

TOWARDS OPTIMISATION OF INDIAN AGRICULTURAL PRODUCTION PROCESSES

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Introduction

The acceleration of agricultural land use processes is influenced by various physical factors (relief features, pedological and agro-climatic influents) and human efforts (primarily the adoption of modern agricultural technology). The land use processes, namely, expansion and intensification, and their limitations have been described by many agricultural scientists following criterion of land capability classification. It was originally developed in the United States of America in early 1960s on the basis of soil suitability description. Oschwald (1966) interpreted it scientifically considering the productive capacity of soils according to their natural potentials and imposed limitations for different types of land uses. This land evaluation scheme in the USA was further modified on quantitative basis in the United Kingdom (Bibby and Mackney 1969, Wilkinson 1974).

In fact, the soil suitability interpretation was recognised as a fundamental tool for land use planning during 1960s. The work of A. P. A. Vink is noticeable in the land evaluation interpretation in the Netherlands in this connection. He developed soil maps interpretation in terms of soil suitability for agricultural land use (Vink 1955) and, lately, it was pursued by Hewgill (1971).

Although, soil is a fundamental component of describing land use planning, this soil survey approach was criticised and instead an integrated ecological approach was appreciated and preferred to proper acceleration

of land use processes (Stamp 1962, Stewart 1968, Singh and Sharma 1985). In preparing scheme of ecologically based land evaluation, when integrated interpretation of physical phenomena (soil, climate and vegetative cover) is essential, a criterion of human responses (i. e., the modern techniques of land use practices) must be/has been considered and incorporated. Therefore, agro-ecological description of land evaluation was tried by Food and Agricultural Organisation in 1976 and its team prepared agro-ecological frame for determining the optimal conditions of agricultural production with developing a general model for assessing Potential Population Supporting Capacities, PPSC, (FAO/UNFPA/IIASA 1982). Later on, it was slightly modified according to geo-economic conditions of micro/meso regional framework. For example, Grosjean and Messerli (1988) changed the PPSC model according to agro-ecological constraints for the mountain areas of Africa. They measured subsistence production possibilities and land suitability of these areas in terms of potential crop-yields per unit of land. Similarly, Indian Council of Agricultural Research, New Delhi has also tried to evaluate the Indian agricultural systems by starting many scientific projects (e.g., National Demonstration Projects, Operational Research Projects and Lab-to-Land Programmes) for transfer of agricultural technology to the farmers in an integrated manner. The effectiveness of all such projects/programmes is evaluated in achieving a goal of the levels of potential crop-yields which have been assessed on providing human responses in agro-ecological conditions (Prasad, et.al. 1987). Utilising district-wise potential crop-yields data compiled by the team of ICAR, New Delhi under Demonstrations Project (Mathur and Gupta 1985), a systematic study of agricultural production processes in relation to its important interacting component, potential crop-yield, is logically tried here by measuring its optimality on the basis of agro-climatic zones of India.

Therefore, the main aim of this article is to explain and illustrate the intensity and magnitude of usable agricultural potential yield and their regional patterns. Indeed, ecological conditions of land which determine the magnitude and intensity of potential yield in its physical term, and, secondly, the prices of production and its factors that affect directly the

indices of value productivity and output, have been incorporated in the present study. Initially, price factor is assumed to be invariant, although this assumption may be relaxed in further researches on these aspects. Thus, the theoretical base of the componental analysis of agricultural production processes and its related new kind of production function are included in the first section, while the second section of the article deals with the generalisation and empirical testification of production processes in various agro-climatic conditions of India.

Definitions And Components of Production Processes

The structural features of agricultural production processes are initially associated with its two important elements : (a) potential crop-yield (i. e. named here the highest possible yield, A, measured on the basis of agro-ecological criteria) and (b) the level of existing crop-yield, Y (means the efficiency constraints). The differential quantity of these elements may be defined as physical magnitude of usable potential of crop-yield, P. In a logical term, $P = (A - Y)$. The ratio of these two basic elements of the system may be defined as production efficiency, E, termed as $E = (Y/A)$. On account of universal conditions of these elements that A will always be greater than Y in the system, production efficiency must be less than unity. The two fundamental, components of the system, P and E, have been named 'yield gap' and 'realisation factor' respectively by the Indian agricultural scientists (Kumar 1986, Varadarajan 1986). Further, the third component is production elasticity, P_e , which has been defined by the economists as a quantity of marginal product per unit of average productivity. It is the relative concept of production function which would further be analysed in the present context. In absolute term, it is redefined as intensity of usable potential yield per unit of the highest possible yield;

$$P_e = [(A-Y)/A] \quad (1)$$

Essentially these components are fully dependent on the factors and forces (means inputs) applied in agricultural production systems. Thus inputs are independent variables. Further, the variations occurred in the magnitude and intensity of the fundamental component usable potential of crop-yield

are highly associated with two basic processes : potential generation and its absorption. They are operated simultaneously when inputs are intensified. Potential generation has 'multiplier effects' on potential phenomena and intensifies level of A in the system. Mostly natural forces and geo-factors (e.g., extant surface, moisture availability, suitability of temperature for crop growth, rate of evapo-transpiration, suitability of soils) have positive relationships and constructive interactions with the generation process of potential crop-yields (Grosjean and Messerli 1988, Mensching 1988). Bio-technological researches concerned with the plant genetics which protect plant growth (Wenzel 1987) also influence directly the levels of the highest possible yields.

Likewise, the process of potential absorption is accelerated by the researches doing in the field of bio-chemical and agro-engineering. It (absorption process) affects directly and positively the intensity of existing yield absorbing the magnitude of potential crop-yields. The empirical testification of these agricultural production processes would be discussed separately in the coming text. Now, methods and modelling for finding out the system's optimality are described as follows :

Frame of Analysis

Indeed, agricultural intensity is the degree of intensification of production-factors to land. In the present analysis production factors are divided into two components : labour and non-land capital, because they are unlikely usable in their complementary forms in agricultural operation. For analysing the economic aspects of production processes and practicable solution of utilising properly the usable potential yields, a criterion of agricultural rent which has already been adopted in the spatial perspective of agricultural landuse studies (Dunn 1954, Hall 1966, Garrison and Marble 1957, Kutzman 1974, Visser 1982) is applied. In a simple manner, agricultural rent is defined as the residual flow of returns accruing to land, a quantity which is maximised by farmers as they maximise their profits (Visser 1982, p. 168). In non-spatial perspective, the agricultural rent from production process is

$$(R(x_1, x_2) = pY(x_1, x_2) - wX_1 - rX_2 - c, \quad (2)$$

for which names of the variables have been given in Table - 1.

This rent equation is called profit function by the agricultural scientists (Maji 1977, Kennedy 1988). Now the conditions of profit maximisation and system's optimality are determined by setting first-order differentiations of equation (2) as zero. It is

$$dR(x_1, x_2)/dX_1 = p dY(x_1, x_2)/dX_1 - w = 0 \quad (3)$$

when X_2 is held constant, and

$$dR(x_1, x_2)/dX_2 = p dY(x_1, x_2)/dX_2 - r = 0 \quad (4)$$

When X_1 is held constant,

$$\text{where } p dY(x_1, x_2)/dX_1 = w, \text{ and} \quad (5)$$

$$p dy(x_1, x_2)/dx_2 = r \quad (6)$$

In the above equations (5 and 6), it is obvious that for optimal input levels the value marginal product to input intensity equals the prices of inputs.

Without specifying the proper form of production function of two-factor model for the above equations, the complex relationships and general tendencies of production processes and even the variable forms of the component of potential production can not be stated. The 'reciprocity form' of agricultural production function which is based on the law of diminishing marginal returns to input intensity (Singh 1987) and which also satisfies the equation of production elasticity (eqn. 1) has been chosen. The form of production function used here is

$$pY(x_1, x_2) = pA[1.00 + B_1(wX_1)^{-1} + B_2(rX_2)^{-1}]^{-1}, \quad (7)$$

where A , B_1 and B_2 are constants (see Table 1). According to this production function the nature of production curve is asymptotic because when X_1 and /or $X_2 \rightarrow \infty$

$$\text{so that } B_1(wX_1)^{-1} \text{ and /or } B_2(rX_2)^{-1} \rightarrow 0$$

$$\text{then } pY(x_1, x_2) = pA.$$

Variable form of usable potential yield in value term, that is obtained from defined equation as

$$Pp(x_1, x_2) = pA - pY(x_1, x_2) = p[A - Y(x_1, x_2)] \quad (8)$$

may be derived by substituting given production function (eqn. 7) into the above form (eqn. 8). Its simplified form must be

$$Pp(x_1, x_2) = pA(1.00 + wrX_1X_2 (B_1rX_2 + B_2wX_1)^{-1})^{-1} \quad (9)$$

The careful inspection of the above equation of usable potential yield reveals that it decreases with decreasing rate in non-negative manner when inputs are intensified. Taking first-order partial differentiations on production function (eqn.7), setting them equal to w and r (for satisfying equations 5 and 6) and simplifying them for x_1 and x_2 , the optimal quantities of input intensities are derived by simultaneous solution of these quantities. The results are

$$X_1 = (pAB_1 - B_1) [1 + B_1(rX_2)^{-1}]^{-1} \quad (10)$$

$$X_2 = (pAB_2 - B_2) [1 + B_2(wX_1)^{-1}]^{-1}, \quad (11)$$

subject to the other variables held constant in each case.

Insertion of these equations into the initial forms of production function and potential yield (eqns. 7 and 9) must determine the optimal quantities of existing as well as usable potential yields : $pY^*(x_1, x_2)$ and $Pp^*(x_1, x_2)$.

Empirical Specification

The logical conditions of the fundamental components of agricultural production processes presented in the previous section of the article which present the solution of optimal quantities of input intensification and level of usable potential yield have been empirically testified on macro-regional grounds of the conditions prevailing in the agriculture of India. It is a well known fact that agricultural production processes in India have wide scope of enhancing input intensities because of enough quantity of usable yield potential.

The results of the analysis are described with the consideration of macro-regional suitability of land which has been delimited recently by the Planning Commission, New Delhi (Alagh 1987) by distinguishing India into fifteen

agro-climatic zones on agro-ecological approach of land evaluation. District, a micro-regional unit, is chosen for data interpretation and for describing areal patterns. The ratio of output to its factors like land, labour, capital etc. is a simple measurement of agricultural productivity. The computation of this ratio evolves the problem of aggregating a variety of crop-outputs in a single index (Dayal 1984). Reviewing critically the problem of aggregation, Dayal (1984) suggested the economists' approach of crop yield conversion into money value. The same criterion was followed by Thakur (1987) for analysing regional variations of agricultural labour productivity in the Western Uttar Pradesh. Agricultural labour productivity, output per unit area, pY , and aggregated highest possible production, pA , are computed here in terms of money value taking regional farm harvest prices to convert the physical output into money value, formulated as :

$$pY = \frac{\sum_{i=1}^n [I_n (\sum a_i y_i p_i / \sum a_i)]}{\sum_{i=1}^n} \quad \text{and} \quad (12)$$

$$pA = \frac{\sum_{i=1}^n [I_n (\sum a_i y_h p_i / \sum a_i)]}{\sum_{i=1}^n} \quad (13)$$

$i = 1, 2, 3, \dots, n$ crops.

Composite indexes of existing as well as highest possible yield are based on sixteen principal crops. Similarly, the indexes of labour input and technology have also been converted into money values by multiplying labour units per unit of area into their annual wages and by aggregating irrigation, High Yielding Varieties of crops, use of fertilizers and number of tractors per unit of area in terms of money. Indeed, the same scales of output and input indexes will be suitable for homogeneous comparison of all the components of agricultural production processes. The agricultural parameters, indexes and factors are based on the secondary information obtained from the various government offices and their data publications such as, estimates of area, yield, production and farm production prices figures are collected from the various volumes of Agricultural Situation in

India, published by the Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi. The data of total agricultural workers (cultivators and agricultural labourers) have been compiled from the Census of India 1991. Three-year's averages, triennium ending 1991-92, have been worked out and used for proper reliability of result interpretation by eliminating annual data fluctuations due to climatic variation.

Interpretation of Agricultural Structure

It is widely accepted that enhancement of agricultural technology affecting positively the level of agricultural output, productivity and production efficiency (Solow 1957, Binswanger and Ruttan 1978, Newman, et.al. 1980, Haley and Abbott 1986), creates gradually the production structure in the direction of crop specialisation (Jensen 1984, Reenberg 1988) and diversifies quickly the areal patterns of crop-structure. Therefore, the boundaries of Indian crop-regions which were contiguous to the boundaries of physical complexes (i.e., natural regions) during pre-green-revolution period (Bhat and Learmonth 1968), have been distorted by evolving diversified patterns of areal distribution. It is due to enhancement of green revolution technology during 1980s. Though the production processes of Indian agriculture are still labour dominated (annual average labour wage Rs. 500 per ha of cultivated land) which leads lesser regional variations than the areal variation of technological input (rX_2), even then, this technological regional variability creates greater regional diversities in the production structure (Table-2). Direct impact of green-revolution technology in India may be seen in the regional structure of the Punjab plains where extremely high level of land productivity (Rs. 2140 per ha of cultivated land) is obtained by increasing non-land capital (Rs. 313 per ha of cultivated land). The highest intensity of agricultural output (Rs. 2770) has been observed in the lower Ganges plains due to fertile alluvial soils of Bengal plains where paddy is a dominating crop in production structure (Table -2). The most suitable agro-ecological conditions of the Brahmaputra Valley of the N. E. Mountain region creates consequently the greatest intensity of usable potential production (Rs. 10985, i. e., more than four times of national average) and the highest rate of labour-potential absorption ($B_1 = \text{Rs. } 2457$)

with the extremely high level of capital productivity (Rs. 174) and production efficiency (87.5%). On the other hand, the dry lands of Rajasthan (i.e., the Thar Desert) and the humid lands of West Coasts (Region XII) have stagnation in production processes. They have lesser intensity and magnitude of usable potential yield, agricultural productivities, and output (Table-3).

Limits to Land Use Processes

The production curves of various agro-climatic regions (Fig-1), that have been drawn by equation (7) of production function, depict the suitability of agro-ecological conditions in the mountaneous regions of the North and North-East, valleys and the middle and lower parts of Northern plains where levels of agricultural production are higher than the national average. But the rates of asymptotic convergence of these production that are faster in the beginning and slower in later stages of input intensification, specify the impact of the production potential processes. Faster convergence at early stage of input intensification denotes saturation of production processes and vice-versa. It can be concluded from Figure - 1 that the middle and lower parts of the Ganges Valley (specially agro-climatic Regions III and IV) have enough labour as well as non-land capital-potentials for further utilisation because of higher rate of asymptotic convergence.

The operation of given data according to equation (10 and 11) specifies the optimal intensities of input, output, and potential yield in various agro-climatic regions (Table-4). Intensive areas for immediate input intensification that have intensity of potential yield higher than and or equal to the optimal intensity [$Pp(wx_1, rx_2) > Pp(wx_1, rx_2)$], can easily be delimited. Figure-2 shows that the *terai* and *bhawar* areas of the foot-hills of the Himalayas, middle Brahmaputra Valley and the deltas of the Mahanadi and the Krishna rivers and the entire Thar parts of Rajasthan have immediate requirements of input intensification.

Conclusion

Several management-oriented tools have been/can be used to find out the suitability of land conditions for its proper utilisation. One tool determines

the limits to land use in terms of agro-ecological base. However, this paper demonstrates a logical thinking of the optimal limits of agricultural processes in Indian conditions as optimality of the components of production function approach by which the magnitude and intensity of potential yield is calculated. It is concluded that, in Indian agricultural processes, usable potential of yield is an important component which is the result of the processes of potential generation and its utilisation that are accelerated by input intensification specially by agricultural technology. The diversified patterns of regional structure of agricultural production are being observed after green-revolution period. These patterns are breaking the ecological norms and physical determinants of agricultural enhancement. Consequently, the Indian production structure is neither ecologically normative nor regionally balanced due to fundamental fallacy of areal orientation of optimal concept of agricultural production processes. The areas of higher potential yields (i.e., above the regional level of its potential) are situated mostly in the intensive cultivation tracts of *terai* and deltas of main rivers of India. The regional difference between average and optimal levels of input intensification may explain its requirements. Its logical parts may separately be explained and examined for more detailed analysis of agricultural production processes.

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Table 1 : Name of Parameters and Agricultural Variables.

Parameter	Description
R	= Agricultural rent per unit of cultivated land,
Y	= physical units of agricultural output per unit of cultivated land (i.e., yield),
X_1	= labour employed in agriculture per unit of cultivated land,
X_2	= units of non-land capital per unit of land (i.e., agricultural technology),
p	= market price per unit of quantity of agricultural output at farm harvest time,
w	= annual wages per unit labour,
r	= annual interest rate per unit of non-land capital,
c	= annual fixed costs of agricultural operations per unit of land,
A	= physical units of the highest possible agricultural output per unit of cultivated land,
B_1	= Maximum response of reproduction of yield attainable from the application of labour input (i.e. rate of yield potential to labour input),
B_2	= Maximum response of reproduction of yield attainable from the application of non-land capital (i. e. Absorption rate of yield potential to capital input)
a	= area occupied by ith crop in the areal unit (i.e., district),
y	= physical quantity of existing yield of ith crop in the areal unit,
y _h	= physical quantity of the highest possible yield of ith crop in the areal unit, and
In	= agricultural intensity, i.e, ratio between gross and net cultivated areas in the areal unit.

N.B. : Stars indicate optimal value.

Table 2 : Intensities of Agricultural Production and Input factors in India in early 1990s

Agro-Climatic Regions		Proroduction				Inputs			
		A	pA	Y	pY	X ₁	wX ₁	X ₂	rX ₂
I	Northern Mountain	36.58	3157	15.64	1350	1.67	85.98	23.94	25.50
II	N. E. Mts. and Valleys	145.46	12553	18.17	1568	1.59	351.00	8.54	9.11
III	Lower Ganges Plains	59.37	5032	32.68	2770	1.73	855.40	102.53	109.21
IV	Middle Ganges Plains	50.34	3590	14.39	1026	2.08	975.00	118.78	126.50
V	Upper Ganges Plains	58.93	3957	21.35	1434	1.40	226.00	147.60	157.21
VI	The Punjab Plains	55.17	4053	29.13	2140	0.65	538.70	293.80	312.91
VII	N. E. Plateaux	38.96	2868	10.27	756	1.26	411.98	23.00	24.52
VIII	Central Plateaux	35.49	2798	8.70	686	0.72	250.00	39.40	41.90
IX	Western Plateaux	30.15	2483	7.41	610	0.77	435.98	56.90	60.60
X	Southern Plateaux	57.98	4222	10.30	750	1.61	609.00	114.83	122.31
XI	East Coast	45.69	3485	19.58	1494	2.18	1030.05	124.04	132.09
XII	West Coast	17.61	1450	7.48	616	1.44	1160.98	85.15	90.68
XIII	The Gujarat	33.00	2420	15.44	1132	0.71	329.00	80.47	85.70
XIV	The Thar	13.80	1159	3.15	265	0.28	26.00	13.80	14.69
XV	The Islands	-	-	-	-	-	-	-	-
National Average		46.01	3589	14.20	1108	1.30	500.00	88.06	43.78

N. B. :

1. Values are regional averages.
2. Values of A and Y are in quintals per ha. of cultivated land and pA and pY are in Rs. per ha. of cultivated land. X₁ is agricultural workers and X₂ is principal amount (in Rs.) for agricultural technology per ha. of cultivated land.
3. w is calculated by multiplying daily wages (in Rs.) per male agricultural worker to annual number of working days and $r = (1 + t)$ where t is annual rate of interest (t = 6.5%).

Table 3 : Productivities (Labour as well as Capital), Usable Potential Yield (in Rs.) and its Absorption Parameters (B_1 and B_2).

Agro-Climatic Regions	Productivities		Pp (in Rs.)	Ag. Efficiency $E = (Y/A)$	Parameters	
	pY/wX_1	pY/rX_2			B_1	B_2
I Northern Mountains	15.70	51.92	1807	.5724	115.10	34.80
II N. E. Mts. and Valleys	4.47	174.22	10985	.8751	2457.49	63.05
III Lower Ganges Plains	3.24	25.41	2262	.4495	698.15	89.02
IV Middle Ganges Plains	1.05	8.08	2564	.7142	2441.90	317.33
V Upper Ganges Plains	6.34	9.13	2523	.6376	397.95	276.34
VI The Punjab Plains	3.98	6.84	1913	.4720	480.65	279.68
VII N. E. Plateaux	1.83	30.24	2109	.7361	1152.46	69.74
VIII Central Plateaux	2.74	16.33	2112	.7548	770.80	129.33
IX Western Plateaux	1.40	10.00	1873	.7543	1337.86	187.30
X Southern Plateaux	1.23	6.15	3472	.8223	2827.76	564.55
XI East Coast	1.45	11.32	1991	.5713	1373.10	175.88
XII West Coast	.53	6.77	834	.5752	1573.58	123.19
XIII The Gujarat	3.44	13.16	1288	.5322	1573.58	123.19
XIV The Thar	10.19	17.67	894	.7713	87.73	50.59
XV The Islands	-	-	-	-	-	-
National Average	2.22	11.31	2481	.6913	1117.56	219.36

N. B. :

1. Pp is calculated according to equation (8). It is difference of A and Y in money terms.
2. B_1 and B_2 indicate the rates of potential absorption w.r.t. labour and non-land capital inputs respectively.

Table 4 : Optimal Values of Input Intensities, Agricultural Production and Usable Potential Yield.

(Values in Rs.)

Agro-Climatic Regions		Inputs				Out-Put	Potential
		X_1	wX_1	X_2	rX_2	pY^* (wX_1, rX_2)	Pp^* (wX_1, rX_2)
I	Northern Mountains	4.05	208.42	119.03	126.77	1728.20	1428.80
II	N. E. Mts. and Valleys	1.75	387.09	97.01	103.32	1577.22	10975.78
III	Lower Ganges Plains	1.31	647.67	300.03	319.53	2135.34	2896.65
IV	Middle Ganges Plains	.32	148.25	201.21	214.29	189.41	3400.58
V	Upper Ganges Plains	1.92	310.49	261.73	278.74	1208.94	2748.06
VI	The Punjab Plains	.58	484.17	389.84	415.18	1520.51	2523.48
VII	N. E. Plateaux	.53	175.15	93.28	99.34	346.30	2521.70
VIII	Central Plateaux	.49	171.02	108.68	115.74	422.37	2375.63
IX	Western Plateaux	.21	119.10	114.12	121.54	180.27	2302.73
X	Southern Plateaux	.30	112.05	164.21	174.88	143.29	4078.71
XI	East Coast	.74	349.54	244.63	260.53	621.94	4078.71
XII	West Coast	-.03	-26.83	119.65	127.43	-25.58	1475.58
XIII	The Gujarat	.58	269.84	170.59	181.68	827.01	1592.99
XIV	The Thar	.56	52.53	40.88	43.54	302.44	856.56
XV	The Islands	-	-	-	-	-	-
National Average		.95	274.05	194.17	206.79	584.64	

N.B. : X_1 and X_2 are optimal units of quantities.

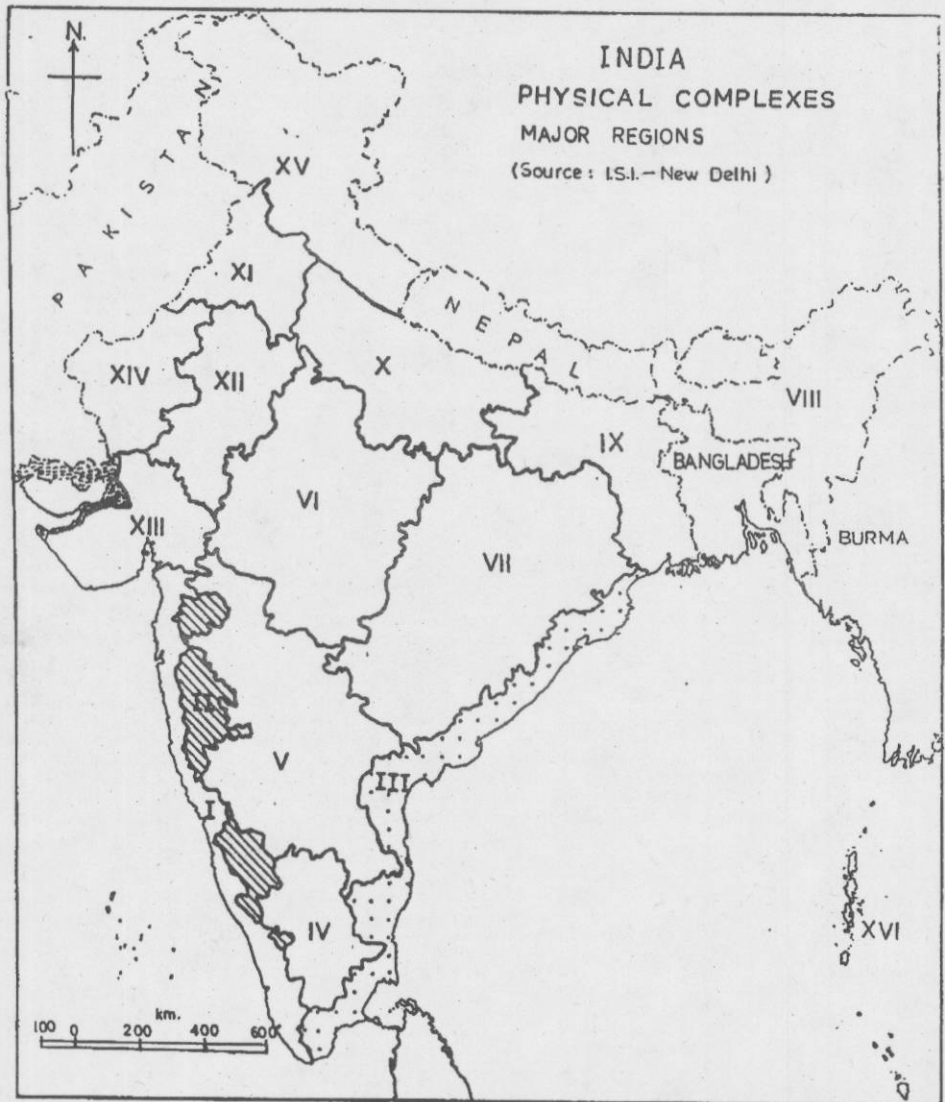
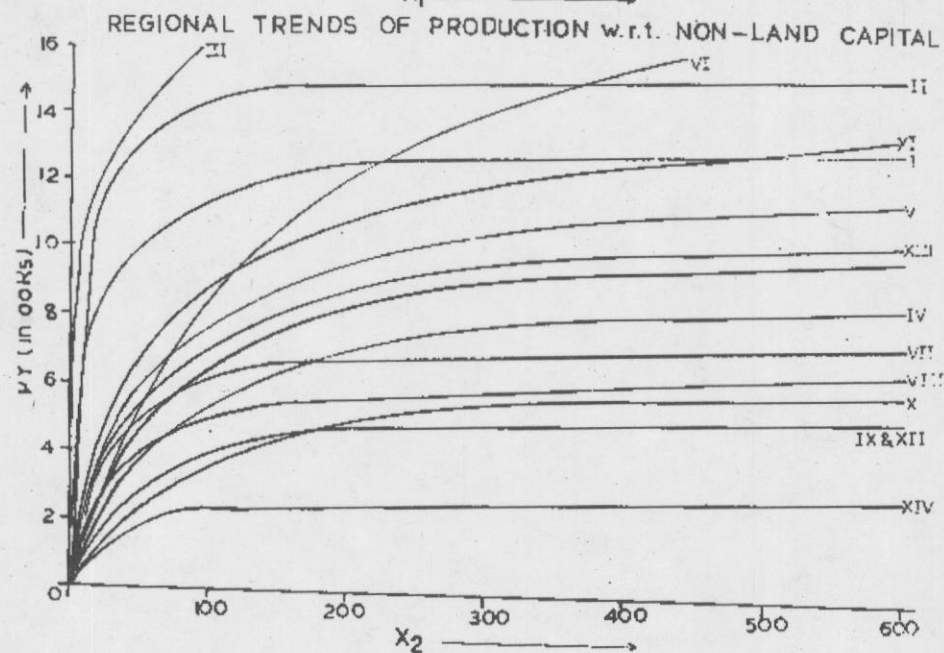
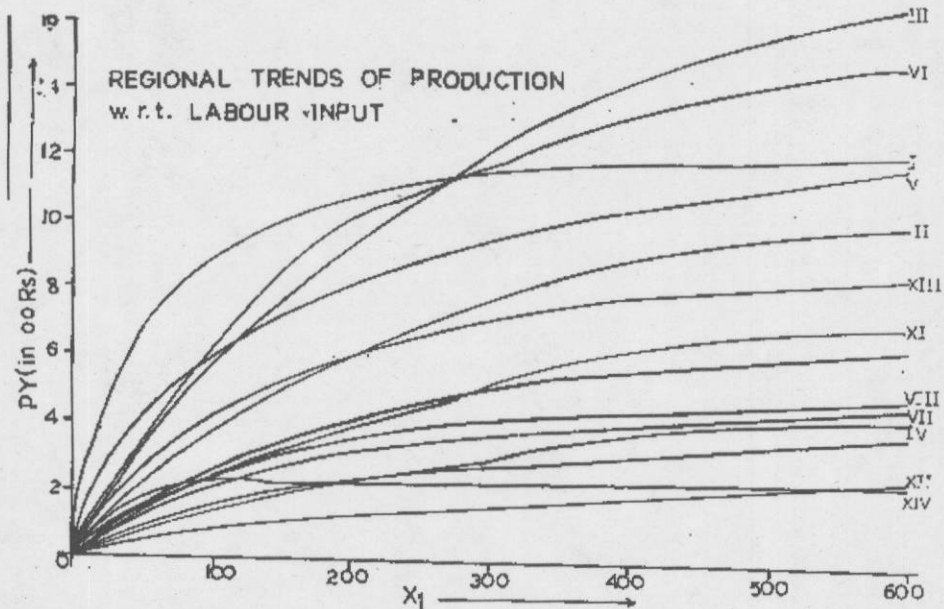


Fig.1



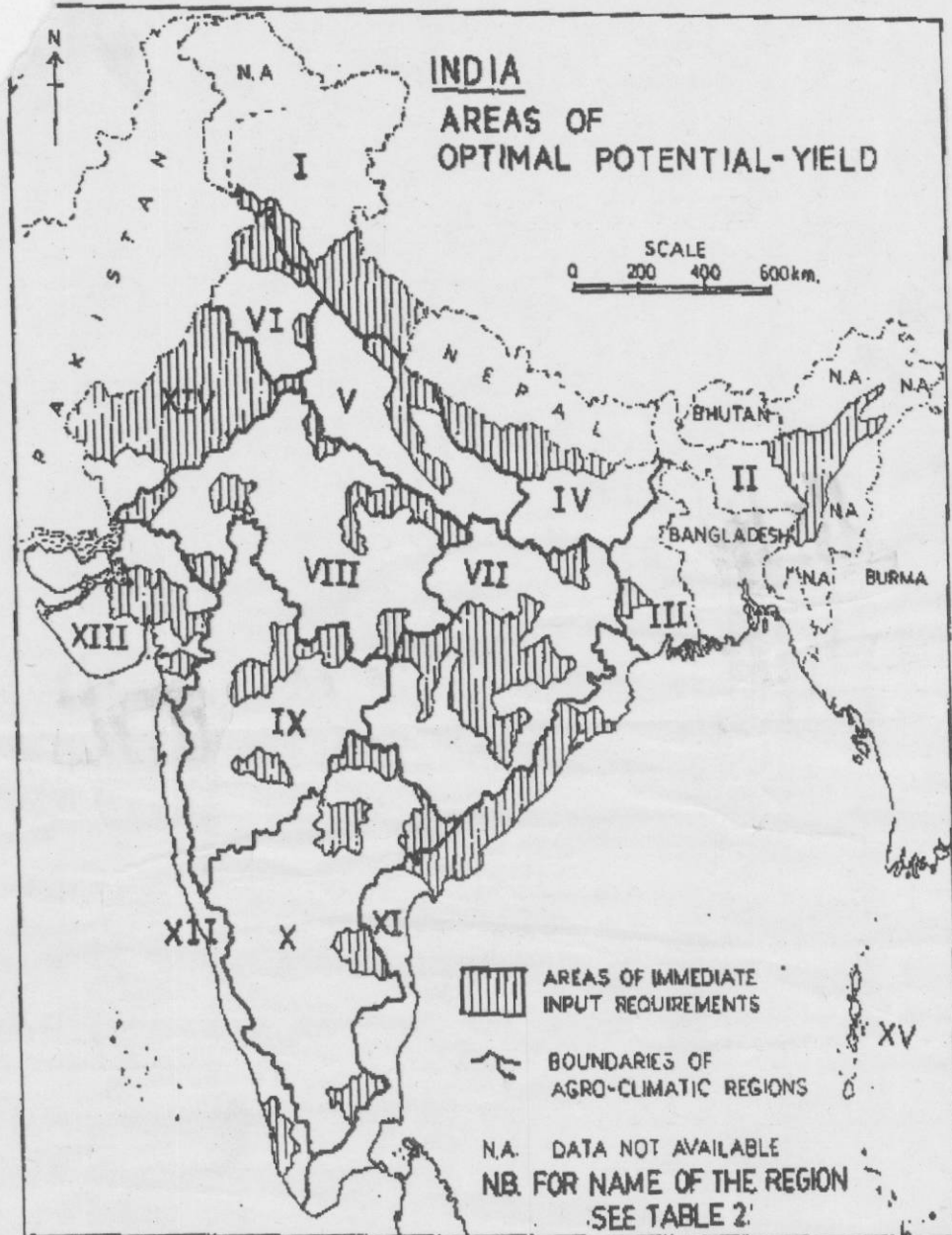


Fig 3