as 2.25 (Kahlon and Singh, 1980). In a different set of situation in the Punjab the benefit-cost ratio varied from 1.15 to 1.20 (Bajwa *et al.*, 1983). The benefit-cost ratio in different situations under farmers' resource constraints in Haryana ranged from 1.34 to 1.42 (Joshi and Agnihotri, 1982). The pay-back period was between 2 and 3 years in Haryana and the Punjab. The long-term results are yet to be observed in Uttar Pradesh. However, few studies have shown that the performance of technology is encouraging and paying (Singh and Bajaj, 1988). The benefit-cost ratio is expected to be about 1.21 in Rai Bareilly under a government sponsored programme in Uttar Pradesh (Government of Uttar Pradesh, 1989). The financial feasibility of the technology, however, depends largely upon the availability and cost of irrigation water. It is, therefore, necessary that in Uttar Pradesh type of situation, the resource endowments of potential beneficiaries and financial feasibility of the technology must be carefully evaluated before embarking on any large scale efforts.

RESULTS AND DISCUSSION

The estimated logistic growth equations are presented in Table II. These provide the origin, slope and ceiling of reclamation of alkali soils in each district, which can be used to interpret the differences in the estimated coefficients.

TABLE II. GROWTH OF RECLAIMING ALKALI SOILS - LOGISTIC TREND EQUATIONS

District (1)	Ceiling (k) (2)	Constant (a) (3)	Rate of acceptance (b) (4)	Adjusted rate of acceptance (b') (5)	F value (6)	R^2 (7)
Jind	0.20	-3.0193	.3729 (.0423)	.0746	77.53	.8959
Karnal	0.40	-2.4112	.3846 (.0596)	.1538	41.56	.8220
Kurukshetra	0.40	-2.2170	.3137 (.0230)	.1255	43.26	.9586
Amritsar	0.20	-3.5687	.4346 (.0523)	.0869	69.06	.8847
Ferozepur	0.30	-3.6292	.4469 (.0409)	.1341	119.07	.9297
Gurdaspur	0.30	-4.2054	.6822 (.0336)	.2047	411.29	.9785
Jullandhar	0.50	-3.0842	.4463 (.0385)	.2232	133.91	.9370
Kapurthala	0.90	-3.5368	.5886 (.0360)	.5297	266.22	.9672
Patiala	0.60	-3.1419	.5339 (.0346)	.3203	238.52	.9636
Sangrur	1.00	-2.5779	.4774 (.0273)	.4774	305.68	.9714
Aligarh	0.20	-3.4939	.4308 (.0639)	.0862	46.34	.8344
Azamgarh	0.30	-2.9201	.4414 (.0581)	.1324	57.72	.8651
Bareilly	0.10	-4.8566	.7011 (.1373)	.0701	26.07	.7434
Etah	0.10	-2.8606	.3822 (.0553)	.0382	47.73	.8414
Etawah	0.20	-5.2853	.6297 (.1746)	.1259	13.00	.5909
Fatehpur	0.10	-3.0235	.4523 (.0625)	.0453	52.27	.8531
Gazipur	0.30	-5.7694	.8892 (.1403)	.2668	40.16	.8169
Hardoi	0.10	-3.3078	.6459 (.0627)	.0646	105.90	.9216
Kanpur	0.10	-2.7943	.3054 (.0531)	.0305	33.09	.7861
Lucknow	0.20	-2.0443	.3319 (.0403)	.0664	67.67	.8826
Mainpuri	0.10	-2.8412	.4213 (.0379)	.0421	123.54	.9321
Meerut	0.20	-4.6448	.6655 (.1617)	.1331	16.93	.6529
Pratapgarh	0.20	-2.9015	.4063 (.0512)	.0813	62.73	.8745
Rai Bareilly	0.20	-2.5484	.3719 (.0278)	.0744	178.34	.9519
Sultanpur	0.20	-3.0272	.4773 (.0210)	.0955	51.58	.9828
Unnao	0.20	-1.9857	.2402 (.0242)	.0480	98.08	.9159

Note:- (*i*) Figures in parentheses are standard errors of the estimated coefficients
(*ii*) All the coefficients and F values are significant at 1 per cent probability level.

Date of Origin

It is argued that the date of origin is broadly identified with supply factors. The technology to reclaim alkali soils for crop production was tested and demonstrated under farmers' resource endowments during the mid-seventies in parts of the Punjab and Haryana. Simultaneously, the government provided strong organisational support by creating land reclamation corporations in the respective states. The broad objective of these corporations was to arrange for chemical amendments and land development. Such incentives interfaced farmers and government officials to begin with the programme in a more effective way.

The date of origin of reclamation technology was assumed as the date at which a district began to rehabilitate 10 per cent of alkali area for crop production. The idea of choosing 10 per cent as an indicator of the date of origin was that at this level the development had passed the experimental stages and that farmers started commercialising the technology.

Table III shows the date of origin of reclamation technology in different districts. Sangrur district in the Punjab was the only district which witnessed the earliest origin of the technology and that too in the initial year itself. The reason for the early adoption of technology in Sangrur district was initiation of a pilot scheme (known as Sangrur scheme) to reclaim about 1,60,000 acres during the sixties (Framji *et al.*, 1984). Kapurthala and Patiala achieved this target in 1979-80, a lag of two years as compared to the district of Sangrur. Similarly, Karnal and Kurukshetra in Haryana and Jullandhar in the Punjab were lagging by three years with respect to origin. Similarly, Jind in Haryana, Amritsar in the Punjab, Aligarh, Etawah and Unnao in Uttar Pradesh were lagging by about seven years in comparison to Sangrur district. About 23 per cent of the selected districts had not reclaimed 10 per cent of the alkali soils by 1987-88. These districts were Bareilly, Etah, Fatehpur, Hardoi, Kanpur and Mainpuri in Uttar Pradesh.

TABLE III. DISTRICTS WITH YEAR OF ORIGIN OF RECLAMATION PROGRAMME

No.	Year	District	Frequency		Cumulative per cent
			Number	Per cent	
(1)	(2)	(3)	(4)	(5)	(6)
1	1977-78	Sangrur	1	3.85	3.85
2	1978-79		-	-	3.65
3	1979-80	Kapurthala, Patiala	2	7.69	11.54
4	1980-81	Karnal, Kurukshetra, Jullandhar	3	11.54	23.08
5	1981-82	Gurdaspur, Azamgarh	2	7.69	30.77
6	1982-83	Gazipur, Lucknow, Meerut	3	11.54	42.31
7	1983-84	Ferozepur, Pratapgarh, Rai Bareilly, Sultan-pur	4	15.36	57.69
8	1984-85	Jind, Amritsar, Aligarh, Etawah, Unnao	5	19.24	76.93

Note:- 23.07 per cent of the districts could not achieve the level of 10 per cent reclaimed area.

Such a state of affairs calls for identifying the factors for spatial differences in the origin of any technology. In general, the basic pre-requisites for any technological innovation, besides profitability, are adequate organisational set-up, appropriate infrastructural network, resource scarcity and knowledge of the technology. To understand this phenomenon, simple correlation coefficients were worked out, taking important variables like date of origin in the district, earliest date of origin in the nearest neighbourhood, growth in reclamation of alkali soils, area reclaimed, cropping intensity and tubewell irrigation. In a broader sense, these variables explain either infrastructural network or resource scarcity or profitability. The results of this exercise are presented in Table IV.

TABLE IV. CORRELATION COEFFICIENTS BETWEEN YEAR OF ORIGIN OF RECLAMATION TECHNOLOGY AND IMPORTANT VARIABLES

Variable (1)	Correlation coefficient (2)
NOR	.6919
b′	-.8006
ARL	-.8943
CIN	-.2935
TWI	-.7099
RPR	-.6817

Note:- NOR is the year of origin in neighbouring district; b′ is adjusted growth rate; ARL is area reclaimed (per cent); CIN is cropping intensity (per cent); TWI is tubewell irrigated area (per cent); RPR is productivity of rice (kg./ha).

Growth in the productivity of rice before the origin of reclamation technology was assumed to be a proxy of profitability. The estimated correlation coefficient between the date of origin and productivity suggested that the origin of reclamation technology started at an early date in areas witnessing slow rate of growth in rice productivity. This shows that stagnating profitability, by and large, was an inducing factor for taking up land reclamation programme. It was expected that land augmentation through reclamation of alkali soils provided an opportunity to either maintain or expand profitability.

The next question arises whether necessary infrastructure is available. This is explained by the availability of tubewell irrigation. A high and negative value of correlation coefficient suggested that the origin of reclamation technology was early in areas having better access to tubewell irrigation. Since assured irrigation is an essential component for reclamation of alkali soils, this factor plays an important role in the adoption of technology. An area of about 84 per cent was irrigated in Sangrur district during 1977-78. On the other hand, the average irrigated area during the corresponding period was about 56 per cent in districts achieving less than 10 per cent of the area reclaimed till 1987-88.

Cropping intensity has been used as a proxy of land scarcity. It is considered that with higher cropping intensity, internal land augmentation is not possible; therefore, external land augmentation through reclamation programme is a possible alternative. The correlation coefficient was negative but the association was very feeble.

The date of origin in the immediate neighbourhood also played an important role and indicated the spatial dimensions of the innovation. A positive correlation coefficient indicated a reasonably good association in these variables, *viz.*, origin in the district and immediate neighbouring district. This has important implications for formulating future research and transfer of technology strategies and policies for an area.

Two variables, *viz.*, the estimated slope coefficient (b) defined to measure the expected rate of acceptance and the area reclaimed were correlated with the date of origin. Both witnessed negative and high correlation coefficients. This indicated that the rate of acceptance was higher in these areas which adopted the reclamation technology at early date. Similar was true with that of area reclaimed.

Rate of Acceptance

The estimated coefficient 'b' is being expressed as the rate of acceptance of reclamation technology. To make estimated coefficients comparable between areas, we have adjusted these with the ceiling value (K). The dimension of b', the adjustment coefficient, indicates by how much the value of logistic transformation will change per time unit (Griliches, 1957). Table II presents the estimated and adjusted logistic rate of growth. The highest rate of acceptance was observed in Kapurthala district (.5297) followed by Sangrur (.4774). Except in Amritsar, the rate of acceptance in all the districts of Punjab was more than 0.10. In Haryana, Karnal and Kurukshetra districts witnessed more than 0.10 logistic rate of growth. A majority of districts in Uttar Pradesh showed slow rate of acceptance of reclamation technology. Only four districts, *viz.*, Gazipur, Meerut, Azamgarh and Etawah showed a logistic rate of growth more than 0.10.

The rate of acceptance is determined by a large number of factors. The interest was to explain the factors responsible for reclamation progress. For the purpose, cross-district equations were estimated. Area reclaimed (per cent) was taken as dependent variable, which was regressed with a number of independent variables, *viz.*, yields of rice and wheat, variability in yields of rice and wheat, cropping intensity, fertiliser consumption, irrigated area and size of holding. Linear and double-log types of regression equations were estimated with the data. Double-log form of equation was found to be the best fit and it was, therefore, selected for explaining our results.

The estimated regression equation with coefficient of multiple determination is given in Table V. A large number of equations were estimated by taking several combinations of different explanatory variables. The best-fit function with 65 per cent coefficient of multiple determination was selected.

TABLE V. FACTORS DETERMINING PROGRESS OF ALKALI SOIL RECLAMATION

Items	Coefficient	Standard error
(1)	(2)	(3)
Constant	-3.7517	-
Rice yield	1.4348**	.5574
Wheat yield	-1.7182*	.9691
Cropping intensity	0.3294	2.0508
Fertiliser consumption	0.6880*	.3801
Irrigated area	1.0475	.6756
R^2	0.6501	-

Note:- ** Significant at 5 per cent probability level.
* Significant at 10 per cent probability level.
@ Significant at 20 per cent probability level.

Rice yield turned out to be the most influential and significant variable explaining the area reclaimed. This suggested that districts with higher yield of rice undertook reclamation at a faster rate. It gives a message that areas with lower productivity have yet to achieve the potential on normal soils, therefore lagging in reclamation of alkali soils. Only those areas are expected to reclaim alkali soils for crop production at faster rate, which witnessed either stagnation or lope movement in yield. Rice being an important crop on alkali soils, the progress of reclamation to a large extent depended on how this crop fared on normal soils.

The effect of wheat yield on reclamation progress was observed to be negative. However, wheat is being grown in crop sequence on reclaimed alkali soils, it does not fare so well as rice. The average productivity of wheat on reclaimed alkali soils ranged from 13 to 20 quintals per hectare, depending upon severity of salt concentration and management of soil.

Fertiliser consumption is found to be significant with a positive sign. It conveys that areas with lower fertiliser use are, by and large, lagging in the adoption of reclamation technology. The significance of this fact was that these areas were yet to use a reasonable quantity of fertiliser on normal soils. The fertiliser consumption was as low as 52 kg. per hectare in Hardoi district during 1986-87. It was 60 kg. per hectare in Fatehpur and Etah districts. On the other hand, fertiliser consumption per hectare was as high as 180 kg. in Kapurthala district, 145 kg. in Patiala and 122 kg. in Sangrur. It was 125 and 120 kg. per hectare in Karnal and Kurukshetra districts respectively. The marginal returns to fertiliser on normal soils are expected to be less in the Punjab as well as in Haryana as compared to Uttar Pradesh; therefore, investment priorities are changing in these states.

Tubewell irrigation has positive influence on reclamation progress. It has nearly one-to-one relationship, which suggested that one per cent increase in tubewell irrigated area would increase reclaimed area by about 1.05 per cent. In this context, the finding of Chopra (1989) is relevant, which showed that the number of tubewells per thousand hectares decreased land degradation in the Punjab. The tubewell irrigated area was the highest (94 per cent) in Kapurthala district, followed by Patiala (78 per cent) and Sangrur (67 per cent). Fatehpur and Kanpur districts had less than 20 per cent of the area irrigated by tubewells. Since assured irrigation is a pre-requisite for reclamation of alkali soils, therefore, the role of tubewells becomes crucial.

CONCLUSION

The analysis tried to provide some insights into the progress of innovation and process of adopting the reclamation of alkali soils in the Indo-Gangetic plains. It is clear that while a large part of the Punjab-Haryana belt was far ahead in reclaiming and utilising alkali soils, a majority of the districts in Uttar Pradesh were lagging in the process of adoption. If profitability is a sufficient condition for reclamation of alkali soils, the necessary conditions are *(i)* demand for external land augmentation for crop production, *(ii)* appropriate infra-structure and *(iii)* well structured organisational network.

The demand for external land augmentation for crop production can very well be linked with the innovation of the new agricultural technology during the mid-sixties. The Punjab-Haryana region was first to translate the new agricultural technology on the fields and results have started stagnating since the mid-seventies. On the other hand, a large number of districts in Uttar Pradesh were lagging far behind in the adoption of the new agricultural technology (Ballabh and Sharma, 1987) and the progress gathered momentum during the late seventies or the early eighties. Theoretically, a rational farmer first utilises the full potential of the best available soil and finally the inferior soils. Eventually, stagnation in productivity or income on normal soils forced the farming community to reclaim and manage desuetude areas in the Punjab and Haryana. Another factor inducing the reclamation of alkali soils was an appropriate tubewell irrigation network in the Punjab-Haryana belt. In addition, the support provided by the land reclamation corporations in the Punjab and Haryana acted as a catalyst in accelerating the reclamation of alkali soils in the respective states.

Policy Implication

(i) Yield of rice on normal soils greatly influences the reclamation of alkali soils. In Uttar

Pradesh, there is considerable scope to increase yields of rice on normal soils. It would be desirable to make efforts to first exploit the potential of normal soils and the alkali soils can probably be allocated for some alternative uses. However, farmers owning large proportion of alkali soils in Uttar Pradesh should not be ignored for taking up the reclamation programme.

(ii) To encourage reclamation programme, tubewell irrigation is a basic pre-requisite. To accelerate the pace of reclamation programme in lagging districts, particularly in Uttar Pradesh, a sizeable breakthrough in tubewell irrigation is warranted.

(iii) Operationalisation of the technology and its demonstration should be encouraged in such a way that the multiplier effect is visualised in the neighbouring areas. It would certainly reduce the cost of additional demonstrations for technical know-how.

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