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RECIPROCITY MODEL, AGRICULTURAL DEVELOPMENT AND REGIONAL PLANNING – A CASE STUDY OF UTTAR PRADESH – INDIA

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ABSTRACT : The present paper attempts to find out the basic regularities, initial relations and their spatial patterns in the complex nature of agricultural activities by applying the reciprocity production function. The prediction of the formulation yields the successful results that should be generally recognized as the major goals of potentiality regarding the optimal magnitude of production factors. It can be a good tool for formulating the regional policies in agriculture. The basic laws of marginal productivity and potential production in agriculture are mathematically identified with the application of partial derivative technique of potential theory.

Introduction

In a particular area, the agricultural production is the result of interrelation and differences of many production factors, that are broadly distinguished into three categories, namely, land, labour and capital by economists and into two types, i. e. immobile (natural aspects of land) and mobile (the human factors as labour and capital investments) by geographers. Both types of production factors lead to the geographic differences resulting into complexity in the nature and varieties of agricultural production. For example, it is widely accepted that the weaker evolving patterns of agricultural production are established not only in Indian areas but in many other developing countries of tropical lands. Therefore, such areas are always put under the list of low productivity owing, no doubt, to the imbalances in mobile production factors and the lack of scientific knowlegde for proper agricultural planning devices (Chang 1977).

The present analytical study is associated with the area of Uttar Pradesh, a fertile and advanced central part of great plains of Northern India where entire economy is dominated by the agricultural activities that include 22.36 million hectares (75.9%) land under cultivation with the extensive irrigation facilities and the predominant use of human labour. Uttar Pradesh carries 43.1% Net Irrigated Area to Net Sown Area and 75.3% agricultural workers to total workers i. e. considerably higher than the national averages during 1970-71. Due to adequate rainfall (average 1000 mm per annum) and fertile alluvial soils of the depositional plains, Uttar Pradesh has always been considered to be an intensive and balanced agricultural region especially in regard to the evolving cropping patterns, their association and combinations (Singh 1978). Despite all these favourable conditions its average rate of increase in foodgrains has been markedly low (65.3%) as compared to national increase (112.1%) during the last 20 years 1950-51 to 1970-71 (Bulletin of Agricultural statistics, U. P. 1972).

Considering all these aspects of the agricultural production of Uttar Pradesh, the attention is, therefore, focussed on the three-fold purpose of this paper as : (1) to

determine the regular patterns of agricultural production; (2) to find and testify the development process and potentiality in agriculture and (3) to analyse the spatial patterns of development stages in order to formulate balanced regional development plans for Uttar Pradesh.

Concept of Agricultural Development

The agrieultural development and its process are associated with the potential theory of production which is based on the rate of change in the agricultural production (Z) in relation to input factors like X, Y, ... The potential theory of agricultural production contains a regular input-output tendency with its three main components, viz., (1) average productivity which is agricultural production per unit of input (Z/X); (2) marginal productivity (dZ/dX) -the absolute rate of change in the agricultural production (dZ) with respect to the absolute rate of change in the input factor (dX); and (3) the potentiality which is recognised as relative rate of change and defined as proportionate change in the quantity of agricultural production (dZ/Z) with respect to proportionate change in the input factor (dX/X). It may be expressed as –

$$\frac{dZ}{Z} / \frac{dX}{X} \text{ Or } \frac{dZ}{dX} / \frac{Z}{X} \quad -----(1)$$

Now, it is obvious from equation I that potentiality coefficients are the ratios between marginal and average productivity coefficients. The term potentiality is highly related with the flexibility or elasticity in agricultural production. In the given production components, potentiality of input factors determines the stages for balanced agricultural development to formulate spatial investment strategy and policies.

Hypothesis and Reciprocity Model

It is hypothesized in the present study that increase in total agricultural production and decrease in its rate of change always occur with the increasing application of production factors (inputs) in the developing countries like India. Therefore the hypothetical curve of agricultural production assumes convex in nature which is positive and declining rate of change.

The present hypothesis of agricultural production (Z) is testified by considering the two input – factors, natural (X) as well as human (Y) of Uttar Pradesh by applying the reciprocity model, mathematically expressed as

$$Z = A(1 + BX^{-1} + CY^{-1})^{-1} ---- (II)$$

Where A, B & C are the positive parameters of the function that are calculated by least square method of estimation and X, Y are the strictly positive quantities used for two factors of production (Z), natural as well as human respectively).

The model is defined with three specified conditions that satisfy the whole nature of present hypothesis, as (1) the positive increase in average productivity because $Z/X > O$; (2) the marginal productivity is positive, $dZ / dX > O$, with the declining rate of change, $dz^2/dX^2 < O$ and (3) potentiality coefficients are also positive and declining.

Aggregation of Agricultural Production And Input Factors

The study relates to the data of gross output and input factors of three years average (1969-70 to 1971-72) pertaining to 48 districts out of total 54 of Uttar Pradesh. The 6 hill districts are not included on account of non-availability of agricultural data. The agricultural productivity index is prepared by considering three dimensions of agriculture, viz. (1) yields of principal crops and their relative weights; (2) relative importance of crops or crop-equivalents based on their rates, national income and caloric significance; and (3) the relative cropping intensity index, that is, agricultural productivity per unit area of Net Area Sown (NAS). All these dimensions have been composed by applying the multiplication formulation (Table-I; Singh 1977).

On the other hand, all input factors are grouped into two, namely, (A) the index of

Table I

Index Values of Natural Input (X), Human Input (Y) and Agricultural Productivity (Z) in Uttar Pradesh

Sl. No.	Name of the District	Natural Input (X)	Human Input (Y)	Agricultural Productivity
1.	Dehradun	1.2907	2.1671	1.1208
2.	Saharanpur	1.1613	1.3245	1.0591
3.	Muzaffarnagar	1.0712	1.8664	1.1961
4.	Meerut	1.0320	2.0151	1.1790
5.	Bulandshahr	.9925	1.3184	1.2792
6.	Aligarh	.9712	1.1337	1.2487
7.	Mathura	1.0312	1.0246	1.0880
8.	Agra	1.0224	1.1793	.9612
9.	Mainpuri	1.0321	1.00105	1.1049
10.	Etah	1.0321	.9338	1.1381
11.	Bareilly	1.0321	1.1913	1.0576
12.	Bijnor	.9505	.9872	1.0501
13.	Badaun	1.0059	.7987	1.0561
14.	Moradabad	.9201	1.1262	1.1869
15.	Shahjahanpur	.9776	.8512	.9651
16.	Pilibhit	.8498	.9989	.9502
17.	Rampur	.9776	1.2698	1.1650
18.	Farrukhabad	1.0321	1.0677	1.1595
19.	Etawah	1.0863	.8407	1.1214
20.	Kanpur	1.0959	.8968	1.1195
21.	Fatehpur	1.0321	.5506	.7524
22.	Allahabad	.9712	1.1087	.7894
23.	Jhansi	.9612	.5145	.8330
24.	Jalaun	.9612	.5596	.6455
25.	Hamirpur	.9612	.3296	.6862
26.	Banda	.8690	.3972	.6811
27.	Jhansi	.9676	1.3748	1.0456
28.	Mirzapur	.9201	1.3115	.8913
29.	Jaunpur	.9712	.9887	1.1495
30.	Ghazipur	.9201	.6188	.9892
31.	Ballia	.9776	.8336	,9855
32.	Gorakhpur	1.0224	.2836	.8434
33.	Deoria	.9680	1.1688	.9960
34.	Basti	1.0321	.9274	.9701
35.	Azamgarh	1.0221	.9895	1.1147
36.	Lucknow	1.0221	1.4191	1.0452
37.	Unnao	1.0321	.5788	1.0357
38.	Rae-Bareilly	.9776	.7398	.8763
39.	Sitapur	.9201	.7286	1.0157
40.	Hardoi	.9720	.5939	1.1525
41.	Kheri	1.2220	.7405	.9953
42.	Faizabad	.9201	1.2317	.9648
43.	Gonda	1.0321	.8030	1.0597
44.	Bahraich	1.0220	.4812	.7958
45.	Sultanpur	1.0321	.6652	.9820
46.	Pratapgarh	.9710	.7799	.8462
47.	Barabanki	1.0863	.9031	1.0151
48.	Nainital (Plain)	1.2900	2.3757	1.1766

natural inputs– it includes factors of physical nature, particularly character of soil fertility, topography, texture and structure, degree of climate suitability, salinity, stoniness and tendency of erode. For the purpose of preparation of this index, the district-wise raw data of the ratings of soils, which is analysed by Shomeand Raychaudhari (1960), is utilized. (B) The index of human inputs accounts for the eight variables, namely, (1) % of Gross Irrigated Area, (2) Chemical fertilizer (NPK Kg/ha. of NAS), (3) Mechanical aids as number of tractors per areal unit of NAS, (4) Electricity consumption in agricultural activities (Kw / hours per ha. of NAS) (5) % area under High Yield Varieties (6) Animal power as number of working cattles engaged in agricultural activities per areal unit of NAS, (7) Manual power as total agricultural workers per areal unit of NAS, and (8) Transportation index–roads in Km. per areal unit of NAS.

For finding out the composite index of such factors, the state average of each factor is taken as 1.00 and the relative performance of each district is obtained in relation of state average. The composite index of all relative performance of each district is prepared by applying the ' Geometric Mean Technique.'

Following the above procedure, both the indices of input factor (natural as well as human) have been prepared for recognition of various patterns of agricultural development in Uttar Pradesh (Table I). Figure–1 correlates the interesting results of the spatial patterns of agricultural productivity as well as natural and human inputs indices. The relationship between agricultural productivity and input factors is positive and therefore, the high agricultural productivity is generally marked in such areas where the application of inputs is high and vice-versa. Very high (above 1·100) agricultural productivity is observed in the Upper and middle Ganga-Jamuna doab including middle Rohilkhand and Nainital district of **tarai** where fertile alluvial soils and very high application of human inputs, particularly irrigation, mechanical aids and electric consumption are dominantly used in agriculture, Jaunpur and Azamgarh districts of lower Ghaghra–Gomati doab are also incorporated in the same category of very high agricultural productivity where natural factors are more dominant in the agricultural activities (Figure-1A). On the other hand, the low and very low agricultural productivity is noticed in the dry and rugged topography of Bundelkhand and Baghelkhand including two belts namely, (1) mid-eastern parts of Uttar Pradesh (middle Ganga-Gomati **doab**) where the application of human inputs is very low and the fertility of soils is also low; and (2) the northern **tarai** belt - from Pilibhit to Deoria districts - where the humid soils are sufficiently fertile but the facilities of transportation and electrification in the rural areas are marked low (Figure-1 B & C).

Applicability of reciprocity model and agricultural development process

The basic types of input - output relations, the general slope of production factor curves and their convexities, as portrayed in figure 2 A, are calculated by equation II for predicting the production values for Uttar Pradesh $Zc = 1.347964\ (1 + .077542\ X^{-1} + .219138\ Y^{-1})^{-1}$, the predicted values are significant at the level of 1·0%). The more convexity is marked in the production curve of natural inputs owing to a higher degree of uniformity in the spatial patterns of natural factors in Uttar Pradesh and vice-versa.

The crossing points of marginal productivity and potentiality curves provide the significant solutions and homogeneous spatial patterns of potential production and determine the development stages in the agriculture of Uttar Pradesh. The whole process of agricultural development is distinguished into four stages. The first stage is noted for high potentiality and still higher (double the potentiality) marginal productiAity with a maximum gap between both the

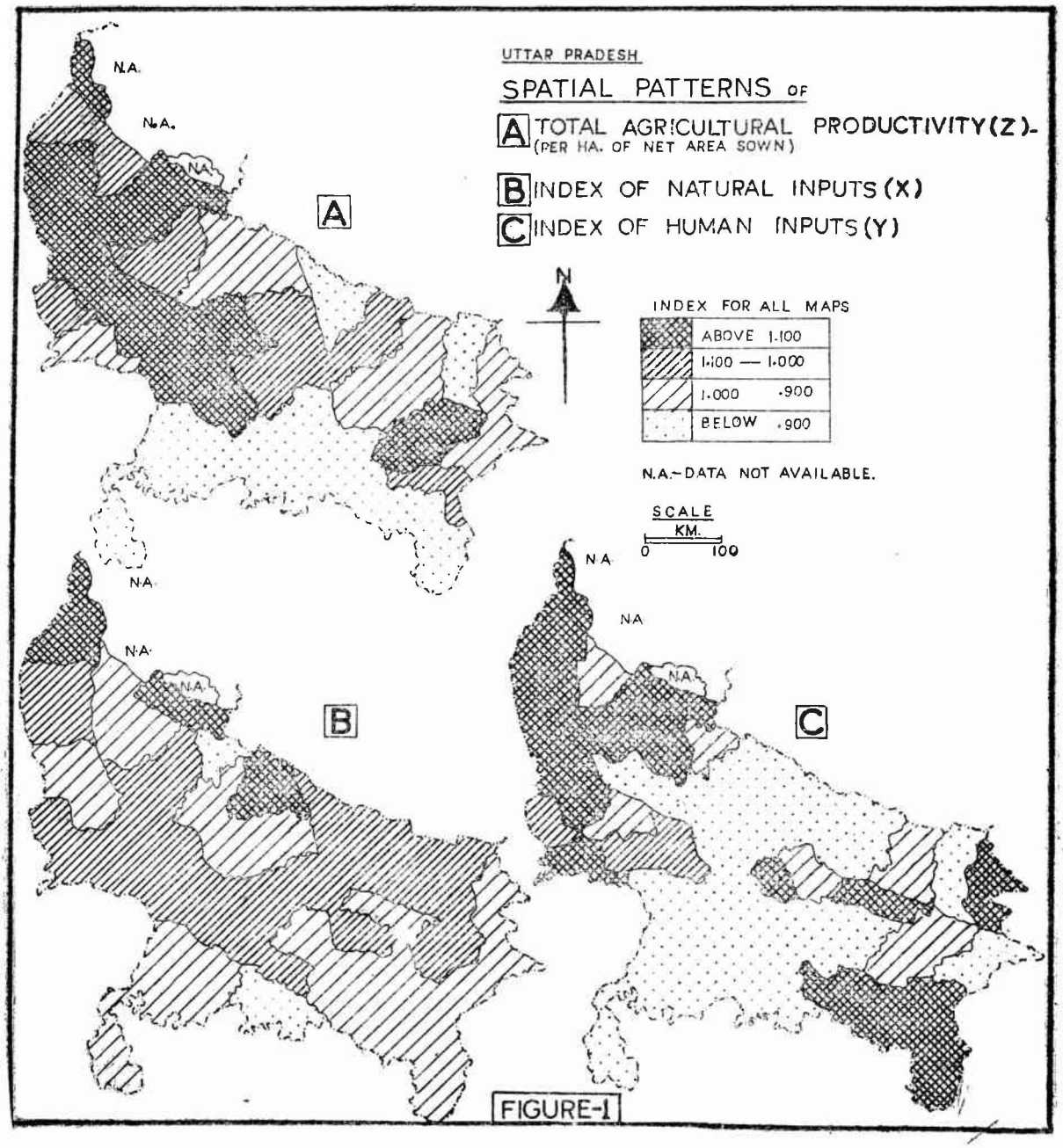
UTTAR PRADESH
SPATIAL PATTERNS OF
A TOTAL AGRICULTURAL PRODUCTIVITY (Z)-
(PER HA. OF NET AREA SOWN)
B INDEX OF NATURAL INPUTS (X)
C INDEX OF HUMAN INPUTS (Y)
N
INDEX FOR ALL MAPS
ABOVE 1.100
1.100 — 1.000
1.000 .900
BELOW .900
N.A.-DATA NOT AVAILABLE.
SCALE
KM.
0 100
N.A.
A
B
C

FIGURE-1

curves where more application of inputs are suggested. At the second stage of agricultural development, where the rates of change in marginal productivity and potentiality are medium with the result of medium gap, the marginal productivity is higher than potentiality. Such areas are more potential and may be developed in future. The third stage which starts from the optimal point (equilibrium of both the curves) where marginal productivity is lower than potentiality with increasing gap between the curves, is considered as developed conditions in agriculture while the fourth stage incorporates the more developed conditions where the potentiality is low with very low marginal productivity (less than half to potentiality) and the increased gap between both components is maximum (Figure-2 B).

Table II

Significant Solutions in the various Development Stages of Uttar Pradesh

Changes in Production	Natural		Human	
	$\frac{dZ}{dX}$	$\frac{dZ}{dX} / \frac{Z}{X}$	$\frac{dZ}{dY}$	$\frac{dZ}{dY} / \frac{Z}{Y}$
First Stage :				
1. Very High Rate of change	.2301008	.1150504	.5230000	.2615000
Second Stage :				
2. Optimum rate of change	.0575252	.0575252	.1625696	.1625696
Third Stage :				
3. Very Low rate of change	.0143813	.0287626	.0406424	.0812848
Fourth Stage :				

N. B. – Above agricultural development stages are delimited on the following equilibrium conditions :

1. Very high rate of change – $X \& Y = Z/2 = (A-2B-2C)/2$, Potentiality = 1/2 Marginal productivity.
2. Optimum rate of change – $X = Y = (A-B-C)$ Potentiality = Marginal Productivity.
3. Very low rate of change – $X \& Y = 2Z = (2A-B-C)$ Potentiality = 2 Marginal Productivity.

Spatial patterns of agricultural potentiality and initial findings

The important results drawn from the reciprocity model are given in Table-II which reveals the systematic logic of Spatial Investments Strategy and find the significant solutions for the various development stages of Uttar Pradesh. The inputs' levels (1.0513) of optimum rate of changes, where the intensive use of agricultural resources is suggested to establish an equilibrium between potentiality and marginal productivity.

The interesting results of the development stage and their regional variations are depicted by the map of agricultural potentiality(Figure-3). The agricultural production of Uttar Pradesh with respect to natural inputs is passing through the second and

third stage of development process (Figure-3 A). It is due to the less heterogeneity in the physical resources. The equilibrium point (optimum level) is, 0·0575 which divides Uttar Pradesh into two equal parts. The areas of high potentiality with respect to natural inputs (second stage of development) cover 27 districts (50·26% area) that generally lie in the two parts of Uttar Pradesh, namely, (1) entire western part excluding two or three districts of Upper Ganga–Jamuna **doab** and northwestern **tarai**, where the values of natural input index are high due to high fertility of alluvial soils. The soils of this part have great potential and therefore, they may be utilized as base for future development in agriculture: and (2) the low fertility belt of lower Ganga-Ghaghra tract including Deoria district of north-eastern **tarai** of Uttar Pradesh, where river floods extensively dominate the agricultral activities. In spite of all these facts, the agricultural potentiality in the natural phenomena is high and may be increased and utilised by controlling the river floods. On the other hand, the high soil fertility longitudinal belt of northern **tarai** has low potentiality in natural inputs due to the water-logging and water-oozing problems and therefore, such areas are included in the third stages of development. Further, the larger parts of Bundelkhand and Baghelkhand the dry zone of Lucknow plains (central part of Uttar Pradesh of low soil fertility) are also included in the same category of low potentiality-development stage. Rugged topography and dry climatic conditions constitute the poor base of natural phenomena and agricultural activities (Figure-3A).

The distribution of agricultural potentiality in relation to human inputs falls within first three stages of agricultural development (Figure-3B). The areas of very high potentiality, i. e. only 19·26% of Uttar Pradesh are generally dispersed in the north-eastern and south-western parts of Uttar Pradesh (Gorakhpur and Bahraich districts of **tarai**, Hardoi and Unnac districts of central dry plains, and the entire Bundelkhand region having rugged topography) (Table-III).These areas are included into the first stage of agricultural development where the application of human inputs in the development of agriculture is very low and therefore, such areas need high application of human factors in the immediate future. In the central dry plains and **tarai** areas, the high applicability of rural electrification, road construction and use of chemical fertilizers must be suggested for the proper snd balanced agricultural development, while Bundelkhand region needs new development of irrigation system through state tubewells and means of transportation. Further, the areas of high potentiality level (.1625-.2615, the second stage of development) cover more than half part of Uttar Pradesh (50·61%) which lies in the major **doab** of Uttar Pradesh (those of middle and lower Ganga-Jamuna, Ganga-Ramganga and Ganga-Ghagra). In such areas of high potentiality, the development process has become slower than the first stage of development. For improving the agricultural conditions and the proper utilization of agricultural potentiality, the longrun development planning should be made for human inputs. Increase in irrigated area and rural electrification should be given priority for future development in the agricultural conditions. On the other hand, the areas of low potentiality that have reached and entered in the third stage of development are nearly 1/3rd of total area and are generally dispersed in three main belts, viz., Upper Ganga-Jamuna **doab**, Upper Ramganga basin (Rohilkhand **tarai**) and Baghelkhand (south-eastern Uttar Pradesh) including two central districts of Lucknow and Faizabad where the saturation condition of human inputs is being observed in the agricultural activities. Being high potentiality in the natural phenomena of Western Uttar Pradesh, in the upper Ganga-Jamuna doab, and uppar Ramganga basin where wheat and sugar cane are the dominant crops, the diversification in the cropping patterns and the cottage industries

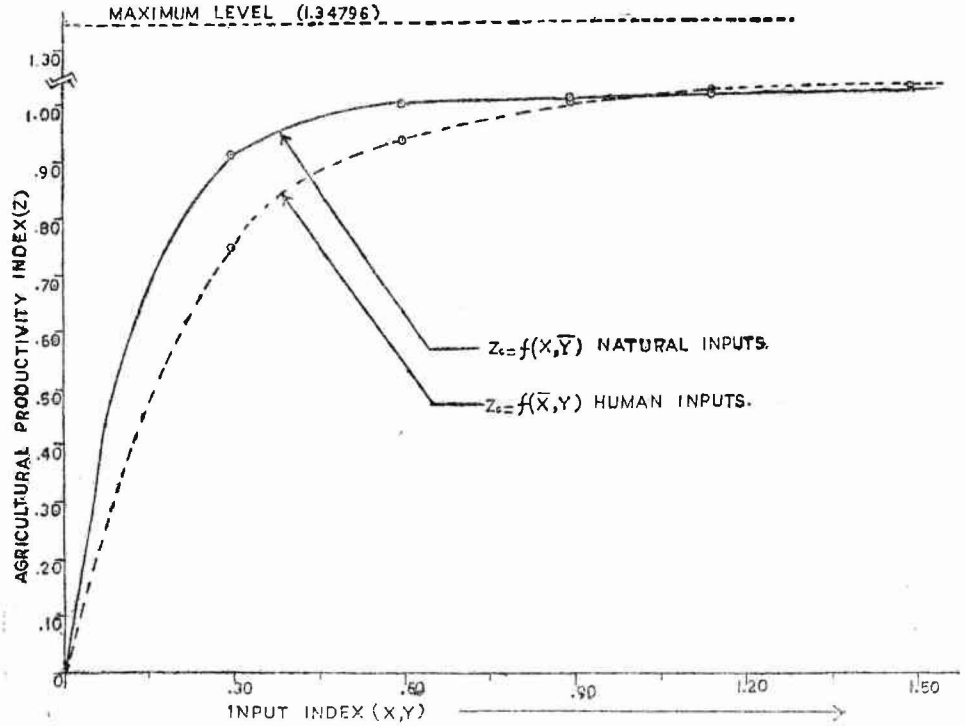

FIGURE-2A: THE BASIC TYPES OF INPUT--OUTPUT RELATIONS.

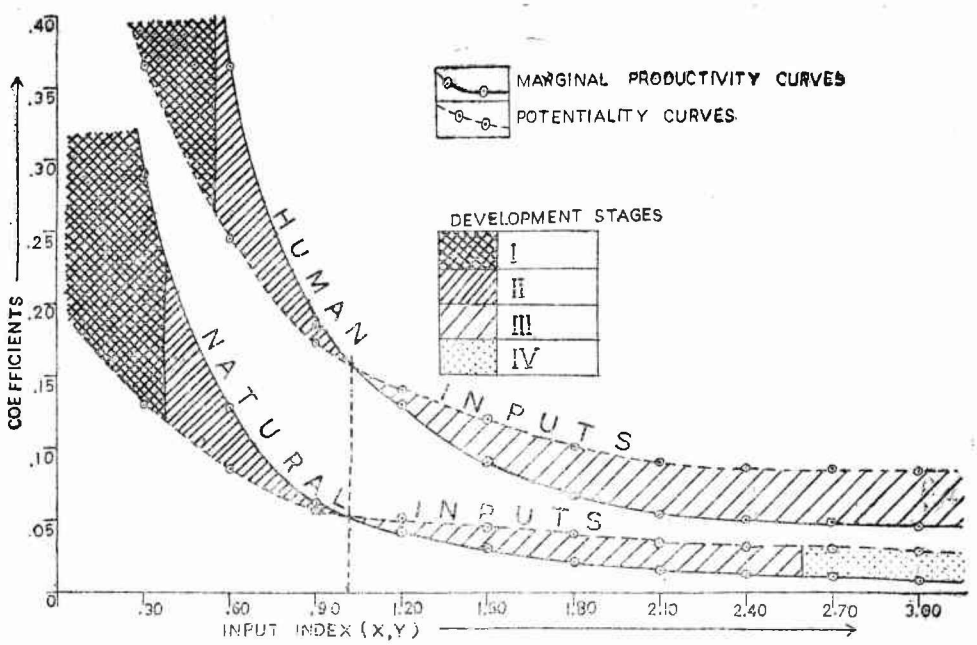

FIGURE-2B: NATURE OF VARIOUS PRODUCTIVITY CURVES.

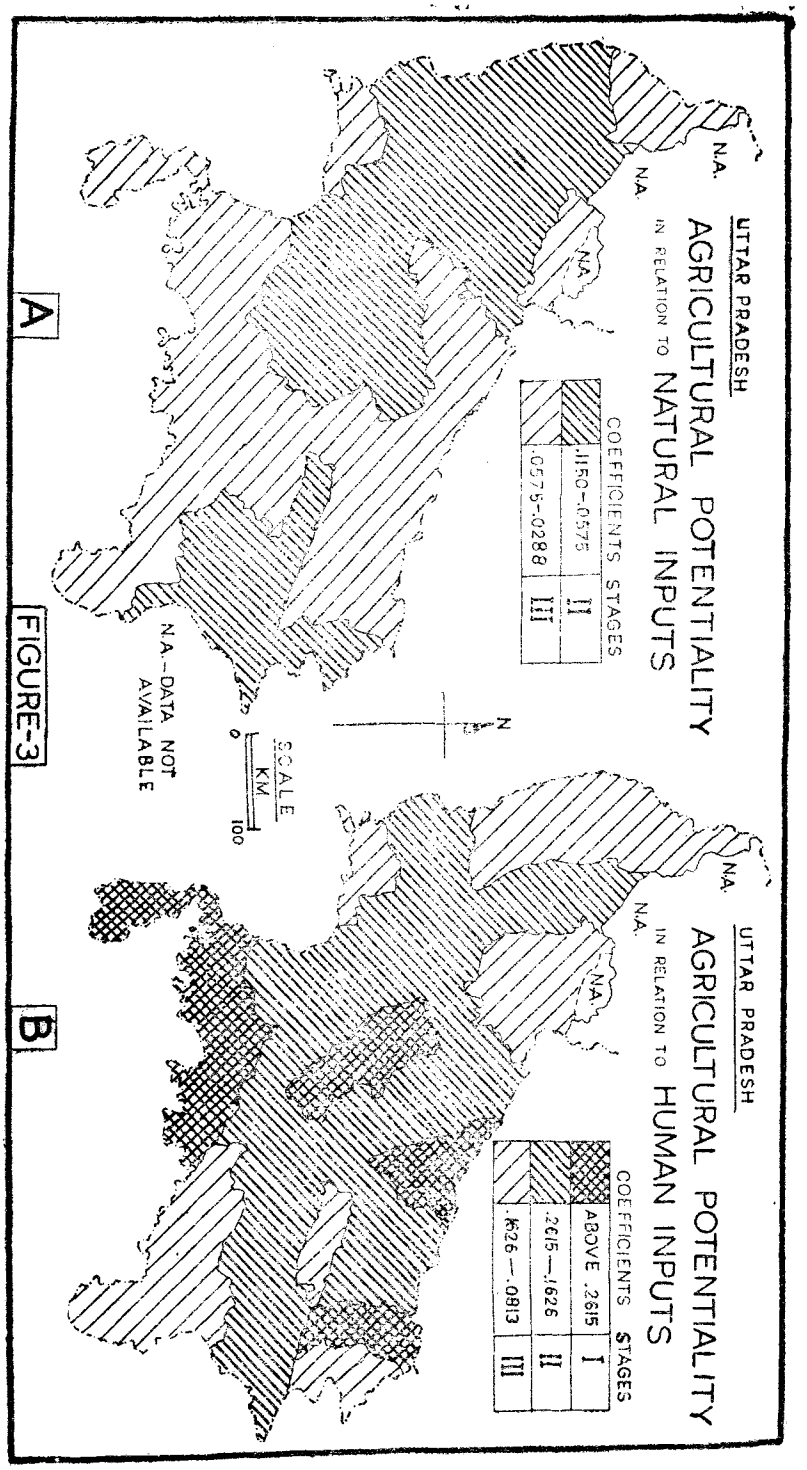
A
UTTAR PRADESH
AGRICULTURAL POTENTIALITY
IN RELATION TO NATURAL INPUTS
COEFFICIENTS STAGES
.1150-.0575 II
.0575-.0288 III
N.A.
N.A.
N.A.
N.A.
N.A.-DATA NOT AVAILABLE
SCALE
KM
0
100
N
B
UTTAR PRADESH
AGRICULTURAL POTENTIALITY
IN RELATION TO HUMAN INPUTS
COEFFICIENTS STAGES
ABOVE .2615 I
.2615—.1626 II
.1626—.0813 III
N.A.
N.A.
N.A.

FIGURE-3

Table - III

Marginal productivity and Potentiality Coefficients in the various districts of Uttar Pradesh (1969-70 to 1971-72)

S l. No.	Name of the District	Natural Inputs $\frac{dZ}{dX}$	Natural Inputs $\frac{dZ}{dX} / \frac{Z}{X}$	Human Inputs $\frac{dZ}{dY}$	Human Inputs $\frac{dZ}{dY} / \frac{Z}{Y}$
1	2	3	4	5	6
1.	Dehradun	.04336	.04994	.04349	.08408
2.	Saharanpur	.04784	.05246	.10395	.12999
3.	Muzffarnagar	.07109	.06395	.06676	.10418
4.	Meerut	.07507	.06572	.05565	.09512
5.	Bulandshahr	.09553	.07413	.15303	.15773
6.	Aligarh	.09500	.07396	.19721	.17905
7.	Mathura	.06404	.06069	.18331	.17263
8.	Agra	.05084	.05408	.10800	.13250
9.	Mainpuri	.06843	.06274	.19806	.17944
10.	Etah	.06998	.06345	.24144	.19812
11.	Barailly	.06041	.05895	.12814	.14433
12.	Bijnor	.07021	.06355	.18396	.17294
13.	Badaun	.06405	.06070	.28426	.21497
14.	Moradabad	.09571	.07420	.18054	.17132
15.	Shahjahanpur	.05547	.05649	.20900	.18433
16.	Pilibhit	.07188	.06431	.14712	.15465
17.	Rampur	.08168	.06855	.13684	.14915
18.	Farrukhabad	.07268	.06466	.19172	.17654
19.	Etawah	.06130	.05938	.28921	.21683
20.	Kanpur	.06002	.05876	.25333	.20294
21.	Fatehpur	.03058	.04194	.30357	.22215
22.	Allahabad	.03801	.04676	.08243	.11576
23.	Jhansi	.04320	.04985	.42613	.26321
24.	Jalaun	.02594	.03863	.21631	.18753
25.	Hamirpur	.02949	.04119	.70879	.33945
26.	Banda	.03534	.04509	.47794	.27874
27.	Varanasi	.067172	.06216	.09402	.12363
28.	Mirzapur	.05398	.05572	.07508	.11048
29.	Jaunpur	08059	.06809	.21974	.18901
30.	Ghazipur	.06649	.06184	.41543	.25988
31.	Ballia	.05846	.05799	.22721	.19219
32.	Gorakhpur	.03215	.04746	1.43829	.48355
33.	Deoria	.06900	.05919	.11805	.13853
34.	Basti	.05003	.05407	.17788	.17005
35.	Azamgarh	.06842	.06274	.20630	.18313
36.	Lucknow	.06017	.05883	.08820	.11975
37.	Unnao	.05816	.05784	.52049	.29089
38.	Rae-Bareilly	·04622	.05157	.22813	.19258
39.	Sitapur	.07011	.06351	.31599	.22665
40.	Hardoi	.08091	.06822	.61432	.31602
41.	Kheri	.03816	.04685	.39369	.21851
42.	Faizabad	.06325	.06032	.09974	.12734
43.	Gonda	.05088	.05488	.28313	.21454
44.	Bahraich	.03488	.04479	.43379	.26556
45.	Sultanpur	.05209	.05474	.35433	.24001
46.	Pratapgarh	.04369	.05013	.19141	.17640
47.	Barabanki	.05053	.05375	.20539	.18273
48.	Nainital (Plain)	.04786	.05247	.03988	.08052

associated with the raw material of agriculture must be preferred for the balanced development, while Baghelkhand, where total agricultural productivity and the agricultural potentiality with respect to natural inputs are low with the high applicability of human inputs, that also falls in the same category of development. For balancing the agricultural economy of Uttar Pradesh, preference should be given to the commercial crops in the area by which the total agricultural productivity will increase and the cropping patterns will also change.

Conclusion

From a variety of production models, an analytical model (extending the input-output relations on the receiprocity base) may be testified and devised for the speculation of an alternative Spatlial Investment Strategy for agricultural development. The logical planning-oriented taxonomy based on the non-negative partial derivatives in relation to two factor input is adopted to establish the inequality of the optimal forms and formulations of spatial organisation. The reciprocal relations in the agriculture of Uttar Pradesh are mathematically established by estimating the parameters of the function and predicting the production regularities that are examined by partial derivative technique of potential theory.

The three potential levels or development stages and their spatial patterns have been recognised in the agriculture of Uttar Pradesh. The maximum agricultural development is possible in high potentiality areas which cover the middle and lower Ganga–Jamuna **doab**, entire Ramganga basin (Rohilkhand) and lower Ganga--Ghaghra **doab** of eastern Uttar Pradesh and where the higher production can be achieved by application of lesser human inputs in the existing physical set-up.

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