CHANGES IN CROPPING PATTERNS AND WATER PRODUCTIVITY IN INDIA: AN INTER STATE ANALYSIS (1980-2006)

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CERTIFICATE

I, NISHU, do hereby declare that the dissertation entitled, 'Changes in Cropping Patterns and Water Productivity in India: An Inter State Analysis (1980-2006)'for the degree of Master of Philosophy is my bonafide work and may be placed before the examiners for evaluation.

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It is herby recommended that the dissertation may be placed before the examiners for evaluation.

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To my loving parents

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Of all the drawbacks and limitations of this work, I alone bear the responsibility.

CONTENT

List of Tables

List of Figures

LIST OF MAPS

LIST OF ABBREVIATIONS USED

ACR	AGRO CLIMATIC REGIONS
AP	ANDHRA PRADESH
ASM	ASSAM
BJ	BAJRA
CCL	COARSE CEREALS
CCTN	COCONUT
CSO	CENTRAL STATISTICAL ORGANISATION
CST	CASTOR
CTN	COTTON
G.NUT	GROUND NUT
GCA	GROSS CROPPED AREA
GRM	GRAM
HI	Herfindahl Index
IEXT	IRRIGATION EXTENT
II	IRRIGATION INTENSITY
J & K	JAMMU AND KASHMIR
JT	JUTE
JW	JOWAR
MH	MAHARASHTRA
MP	MADHYA PRADESH
MZ	MAIZE
NIA	NET IRRIGATED AREA
NSA	NET SOWN AREA
OLS	OILSEEDS
OTPLS	OTHER PULSES
P.BLK	PAPER BLACK
R & MST	RAPE SEED AND MUSTURD
RBR	RUBBER
RC	RICE
S.MIL	SMALL MILLETS
S.PT	SWEET PATATO
SANHM	SANHEMP
SC	SUGAR CANE
SNFL	SUNFLOWER
SYB	SOYABEEN
T.PLS	TOTAL PULSES
TR	TUR
UP	UTTAR PRADESH
WB	WEST BENGAL
WP	WATER PRODUCTIVITY
WT	WHEAT

Chapter I

Introduction

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

India is endowed with vast water resources and it is also fortunate that its soil and climates permit by and large year-round cropping of its limited resources. It is estimated that irrigation has contributed about more than 60 percent to the growth in agriculture productivity. As we know that land and water are the two vital resources which determine the yield and productivity of crops per unit. It could be enriched or deteriorated so there is need to have sustainability by the proper management and appropriate techniques with progressive manners and qualitative dimensions. As we are concerned about the spatial and temporal variations in terms of land and water productivity across the different agro-climatic regions in India, it reveals the fact in some states that the yield and productivity of crops per unit of land and water have been steadily declining due to irrational use and mismanagement of this two vital resources for instance in Punjab, soil are being deteriorated by twin menace of water logging and salinity due to excessive use of ground water and due to cultivation of (crop specialization) of crops like rice and sugarcane (which needs and consumed high water requirements) and water availability.

One dimension of land and water productivity is the number of crops grown in a sequence on a unit area of crop land in full agricultural year (July-June) which is quantifiable as cropping intensity which also affects on yield per land and water productivity and another one is the changing nature of cropping patterns or we can say the diversification of crops opted by the farmers over the period of time from those crops which require high water consumption to those which need comparatively less water consumption in the different agro-climatic regions in India. It is determined by the irrigation potential, technological innovations and mainly by the existence of wide heterogeneity in different agro climatic conditions of the particular region which ultimately affects the water consumption, stability of yield, resource use efficiency, cropping intensity and sustainability as well. So from this exercise, we are trying to understand the nature of changing cropping patterns and its impact on water productivity across the states in different agro climatic regions in India by the virtue of varying nature of total water consumption and requirements of different crops across the states in different agro climatic regions on the basis of water availability either by rainfall or by development of irrigation.

1.2 STATEMENT OF PROBLEM

Indian agriculture is gamble of monsoon. As we know that Indian monsoon plays significant role to determine the agricultural production of our country which directly affects our national economy and the growth of the other sectors as well. If we see the present scenario, year 2009 can be viewed as an agricultural drought year. With each passing day, the threat of an unprecedented drought seems closer to reality. Desperate farmers have sown paddy two to three times, only to see the crop wither. The trouble, the report showed, was brewing especially for the wheat crop with production showing a perceptible decline since 2000. The gross capital formation in agriculture, as a proportion to the GDP, has shown a decline from 2.9% in 2002-02 to 2.5% in 2007-08, the economic survey said. The overall food grain produce as a consequence fell short of the target for 2007-08 as well as 2008-09.[1] In 25 out of 36 sub-divisions in the country, rains have been scanty or we can say deficient. So this monsoon is turning out to be India's season of despair. So to address these challenges we need to have shift or to get the changes in the traditional cropping patterns towards more feasible in terms of land and water productivity as well by rational use and proper management of land and water resources. With increasing water scarcity, the need to increase water productivity (WP) is receiving significant attention. Many regions in India are reaching the threshold of physical water scarcity (Amarasinghe et al., 2007). This is primarily due to inadequate water resources to meet increasing water demand in different sectors. Among alternative options, improving productivity of water use has significant potential. Thus, like the campaign for more crops per unit of land during the period of the green revolution, improving water productivity is also gaining prominence now.

As we know that there is a continuous change in cropping pattern across all the regions over the period of time, here the study will examine whether these cropping

[1] *Heat on wheat as agri hits a dry patch, Team TOI, Times of India, New Delhi, July 3,2009, pp. 22*

pattern changes is shifting towards more water intensive crops and what its implications with total water consumption of crops in different states also examine the spatial and temporal variations in trends and patterns of water productivity of different crops in different agro climatic regions in India.

Therefore, taking the rising aforesaid issues into consideration, the present study would make a detailed analysis of changes in cropping pattern, crop diversification and water productivity in India during 1980-2006 by following objectives and research questions.

1.3 OBJECTIVES OF THE STUDY

I. To examine the extent and nature of changes in cropping pattern in India.
II. To find out relationship between cropping pattern and irrigation sources and extent.
III. To study the trends and patterns of water productivity of different crops across the different regions in India.
IV. To examine the interrelationship between land and water productivity of irrigated and less irrigated regions in India.

1.4 RESEARCH QUESTIONS

1) Which are the crops that are emerging as more important in India in recent periods of time?
2) What is the trend of diversification in different states of India?
3) Which are the regions that dominate in water intensive crops?
4) What is the difference in changes in cropping pattern in highly irrigated and less irrigated states?
5) Is the cropping pattern changing with the irrigation extent?
6) Are the cropping patterns significantly different in areas where tube well irrigation is the dominant source compared to other irrigated tracts?
7) Is there a convergence between the variations of land productivity and water productivity?
8) Does the aggregate water productivity in a region decline with increase in irrigation extent?

9) Is the aggregate water productivity of crops higher in dominantly tube well irrigated area compared to other irrigated areas?

1.5 DATA SOURCES

For analyzing the general trends of cropping patterns changes, data of area, production and yield across the states in different agro climatic regions in India following data sources have been used

- Agriculture statistics of India, Ministry of Agriculture, Government of India for the study period.
- Year book of area, production and yield of principal crops in India, ministry of agriculture of govt. of India since 1980-83 to 2005-06 [2].

For analysis of different sources of irrigation,

- The Statistical Abstract of India and,
- Agricultural statistics of the Directorate of Economics and Statistics, Ministry of Agriculture have been used for the study period.

For analysis of total water requirement and consumption of different crops the data used from:

- Agricultural Research Data Book, 2001, Indian Agriculture Research Institute (I.A.R.I) Pusa, New Delhi.

The data of value of output for selected crops has taken from

- State wise and Crop wise Estimates of Value of Output from Agriculture, Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India for the study periods.

For deflate and inflate the prices of value of outputs of different crop following index has been used:

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[2] *For analysis of changes in cropping patterns, different sources of irrigation, total water consumption land and water productivity, database from 1980s onwards taken decade wise except the year of 2005-06.*

- For, Whole Sale Price Index – Annual Average, Base 1993-94 of All Commodities has taken by Office of the Economic Adviser, Ministry of Commerce and Industry, Government of India.

1.6 METHODOLOGY

In order to classify different agro climatic regions the criteria and concepts of Agro-climatic Regional Planning Project (ARCP) of the Planning Commission has been used. The project was initiated by regionalizing the country in to 15 agro-climatic regions and later in to 73 sub regions, having a higher degree of commonality. The principles used for this sub-regionalisation related intrinsically with the character of the agricultural economy, namely, soil type, climate, temperature and its variations, rainfall and other-meteorological characteristics, water demand and supply characteristics including quality of water and aquifer conditions [3]. For fourth chapter, Humid region is further divided into moderate and low irrigated regions while semi arid region has three sub divisions viz. highly irrigated, moderately irrigated and less irrigated regions on the basis of their levels of irrigation extent.

To examine the extent and nature of changes in cropping pattern at all the levels in India, the study examines the changes in cropping pattern in three aspects such as absolute area, proportionate share to gross cropped area (GCA) and changes in share and simple growth rates of area under major crops. The share of area under a crop in gross cropped area (GCA) is computed by dividing area under a crop with GCA. The nature and extent of cropping pattern changes are assessed for the major crops namely rice, wheat , sugarcane, three 'coarse cereals' which are clubbed such as jowar, maize and bajra, and fiber crops like jute and cotton grouped together . Then all pulses and all oilseeds are taken into consideration.
Secondary data has been used for entire study.

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[3] *Report of crop output projections for states by agro-climatic sub regions, based on inter-regional area allocation model, ARPU Working Paper No.8,January 1994*

1. **Proportion of Crops from Total Cropped Area (GCA)**

Pi = proportion of area under ith crop in total cropped area =Ai/ Σ Ai

Ai = area under ith crop

Σ Ai = total cropped area

i = 1, 2, 3, 4..........N (Total No. of crops)

2. **Simple Growth Rate** has been calculated for a period of time by the formula i.e.

$r = ((Y_f - Y_b)/ Yb)*100$

Where,

Y_f – final year

Y_b – base year

3. **Rafiullah's Method** of crop combination – it is actually a modification in Weaver's method. His modified index small sigma is given as-

$$\sigma = (\Sigma D_p^2 - \Sigma D_n^2) / N^2$$

Where, ΣD_p^2 and ΣD_n^2 are the sum of squares of positive and negative deviations from the middle of the theoretical values. Here the maximum value of small sigma gives the critical combination.

It has been accepted due to following problems of Weaver's method-

- It ignores the signs of the deviations, and
- For a higher number of crops or functions the theoretical percentages go down and so the deviations caused by last values are underestimated.

4. **Herfindahl Index** is computed by taking sum of squares of acreage proportion of each crop in the total cropped area-

Herfindahl index is defined as: $H = \sum_{i=1}^{N} pi^2$

Where, H=Herfindahl index

Where, Pi = Proportion of area under i^{th} crop = Ai / $\sum_{i=1}^{N} Ai$

In which, Ai = area under ith crop (hectare),

$$\sum_{i=1}^{N} Ai = \text{total cropped area (hectare)}$$

Where, i = 1, 2, 3 ... N (No. of crops)

With the increase diversification, the Herfindahl Index would decrease. This index takes a value one when there is a complete specialization and approaches zero as N gets large, that is, if diversification is 'perfect'. Thus the Herfindahl Index is bounded theoretical minimum, i.e., and zero for smaller values of N (number of activities). Since the Herfindahl Index is a measure of concentration, it was transformed by subtracting it from one, i.e., 1-H.I. the transformed value of H.I. will avoid confusion to compare it with other indices.

In second and fourth chapter bar graph and line graphs have been used to show the trends of spatial and temporal variations at all the levels.

5. For classifying the level of Irrigation status of a particular state, Irrigation Extent [4] and Irrigation Intensities[5] have been calculated. Proportion of different sources of irrigation to net Irrigated area has also been calculated.

6. Weighted Water Requirements

The data of different crop water requirement (in mm) is based on the regional level, to make this available data useful at the state level. The aggregate water requirement has have been worked out by weighting the water demand of each agro-climatic type with the areal extent of the region in the state.

E.g. - suppose there are three regions in the state A (arid), SH (Semi arid) and H (humid).

Now if the areal extent of there agro climatic types are 60%, 30% and 10% respectively, the weights of these regions in the state become .6, .3 and .1 respectively.

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[4] *Irrigation Extent: It is defined as the ratio between Net Irrigated Area to Net Sown Area of a particular state.*

[5] *Irrigation Intensity: it is defined by the ratio between Net Irrigated area and Gross Irrigated area.*

Suppose the water demand of rice for state 'A' is 1200(mm), 900(mm) and 600 (mm) respectively for arid, semi arid and humid conditions, the weighted water demand of the state can be calculated as (1200*.6) + (900*.3) + (600*.1). The weighted water requirement for the given example of rice for state 'A' would be 1050 mm. It should be noted here that the water requirement data is given in units of depth.

Likewise it can be derived the weighted water requirement of various crops for the states in different agro climatic regions. Hence weighted water requirement of different crops across the states has been used for the study.

This estimation would have problems as it would be assuming that rice is grown in the state uniformly in all regions- i.e. ratio of area under rice in all the regions to their respective GCA is similar.

The data for water requirement of crops has been taken from sources of Indian Agricultural Research Institute[6].

7. Total Water Consumption Index

To identify the total water consumption of crops in a particular state, the values of total water consumption has been calculated:

It is computed by the multiplication of weighted water requirements of ith crop with the areal extent of ith crop divided by GCA of selected ith crops.

$$\textbf{TWCI} = \frac{\Sigma\ (\text{Weighted Water requirement of ith crop}) \times (\text{area of ith crop})}{\text{GCA of ith crop}}$$

Where, i = 1, 2, 3 ... N (No. of crops)

Value of total water consumption index would give the level of total water consumption of the particular states with respect to areal extent of different crops

[6] Hukkeri, S.B and Pandey S.L, Water requirement and irrigation of crops, I.A.R.I, Pusa, New Delhi

which have different water requirements. It will be accounted water consumption as mm in particular state.

8. Land Productivity: It is the ratio between the productions of ith crop and area of ith crop. Its unit is Kg. /hectare.

$$\textbf{Land Productivity (Yield)} = \frac{\text{Production of ith crop}}{\text{Area of ith crops}}$$

9. Water Productivity: It is the ratio between the yield of ith crop and water requirement of ith crop. Its unit is Kg. /hectare millimeter.

$$\textbf{Water Productivity (WP)} = \frac{\text{Yield (in Kg. /hectare) of ith crop}}{\text{Water Requirement of ith crop}}$$

10. Aggregate Land Productivity

It is the aggregate sum of total productivity of ith crop with respective to the GCA of the state. For monetary value of aggregate land productivity, value of output (in Rs.lac.) has been used by making it constant so we have inflated and deflated the current price of value of output [7] with the wholesale price index, for all commodities with linking factors have been used. Its unit is Rs.lakh/hectare.

$$\textbf{Aggregate Land Productivity} = \frac{\Sigma\text{ (Production of ith crop* Price of ith crop)} \times \text{area of ith}}{\text{GCA}}$$

Where, i = 1, 2, 3 ... N (No. of crops)

[7] *Value of output include the production and price of ith crops*

11. Aggregate Water Productivity

It is the aggregate sum of total productivity of ith crop with respective to water requirements and areal extent of ith crops of the state. For monetary value of aggregate water productivity, again value of output (in Rs.lakh.) has been used. It can be derived by:

$$\textbf{Aggregate Water Productivity} = \frac{\Sigma\,(\text{Production of ith crop* Price of ith crop}) \times (\text{area of ith})}{\Sigma\,(\text{Water req. of ith crop}) \times (\text{area of ith crop})}$$

Where, i = 1, 2, 3 ... N (No. of crops), its unit is Rs lakh./hectare millimetres.

Areas of ith crop as numerator have been used for giving the weightage to all crops.

For making the understanding of interrelationships between various variables, such as land and water productivity, aggregate water productivity with area under tube well irrigation, irrigation extent, cross tabulations and correlation analysis etc, and statistical operations for such analysis has been done by using SPSS software. To show the spatial and temporal variations, various maps have been used by the help of Arc GIS 9.1 software which is extensively used for the study for each chapter.

1.7 LIMITATIONS OF THE STUDY

The study suffers from some limitations.

a. Data of water requirement of all the crops is not available for all agroclimatic zones. For the ones that are not available, like coarse cereals, oilseeds and pulses, water requirement data has been taken from the Vaidyanathan Commettee Report on Irrigation Water Pricing, 1992.

b. The area under crops in case of newly formed three states such as Uttrakhand, Chattishgarh and Jhakhand is included in the area of their respective parent state to make convenient to the comparative study of pre and post reform periods.

c. Due to unavailability of total data of all seven north-eastern states have been excluded from the study.

1.8 CHAPTER SCHEME

The study is organized into five chapters. The first chapter contains of introduction and covers the review of literature. The second chapter deals with the changes in cropping pattern, in terms of absolute area, proportionate share to gross cropped area and share changes of different crops and also magnitude and directions of crop diversification scenario and changes in crop combinations for different states . The third chapter studies the changes in cropping pattern with development of irrigation extent, growth of different sources of irrigation for all the states. The fourth chapter studies the nature and extent of land and water productivity (individual and aggregate both), total water consumptions of different crops in different agro climatic regions in India. The fifth chapter would include the aspects of conclusion, major findings and policy recommendations.

1.9 Literature Review:

i. Issues and Retrospect for Indian Agriculture

India is the seventh largest country in the world in terms of geographical area; it is second largest one in terms of arable land. It ranks first in terms of irrigated area. India, located geographically in tropical and subtropical regions, is gifted with various climatic conditions and soil types which are suitable to cultivate different types of crops. It is a country of about more than one billion people. Around 70 percent of India's population lives in rural areas where the main occupation is agriculture, making up these rural populations depend on agriculture and allied activities for their livelihoods that is why, agriculture is described as the backbone of Indian economy, mainly because of the following three reasons:

First, agriculture constitutes the largest share of country's national income, though the share has declined from 57 percent in early 1950s to about 25 percent by the turn of the Century. Data reveals that agriculture with its allied sectors contributes to 18.5 percentage of GDP in 2006-07 (economic survey, 2006-07)

Second, around 70 percent of India's population lives in rural areas where the main occupation is agriculture, making up these rural populations depend on agriculture and allied activities for their livelihoods and agriculture's share in total employment is 56.5 percent in 2006-07 however it has been declining marginally at a slow pace as we compared it with sharp declining percentage rate of GDP, even there is a evidence is that labour absorbing capacity of agricultural sector is also reaching its limit (bhalla,1987).

Third, the growth of other sectors and overall economy depends on performance of agriculture to a considerable extent. Besides, agriculture is a source of livelihood and food security for large majority of vast population of India. Agriculture has special significance for low income, poor and vulnerable sections of rural society. Because of these reasons agriculture is at the core of socio economic development and progress of Indian society, and proper policy for agriculture sector is crucial to improve living standards and to improve welfare of masses.Thus we can state that, India is a primarily an agricultural economy but it faces various challenges. The challenges that Indian agriculture are facing can be grouped in four categories

Relating to (1) growth (2) sustainability (3) efficiency and (4) equity.

There are also other important concerns like water productivity, food security, livelihood, employment, improvement in standard of living of agricultural population.

Addressing above aforesaid challenges, India's performance during the post-independence period has been a matter of pride and satisfaction. The agricultural sector has left behind the era of shortages and dependence on imports and arrived at a stage of self-sufficiency and occasional surpluses. The Green, White, Yellow and Blue revolutions have been landmarks that have been claimed and recognized the world over. India is now the largest producer of wheat, fruits, cashew nut, milk and tea in the world and second largest producer of vegetables and fruits. India is the largest producer, consumer and exporter of spices in the world and the largest exporter of cashew. Food grains production has increased four-fold since independence, from 51 million tones (Mt) during 1950/51 to 203 Mt during 1998/99. The scourge of severe food shortages is now a thing of the past as is the dependence on imports. India's agriculture has passed through four distinct phases of strategy: a) starting with the intensification of efforts in identified areas, using traditional technology and expansion of area during the pre-Green Revolution period; b) through a new strategy of use of modern inputs and high yielding varieties in irrigated areas during the late sixties and the seventies, (Green Revolution); c) further through a period of greater focus on management of linkages and infrastructure, such as, marketing, trade and institution building; and, d) to an era of liberalization and relaxation of controls during the nineties. The journey has been arduous but rewarding. The agriculture sector has been successful over the past five decades in keeping pace with the rising food demand of a growing population (already crossed one billion in May, 2000).These achievements are the result of a policy framework of improving rural infrastructure including irrigation, research, extension, provision of agricultural inputs at reasonable prices, and marketing support through minimum price mechanism.

In spite of the impressive achievements, the Indian agricultural sector continues to face poor infrastructure conditions. Less than 36 percent of the cultivated land is under any assured irrigation system. Farmers on the remaining two thirds of the land are completely dependent on rainfall, which is also greatly characterized by large variations in terms of precipitation both spatially and in time (Jodha, 1986). For a large majority of farmers in different parts of the country gains from application of science and technology in agriculture have yet to be realized. As a result, the productivity levels of many major crops in India can not be compared very favorably with the yields obtained in agriculturally advanced countries. Further, these factors coupled with high illiteracy constrain the farmer's ability to shift to more remunerative cropping patterns in response to market signals. Therefore, their capacity to take advantage of the opportunities presented by liberalization of trade is limited. The country's agriculture has gained in strength and resilience since independence, although growth in agriculture is highly skewed over regions and crops. However, the agriculture sector in India is now faced with intense internal and external pressures arising from the impact of policies of economic liberalization. Efficient and effective management of agriculture will be crucial in the years to come for acquiring enduring self-reliance and ensuring sustainable growth with an emphasis on consideration of equity.

Addressing these above challenges new agriculture price and policy requires efforts on several fronts like incentive structure, infrastructure, technology market development, extension, regulations, input supply, tenancy etc. By the seeking of solution and alternatives of these challenges one another way is to changing the nature of cropping patterns to more feasible in terms of economically such as higher income, higher employment, and stabilisation of incomes and conservation of natural resources by improving the potential of water productivity in water scares or rainfed regions by opting the deficit irrigation in surplus regions.

Before detailed study of the cropping patterns changes in India, making understanding about the cropping systems is very essential.

ii. Major Cropping Systems in India

The cropping pattern in India has undergone a significant change during last 60 years of independence. The introduction of new technology that is popularly known as green revolution was the major breakthrough in the history of Indian agriculture. This has resulted in phenomenal change in crop economy in terms of cropping pattern and levels of crop production and productivity. The performance of agriculture sector can be assessed through the detailed study of cropping pattern, production and productivity levels at various levels. Cropping pattern can be described as the kind and sequence of crops grown over a period of time under the specified soil conditions and it may be a pattern of regular rotation of different crops or the crops composition. The land can be sown/planted under a single crop during one season (mono-cropping) or under two crops in a year (double cropping) or even more than two crops in the same piece of land in a crop year (multiple cropping). This is the important ingredient in describing a cropping system. For example, in semi-arid tropics, keeping deep verticals fallow during the rainy season and growing the post-rainy season (rabi) crop is a common cropping system. Cropping pattern is a manifestation of the cropping systems. Cropping pattern is a dynamic process and occurs due to changes over space and time with cumulative effects of past and present decisions. The cropping decisions are taken by communities or the State and their agencies. The decisions about the cropping system are usually based on experience, tradition, expected profit, personal preferences, as well as technological and institutional factors. Farmers allocate their land among alternative crops in order to maximise their expected returns subject to economic, technical and institutional constraints.[8]

[8] *Deshpande,R.S et.al (2004): Crops and Cultivation: State of the Indian Farmer: A Millennium Study: Academic Foundation.*

India is endowed with diverse climatic, edaphic and socio-economic conditions and this has given rise to many location-specific cropping systems. Peter Robb while searching for the Meaning of Agriculture through experts in South Asian context writes "Agriculture also relates differently to physical environments. Its role and conditions are different in marginal areas and in the areas with various forms of artificial irrigation. It appears differently in villages, small holdings and states. It has different imperatives and rhythms according to whether the main crop is wheat or rice, sugarcane or coco, pulses or groundnut or cotton, and so on. Hence, different practices are associated with the demands of particular crops. But there are also standardisations existing from beliefs and customs, social or gender roles, or indeed in accordance with broader forces derived from law, terms and trade and so on – factors which might extend across different agricultural regimes" (Robb, 1996: 6).

Therefore, variations in the cropping system are based on soils, rainfall, temperature regimes, latitude and altitude. There are a number of region-specific cropping patterns followed by farmers. However, it is difficult to present all the cropping patterns here due to enormity. Hence, we discuss five major cropping systems based on the main or dominant crops and subsequent patterns within that. These are as follows:-

- The first one is Paddy based cropping system which is practiced in the region extending from the eastern part to include very large part of north-eastern and south eastern India and also strips along the eastern and western coast. This is predominant in Assam, West Bengal, Orissa, Bihar and Eastern States, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala and Western coast.
- Secondly, Wheat based cropping system which is dominant in most of the northern, western and central India.
- Thirdly, the millet-sorghum based system that is common in Rajasthan, Madhya Pradesh, Maharashtra and Deccan Plateau.
- Fourthly, the temperate Himalayan regions of Kashmir, Himachal Pradesh, Uttar Pradesh and some adjoining area are dominated by horticultural crops like Potato which is as important as cereal crops like maize and paddy. Tree

fruits from a large part of agricultural production. Potato is also grown in the states of Bihar, West Bengal, Assam and Orissa.

- Fifthly Plantation crops which are quite common in the regions of Assam, West Bengal and the hills of southern India (Kerala, Tamil Nadu and Karnataka) where good quality tea is produced. High quality coffee is produced in the hills of western peninsular India. Rubber is mostly grown in Kerala, parts of Karnataka and Tamil Nadu. Coconut plantations are found in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh and Cashew is grown in Kerala, Karnataka, Andhra Pradesh, Tamil Nadu and Maharashtra.

The alarming population growth has led to a drastic fall in per capita availability of gross and net cultivable area(in spite of bringing some uncultivable land under cultivation and extension of multiple cropping) to raise revenue as much as possible from limited holdings.

With the expansion of irrigation potential, development of technology, market structure and institutional mechanism, cropping pattern changes fulfils the increasing demand and the matches the changing conditions. Sometimes a new cropping pattern is introduced to raise the expected farm income from the limited farm holding and to avoid risk and uncertainty. Changes in technology are also invited to make the land suitable for the cultivation of more desired crops. Improvement of infrastructure also helps in accelerating the process of diversification that also varies across the regions for various agro climatic conditions and resource bases.[9]

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[9] *Utpal Kumar De (2003) changing cropping system in theory and practice: an economic insight into the agrarian West Bengal, Indian Journal of Agricultural Economics, Vol.58, No. 1 Jan-Mar 2003*

iii. Changing Nature of Cropping Patterns in India

The changes in crop acreage take place in two ways: (i) through expansion in the gross cropped area, and (ii) due to substitution of low-value high-volume crops with low-volume high-value crops. A study of "Growth rates and cropping pattern changes in agriculture in six states in India: 1950 to 1975" by L.S Vekataraman and M Prahladachar in 1980 has suggested the method of "aggregate" change in the cropping pattern of a state in terms of "substitution" and "expansion" effect by comparing the area growth rates of individual crops with the corresponding growth rates in gross cropped area. The study analysed the change in area under various crops with the help of change in share of area under a crop to total cropped area, over a period of time. The effect of contribution of area and yield to the crop output was explained with the help of compound growth rates of area, yield and production of crops.

The changes in the cropping pattern at the all India level during 1967 through 1981 indicated that crops like paddy, maize, ragi, wheat, tur, cotton, sugarcane, rape seed and mustard etc. registered increased acreage to the extent of 14.5 million hectares. On the contrary, sorghum, bajra, gram, groundnut, linseed, small millets and sesamum were the net losers (Kumar, 2001).

The expansion effect was more pronounced when compared to substitution effect during 1967-80. In 1982-96, changes in the cropping pattern were effected more through substitution of crops rather than expansion in the gross cropped area.

The acreage under crops like paddy, wheat, soya bean and sugarcane increased at the cost of coarse cereals. The area under oilseeds as well as cotton and sugarcane indicated increasing trend in the 1990s.

The changes in the cropping pattern varied greatly over space and time. However, a regional pattern in crop specialisation seems to be emerging cumulatively over the years. In the eastern region, area under non-foodgrains increased whereas, the area under coarse grains declined during the last three decades. States in the northern region experienced substitution of area under coarse grains and pulses in favour of wheat and paddy. States in the Western region experienced an increase in the area under non-foodgrains, and substantial decline in the area under coarse grains.

However, the share of area under wheat, paddy and pulses has been stable. In southern states, area under coarse grains has been substituted by non-foodgrains .

It is interesting to note that the share of non-foodgrains in the gross cropped area has increased in all the regions except in the North-western region where it declined from 20.5 percent in 1962-65 to 17.5 percent in 1992-95. The increase in the share of non-foodgrains was conspicuous in Southern region where it increased from 27.53 percent in 1962-65 to 32.70 percent of the gross cropped area in 1980-83 and further, to 42.73 percent in 1992-93. Changes in the cropping patterns resulted in changes in the relative share of different states in the total cropped area in the country.

About the crops the area under commercial crops has doubled since the 1960s and now equals half the area under food crops. (Vyas V.S. 1996). Among the food crops the area under superior cereals i.e. wheat & rice is increasing while that under the inferior cereals (Vyas V.S. 1996) although there is not any major change in the share of foodgrains and non foodgrains in the total value of production over time (Satyasai K.J.S., Viswanathan K.U. 1996).

Research studies in India on farm diversification have mainly focused on traditional crops like paddy, sugarcane, groundnut, wheat, cotton as the main crops, and pulses and horticultural crops as subsidiary crops. A few studies have also focused on crop diversification in irrigated and rain fed crops (Balga and Tambad, 1964; Sarkar, 1972), and on the impact of a new enterprise like dairying, animal husbandry in the farm enterprise (Saini and Singh, 1985). In regional case studies generally it was found that the farmers have shifted their cropping pattern from the subsistence crops to the commercial crops especially in Gujarat & also in other states (Shiyani R.L., Pandya H.R. 1998). But at the same time in some states such as Bengal some varieties of traditional crops like boro rice, mustard & potato have gained in area significantly (Utpal Kumar De 2000).

In India after green revolution agriculture had been passed through several changes. One of the important phenomena is the crop diversification in the different states at different level. The states like Bihar, Punjab, Haryana, U.P., & west Bengal are experiencing specialization while other states are experiencing diversification

(Bhal S.K., Prasher R.S., Mehta P 1997). Punjab & Uttar Pradesh are the states which reports specialization by using any methodology (Chadha, Sen S 2004).

The study of Regional Dimension of Inter Crop Diversification in India: Implication for Production and productivity Growth by (Bathla,S ,2006) has revealed that there is inter crop area shifts in favour of high yielding crops viz. wheat , paddy ,oilseeds ,cotton and sugarcane up to the eighties and towards paddy ,sugarcane ,fruits-vegetables ,fibres ,plantations, condiments and spices during the nineties and early 2000. While area under wheat and paddy (rice) has expanded solely at the cost of low yield growth crops viz. coarse cereals and pulses due to price support and HYV programmes, high value commercial crops have benefited both from area shifts as well as fresh land brought under cultivation .A significant aspect of area shift in the case of oilseed is that an initial spurts in their acreage (in both absolute and relative terms) provided mainly by the Technology Mission Programme and a restrictive import policy on edible oils has got subsidized over time. Besides decline in area under oilseeds , there has been a considerable change in its structure and composition with the result traditional oilseeds notably ground nut , rapeseeds-mustard, castor and coconut are losing out their area share to new oilseeds such as soyabean , safflower and sunflower .the state level picture provides mixed results ,while of cereals(wheat-paddy) is visible in all the states , commercial crop acreage has become more prominent in the western ,central, and southern parts in the northern states. The rice growing eastern states viz. Bihar, Orrisa, Assam grouped under 'other states', are also heading towards cultivation of cotton and oilseeds. Further locational shifts have also been identified during the nineties for rice to almost all the states , for cotton away from Punjab ,Gujarat and Rajasthan and for sugarcane from Uttar Pradesh to Karnataka , Andhra Pradesh and Maharashtra.

Such trends in cropping pattern results an increased level of specialization towards cereals, sugarcane, fruits and vegetables , plantation and fodder crops and bent towards diversification within pulses during the last more than two decades. Picture with respect to oilseeds and fibre indicates an increasing tendency towards diversification till the end of eighties and specialization during the nineties and early 2000. This could be due to change in area and composition of oilseeds during the nineties, that is the period marked by Economic Reform in terms of Globalization and Liberalization of Indian agriculture but, during this period there is also a marked shift in the patterns of agricultural investment in favour of the private sector and this period not only covers such important policy changes as unleashed by agricultural liberalization policies but also represents the consolidation phase of rural infrastructure (Hazra, C.R 2005).

Across the states, the rice and wheat cultivating states viz. Punjab, Haryana, Uttar Pradesh and West Bengal reveal an increasing specialization in food grains, oil seed and all crop categories. In contrast, states other than these are expanding acreage under wheat, paddy, cotton, pulses, sugarcane and other commercial crops evince a bent towards diversification. The states, which have witnessed diversification in the non food grains crops crop category till the mid-nineties and then trends towards specialization in the subsequent periods, include Maharashtra, Punjab, Rajasthan and Uttar Pradesh.

The overall scenario of the changing cropping pattern in India revealed that in present context the area under commercial crop has doubled since the 1960s and now equals half the area under food crops. Among the food crops the area under superior cereals, i.e., wheat and rice, is increasing while that under inferior cereals (pearl millet, sorghum, minor cereals) is declining (Bhalla, G.S, 2006).

iv. Crop Diversification in India

The concept of diversification at the macro level is well understood. A move away from agriculture to industries and services denotes diversification at the macro level. But there is a lack of clarity when it comes to the context of diversification within agriculture. Because within agriculture there could be changes which are in the nature of shift from one crop (say, rice) to another crop (say, oilseeds), or from one enterprise (say, crop raising) to another enterprise (say, livestock). Thus diversification could suggest any one, or all, of the three situations; (a) a shift from farm to non-farm activities, (ii) a shift from less profitable crop or enterprise to more profitable crop or enterprise, and (iii) use of resources in diverse but complementary activities. [10] First type of shift from one crop to another crop is known as crop diversification.

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[10] *Vyas,v.s,(1996): Diversification in Agriculture: Concept, Rationale and Approaches, Indian Journal of Agricultural Economics, Vol.51, No.4, Oct-Dec. 1996*

In the context of Indian agriculture diversification has occurred both across and within crop, livestock, and forestry and fishery sectors. Besides the initiative of the individual farmer to diversify his farm enterprises for meeting cash needs of agriculture as well as to combat risk associated with mono-cropping, technological change and deliberate government policies are the factors that accelerated diversification. In more recent times, especially with the General Agreement on Tariffs and Trade throwing open several opportunities for agricultural exports, diversification towards high-tech ,innovative enterprises within the agricultural sector such as floriculture, horticulture and towards agro/food processing and rural non – farm sector has been gaining momentum[11]

"Crop diversification is a transition towards commercialized agriculture under which high remunerative crops are grown mainly with the aim of selling in the market and export purposes". In another way crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops & also to lessen risk (Hazra,C.R, 2005: Crop diversification in India).

"Agricultural diversification is considered to be the most appropriate strategy that augments growth, stabilizes farm income especially of the small and marginal farmers, generates full employment, protects natural resources and attains the goals of food security." [12]

v. Need of Crop Diversification in the Indian Perspective for Sustainability of Resource Use

Crop diversification in India has been an important concern in the agriculture sector. Agriculture sector is the most important sector in India. But from the long period of time it faces various challenges that already discussed. Crop diversification may one solution for these challenges which Indian agriculture has been facing. But there are multiple schools of thought regarding this solution. So to make the better

[11] *Satyasai,k.j.s,and viswanathan,k.u.(1996):Diversification of Indian agriculture and food security; Indian Journal of Agricultural Economics, Vol.51, No.4, Oct-Dec. 1996*

[12] *Bathla S,(2006), Regional Dimensions of Inter Crop Diversification in India: Implications for Production and Productivity Growth, Agriculture Situations in India,Vol.58,No.9,December pp 1-30*

understanding of it, we have to examine its various positive and negative aspects in Indian agriculture.

vi. Crop Diversification and Its Positive Impact on Sustainability of Resource and Agricultural Growth

Crop diversification has been taking place from the shift of traditional varieties or low value crops to new high yield varieties of crops, which are relatively more remunerative than the earlier ones. Such type of changes in cropping pattern may lead to redistribution of land resources to different crop enterprises which ultimately, have bearing on accelerating growth of crop efficiency in the region[13]

Sustainable use of resources is possible through diversification because large scale production systems are absent in this case (Chadha,2004).Crop diversification is effective strategy for the purpose of agricultural growth , judicious use of land and water resources , sustainable agricultural development and also for an environment improvement (FAO,2001 Singh 2001).

vii. Crop diversification and its positive impact on income, employment, environment and for poverty alleviation

Crop diversification may be adopted as a strategy for profit maximization through reaping the gains of complementary and supplementary relationship or in equating substitution and price ratios for competitive products. Crop diversification also acts as a powerful tool in minimizing of risk in the farming business. Under the situation of weather market induced risk and capital constraints, diversification helps in stabilizing farm income at a higher plane. These considerations make a strong case for farm diversification in Indian conditions (Gupta and Tiwari, 1985). Evidences show that under specific circumstances it has positive impacts both on income and employment (Chada,2004). So the net impact would depend on the nature of diversification undertaken by the farmer. Diversification to commercial crops/commodities becomes an essential strategy that can increase incomes in agriculture, minimize risks due to crop failures and above all earn foreign exchange[14].

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[13] *K. S. Dhindsa and Anju Sharma(1995): Analysis of Cropping pattern Changes in Punjab, India Economic Review, Vol.30, No:1 pp 69-87*

[14] *Hazra,C.R (2005), Crop diversification in India, pp 1-17*

Further, diversification can be designed to help poverty alleviation, employment planning and environment conservation (Bathla; S.2006) and a planed diversification increases both individual and social gains.

The crop diversification also brought several other indirect benefits, such as establishment of commercial tea nurseries to meet the demand for planting materials, establishment of private leaf tea factories and industrial co-operative factories. All these generated employment and provided regular income to small tree growers and unemployed youths. The crop diversification also had positive effect on soil conservation and ecology. Taking in to account the advantages of crop diversification from potato to tea, it is suggested that continuance of the scheme for sustainable development as it creates both forward & backward linkages (Ajjan,N,Selvaraj,K.N.: Crop Diversification and its Implication in Tamil Nadu-A Micro Analysis).

Crop diversification towards horticulture crops also generating the income and employment in hill regions, temperate belt where agro-climatic conditions are adverse, seasonal unemployment also found and not so developed agriculture.(Chand,R: Agricultural Diversification And Farm And Non-Farm Employment in Himachal Pradesh).

The diversification of agriculture towards selective high value cash crops including fruits and off-season vegetables, compatible with the comparative advantage of the region, is suggested as a viable solution to stabilise and raise farm income, increase employment opportunities, and conserve and enhance the natural resources, principally land and water (Vyas, 1996). The adoption of high value cash crops, particularly fruit crops, helps the mountainous regions in two ways. First, it promotes the productive use of abundant marginal lands available in these regions.

Second, these crops help in maintaining and improving the ecology and environment by promoting soil conservation and improving soil fertility. In economic terms, it leads to significant improvement in the quality of life of the people. According to the study of Agricultural Development and Crop Diversification in Himachal Pradesh by H.R Sharma, Agricultural diversification towards fruit and vegetable crops in Himachal Pradesh, especially in some areas in the districts of Shimla, Kullu, Solan and Lahaul and Spiti, started in the late sixties, which gathered pace in the seventies and eighties. The process of crop diversification to high value crops has gained further momentum in the late nineties and is spreading, to many new areas in the low and mid-hill districts. It has made a significant impact on the quality of life of the local people. The micro level experiences further show that diversification through high value crops are not only economically beneficial but ameliorate stress on natural resource base (Chand, 1996). At the macro level, the agricultural transformation led rural prosperity is manifested in a number of socio-economic indicators and poverty level that compare favorably both with mountainous states and other developed states like Haryana. These accomplishments have attracted the attention of development economists and policy makers, and the state has come to be known as a model for other hilly/mountainous regions/states to follow.

Still positive aspects of the crop diversification have been taken in to consideration but now another school of thought who explained the negative aspects, its constraints/challenges and its various problems are following.

viii. Negative Impacts of Crop Diversification

There is no doubt about that diversification from low value crops towards high value crops have created development in terms of land/labour productivity, enhance farm income including small farms etc. but it has also a endangered a number of undesirable side effects like reduced farm employment and crop imbalances. Although the expansion of commercialized agriculture has fomented new sets of rural non-farm activities and strengthened the rural-urban growth linkages, it has also weakened the traditional inter-sectoral linkages between the crop and livestock sectors.

ix. Negative Impact on Resource Sustainability, Environment

The emerging trend of diversification has also created the problem of sustainability of the cropping system itself. Cropping pattern changes also lead to serious environmental consequences that take such forms as groundwater depletion, soil fertility loss and water logging and salinity all of which can reduce the productive capacity and growth potential of agriculture over the long-term. There are reports, however, that extensive cultivation of rice and sugarcane in northern region was causing negative externalities related to soil and water resources. A classical example is the rice-wheat system in North-western India replacing traditional crops like pulses, oilseeds and cotton.

The soil fertility with respect to macro and micro nutrients was declining, and the water resources are depleting. These negative externalities have adversely affected the total factor productivity of rice wheat cropping system in this region (kumar et al. 1998). Specialization of rice leading a progressive lowering of ground water table in Punjab, large progressive decline in ground water level is a cautionary signal which should be taken seriously and investigated in detail (Vaidayanathan, A).

The cereal based specialization had created some problems such as low value addition, declining biodiversity, seasonality in farm employment & also reduction in labour absorption due to mechanization.

The cereal based cropping system, extensively adopted and extended even on marginal land, has endangered the soil health and water resource availability in the country.

Some researchers pointed out several limitations associated with high value crop diversification. The problem of market unpredictability remains even when farmers diversify to high value crops because market mechanics are beyond their control. Moreover, the input costs for high value crops are often out of reach of small and marginal farmers. Low risk bearing capacity and the absence of assured transport, storage and markets compounded the problem[15].

x. Debate on These Positive and Negative Effects of Crop Diversification

There are multiple schools of thought who suggest their different opinion regarding the positive and negative impact of crop diversification in India. Some of the opinions are following:

By crop diversification the optimism on income generation and the scepticism on food supply have generated considerable controversy especially on crop diversification. Rao and Gulati(1994) suggest that agricultural growth need not any longer be limited by a goal of self-sufficiency, but it demand, particularly in dry land. Krishnaswamy (1994) questions restructuring of agricultural production towards

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[15] *Pandey,v.k and sharma,k.c(1996):Crop diversification and self-sufficiency in food grains, Indian Journal of Agricultural Economics, Vol.51, No.4, Oct-Dec. 1996*

export market and argues that when those below the poverty line have enough means to satisfy their food needs, then the present levels of agricultural output for rise in agricultural exports. Vyas(1994),while recognising the growing trend towards the world market as significant developments arousing our interest in taking advantage of these favourable trends, holds that they do not warrant any substantial change in India' strategy of self-sufficiency in staple foodgrains. He favours diversification only when effective food self-sufficiency in cereals is achieved (Ibid). This debate necessitates an evaluation of the performance and prospect of growth in foodgrain crops as against the performance and possibilities of crop diversification in the country. Where by other hand there is statement by (Chada,2004) is that diversification becomes necessary for developing countries since growing of basic staples such as cereals cannot alone support economic development, notwithstanding the need to ensure food security to the people. Expansion of commercial crops has negative effects on the supply of feed and fodder and this has implications for livestock economy (Saleth, 1999).

Some scholars suggested that there are the need to ensure basic food security while allocating resources such as land water and capital for diversification. Some school of thought suggested promoting marketing of high value products, not at the cost of, but in addition to existing crops, to preserve the local and traditional bio-diversity. They felt a survey prior to diversification could help identify factors such as what crops would be suited to the climatic conditions, how families would benefit, what would be the technological needs and other input costs involved and what is the scope for further processing. These would help minimize many risks of diversification.

Other findings reflected how attempts to shift towards high value crops have not always been successful. Some high-value agricultural commodities also require significant investments, high water requirements including the use of specific inputs. For example, fruit production typically means that the farmer must plant trees and wait 3-5 years for them to begin producing. Finally, the production and marketing of highly perishable high-value commodities benefit from the producing farm being located near markets and good marketing infrastructure (Toreró and Gulati, 2004).Instances from Uttar Pradesh, Orissa, Bihar, Andhra Pradesh and an international example of Afghanistan were indicative of how the wrong crop choice, small land holdings, mono cropping, an inadequate resource base, and lack of adequate technology and market support could serve as impediments to diversification.

On the one hand some author suggested that crop diversification had positive effect on soil conservation and ecology and sustainability of resources (Ajjan, N, Selvaraj, K.N; 1996) on the other hand some author are saying that crop pattern changes also lead to serious environmental consequences that take such forms as groundwater depletion, soil fertility loss and water logging and salinity - all of which can reduce the productive capacity and growth potential of agriculture over the long-term.

There are reports, however, that extensive cultivation of rice and sugarcane in northern region was causing negative externalities related to soil and water resources. The soil fertility with respect to macro and micro nutrients was declining, and the water resources are depleting. These negative externalities have adversely affected the total factor productivity of rice wheat cropping system in this region (Kumar et al. 1998).

xi. Determinants and Factors Affecting Cropping Pattern Changes and Crop Diversification

There are so many factors (on basis of literature) which affect the crop diversification some of them are-

1. **Size of Operational Holding**- distribution of operational holding does, matter for crop diversification. Higher the inequality in the distribution of operational holding, lower the diversification (Bhal S.K., Prasher R.S., Mehta P 1997).

2. **Profitability**- from our analysis it was found that there is diversification towards the commercial crops, horticulture & oilseeds. These are the crops which have high value so it increases the income of farmers. Thus the basic motive to adopting the diversification is profit maximization. Nerlove (1958) in his path breaking analysis of has considered actual and expected normal price for explaining the farmers' response to price variations. Expected normal price was found to play an important role in determining the long-run equilibrium acreage. Prices in his econometric analysis were assumed to be independent data and the farmers were the price takers and adjusted acreage

distribution in response to the variations of prices and their future expectations.

3. **Infrastructure-** In analysis it is found that most of the southern & western states are more diversified. One region may be that these are the developed states & have better infrastructure such as transport & storage. Availability of infrastructure such as transport, power & storage facilities stimulates the farmers to undertake a high value land use diversification *(*Chadha., *2004).* Narian (1965) in his pioneering work has observed that the shift in cropping pattern are traceable to change in the relative prices of crops , expansion of irrigation and changes in technology

4. **Access to Credit & Land Availability** – as farmers have investment & land than they take risk by growing high value crops in a portion of their operational holding (Chadha, 2004). Several studies have been devoted to analyse the role of different factors behind the changes in allocation of land resources towards different crops. In a situation where scope of bringing more land under cultivation and extension of multiple cropping is very limited, proper choice of cropping pattern can help in raising revenue from their limited plots. Inter-linkages between credit and factor market as well as the resource endowment of the farmer also influence the area allocation decisions.

5. **Government Policies-** when sustainability of resources is the concern than government provide some incentives for adopting the diversification. Such as in Punjab govt. is providing incentives for contract farming. Because it is profitable &is accepting as a way of crop diversification (Singh, S. 2000).

6. **Land Holding Sizes-** The cropping pattern varies not only across different regions but also within a region among farm size groups. The analysis of cropping pattern data from Agricultural Census indicates that though the foodgrains are cultivated more by smaller size classes than by larger ones, the proportion of superior cereals is higher on small farms when compared to their large farm counterparts (Nadkarni and Vedini, 1996).

xii. Role of Irrigation Facilities, Environmental Conditions And Other Inputs To Cropping Pattern Changes

The role of irrigation facilities, use of HYV seeds, and use of fertilizers and establishment of markets can play a prominent role in raising the production. The soil and climatic conditions also contribute to change in cropping pattern, that how soil fertility has adversely affected due to changed pattern of various crops in northern regions in India. The soil fertility with respect to macro and micro nutrients was declining, and the water resources are depleting due to crop diversification.

The Eastern region of India is the most backward in terms of per capita income, agricultural growth and infrastructure development. The yield levels are low because of the uncertain production environment and poor adoption of improved verities and technologies. Overall the region was food based concentrating largely on rice, with little diversification. The humid atmospheric conditions and high rainfall make cultivation of rice more favourable in this region and establishing specialized agricultural system.

Hill regions of India due to their specific characteristics like difficult terrain, physical isolation, inaccessibility, tiny land holdings, sparse population and agro-pastoral economy, are generally underdeveloped and dominated by traditional economic activities which do not offer sufficient employment to keep pace with growing population .large scale industrialisation in hill areas is not ecologically desirable and infrastructure in hill regions is poor to attract industries. Therefore agriculture is the key sector for employment and income generation in these areas. due to its ecological adverseness these regions have diversified towards horticulture crops, especially cash crops having low volume ,light weight and high value,(more favourable from geographic and economic perspectives) as the thrust areas for generating income and employment in the hill regions. Fruit cultivation has been adopted in a big way in the temperate belt. Within horticulture; diversification through off-season vegetable seems to possess great potential in most of the areas in both temperate and non temperate belts of Western Himalayan Region. While Climatic conditions in many parts of Western Himalayan Region are suitable to produce crops like tomato, peas, beans, cabbage and capsicum in summer season (April to October) when these crops are not grown in the plains and there is severe shortage of fresh so this point of view agro-climatic conditions are much suitable and give prominent support in term of specific production of horticulture crops in this region. Thus, the strategy of agricultural diversification is location specific (Chand,R: Agricultural Diversification And Farm And Non-Farm Employment in Himachal Pradesh).

The study of "Cropping Pattern in Madhya Pradesh (1966)" by National Council of Applied Economic Research, New Delhi, articulates that soil and climatic conditions of a region usually have a bearing on the crops that are grown there. However, an examination of the secondary data did not show statistically significant relationships between some of the important physical factors like rainfall and irrigation and the extent of area under most of the selected crops in the different districts.

Saleth (1999) grouped the important factors influencing cropping pattern into five broad categories as: (i) resource related factors covering irrigation, rainfall, and soil fertility; (ii) technology related factors covering seed, fertiliser, water technologies as well as marketing, storage and processing; (iii) household related factors covering food and fodder self-sufficiency requirements and investment capacity; (iv) crop-specific factors covering output and input, trade and other economic policies; and (v) Institutional and infrastructure related factors covering farm size, tenancy arrangements, research, extension and marketing system, etc.

xiii. Impact of Irrigation and Its Sources on Cropping Intensity and Multiple Cropping System

Irrigation sector is the predominant user (more than 80 per cent) of water resources and the sector that directly and indirectly affects the growth, equity, efficiency, and sustainability of agriculture. India's economic and social development depends to a large extent on the performance and development of agriculture. The most significant change which has remarkably impacted on the cropping pattern in the country is irrigation. Introduction of Irrigation facilities has largely led to high productivity as well as multiple cropping. In most of the areas where irrigation is introduced the cropping pattern has become more diversified, especially so if there is proper regulation of water delivery. Between the two criteria of land productivity, cropping intensity is greatly influenced by irrigation furthermore; rainfall has it own impact on cropping intensity[16]. It is estimated that irrigation has contributed about 60 percent to the growth in agriculture productivity. Despite such progress, the level of multiple cropping actually prevailing is below the potential mark of three crops per year not even to crops.

In multiple cropping system, water is one of the paramount binding constraints. Besides this, the annual rainfall of the most part of the India is sufficient for raising only one rainfed crop year.

Therefore, irrigation becomes a pre-requisite for raising both the second and third crops in a year to achieve the potential mark of 300 percent cropping intensity (Ibid).

In his study, author concluded that there is a significantly positive interrelationship between tube well & dug well with cropping intensity, but on the other hand it is argued that though there is an evidence of the close relationship between irrigation development and the rise in intensity of cropping at the all-India level but by assessing comparative impact by type of irrigation have not yielded meaningful results, this calls the further enquiry to verify the veracity of the general impression that the irrigation impact on intensity of cropping rises as we from tank irrigation to canal irrigation, and onto well irrigation he concluded that with this hunch that the verification may bring out that this is not so in every region of India[17]. The virtue of tube well irrigation have been extolled for the last two decades. Those who plead for this mode of irrigation must bear in mind its limitations and drawbacks. To begin with, tube well technology is technically feasible for alluvial areas, and not for areas underlain by hard rock as indeed is the case for much of the Indian land mass. Thus it is futile to urge the planners to introduce tube well irrigation every where in the country[18].

The introduction of HYVs cropping technology on residual moisture has partly contributed to the increase in rain-fed double cropping. The growth in cropping

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[16] *Karunajaran, k.r and Palanisami ,K, An Analysis of Impact of Irrigation on Cropping Intensity in Tamil Nadu, Indian Economic Review, vol. 34,No. 2, 1998,pp.207-220*

[17] *Dhawan,B.D and Datta, H.S, (1992), Impact of Irrigation on Multiple Cropping, Economic and Political Weekly, pp-A-15 to A-18*

[18] *Dhawan,B.D, Questionable Conceptions and Simplistic views about Irrigated Agriculture in India, Indian Journal of Agricultural Economics,Vol:60, pp-1-13*

intensity shows quite variations between the states. It reflects different rates of irrigation development, the kind of irrigation investment, and rainfall distribution. Rapid development of irrigation in Haryana, Punjab, West Bengal and Uttar Pradesh has been accompanied by relatively high changes in cropping intensity. For instance, in Punjab from 127 in 1960 to 186.9 in 2003. The nature of the irrigation development in these northwest areas has had much to do with its impact on cropping intensity. Expansion of tube wells and availability of surface water from snow melt sources outside the monsoon season has enabled the growth of rabi and summer crops. In Bihar, substantial growth of surface irrigation has had no apparent impact on cropping intensity[19] .The expansion of groundwater irrigation will continue to have a very positive impact on cropping intensities (Ibid).

Thus the role of irrigation is being felt more and more to attain self sufficiency in the field of food production and working out of water requirement and irrigation requirement of crops is important both for irrigation project efficiency and crop planning point of views to produce maximum yield per unit of water employed per unit of space and time[20].

xiv. Water Use, Water Productivity and Crop Production in Indian Agriculture

Water productivity means growing more food or gaining more benefits with less water. To feed a growing and wealthier population with more diversified diets will require more water for agriculture on an average annual basis. There is considerable scope for improving physical water productivity, but not everywhere. Increasing water productivity, especially the value produced per unit of water, can be an important pathway for poverty reduction in water productivity (FAO, 2008).

Water is one of the most important inputs is an assured crop production programme in all such areas where crop production suffers due to scarcity and/or irregular distribution of rainfall (Hukkeri,S.B. & Pandey,S.L). The increasing scarcity of water in the arid and semi arid regions is now a well- known problem. The need to produce more food with less water poses vast challenges to reassign existing supplies,

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[19] *R. Srinivasulu (2008), Changing trends of Water Resources in India, An Inter States Analysis ,Focus on Irrigation Sector, The India Economy Review, pp 34-42*
[20] *Lenka,D. (1973), Water requirement of crops in Orissa ,I.A.R.I, Pusa, New Delhi-59*

encourage more efficient use and promote natural resources protection. On-farm water use efficient techniques coupled with improved irrigation management options, better crop mix and suitable cultural practices, genetic make-up and timely socio-economic interventions would help achieving this goal. In water deficit areas, water is more limiting to production than land hence maximizing water productivity, should have higher priority over maximizing yield in the strategies of water management[21].

The literature demonstrates that the water productivity can be increased by optimizing the existing cropping pattern.

The authors intended by this paper that the water productivity can be increased through optimal cropping on a case of Punjab canal. Thus it is possible to substantially increase water productivity through adopting improved irrigation systems, applying sound irrigation management, growing improved crop cultivars and appropriate cropping patterns and cultural practices. Cropping system need to be inherently flexible to take advantage of economic opportunities and/or adapt to environmental realities. It is however, important that these interventions be integrated with full participation of the farmer to develop viable strategies and efficient and sustainable production systems (Ibid). Enhancement of irrigation facilities, efforts are being made to improve the productivity of both irrigated and rainfed agriculture, which at present is low[22].

xv. Water Productivity and Water Saving

Real water saving is defined as the process of reducing non-beneficial water uses and making the water saved available for a more productive use. In situations where water is scarce, reducing non-beneficial uses becomes one of the main ways for reducing water scarcity. Improving water productivity seeks to get the highest benefits from water and hence can be viewed as a major contributor to water saving (Cook et.al,)[23].

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[21] *Hussain,I, et al,(2007),Optimal Cropping Pattern and Water Productivity: A case of Punjab Canal, Journal of Agronomy, Vol:6, pp- 526-532*

[22] *Hazra,C.R. (2002), Water Management for Sustainable Development of Agriculture, Intensive Agriculture, Vol.40,No.7-8*

[23] Cooks et.al, *Agricultural Water Productivity: Issues, Concepts and Approaches Basin Focal Project Working Paper No. 1*

- Real water saving by reducing non-beneficial depletion can be accomplished through:
- Reducing flows to sinks and
- Reducing non-beneficial evaporation.

For example, improving irrigation efficiency is considered to be the most appropriate way to reduce non beneficial depletion and save water. Before this can be done, it is important to understand the water pathways of non-beneficial water use and its re-use. For example seepage losses may be the main way in which shallow groundwater aquifers used for downstream irrigation and domestic water supply are recharged. By failing to take a basin perspective when planning and implementing water interventions, we run the risk of not achieving real water saving and of having a negative impact on water quality, drinking water supply, groundwater balance, and downstream human and ecological users.

Guerra *et al.* (1998) noted that in most cases the arguments regarding water saving do not address other important factors that determine water saving such as the cost of water development and recovery. Increasing water productivity often requires greater use of other resources such as labor, capital and management[24].

Though developing countries depend on both irrigated and rainfed crops to feed their people, much of the increase in food production will need to come from irrigated land. FAO expects that irrigated areas in developing countries could grow by 20 percent by 2030. The most common form of irrigation is surface irrigation in which waters flood fields and sprinkler irrigation, which mimics rainfall. More efficient are localized methods such as drip irrigation, which put water only where it is needed. Rainfed agriculture, which produces more food overall than irrigated agriculture, benefits from practices to maximize the collection of rain water. Even the yield in rainfed areas can be easily doubled with proper management of inputs, especially soil and water (Singh, 2007).

Water harvesting collecting water in structures ranging from small furrows to dams allows the farmers to conserve rainwater and direct it to crops. Water harvesting

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[24] *Guerra, L.C., Bhuiyan, S.I., Tuong, T.P., Barker, R. 1998. Producing More Rice with Less Water from Irrigated Systems, International Rice Research Institute, Manila (Philippines), 19 pp.*

can boost yield two to three times over conventional rainfed agriculture, introducing improved varieties, improved cropping patterns and using minimum tillage methods which conserve water and increase yields (FAO, 2008).

On- farm management and conjunctive use in which good quality water is mixed with poor quality water in different proportions has been found to be very effective in enhancing crop yield. Irrigation with good quality water at sowing or at critical stages (cyclic irrigation) has also been found to be an effective management option. Such practice can also be suitably modified where waste water is available as a source of irrigation near industrial areas or sewage treatment plants (Ibid).

xvi. Ideal Water Use for Sustainable Food Security

The best way out under both water deficit and water surplus situations is optimizing the water use. There is enough of water of sustaining human, animal and plant need, but not human greed. Under water deficit or/land water surplus conditions, by efficient water management with harvesting and recycling of water, replacement o drip, sprinkler, etc., with surface irrigation and regulation of excessive exploitation of ground water, etc., we can achieve the food security at lower cost and with better quality both these being the requirements of WTO[25]

It is estimated that for every Kg. of food grain production one tonne of water is needed and for paddy it is around five tones of water. These grains form the staple human diet and basic food security. Presently (these figures) water productivity do not Seem to be high due to both, the water being available in plenty in irrigated areas, as well as indiscriminate use of water above and underground. But with more than two billion world population estimated by 2030 and dwindling water resources, the water productivity estimates are definitely astonishing and the way out may be enhanced water productivity (Ibid).

[25] *Reddy,P.R, (2007), Paradox of Deficit and Surplus Water: Impact on Food Security, Intensive Agriculture, Vol.40,No.7-8 pp 35-40*

In Andhra Pradesh alone there are 100,00 odd water users association and distributory committees. The Govt. of Andhra Pradesh is successfully running a programme named "Neeru-Meeru" meaning "Water-Yourself" to create awareness in the people with regard to proper use of water in a participatory approach.

Chapter II

Changes in Cropping Patterns between 1980-83 to 2005-06, A state level analysis

Chapter 2

CHANGES IN CROPPING PATTERN BETWEEN 1980-83 & 2005-06: A STATE LEVEL ANALYSIS

2.1 INTRODUCTION

Indian economy is a primarily an agriculture based economy. The growth of other economic sectors and overall economy depends on performance of agriculture to a considerable extent. The current study is contextualized in an environment of increasingly shrinking supply of irrigation that on the one hand, and a stagnating yield in the more developed and irrigated states, on the other. A cropping pattern analysis and its change in the different agro-ecological zones form a basis to understand the efficacy of water-use in these regions.

The cropping pattern in India has undergone a significant change during last 60 years of independence period. The introduction of new technology that is popularly known as green revolution was the major breakthrough in the history of Indian agriculture. This has resulted in phenomenal change in crop economy in terms of cropping pattern and levels of crop production and productivity but on the other hand there has been considerable decline in the growth of area, production and productivity and area under irrigation for the major crops in[1]. In order to augment the growth of agriculture production, adoption of scientific cropping pattern optimally suited to the technological changes is essential.

The present chapter examines the changes in cropping pattern over four point of time i.e.1980—2006. The proportionate share to gross cropped area (GCA) of individual crops and their changes in share of area under major crops has been taken in to consideration while understanding the changes in cropping pattern.

2.2 SPECIFIC OBJECTIVE OF THE CHAPTER

The main emphasis of this chapter is to examine the extent and nature of changes in cropping pattern in India over last 26 years. This study intends to identify that to what extent crop areas are shifting and what crops are emerging as more important crops in

[1] Economic survey 2007-08,Government of India

India in recent periods of time. This study provides an insight of its implication with the crop diversification scenario in different states of India.

This chapter begins with an analysis of the nature and extent of cropping pattern changes across the states which come under the different agro climatic regions in India.

2.3 NATURE AND EXTENT OF CROPPING PATTERNS CHANGES

The nature and extent of cropping pattern changes are assessed for the major crops namely rice, wheat, sugarcane, 'coarse cereals' (jowar, maize and bajra), and fiber crops (jute and cotton), total pulses and total oilseeds are put together. These entire crops for study occupy more than eighty percent of the total area in all most all the agriculture states in India. In all 17 agriculturally states are identified for the analysis. The exercise is carried out in relative terms based on triennum average of area of crops to gross cropped area for the study period. The selected time period is marked by major policies and programmes on agriculture with an expectation that area under various crops have undergone substantial changes after post green revolution period. Crop area shifts during the early eighties represent post-green revolution situation when area under wheat and rice which is more water intensive crop expanded phenomenally in absolute and relative terms not only in the northern parts where irrigation facilities have been improving by the time but to the southern and central regions. The period from mid eighties is characterized by policy changes on oilseed crops which also refer as a less water intensive crops under the technology mission programme and hence expansion of area under several oilseeds. Finally, the period starting from the early nineties holds importance in terms of implementation of major trade liberalization policies, signing up of the WTO and consolidation of phase of rural infrastructure (Bathla: 2006).

2.4 Spatial and Temporal changes in Cropping Patterns in India

Figure: 2.1 Spatial and Temporal Variations of Area under Major Crops in India

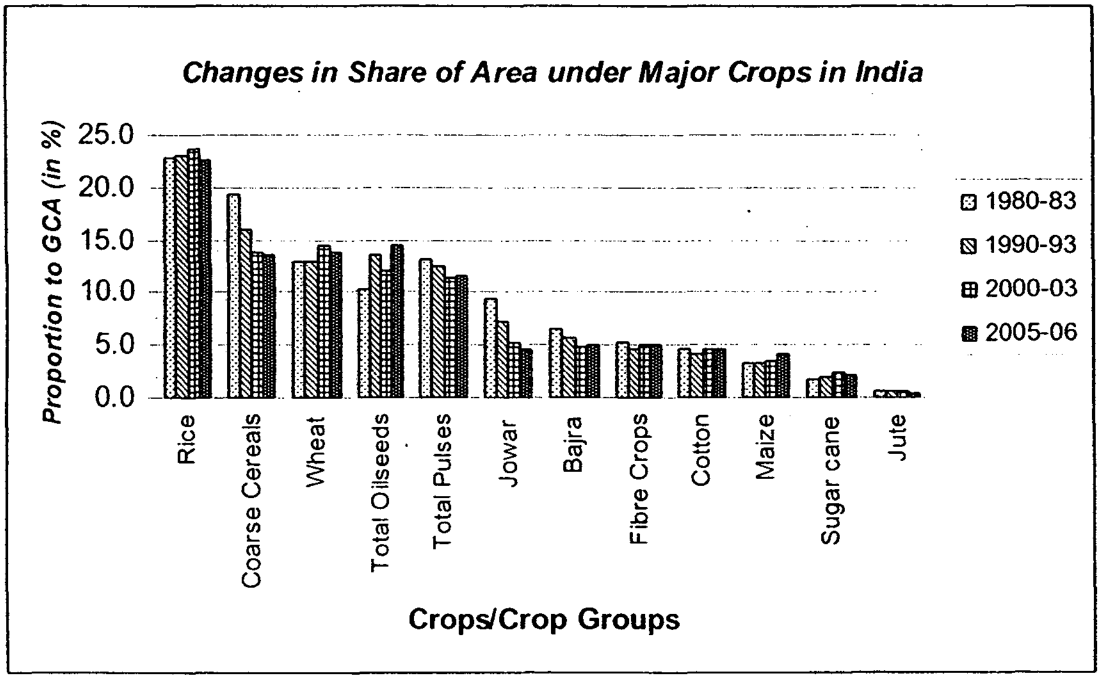


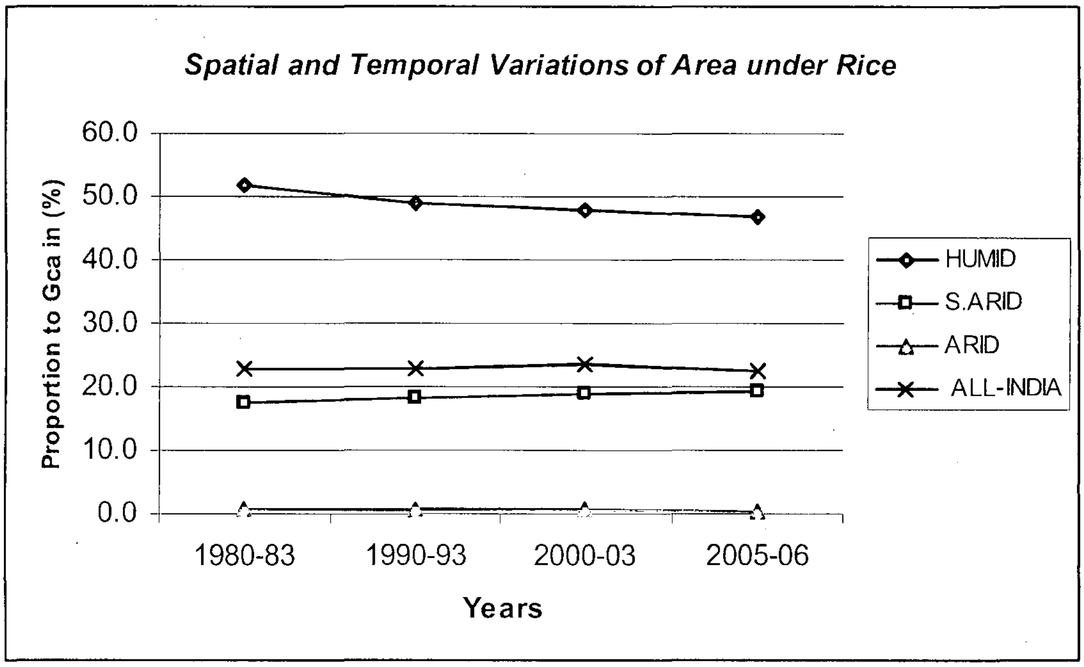
Figure 2.1 reveals that more water intensive crop rice is still dominant major crop in India. It has marginally decreased over the period of time. Coarse cereals have declined significantly bajra noticed marginal decline and maize increased marginally. Moderately water intensive crops like wheat and most water intensive crop like sugarcane increased marginally whereas fiber crops accounted marginal decrease in area share in (GCA).

Least water intensive crops total pulses declined marginally whereas less water intensive crop such as total oilseed accounted moderately increased over the period of time. So in all India level, trend reveals that except wheat, total oilseeds, maize and sugarcane all the crops have registered declining trend over the study period.

2.4 a. Rice

The Table A2.1 to A2.4 in appendix-I provides the analysis of share of area under rice in GCA.

Figure: 2.2 Spatial and Temporal Variations of Area under Rice Across The Different Agro Climatic Regions In India.



There are different trends of area under rice across the different agro-climatic regions. Humid region stands first in its share around 50 percent, while of that semi arid region accounts around 20 percent and arid region around 1 percent over the period of time. There is steadily declining trend of area under rice in the humid region where rice was predominant crop earlier. In the semi-arid region a marginally increasing trend is observed. The point to be noted here is that while the agro-climatic zones traditionally suited for rice is moving away from it, while the one that is water-scarce and dependent on irrigation is moving towards this water-scarce crop.

Humid Region

Figure 2.3 Spatial And Temporal Variations Of Area Under Rice Across The States In Humid Region In India

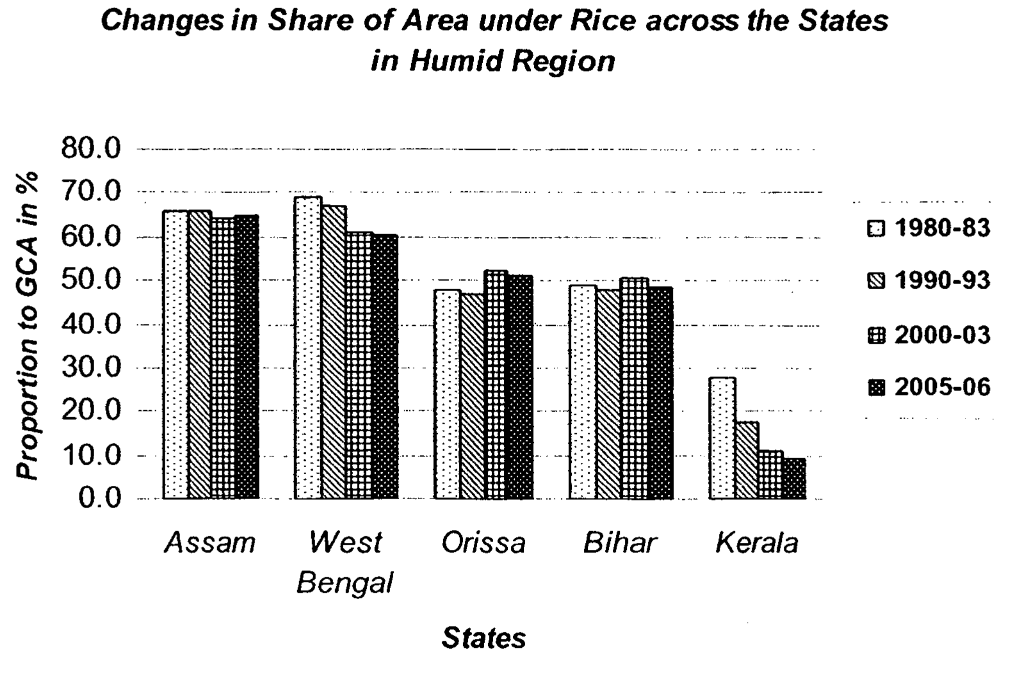


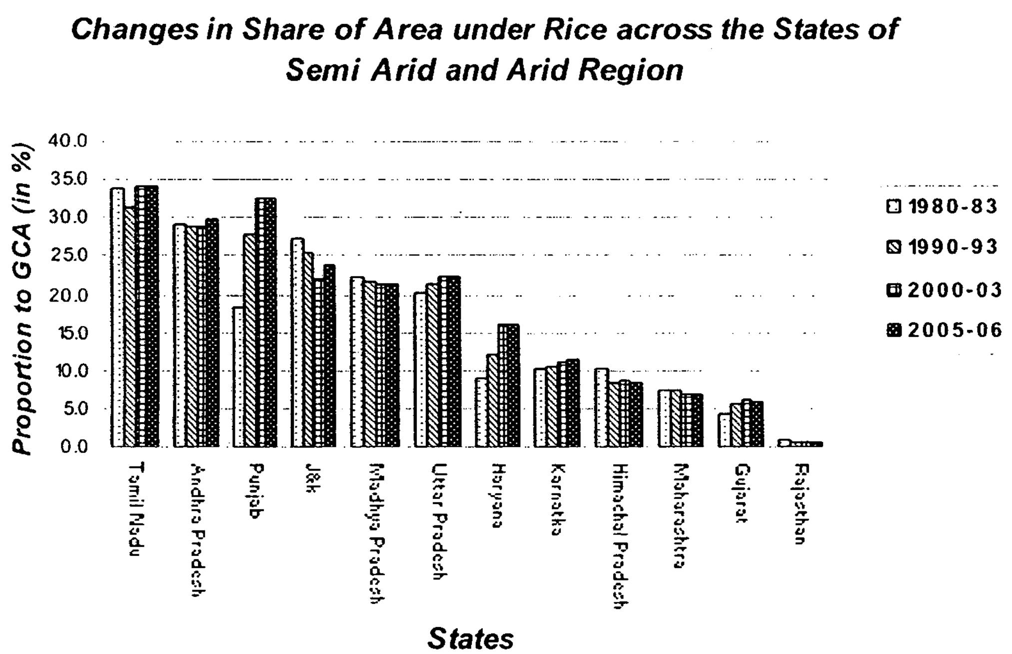
Figure 2.3, however, indicates that rice is still the dominant crop across the states in humid region. Except Kerala it covers more than a half of the respective gross cropped areas for all other states. From 1980-83 to 2005-06, there has been steadily declining change in share of rice in mainly two states i.e. Kerala and West Bengal. Kerala has lost a one third of the share of rice to other crops, while in West Bengal the area under rice has dropped by 10 percent since 1980-83. In Assam and Bihar too there is a marginal decline in the share of area under rice.

So in the states dominated by humid agro-climate, only Orissa has experienced moderate increase.

Semi Arid and Arid Regions

Semi arid region accounts around 20 percent average of rice area to (GCA). From Figure 2.4, it can be observed that in most of the states having a largely semi-arid agro-climatic environment, the share of rice has gone up marginally since 1980-83 to recent years.

Figure 2.4 Spatial and Temporal Variations of Area under Rice Across the States Semi Arid and Arid Agro Climatic Regions in India



There is wide spatial variation among these states, however, in terms of the share of area of rice. While Tamil Nadu, Andhra Pradesh and Punjab, has a significant portion of area under rice,, in the arid state of Rajasthan (>1 percent) followed by the semi arid states of Gujarat, Maharashtra and Himachal Pradesh rice accounts for a small share in the crop basket in terms of its area.

Punjab, Haryana & Uttar Pradesh have experienced the significantly increasing trend, while in the other semi-arid arid states the crop has decreased in importance. These three states have overall accounted for the increasing trend of rice for the semi-arid states.

Table No: 2.1 Changes in Share of Area of Major Crops across States Classified By Agro-Climatic Zones (1980-83 to2005-06)

Crops	Regions	Marginal Increase (Up to 2%)	Marginal Decrease (Up to 2 %)
Rice	Humid	-	Assam, Bihar
	Semi Arid and Arid	Gujarat, Karnataka, Andhra Pradesh and Tamil Nadu	Rajasthan, Madhya Pradesh, Maharashtra and HP
	Rice	**Moderate Increase (2 to 5 %)**	**Moderate Decrease (2 to 5 %)**
	Humid	Orissa	
	Semi Arid and Arid	Uttar Pradesh	Jammu and Kashmir
	Rice	**Significant Increases (More than 5 %)**	**Significant Decreases (More than 5 %)**
	Humid	-	Kerala and West Bengal
	Semi Arid and Arid	Punjab and Haryana	-
Wheat	**Wheat**	**Marginal Increase (Up to 2%)**	**Marginal Decrease (Up to 2 %)**
	Humid	West Bengal	Assam, Orissa

	Semi Arid and Arid	Gujarat, Himachal Pradesh And Punjab	Karnataka, Maharashtra, Madhya Pradesh, Rajasthan and Tamil Nadu
	Wheat	**Moderate Increase (2 to 5 %)**	**Moderate Decrease (2 to 5 %)**
	Humid	-	-
	Semi Arid & Arid	Jammu and Kashmir	-
Wheat	**Wheat**	**Significant Increase (More than 5 %)**	**Significant Decrease (More than 5 %)**
	Humid	Bihar	-
	Semi Arid & Arid	Haryana and Uttar Pradesh	-
Coarse Cereals	**Coarse Cereals**	**Marginal Increase (Up to 2%)**	**Marginal Decrease (Up to 2 %)**
	Humid	Bihar and Kerala	Orissa, Assam and West Bengal
	Semi Arid & Arid	Himachal Pradesh and Jammu and Kashmir	-
	Coarse Cereals	**Moderate Increase (2 to 5 %)**	**Moderate Decrease (2 to 5 %)**

	Humid	-	-
	Semi Arid & Arid	-	Tamil Nadu, Punjab, Uttar Pradesh and Karnataka
	Coarse Cereals	**Significant Increase (More than 5 %)**	**Significant Decrease (More than 5 %)**
	Humid	-	-
	Semi Arid & Arid	-	Andhra Pradesh, Maharashtra, Gujarat, Haryana, Madhya Pradesh and Rajasthan
	Fibre Crops	**Marginal Increase (Up to 2%)**	**Marginal Decrease (Up to 2 %)**
	Humid	Orissa and Bihar	West Bengal, Assam, Kerala,
Fibre Crops	**Semi Arid & Arid**	Rajasthan	Jammu and Kashmir, M.P. Himachal Pradesh, Tamil Nadu, Uttar Pradesh
	Fibre Crops	**Moderate Increase (2 to 5 %)**	**Moderate Decrease (2 to 5 %)**
	Humid	-	-
Fibre	**Semi Arid & Arid**	Andhra Pradesh, Haryana, and Gujarat	Punjab

Crops	Fibre Crops	Significant Increase (More than 5 %)	Significantly Decrease (More than 5 %)
	Humid	-	-
	Semi Arid & Arid		Karnataka
	Sugarcane	Marginal Increase (Up to 2%)	Marginal Decrease (Up to 2 %)
	Humid	-	Assam, Bihar, West Bengal Kerala and Orissa
Sugar Cane	Semi Arid & Arid	Gujarat, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra	Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan
	Sugarcane	Moderate Increase (2 to 5 %)	Moderate Decrease (2 to 5 %)
	Humid	-	-
Sugar cane	Semi Arid and Arid	Tamil Nadu and Uttar Pradesh	-
	Total Pulses	Marginal Increase (Up to 2%)	Marginal Decrease (Up to 2 %)
	Humid	-	Assam and Kerala

Total Pulses	Semi Arid & Arid	Andhra Pradesh, Karnataka and Maharashtra	Madhya Pradesh, Tamil Nadu and Uttar Pradesh
	Total Pulses	**Moderate Increase (2 to 5 %)**	**Moderate Decrease (2 to 5 %)**
	Humid	-	West Bengal, Bihar
	Semi Arid & Arid	-	Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan
	Total Pulses	**Significant Increase (More than 5 %)**	**Significant Decrease (More than 5 %)**
	Humid	-	Orissa
	Semi Arid & Arid	-	Haryana
Total Oilseeds	**Total Oilseeds**	**Marginal Increase (Up to 2%)**	**Marginal Decrease (Up to 2 %)**
	Humid	-	Assam ,Kerala and Bihar
	Semi Arid & Arid	-	Himachal Pradesh
	Total Oilseeds	**Moderate Increase (2 to 5 %)**	**Moderate Decrease (2 to 5 %)**
	Humid	West Bengal	

	Semi Arid & Arid	Gujarat	Jammu and Kashmir, Punjab Tamil Nadu
	Total Oilseeds	**Significant Increase (More than 5 %)**	**Significant Decrease (More than 5 %)**
	Humid	-	Orissa
	Semi Arid & Arid	Rajasthan, Madhya Pradesh, Karnataka, Haryana, Andhra Pradesh and Maharashtra	Uttar Pradesh

Sources: Computed from

(a).Statistical Abstract of India, 1980-83, 90-91, 2000-03, 2006

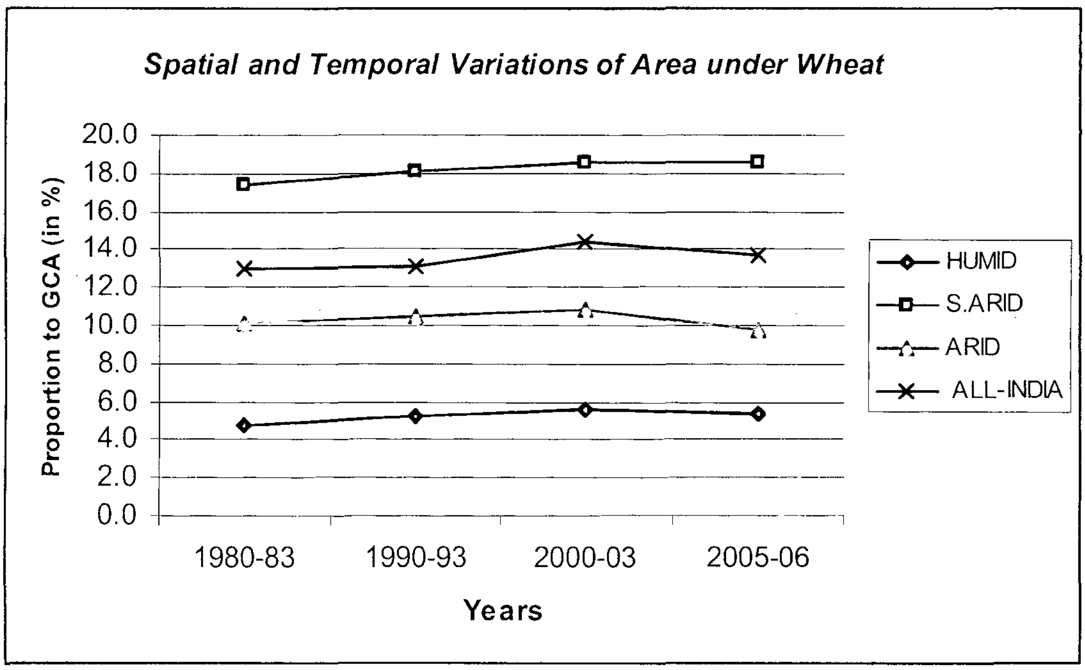
(b). Year book of Area, Production and Yield of Principal crops in India, Ministry of Agriculture

(c). Agricultural Statistics of Glance, Ministry of Agriculture for the period of study.

2.4 b. Wheat

Wheat is the second major individual crop next to rice in India. (The table number: A 2.1 to A 2.4 in Appendix 2.1) provide changes in the share of area under wheat in (GCA). It has accounted for around 14 percent of share in GCA in India during the period 1980-2006. The trends in share of area under wheat in (GCA) are presented in Figure 2.5.

Figure 2.5: Spatial and Temporal Variations of Area under Wheat across the Different Agro Climatic Regions in India



In Figure 2.4 we observe that semi-arid region stands first with its share around 18 percent which is above from the national average. This is followed by arid region (around 10 percent), and humid region accounts the least (around less than 6 percent) share of are in their respective GCAs in the same period. A steadily but slightly increasing trend both in the semi arid region and in humid region is noticeable within the period under study. Overall, we observed that from 1980-83 to 2000-03, there had been an increasing trend for wheat for the semi arid region, and while for humid region and arid regions, and the increase was restricted till 2000-03 after which the relative growth of the crop got stagnated.

Humid Regions

Figure 2.6: Spatial and Temporal Variations of Area under Wheat across the States in Humid Agro Climatic Region in India.

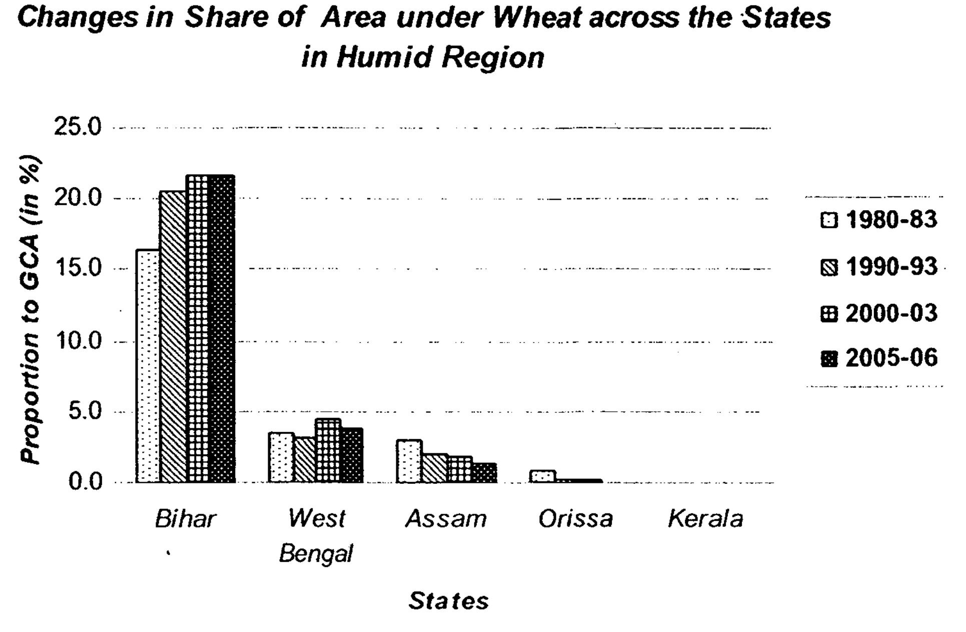
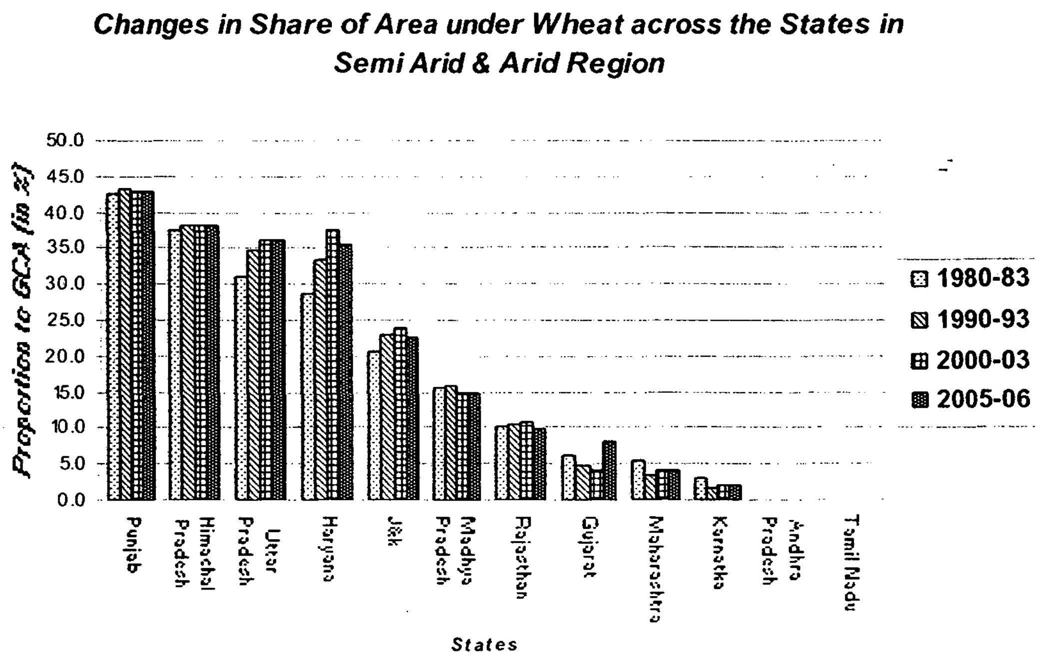


Figure 2.6: reveals that in the states primarily under humid agro-climatic regimes, there is no significant proportion of wheat over the period of study except in Bihar. In recent years in the state, wheat accounts more than 20 percent, which is above the national average and this has been achieved through an increasing trend over the study period. In Assam and Orissa, there is marginal decreasing trend of share in wheat.

Semi Arid Regions

In semi arid and arid regions, wheat is dominant crop in Punjab following by states like Himachal Pradesh, Uttar Pradesh and Haryana. It accounts more than 1/3 area of its (GCA) share in these states.

Figure 2.7: Spatial and Temporal Variations of Area under Wheat across the States in Semi Arid and Arid Agro Climatic Regions in India

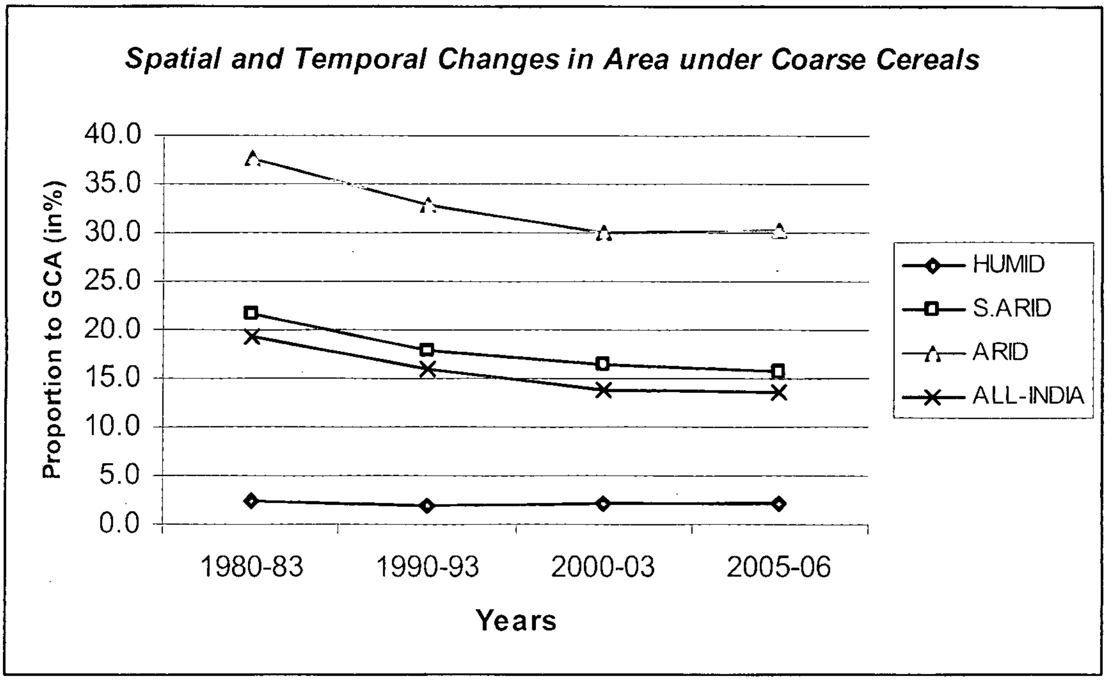


While a significantly increasing trend has been observed in Uttar Pradesh and Haryana, a moderately increasing trend is visible for Jammu and Kashmir; Gujarat, Himachal Pradesh and Punjab have experienced a marginally increasing trend. On the other hand, either a stagnant or a moderately decreasing trend has been observed for rest of the states.

2.4 c. Coarse Cereals:

The tables A 2.1 to A 2.4 in appendix-2.1 provide the scenario of the share of area under coarse cereals in (GCA). Coarse cereals account for a considerable share ranging from around 17 percent in 1980-83 to around 14 percent in 2005-06 in India.

Figure 2.8: Spatial and Temporal Variations of Area under Coarse Cereals across the Different Agro Climatic Regions in India.

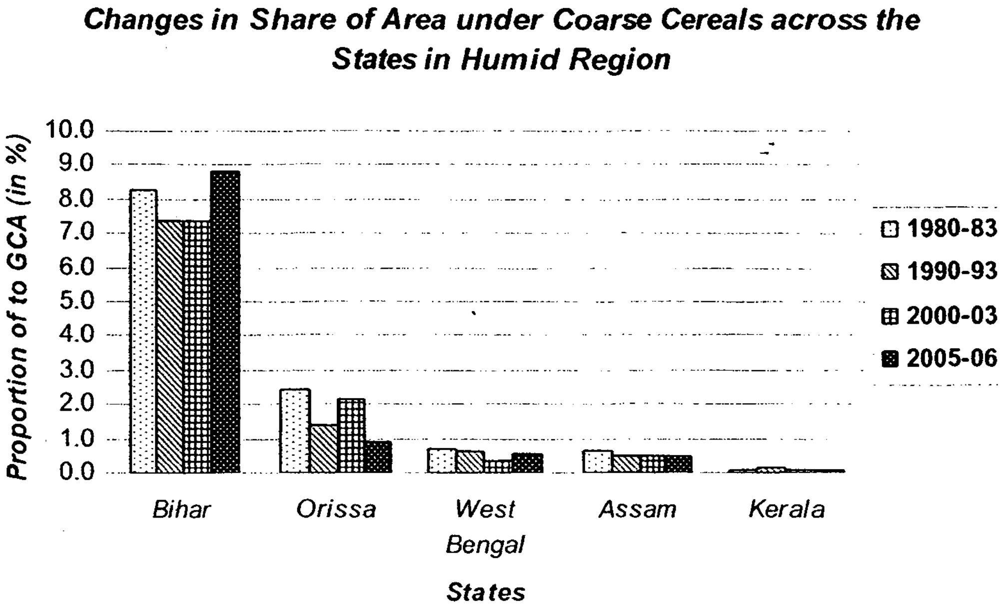


Coarse cereals which has low water requirement and is often grown in unirrigated conditions, is understandably grown most extensively in the primarily arid region where around 30 percent of the GCA is occupied by the coarse cereals, followed by semi arid. There is very negligible proportion of coarse cereals in humid region. Trends are showing that there has been gradual declining of the proportion of coarse cereals to (GCA) for both the regions arid and semi arid regions whereas humid region remain constant.

Humid Region

In humid region, all the states have proportion of coarse cereals to GCA below the national average. Bihar is the only state that accounts for 9 percent share with a marginally increasing trend; rest of the states comprise less than 2 percent share to (GCA) with steadily decreasing trend.

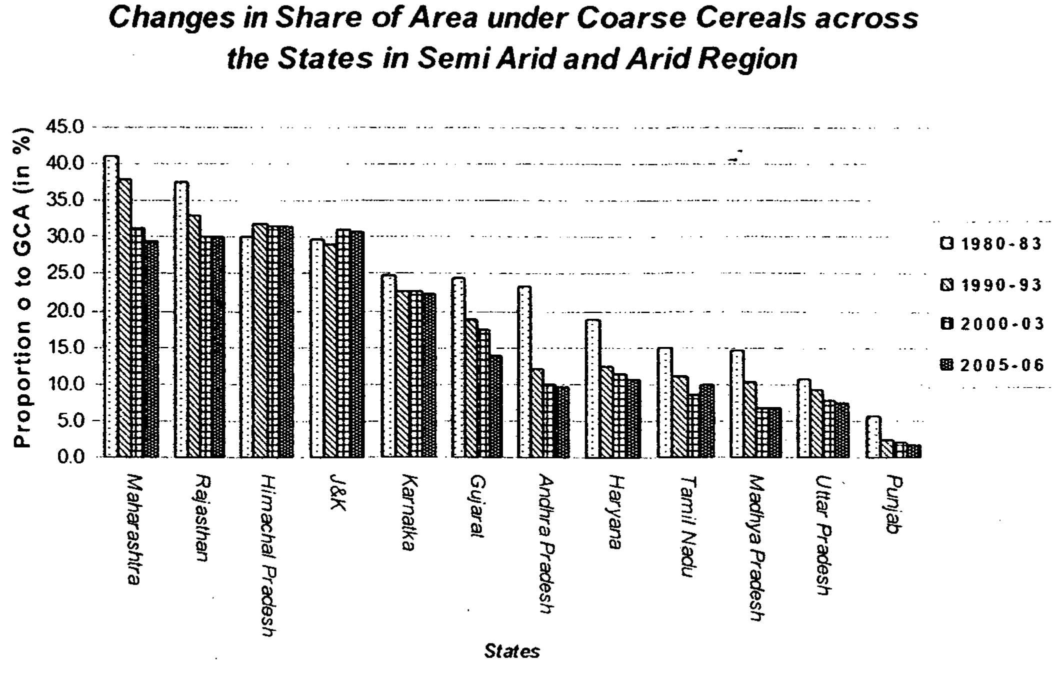
Figure 2.9: Spatial and Temporal Variations of share of Area under Coarse Cereals across the Different Agro Climatic Regions in India



Semi Arid Region:

There is gradually fall in area under coarse cereals in almost the entire semi arid and arid region. There is a continuous decline from the middle of the eighties and their relative share reduced significantly from around 19 percent to 13 percent in India during1980 to 2006. However Himachal Pradesh, Jammu and Kashmir, which comprises more than 30 percent share in their respective GCA, have experienced a sizable increase in the share of maize.

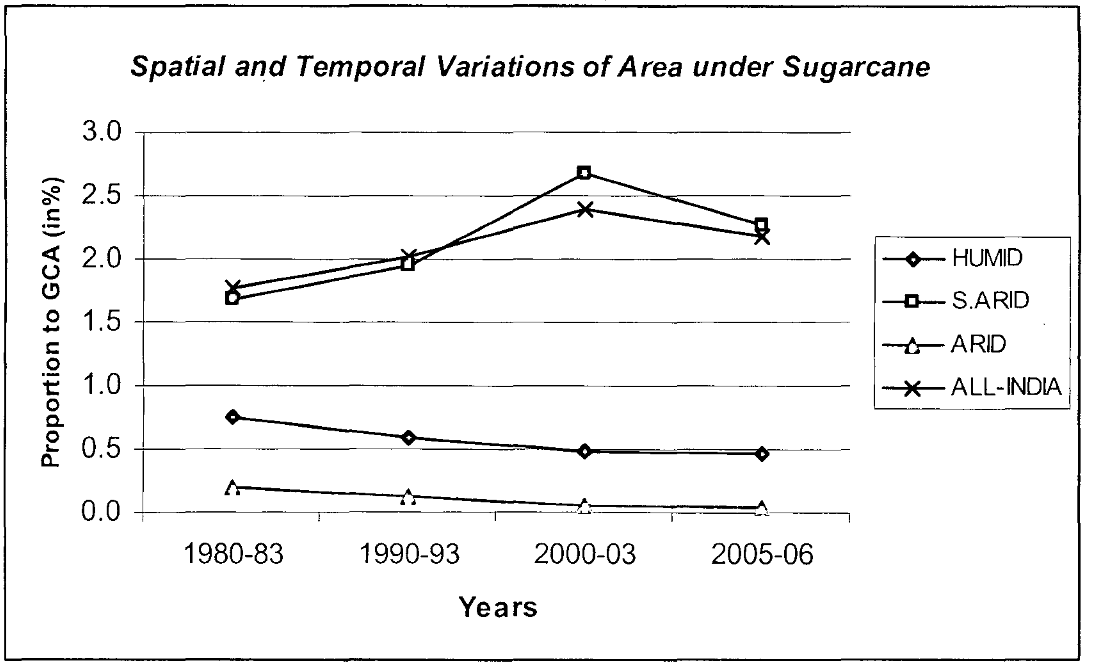
Figure 2.10: Spatial and Temporal Variations of Area under Coarse Cereals in Semi Arid and Arid Agro Climatic Regions in India



Maharashtra stands first in the ranking order because Maharashtra is the only state which occupy highest share of jowar compare to other states and comprises around 1/3 of its share to (GCA) but it has been continuously declining its relative share to (GCA) at present time. Same is happened with Rajasthan in terms of relative share of bajra. All these states have witnessed a fall in the share in recent years i.e. in post liberalization period (1990-03 to 2006).

2.4 d. Sugarcane

Figure 2.11: Spatial and Temporal Variations of Area under Sugarcane across Different Agro Climatic Regions in India

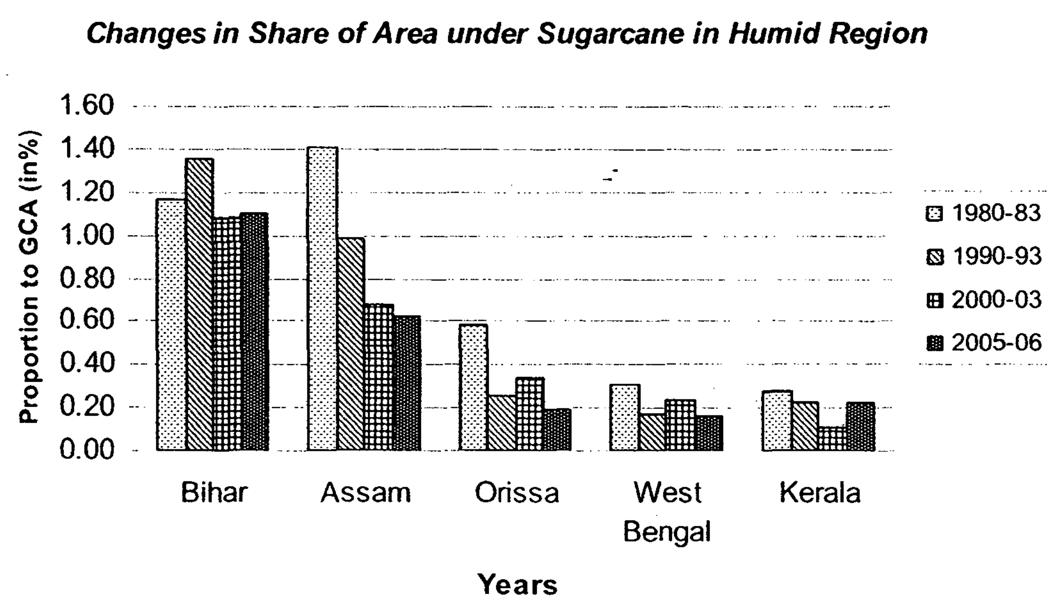


Semi-arid region stands first followed by humid and arid region. There has been consistently increasing trend of sugarcane in semi arid region but in recent period of time it reveals fall in area under sugarcane this is because except two states like Tamil Nadu and Uttar Pradesh all semi arid states registered declining trend in share of sugarcane with respect to GCA. Humid and arid regions reveal consistently declining trend over the study period.

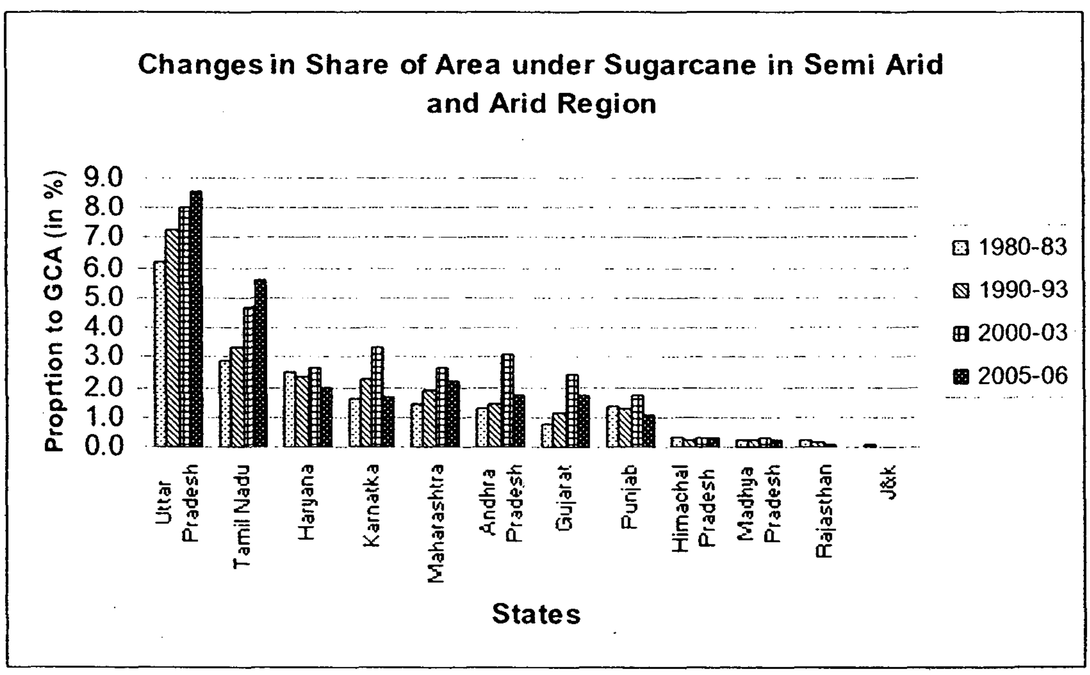
Humid Region:

All humid states reveal marginally declining trend in share area of sugarcane over the period of time.

Figures 2.12 and 2.13: Spatial and Temporal Variations of Area under Sugarcane in Humid, Semi Arid and Arid Agro Climatic Regions in India



Semi Arid and Arid Region



The semi arid states like Gujarat, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra experienced marginal increases in area share of sugarcane whereas states such as Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan noticed marginal declines.

Tamil Nadu and Uttar Pradesh have experienced moderate increase in area under sugarcane in (GCA).

2.4 e. Fibre Crops

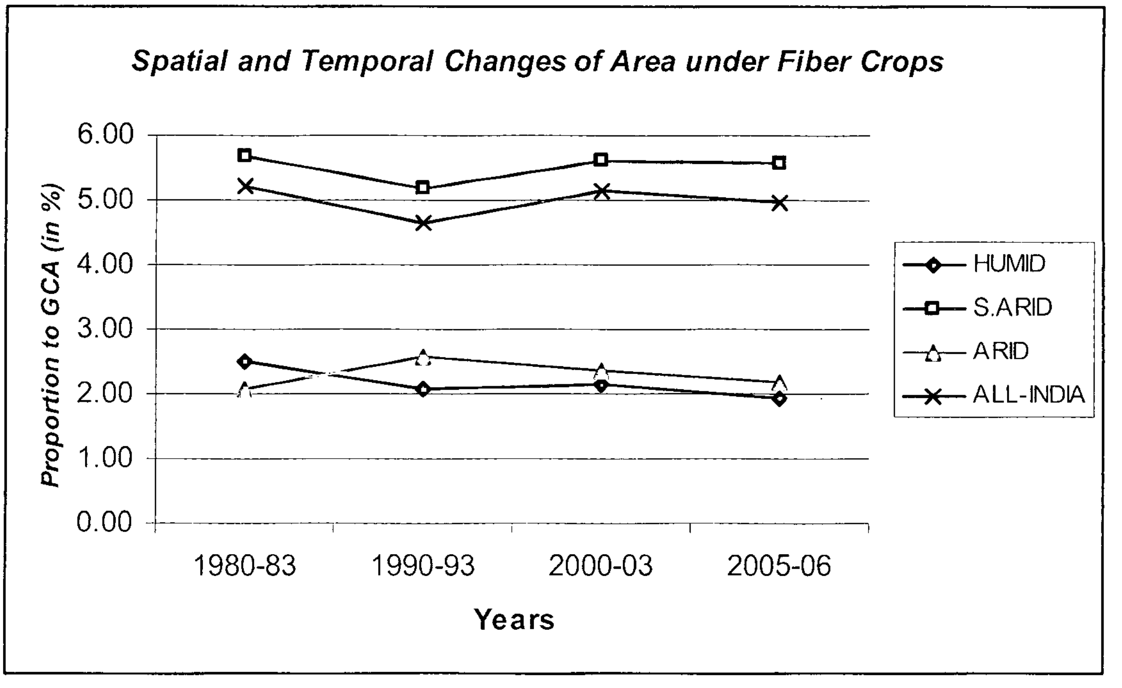


Figure 2.14: Spatial and Temporal Variations of Area under Fibre Crops across the different Agro Climatic regions in India.

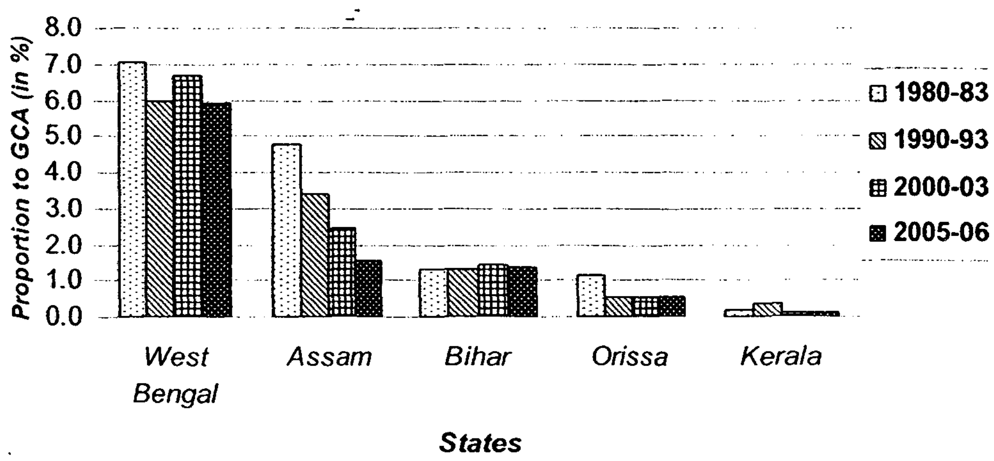
Fiber crops stand first and remain stagnant in semi arid region. It has been slightly decreasing in humid region. In recent period of time it is steadily declining for both arid and humid regions.

Humid Region

In humid region, states like Orissa and Bihar it has increased marginally and for states such as West Bengal, Assam, Kerala marginal gains in area share has been observed.

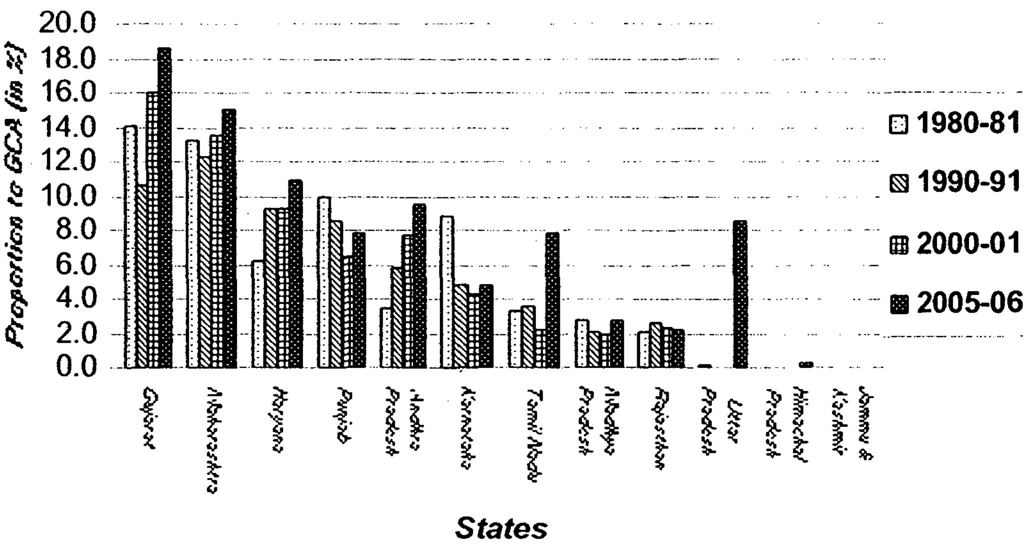
Figures 2.15 and 2.16: Spatial and Temporal Variations of Area under Fibre Crops across Different States in Humid, Semi Arid and Arid Agro Climatic Regions in India.

Changes in Share of Area under Fibre Crops in Humid Region



Semi Arid and Arid Regions

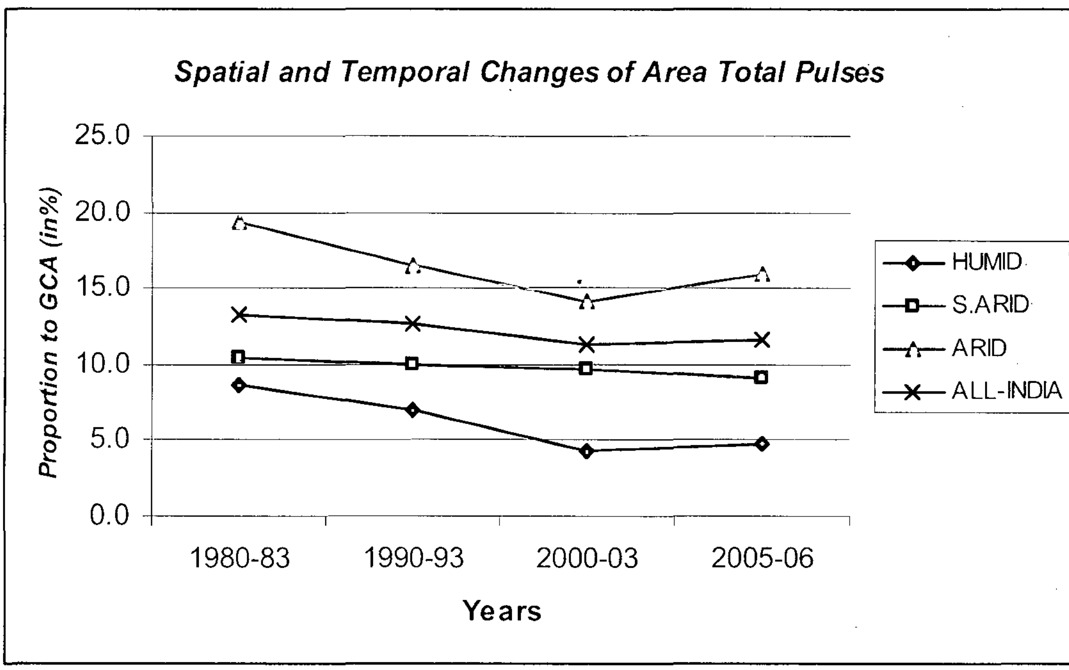
Changes in Share of Area under Fibre Crops across the States of Semi Arid and Arid Region in India



In semi arid region, the area share of fibre crops significantly decreased in Karnataka and moderately declined in Punjab whereas rest of the states such as Jammu and Kashmir, Madhya Pradesh, Himachal Pradesh, Tamil Nadu and Uttar Pradesh registered marginally decline. The arid state experienced marginal increase while Andhra Pradesh, Haryana, and Gujarat noticed moderate increases.

2.4 e. Total Pulses

Figure 2.17: Spatial and Temporal Variations of Area under Total Pulses across Different Agro Climatic Regions in India



Pulses have been accounting for considerable amount of the share ranging from around 11 percent in 1980-83 to around 8 percent in 2006-07 in India. The data reveals the fact that at the all India level, there is a marginal fall in the share of area under pulses in GCA in recent years. The trends of the share of area under pulses in (GCA) are presented in Figure 2.17.

Arid region accounts the largest share around 17 percent in (GCA) share followed by semi-arid which account 10 percent than lastly humid region comes with its least share.

There is a steadily marginal fall in the share of area under pulses in (GCA) in all the regions but from 2001 to recent period, the arid region is gaining with a marginal increase in pulses.

Humid Region

Figure 2.18: Spatial and Temporal Variations of Area under Total Pulses across Different States in Humid Agro Climatic Region in India

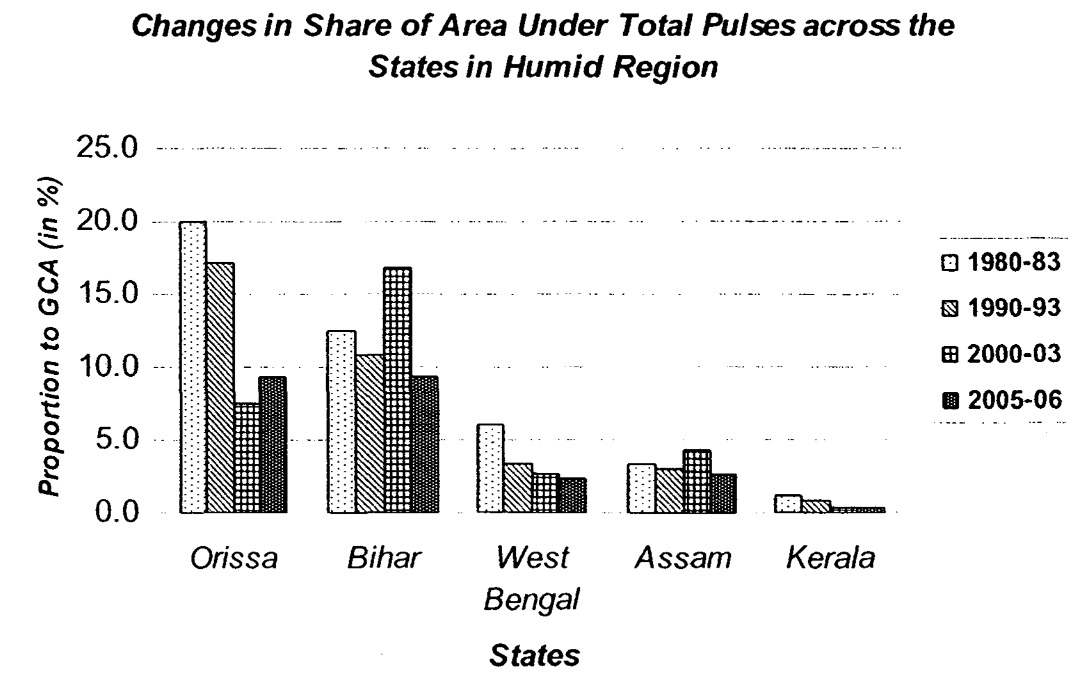
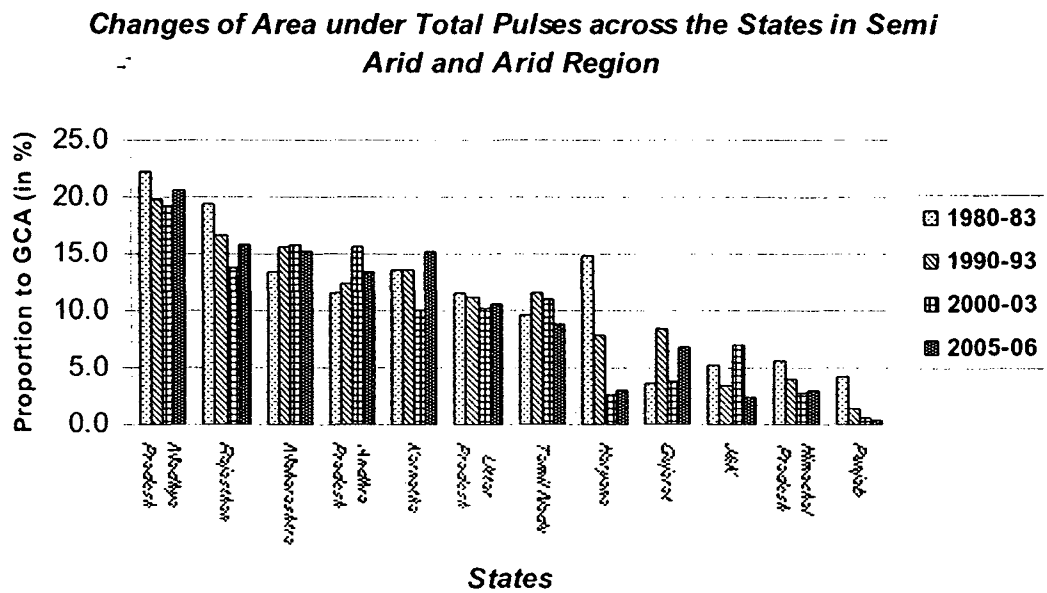


Figure 2.18: indicates that Orissa accounts the significant share in total pulses but it has continuously reduced its relative share significantly from 20 percent to 9 percent. The states like West Bengal, Assam and Kerala do not have significant proportion of area under total pulses. All these states are experiencing fall in relative share of total pulses. So all the states which come under the humid region experienced dramatically fall in relative share of total pulses in (GCA).

Semi arid and Arid Region

Figure 2.19: Spatial and Temporal Variations of Area under Total Pulses across Different States in Arid and Semi Arid Agro Climatic Regions in India.



The Central semi-arid region, i.e., Madhya Pradesh has always accounted for the highest share of area under total pulses (around 20 percent) in the period between 1980-2006. In terms of importance of pulses, Madhya Pradesh is followed by arid states such as Rajasthan and other states in semi arid regions like Maharashtra, Andhra Pradesh and Karnataka. All these states also account for considerable share in 1980-2006.

The falling trend of the share of area under pulses in (GCA) in recent years can be witnessed among all the states except Andhra Pradesh, Karnataka, Maharashtra and Gujarat which has experienced marginal increases and or a stagnant trend.

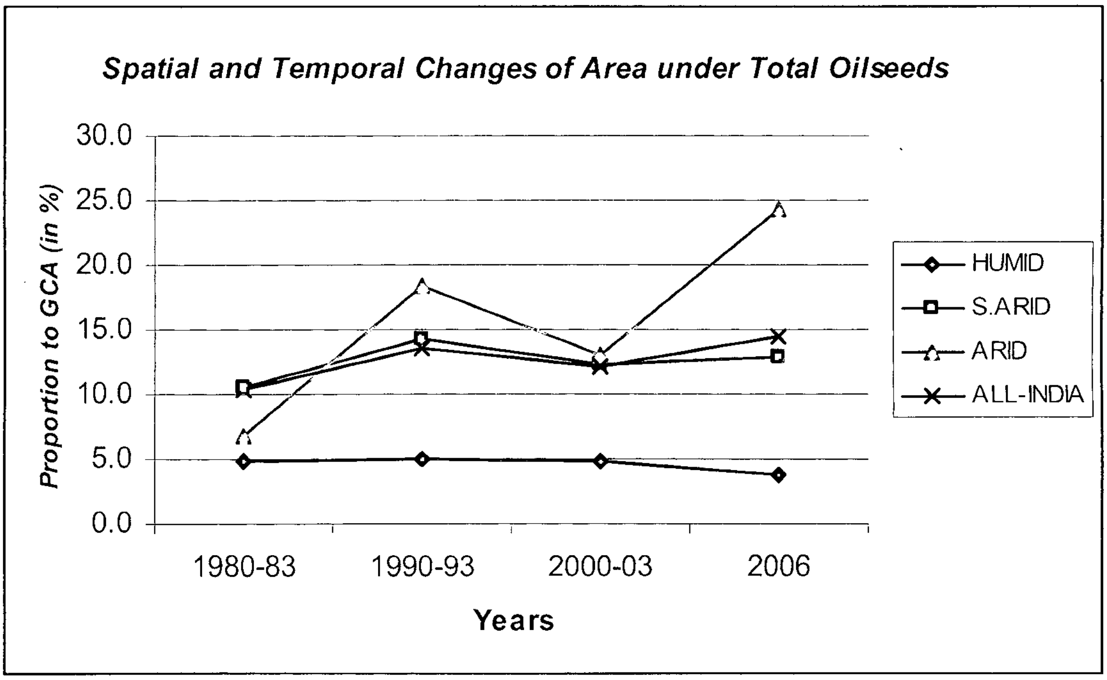
States such as Madhya Pradesh, Tamil Nadu and Uttar Pradesh witnessed marginal fall while Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan registered moderate decreases in area share. Haryana has experienced significant decrease in area share. So in majority of the states total pulses witnessed declining trend but some increases have been observed in arid and humid region from 2001.

2.4 F. Total Oilseeds

Table A-2.1 to A-2.4 reveals the spatial and temporal variations of the share of area under oil seeds in (GCA). Oil seeds accounts for considerable share of area which is around 8 .6 percent to around 11 percent at all India level during 1980-2006. The group showed a gradual increase in mid eighties which can be attributed to the major government program known as the "technological mission of oilseeds" in mid eighties.

The trends in the share of area under oil seeds in (GCA) are presented in Figure 2.19.

Figure 2.20: Spatial and Temporal Variations of Area under Total Oilseeds across Different Agro Climatic regions in India



The arid region has made significant progress in terms of area of total oilseeds over the period of time. Initially it occupied only 6 percent share but increased remarkably to 24 percent in 2006. To some extent the increase can be attributed to policy changes on oilseeds crops under the technology mission programme and favorable price support systems that were launched. The states in the semi arid region reveal a fluctuating trend though overall it has increasingly marginally in these states. Humid region registered a stagnating trend till 2003 which now is declining in the recent years.

Humid Region

Figure 2.21: Spatial and Temporal Variations of Area under Total Oilseeds across Different States in Humid Region in India

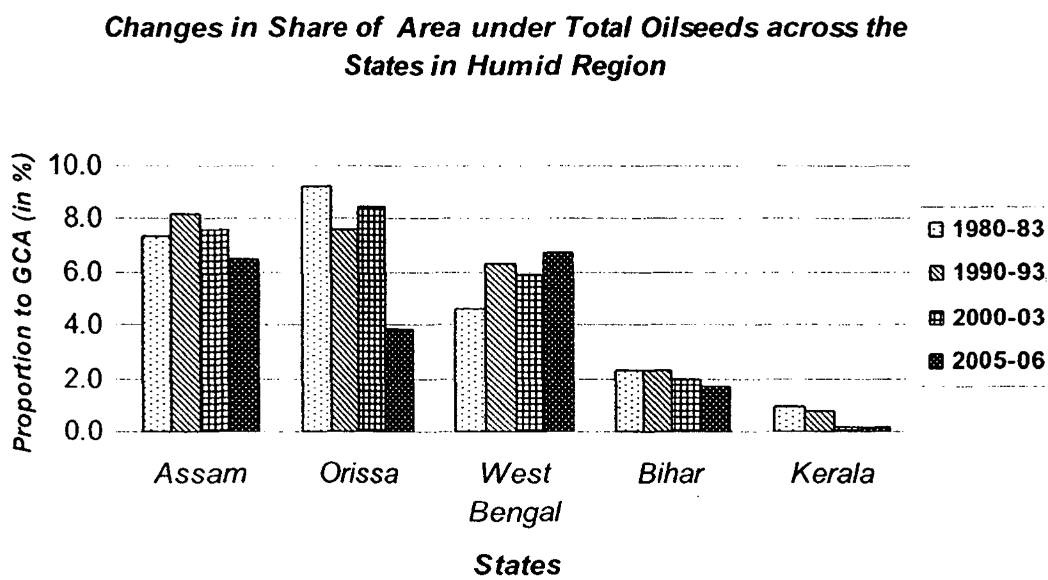
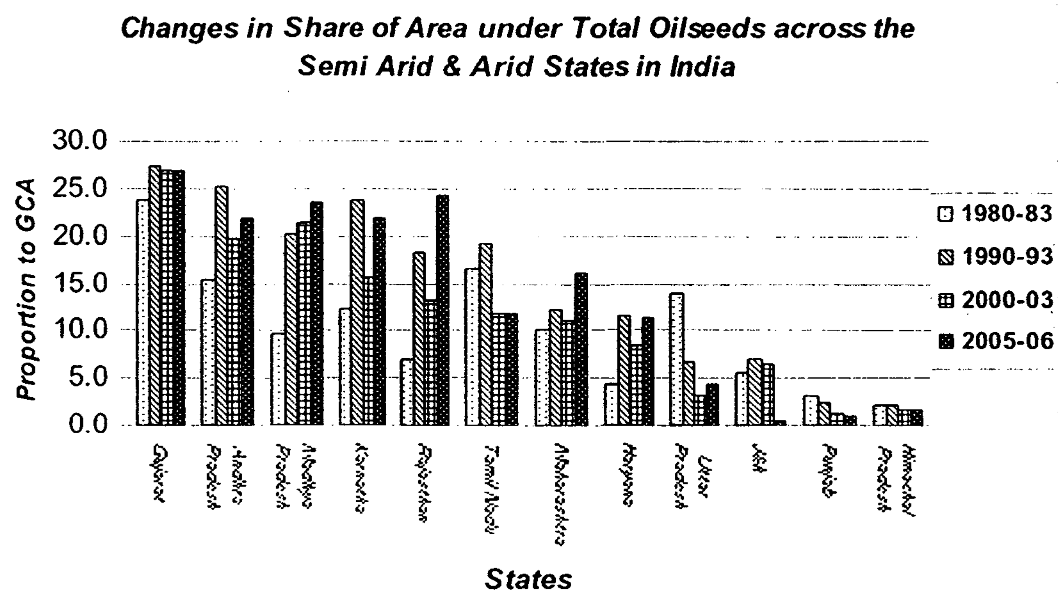


Figure 2.21 depicts that states in the humid region except West Bengal, all the states experienced a declining trend.

Semi-Arid and Arid Region

Gujarat accounts for the highest proportion of total oilseed in terms of relative area in (GCA) which experiencing increasing trend as well. Andhra Pradesh has also had a cropping pattern in which proportion of groundnuts have dominated throughout the study period.

Figure: 2.22: Spatial and Temporal Variations of Area under Total Oilseeds across Different States in Arid and Semi Arid Agro Climatic Regions in India



The Central region Madhya Pradesh (around 23 percent) and Karnataka (around 22 percent) have significant share of area under oilseeds in GCA during 1980-2006. Rajasthan arose from 6 percent to 24 percent; In Maharashtra and Haryana too, the importance of oilseeds has increased, though not at the same level. Himachal Pradesh experienced marginal decline while Jammu and Kashmir, Punjab, and Tamil Nadu noticed moderate decrease in area share of oilseeds. Significant decline in Uttar Pradesh amounting to 10 percent of the relative share of oilseeds is noticed.

Major findings of section 2.4

Figure 2.23: Share of Area under All Different Major Crops in Humid Region

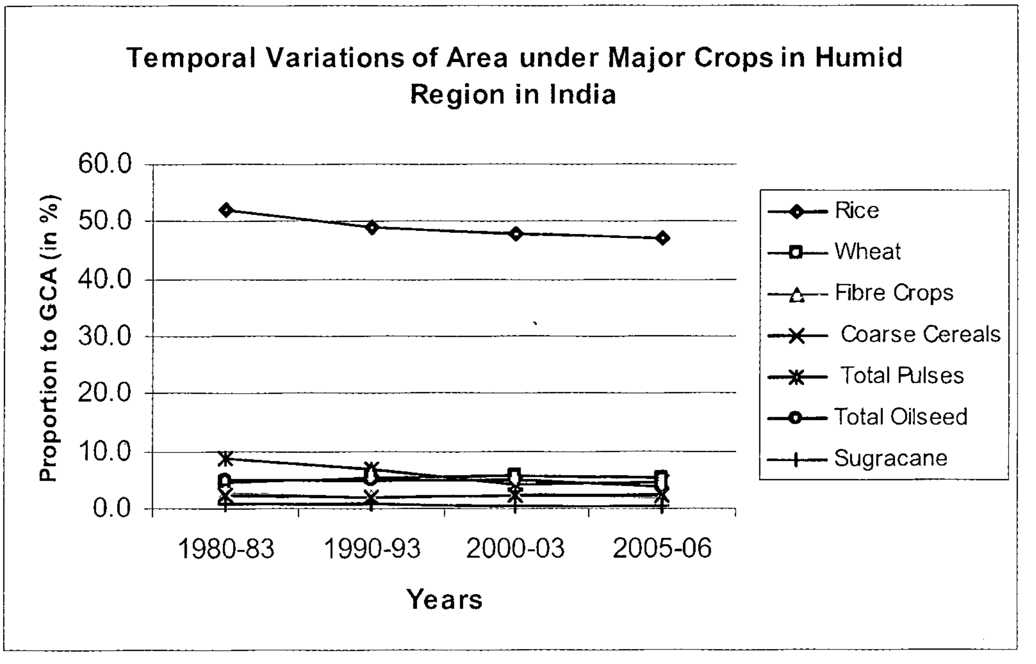
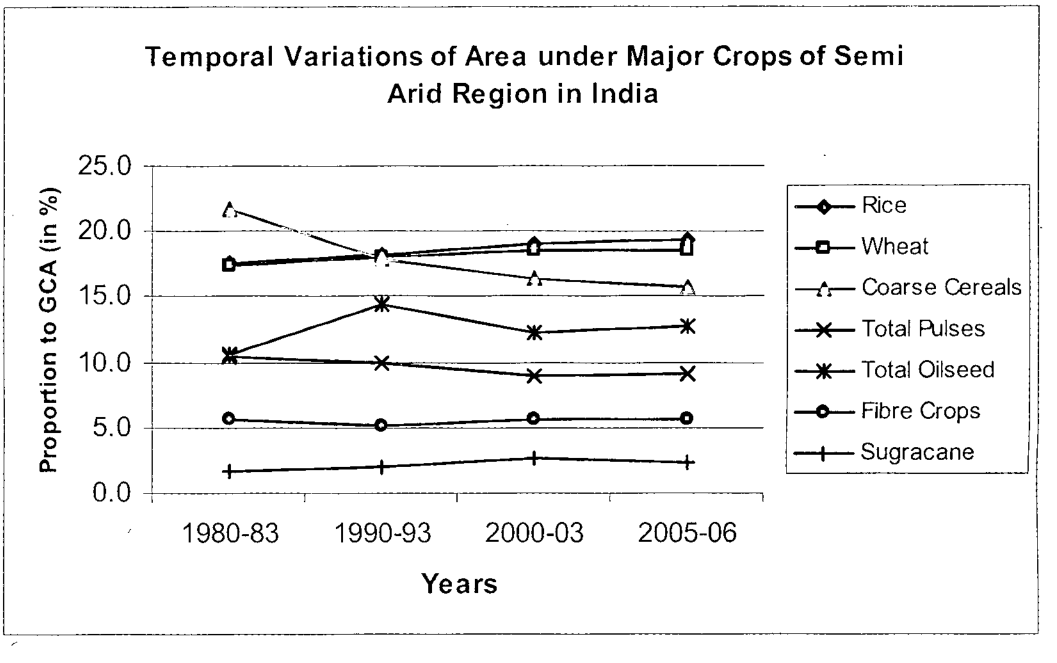


Figure 2.24: Share of Area under All Different Major Crops in Semi Arid Region



The broad findings of the preceding section are captured in Figures 2.23 to 2.24. It is observed that in the states having a primarily humid climate and with tradition dominance in rice due to the water availability regime, the area under rice has fallen visibly. The importance of wheat has somewhat increased, primarily due to the trend in Bihar. On the other hand, in the states dominated by a semi-arid regime, the rice wheat cropping pattern has emerged as a more important combination, clearly replacing coarse cereals and pulses. Though such trend is visible in areas that are supported by irrigation, which is what would be revealed from the subsequent chapter, there is no doubt that overall in India, the water-scarce areas are moving towards a water-intensive cropping system, while the reverse is the case in the humid regions. In the arid region, coarse cereals have given way to oilseeds, and though there is some difference in the water requirement of these two sets of crops, the difference is not so visible.

2.5 Crop Diversification, Crop Combinations and Cropping pattern changes in India

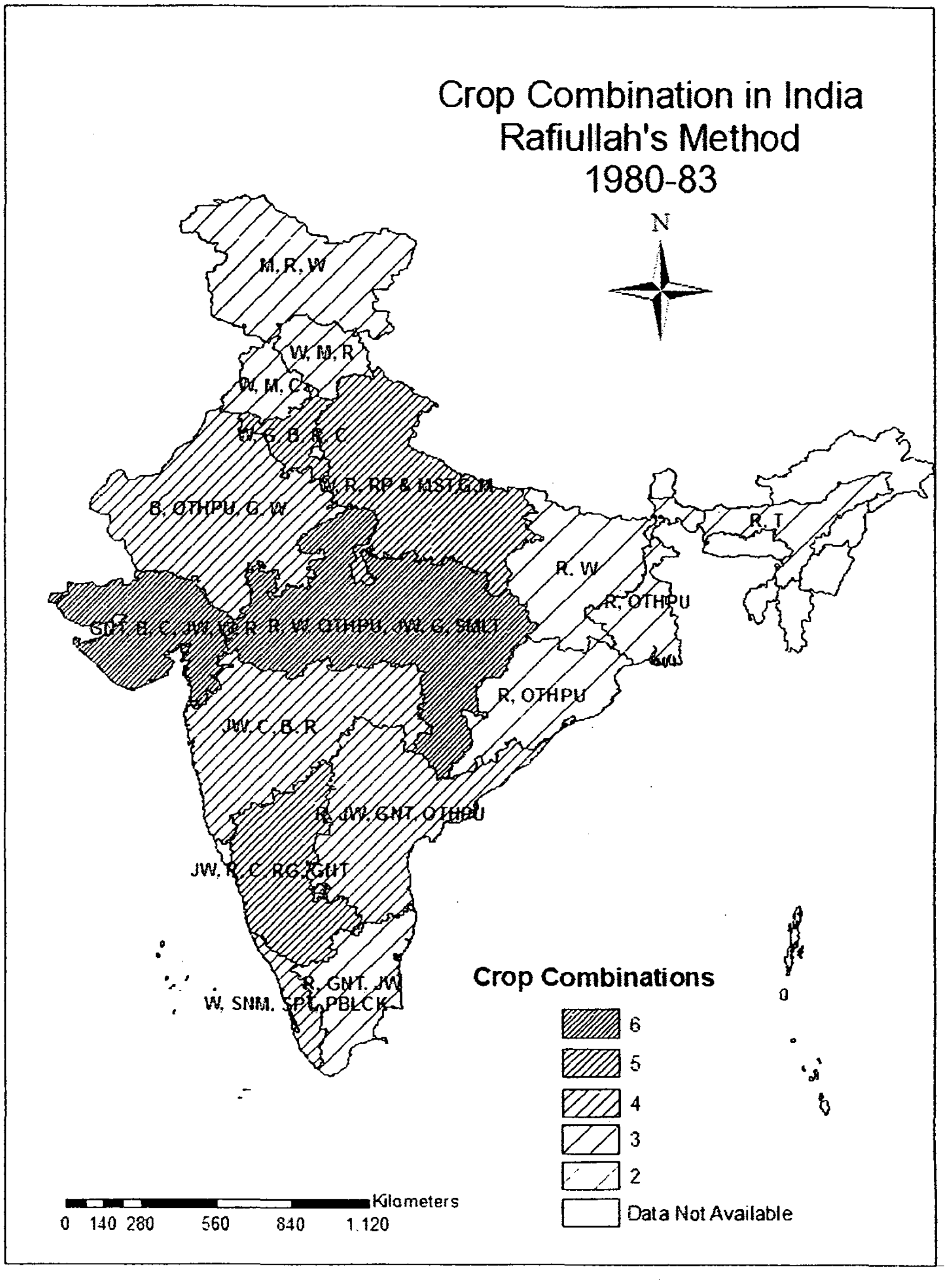
To understand the nature & extent of agriculture diversification in India, a state level analysis has been done. This analysis explains the changes in two sections.

First section represents the changes in cropping pattern which has been identified by the help of Rafiullah's crop combination method. The explanation in changes is supported by changes in relative share of crops in (GCA) for the time period of 1980-83 to 2005-06. Second section explains the temporal & spatial variations in the nature & extant of crop diversification in India. In this section method of Herfindahl index has been used.

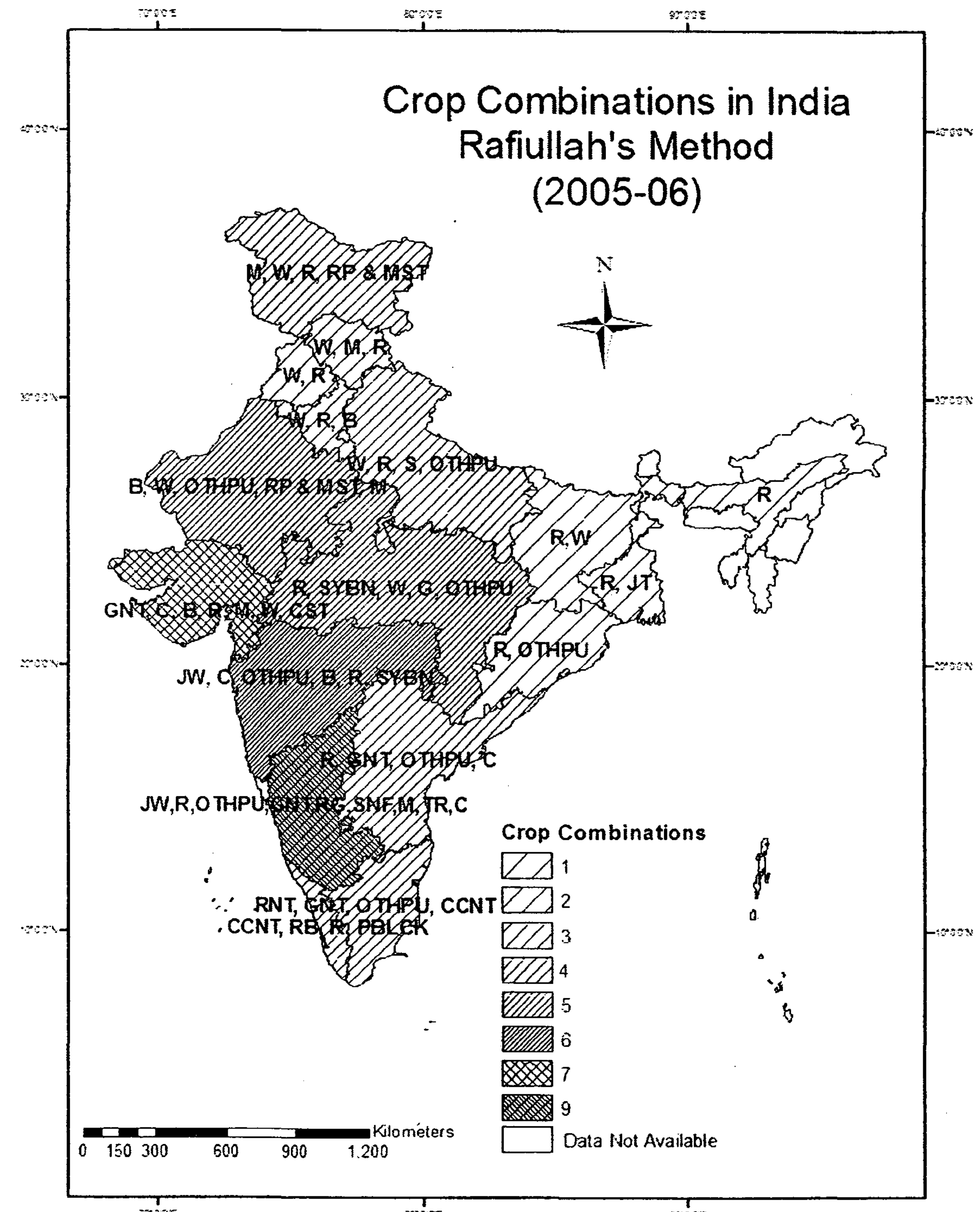
2.5 A: Crop Combinations in India

Our analysis reveals that in early 1980s the number of crops in the crop basket did not vary as much across the states as in the later periods. To elaborate, the minimum crop combination was 2 & maximum was 6 in the early 1980s.

Map Number: 2.1



Map Number: 2.2



All the eastern states were two crop combination regions. In all the four states, the dominant crop was rice. Thus this whole eastern region was 2 crop region with a predominantly specialization in rice crop. The north & north western region J&K (maize, rice, wheat), Himachal Pradesh (wheat, maize, rice), Punjab (wheat, maize, cotton) was the three crop region and wheat was a predominant crop. So this was a wheat region. Tamil Nadu was also a three crop region with rice, ground nut & jowar crop.

Table Number: 2.2: Changes in Crop Combination in India[2]

Changes in the Crop Combination between 1981 & 2006 (RAFIULLA MATHOD)									
Assam (1981)	RC	TEA							
Assam(2006)	RC								
Bihar	RC	WT							
Bihar	RC	WT							
Orissa	RC	OT PLS							
Orissa	RC	OT PLS							
W.B	RC	OT PLS							
W.B	RC	JT							
Kerala	W	SANHM	S.PT	P.BLK					
Kerala	CCNT	RBR	RC	P.BLK					
Haryana	WT	GRM	BJ	RC	CTN				
Haryana	WT	RC	BJ						
H.P	WT	MZ	RC						
H.P	WT	MZ	RC						
J&k	MZ	RC	WT						
J&k	MZ	WT	RC	R&MST					
Gujarat	G.NT	BJ	CTN	JW	WT	RC			
Gujarat	G.NT	CTN	BJR	RC	MZ	WT	CST		
M.P	RC	WT	OT PLS	JW	GRM	SMIL			
M. P.	RC	SYBN	WT	GRM	OT PLS				
MH	JW	CTN	BJ	RC					
MH	JW	CTN	OT PLS	BJ	RC	SYB			
Rajasthan	BJ	OT PLS	GRM	WT					
Rajasthan	BJ	WT	OT PLS	R&MST	MZ				
A.P	RC	JW	G.NT	OTHPU					
A.P	RC	G.NT	OT PLS	CTN					
Karnataka	JW	RC	CTN	RAGI	G.NT				
Karnataka	JW	RC	OT PLS	G.NT	RAGI	SNFL	MZ	TR	C
Punjab	WT	MZ	CTN						

[2] *For Crop abbreviations, Please see List of Abbreviations*

Punjab	WT	RC							
Tamil Nadu	RC	G.NT	JW						
Tamil Nadu	RC	G.NT	OT PLS	CCNT					
U.P	WT	RC	R&MST	GRM	MZ				
U.P	WT	RC	SC	OT PLS					

Sources: *(a).Statistical Abstract of India, 1980-83, 90-91, 2000-03, 2006*
(b). Year book of Area, Production and Yield of Principal crops in India, Ministry of Agriculture
(c). Agricultural Statistics of Glance, Ministry of Agriculture for the period of study.

States such as Rajasthan (Bajra, other pulses, Gram, Wheat), Maharashtra (Jowar, cotton, Bajra, rice), Andhra Pradesh (rice, Jowar, ground nut, other pulses) & Kerala (wheat, sanhemp, sweat potato, & paper black) were four crop regions Actually the states which have 4 or more than 4 crop combinations were not specialized in any crop. Haryana (wheat, gram, Bajra, rice, cotton), Uttar Pradesh (wheat, rice, rapeseed & mustard, gram, maize) & Karnataka (Jowar, rice, cotton, ragi, ground nut) were the five crop regions.

The region which was highly diversified than others were the Madhya Pradesh (rice, wheat, other pulses, Jowar, gram, small millet) & Gujarat (groundnut, Bajra, cotton, Jowar, wheat, rice) with 6 crop combinations. Thus we can say that the eastern was highly specialized & central & western region was highly diversified in early1980s.

In 2006, it was found that variations in terms of the number of crops in the crop-combination baskets increased visibly. In this period, while the minimum crop combination was 1,, the maximum was 9. Assam had specialized in rice & became mono crop region. Bihar & Orissa remained constant (2 crop region) without any change in cropping pattern while in West Bengal other pulses was replaced by jute. Haryana which was a 5 crop region experienced specialization & got converted into a three crop region with wheat, rice, bajra. Gram & cotton are now out of cropping pattern. Himachal Pradesh remained constant as three crop region. Punjab experienced specialization & transformed into a 2 crop region with wheat & rice. Rice is the new crop earlier which was not in the cropping pattern. Andhra Pradesh remained constant as 4 crop region with cotton replacing jowar. Kerala is also now 4 crop region but cropping pattern had been changed because coconut, rubber, & rice are the new crops which were not there in its crop basket in the 1980s. Kerala had experienced a clear specialization in coconut &

rubber crops which are commercial crops. The diversification towards the commercial crops is clearly visible in this state. Tamil Nadu also experienced diversification & changed into a 4 crop region with two new additional crops, pulses & coconut. Uttar Pradesh experienced specialization & course cereals which earlier were in the cropping pattern had been replaced by the new crops sugarcane & pulses. Madhya Pradesh experienced a change in cropping pattern with gram & small millets going out of its crop combination, making way for soyabeen. Gujarat & Rajasthan both had experienced diversification as one additional crop had entered in the cropping pattern. In Gujarat it is caster seed while in Rajasthan it is rapeseed & mustard. Thus highest diversification had been experienced by Karnataka. It got converted from 5 crop region to 9 crop region. Sunflower, maize, tur & other pulses are the crops that entered in its cropping pattern. So this region is diversifying towards the commercial crops & also for pulses.

Thus we can summarize these results in following manner:

Table Number: 2.3 Changes in Crop Combinations in India (1980-83-2005-06)

States Experienced		
Diversification	**Remain Constant**	**Specialization**
J&K (3-4)	Himachal Pradesh (3-3)	Haryana (5-3)
Gujarat (6-7)	Bihar (2-2)	Punjab (3-2)
Maharashtra (4-6)	Orissa (2-2)	U.P. (5-4)
Rajasthan (4-5)	West Bengal (2-2)	Assam (2-1)
Karnataka (5-9)	Andhra Pradesh (4-4)	M.P. (6-5)
Kerala (4-4)		
Tamil Nadu (3-4)		

In (-) numbers left of - are the crop combination in 1980-83 & right of – are the crop combination in 2005-06.

2.3: B: Crop Diversification in India

This section explains the temporal & spatial variations in the nature & extent of crop diversification in India. In this section Herfindahl index has been calculated for the first 40 crops in order of their areal extent. On the basis of Herfindahl Index, India can be classified into 5 regions according to the level of diversification which are[3]-

Table Number: 2.4

Crop Diversification Scenario in India

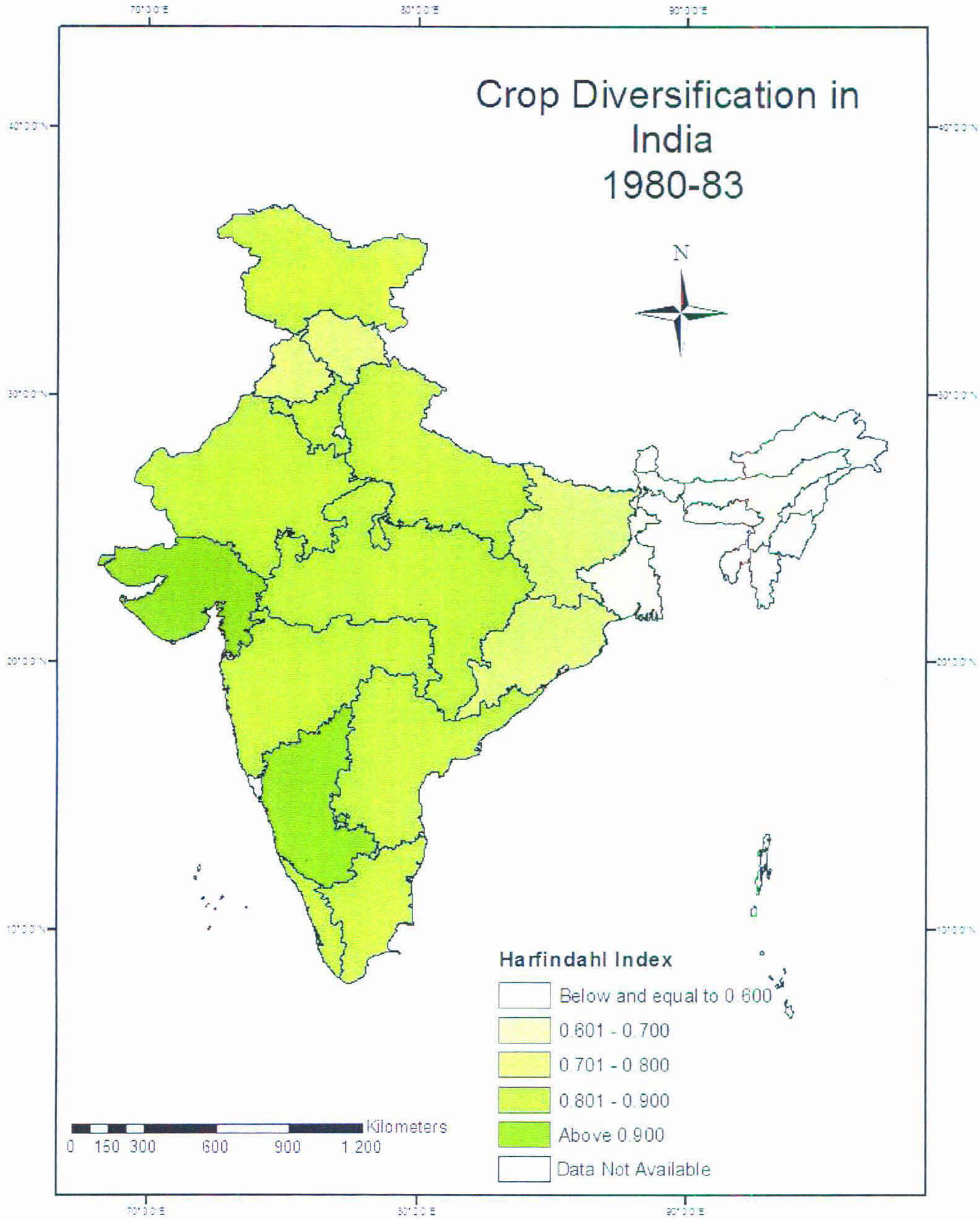
Crop Diversification Index (1981-2006)			
States	**HI 1981**	**HI 2006**	**HI 1981-2006**
Andhra Pradesh	0.859	0.875	0.016
Assam	0.557	0.578	0.021
Bihar	0.715	0.687	-0.028
Gujarat	0.908	0.917	0.009
Haryana	0.860	0.808	-0.053
H.P	0.753	0.745	-0.008
J&K	0.800	0.800	0.000
Karnataka	0.918	0.932	0.014
Kerala	0.850	0.863	0.012
Madhya Pradesh	0.887	0.894	0.007
Maharashtra	0.850	0.906	0.055
Orissa	0.731	0.697	-0.034
Punjab	0.771	0.707	-0.064
Rajasthan	0.890	0.920	0.030
Tamil Nadu	0.841	0.884	0.043
Uttar Pradesh	0.840	0.809	-0.032
West Bengal	0.511	0.617	0.106
ALL-INDIA	0.903	0.908	0.005

Source: Same as Table Number – 1

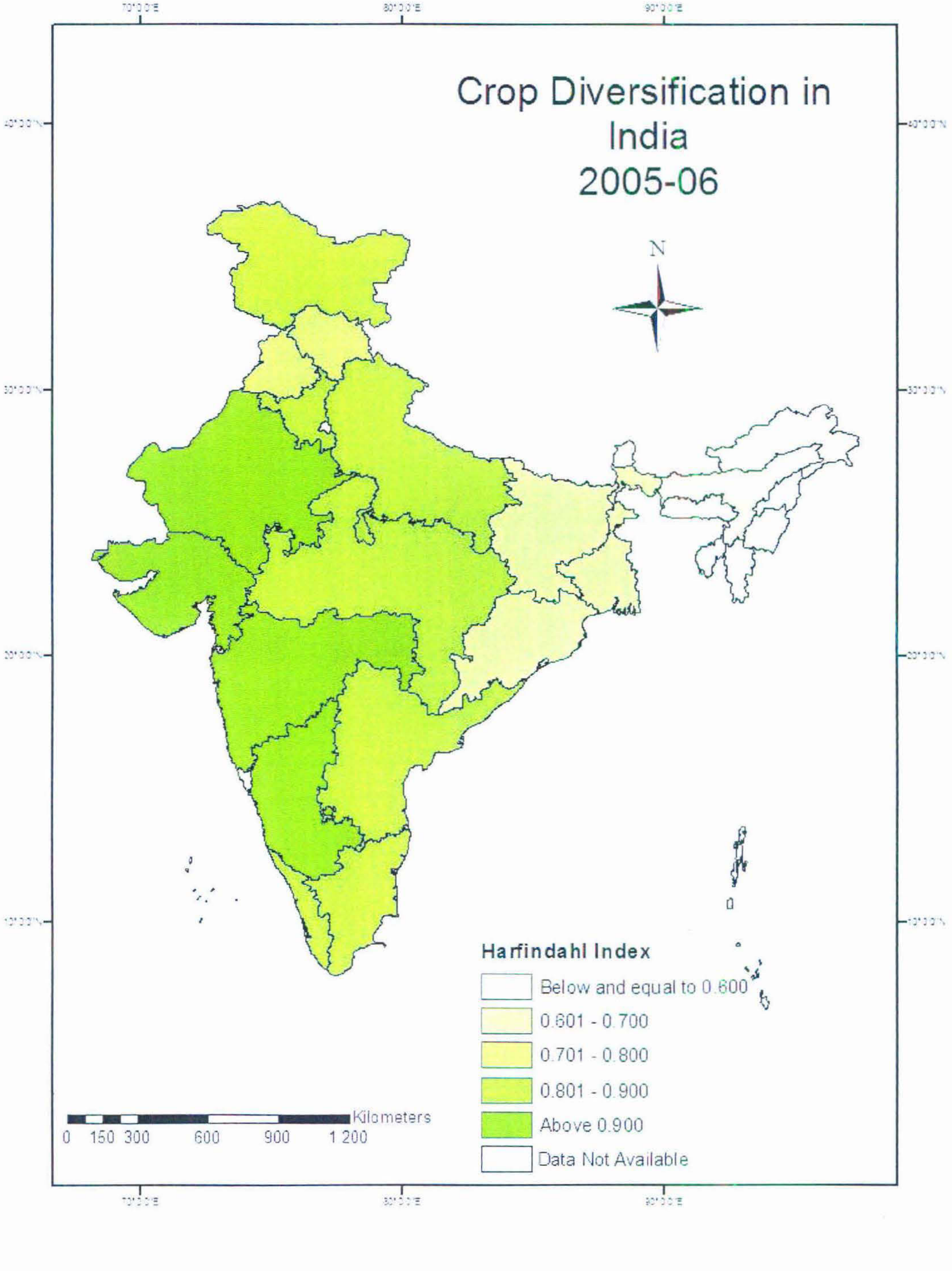
a) Least Diversified Regions
b) Less Diversified Regions
c) Moderately Diversified Regions
d) Highly Diversified Regions
e) Most Diversified Regions.

[3] *According to Zinc's Method, India can be classified in to 5 Regions.*

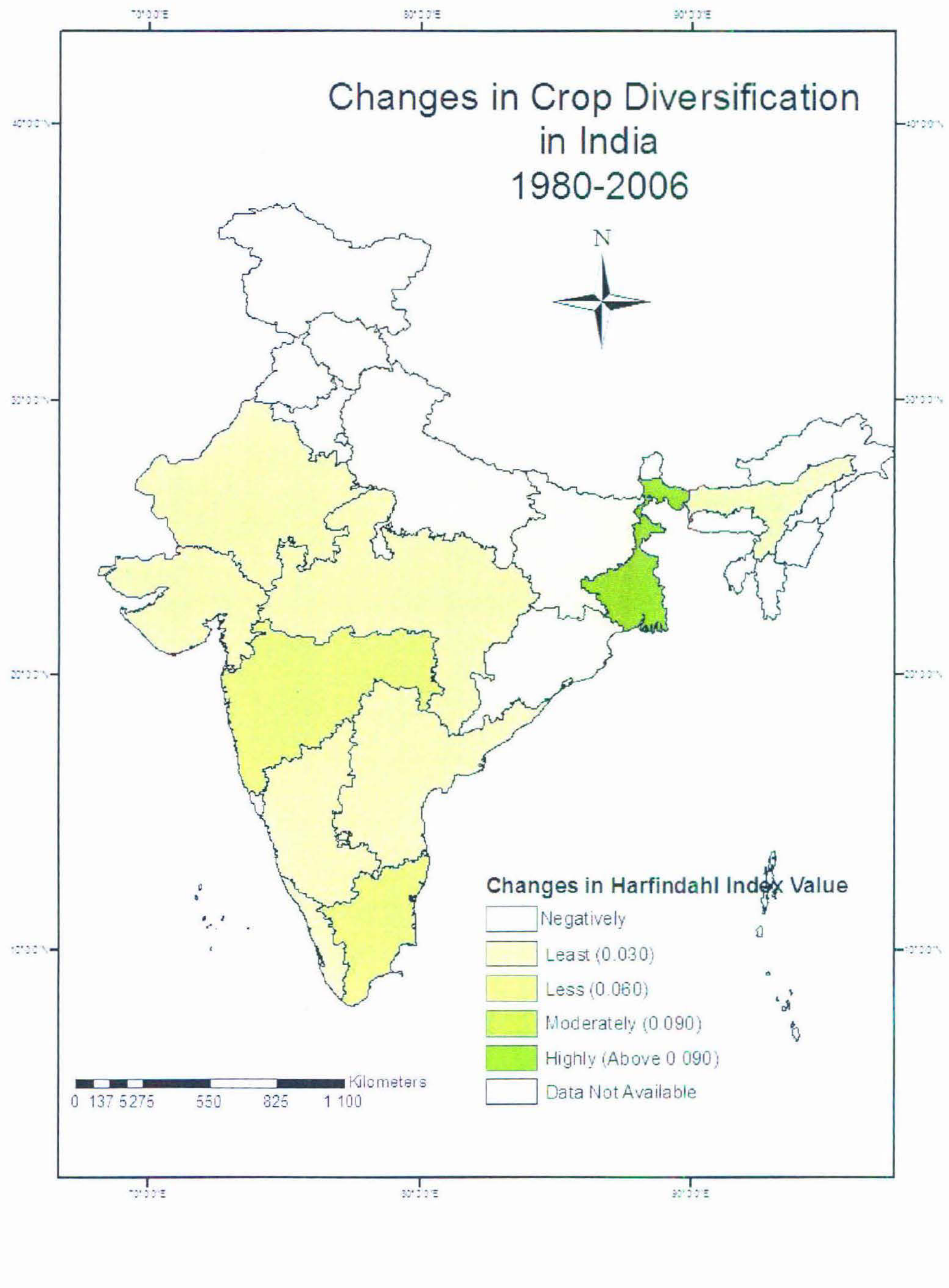
Map Number: 2.3



Map Number: 2.4



Map No. 2.5


Changes in Crop Diversification in India 1980-2006
N
Changes in Harfindahl Index Value
Negatively
Least (0.030)
Less (0.060)
Moderately (0.090)
Highly (Above 0.090)
Data Not Available
Kilometers
0 137.5275 550 825 1 100

A. Least Diversified Regions

In early1980s according to the index there were two states Assam and West Bengal which fall in this category these were the rice crop dominant regions. Orissa and Bihar experienced some diversification by 1980s and has been categorized as moderately diversified category. In the terminal period, Assam is the only state which has retained the dominant status of rice comparable to the 1980s, and hence remained as the only least diversified state.

B. Less Diversified Regions

In 1980s there was no any single state registered in less diversified category but in 2006 three humid states such as West Bengal, Orissa and Bihar fall in this category. While West Bengal moved one status towards diversification from the 1980s to mid 2000, the other two states have moved one status towards specialization.

C. Moderately Diversified Regions

In 1980s according to Herfindahl index four states such as Himachal Pradesh, Punjab, Orissa and Bihar were in this category but in 2006, Punjab and Himachal maintain their status quo as a moderately diversified state. However both these states have experienced some specialization over the study period, though they have remained in the same category.

D. Highly Diversified Regions

In 1980 according to Herfindahl index states such as Jammu and Kashmir, Uttar Pradesh, Andhra Pradesh, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Rajasthan Tamil Nadu and Kerala all these states were in this category. This states experienced diversification and it was towards the oilseeds, horticulture & other commercial crops (on the basis of growth rates).

In 2006 Maharashtra and Rajasthan got excluded from the category due to their high pace of diversification.

It can be stated that south & western region were moving towards diversification while northern & eastern region towards specialization. Actually this region was moving towards more & more food grains especially rice which is high water intensive crop.

E. Most Diversified Regions

In 1980s two states Gujarat and Karnataka have been categorized as the most diversified states. These two states were which was most diversified in India. In 2006 states like Rajasthan and Maharashtra which are continuously experiencing diversification were also included in the most diversified category. Thus in 2006 there were four states (Rajasthan, Gujarat, and Maharashtra & Karnataka) were in this category.

Finally, according to values of Herfindahl index, we found that Western region is highly diversified than Southern, South-Eastern & Central region, followed by the north western region and the hilly state of Himachal Pradesh, while the eastern states are highly specialized states.

Table 2.5 summarizes the movement of the states in terms of specialization and diversification between the 1980s and mid 2000s.

Table Number: 2.5

Specialization	Diversification	Remain Stagnant
Punjab, Uttar Pradesh, Bihar, Haryana, Himachal Pradesh, Orissa	West Bengal, Assam, Karnataka, Andhra Pradesh, Rajasthan & Maharashtra, Tamil Nadu, Kerala, Gujarat, Madhya Pradesh	Jammu and Kashmir,

Source: Computed by statistical abstract of India from 1980-83-2005-06

CONCLUSION AND MAJOR FINDINGS

The analysis of cropping pattern reveals that in India crop area shifts has taken place in favour of rice, wheat, total oilseeds and some non-food crops. However, regional trends throw up interesting points. Most of the states having primarily humid agro-climatic regime, which are also the traditional growers of rice, have experienced a reduction in the relative share of rice in their respective cropping patterns. On the other hand, the states having dominantly a semi-arid agro-climatic regime are moving towards rice, and in many cases, towards a rice-wheat cropping cycle, which is highly water intensive. There two crops are replacing broadly two categories of crops, coarse cereal, and pulses. It is clear that such cropping pattern shifts can be explained only by expansion of irrigation. This trend has been a cause for concern as though the irrigated semi-arid states have been the more productive states in terms of yield levels; previous studies reveal that in many of these states the growth rate of production, more particularly the yield has been stagnating in these states, for crops that are water intensive. It is thus important to analyse the irrigation changes along with the cropping pattern changes and also the water-productivity of the crops along with the land productivity.

The following chapter compared the changes in the irrigation extent and sources along with the cropping pattern changes.

Chapter III

Irrigation Extent and Cropping Pattern changes

Chapter 3

IRRIGATION EXTENT AND CROPPING PATTERN CHANGES

3.1 INTRODUCTION

Irrigation sector is the predominant user (more than 80 per cent) of water resources and the sector that directly and indirectly affects the growth, equity, efficiency, and sustainability of agriculture. India's economic and social development depends to a large extent on the performance and development of agriculture. The most significant change which has remarkably impacted on the cropping pattern in the country is irrigation. Introduction of Irrigation facilities has largely led to high productivity as well as multiple cropping. In some of the areas where irrigation is introduced the cropping pattern has become more diversified, especially so if there is proper regulation of water delivery.

In spite of the impressive achievements, the Indian agricultural sector continues to face poor infrastructure conditions. Two third of the agricultural land is rainfed which largely depend on rainfall. The expansion and improvements of irrigation infrastructure constitutes the single largest component of overall agricultural investment and particularly in public sector. [1]

The performance of irrigated agriculture, which contributes more than 55 per cent of agricultural output, will be the most important influence on the objectives of growth, employment generation, food security and poverty reduction[2].

Since irrigation is a major source of increased productivity, its distribution between regions and classes is naturally a very critical issue in irrigation infrastructure development. Irrigation plays important role in shaping regional crop pattern, while trans-seasonal crops account for a major share of (GCA)in canal and tank areas , seasonal crops have that distinctions in ground water and rainfed areas[3].

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[1] *Bhalla,G.S. (2006) Indian Agriculture Since Independence. National Book Trust of India pp 121.*

[2] *Dhawan B.D (1988)* Irrigation *in India's Agriculture Development: Productivity, Stability, Equity,* Sage Publication, New Delhi.

[3] *Saleth,R.M. " diversification strategy for small farmers and landless: some evidence from Tamil Nadu", Indian Journal of Agri. Econ., Vol. 52, No.1, Jan-March 1997 Pp. 73-86.*

3.2 FOCUS AND OBJECTIVES OF THIS CHAPTER

In this chapter, an attempt has been made to analyze the relationship between cropping pattern and irrigation extent. The two issues that are being handled here are one, the extent to which cropping pattern responds to changing irrigation extent, and two, whether the sources of irrigation is a major determinant of cropping pattern changes.

To identify whether the direction of crops are changing towards the more water intensive crops across different states in India, following points needs to be considered:

- Which are the regions that dominate in water intensive crops?
- What is the difference in changes in cropping pattern in highly irrigated and less irrigated regions?
- Are the cropping patterns significantly different in areas where tube well irrigation is the dominant source compared to other irrigation tracts?

So, in this chapter changes in cropping pattern is analyzed in the framework of irrigation.

3.3 (a) CHANGES IN CROPPING PATTERNS WITH IRRIGATION EXTENT

Table - 3.1 Changes in Irrigation extent (in %) since 1981-2006

I. Ext.	A. C.R	Regions	1981	1991	2001	2006	Total
High (Above 44 %)	Humid	Bihar	-	-	-	45.29	
		W.Bengal	-	-	-	59.23	2
	Semi Arid	Punjab	80.70	92.72	94.70	94.93	
		Haryana	59.24	72.71	83.89	83.85	
		Uttar Pradesh	54.89	60.94	69.26	74.96	5
		Tamil Nadu	47.95	-	54.46	55.06	
		J & K	42.52	-	-	-	
	Total		**5**	**0**	**1**	**1**	**7**
Moderate (22 to 44 %)	Humid	Bihar	35.51	43.45	39.03	-	
		W.Bengal	26.76	35.83	43.46	-	3
		Orissa	-	30.68	33.16	32.17	
	Semi Arid	Tamil Nadu	-	42.54	-	-	
		J & K	-	40.80	41.58	41.09	
		A. Pradesh	32.24	39.06	40.74	41.44	
		Gujarat	-	26.01	29.72	34.39	7
		M. Pradesh	-	22.06	26.35	32.85	
		Karnataka	-	-	25.39	28.03	
	Arid	Rajasthan	-	23.84	30.93	38.58	
	Total		**3**	**6**	**1**	**constant**	**10**
Low (Less than 22 %)	Humid	Kerala	10.92	14.84	17.27	18.39	1
		Orissa	19.42	-	-	-	1
	Humid	Assam	21.54	21.14	6.22	3.75	1
	Semi Arid	Gujarat	20.92	-	-	-	1
		H. Pradesh	16.08	17.07	21.93	19.22	1
		Maharashtra	10.53	11.31	16.78	16.89	1
		M. Pradesh	12.47	-	-	-	1
		Karnataka	13.75	20.36	-	-	1
	Arid	Rajasthan	19.54	-	-	-	1
	Total		**9**				**9**
		All India	**27.66**	**33.15**	**38.78**	**43.02**	

Source: Computed by

(a). Directorate of Economic and Statistics, Ministry of Agriculture, 2001

(b). Statistical Abstract of India, 1981 to 2006

3.4 (b) CHANGES IN IRRIGATION EXTENT IN DIFFERENT AGRO CLIMATIC REGIONS

Table- 3.2

Changes in Share of Irrigation Extent (in %) (1981-2006)				
Humid Region	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
West Bengal	9.07	7.63	15.77	32.47
Bihar	7.93	-4.42	6.26	9.78
Orissa	10.86	2.48	-1.00	12.35
Kerala	3.92	2.43	1.12	7.47
Assam	-0.40	-14.92	-2.47	-17.79
Semi Arid				
Haryana	13.46	11.18	-0.04	24.60
Uttar Pradesh	6.05	8.32	5.69	20.06
Madhya Pradesh	9.59	4.29	5.90	20.38
Karnataka	6.61	5.03	2.64	14.28
Punjab	12.02	1.98	0.23	14.24
Gujarat	5.09	3.71	4.67	13.47
Andhra Pradesh	6.82	1.67	0.70	9.20
Tamil Nadu	-5.41	11.92	0.63	7.14
Maharashtra	0.78	5.47	0.11	6.36
Himachal Pradesh	0.99	5.63	-3.48	3.14
Jammu & Kashmir	-1.72	0.78	-0.49	-1.43
Arid				
Rajasthan	4.30	7.09	7.65	19.05
India	5.49	5.63	3.95	15.06

Sources: same as table number 3.2

Highly Irrigated regions

Humid Regions

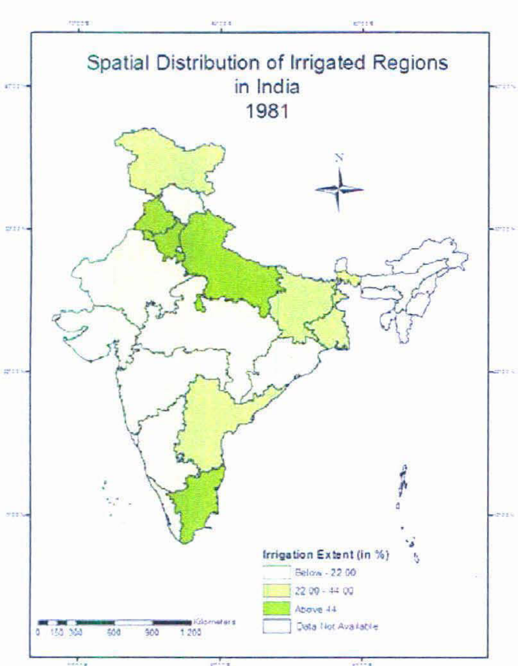
In 1981, the humid region does not show any state in the category of high (above 44 %) irrigation extent. Bihar has increased and entered in the category in 2001 whereas West Bengal was included in it from 2006.

West Bengal accounts for the highest increase in irrigation extent, which has primarily comes from increase in area under tubewell irrigation has also registered significant increases in their irrigation extent.

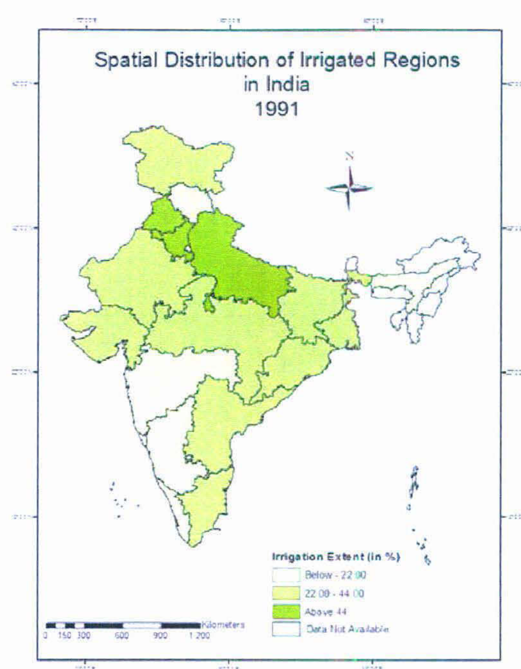
Semi Arid Region

In semi arid region, presently there are 4 states namely Punjab, Haryana, Tamil Nadu and Uttar Pradesh. Throughout the study period, Punjab topped the list in terms of irrigation extent, starting from around 80% in the early '80s to around 95% in the 2006. Haryana, Uttar Pradesh and Tamil Nadu are the other states that figure in the highly irrigated region throughout the period. Haryana and Uttar Pradesh, out of these other states have registered large increases in the irrigation extent, accounting for more than a shift of 20 percentage points.. For these category of states too, the increases has primarily come from the tubewell irrigated areas.

Spatial Distribution of Irrigation Extent across the different States in India



Map Number: 3.1



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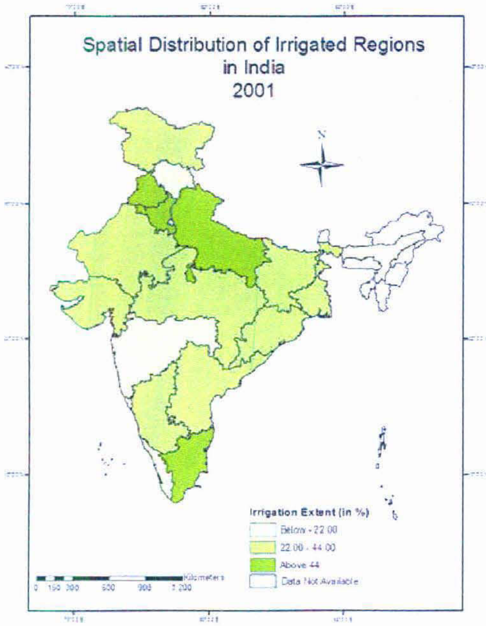

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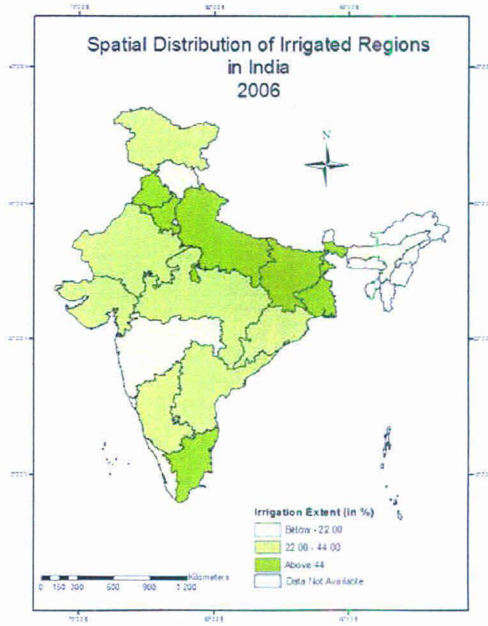

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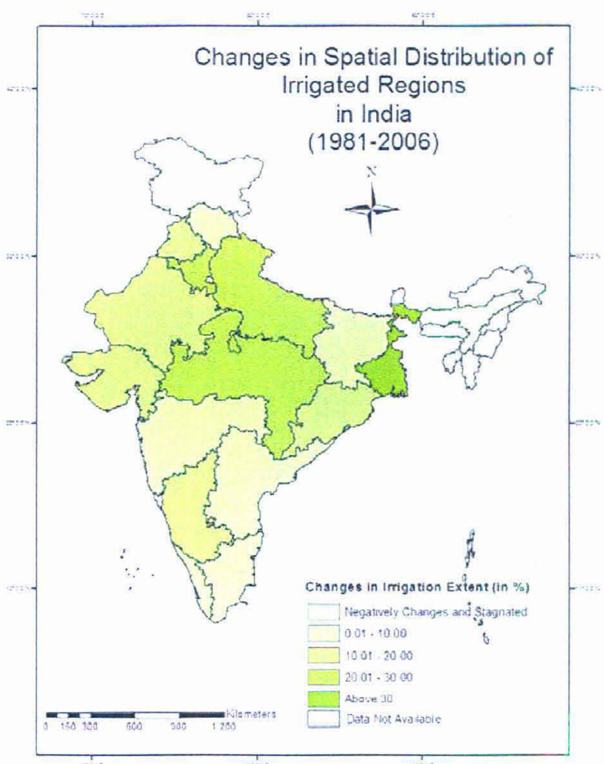


Map Number: 3.5

Moderately Irrigated Regions

Humid Region

During 1981, there were only two states Bihar and West Bengal in this category. Both got promoted to highly irrigation region. Since 1991, Orissa is the only state from the humid region in this category.

Semi Arid Regions

In 1981, Andhra Pradesh was the only state in this category. From 1990s, three states namely Jammu and Kashmir, Gujarat, Madhya Pradesh and Andhra Pradesh occupied place in this category.

Arid region

In 1981 Rajasthan was under low irrigated region, but has shifted to moderately irrigated region from 1991.

Less Irrigated Regions

Humid Regions

Two states Kerala and Assam have remained in this category from the base period to the terminal period. Though in Kerala the irrigation extent has increased by 8 percentage points, it continues to be categorized in the less irrigated region.

Semi Arid Region

Himachal Pradesh and Maharashtra has low irrigation extent and continued to be categorized in the same group till 2001. Gujarat, Madhya Pradesh and Karnataka, on the other hand, moved a category upwards in the subsequent periods. Like our observation earlier, most of the irrigation growth, the leader being Madhya Pradesh in this respect, has come from tube well irrigation.

Arid Region

As mentioned above, Rajasthan was in this category only in the eighties, after which it shifted upwards gain due to the expansion of tube well irrigation.

3.4 (c) SPATIAL AND TEMPORAL VARIATIONS IN IRRIGATION INTENSITIES IN INDIA

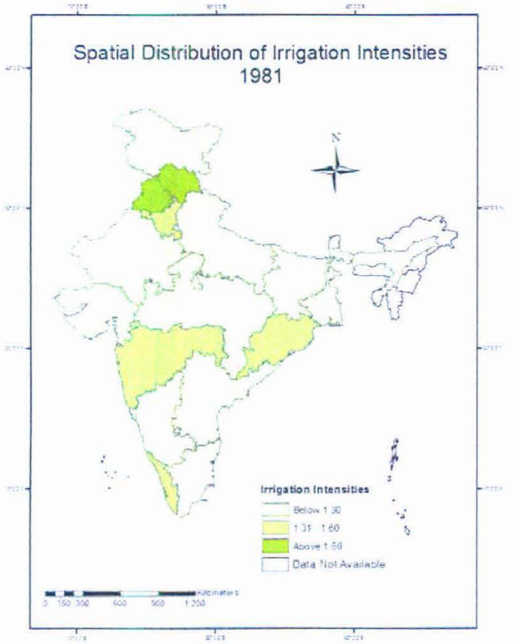
Table - 3.3

Irrigation Intensity (1981-2006)					
	Decades				Changes
States	1981	1991	2001	2006	1981-2006
Humid States					
Assam	1.00	1.00	1.27	1.44	0.4
Bihar	1.23	1.25	1.33	1.36	0.1
Orissa	1.41	1.20	1.32	1.46	0.0
Kerala	1.60	1.15	1.13	1.17	-0.4
West Bengal	1.03	1.30	1.56	1.57	0.5
Semi Arid States					
Andhra Pradesh	1.25	1.25	1.31	1.36	0.1
Punjab	1.71	1.80	1.90	1.93	0.2
Haryana	1.55	1.63	1.80	1.82	0.3
Uttar Pradesh	1.20	1.40	1.43	1.39	0.2
Karnataka	1.23	1.23	1.24	1.22	0.0
Madhya Pradesh	1.05	1.03	1.04	1.26	0.2
Maharashtra	1.31	1.22	1.30	1.31	0.0
H. Pradesh	1.70	1.68	1.44	1.77	0.1
J and K	1.29	1.46	1.44	1.49	0.2
Tamil Nadu	1.28	1.22	1.21	1.15	-0.1
Gujarat	1.17	1.18	1.19	1.21	0.0
Rajasthan	1.26	1.19	1.25	1.23	0.0
All India	1.28	1.33	1.38	1.36	0.08

Source: Computed by Statistical Abstract of India, 1981 to 2006

Highly irrigated States such as Punjab, Haryana, Uttar Pradesh and West Bengal which are predominately having high irrigation intensity have also registered high degree of Irrigation level whereas in states like Assam, Kerala, Maharashtra, Gujarat, Himachal Pradesh, Karnataka and Madhya Pradesh experiencing low level of irrigation intensities. Other states account irrigation intensity at moderate level. Where there is higher degree of irrigation extent persists, irrigation intensities are also account significantly higher in those regions, so there is positive interrelationship between the irrigation extent and irrigation intensities for all the regions.

Map Number: 3.6



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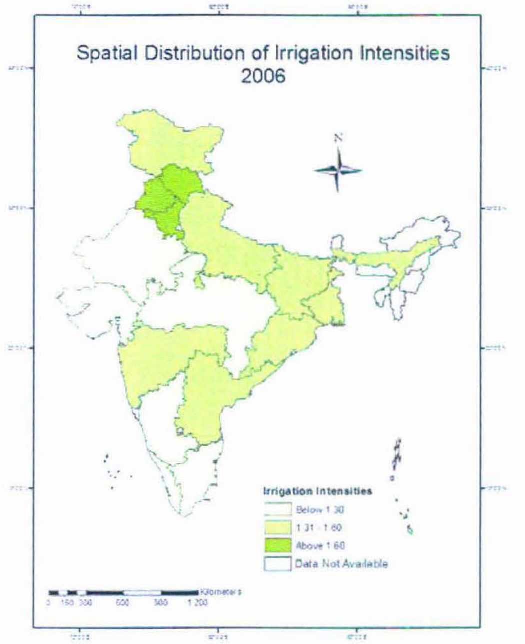

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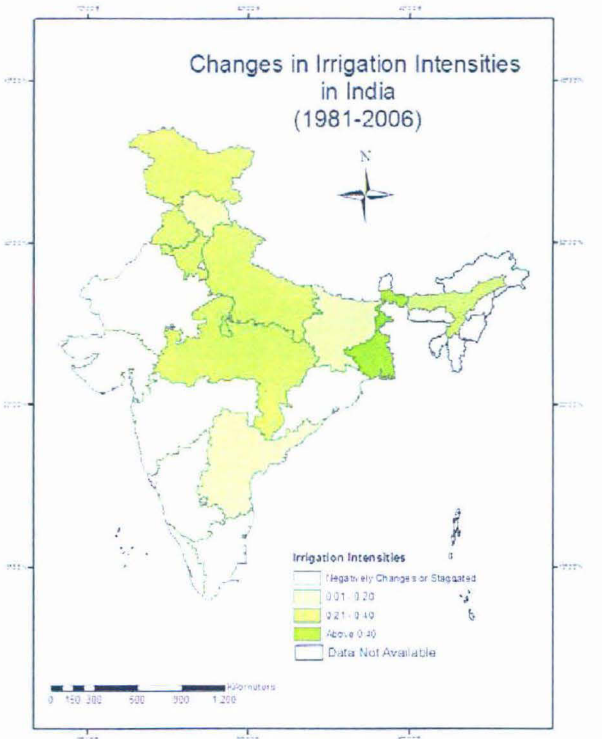


Table – 3.4

Changes in Share of Irrigation Intensities in India (From 1981-2006)					
Regions	**Less than 0.2**	**0.2 to 0.4**	**Above 0.4**	**Stagnated**	**Decreased**
Humid States	Bihar	Assam	W.Bengal	Orissa	Kerala
Semi Arid States	Andhra Pradesh	Haryana	-		Tamil Nadu
	-	-	-	Maharashtra	-
	Jammu and Kashmir	Madhya Pradesh	-	-	-
	Himachal Pradesh	Punjab	-	Gujarat	-
	-	Uttar Pradesh	-	Karnataka	-
Arid	-	-	-	Rajasthan	-

Sources: Computed by
(a). Directorate of Economic and Statistics, Ministry of Agriculture, 2001
(b). Statistical Abstract of India, 1981 to 2006

Due to increases in irrigation extent, area under ground water and tube well irrigation, irrigation intensity has increased significantly in the two states of West Bengal and Haryana. In fact West Bengal has experienced highest growth rate in area under ground water and its percentage share to irrigation is also high over the period of study.

It has increased moderately in states such as Madhya Pradesh, Uttar Pradesh and Punjab. Highly Irrigated States like Punjab, Haryana and West Bengal accounted significantly increased in area under tube well and ground water irrigation that influenced the positive growth rate in the gross irrigated area of all these states and that ultimately accelerated the irrigation intensities as well there. However in those states where intensities of irrigation have not increased or remain stagnant that also consist below the share national average in terms of both tube well irrigation and area under ground water irrigation.

3.4(d) IRRIGATION EXTENT AND CROPPING PATTERN CHANGES (CROP GCA RATIO)

Table Number- 3.5

Changes in Cropping Pattern Percentage (From TE 1980-81 to 2006)							
Irr.Ex.	**Region**	**Shift To (in %)**			**Shift From (in %)**		
	Humid	**More than10**	**5% to 10%**	**2% to 5%**	**More than10**	**5% to 10%**	**2% to 5%**
High	Bihar		WT				T.PLS, RC, T.OLS
	W.Bengal		OTH	T.OLS		RC	T.PLS
Mod.	Orissa	OTH		RC	T.PLS	T.OLS	
Low	Kerala	OTH			RC		
	Assam			OTH			JT
	S. Arid						
High	Punjab	RC					CCL,T.PLS, CTN,T.OLS
	U.P		WHT	RC,SC		T.OLS	CCL.
	T.Nadu			SC,OTH			CCL,T.OLS
	Haryana		RC,T.OLS,WT	CTN	T.PLS	CCL	
Mod-rate	A.P		T.OLS	CTN	CCL(JW)		
	Gujarat			CTN, T.PLS, T.OLS	CCL(JW)		
	J & K			WHT,OTH			T.OLS,RC, T.PLS
	M.P	T.OLS				C.CL(JW)	OTH
	Karnataka		T.OLS			CTN	CCL
Low	H.P			OTH			T.PLS
	M.H		T.OLS,OTH		CCL(JW)		
	Arid						
Mod.	Rajasthan	T.OLS				CCL.(BJ)	T.PLS

Source: Computed, Same as Table Number: 3.8

Crop Abbreviations: R-rice, W-wheat, CCL-Coarse Cereal, T.OLS -Total Oilseeds, CTN-Cotton, SC-sugarcane, JT-jute and OTH – Other Crops

Some notable observations are emerging from Table 2.8. In the humid region, the states that have made higher progress in terms of expansion of irrigation facilities have actually shifted away from rice and gone towards diversification, in some cases, in favour of horticultural crops. Bihar is the only state where a substantial increase in area under wheat has increased with increased irrigation. The crops that have reduced in importance other than rice are pulses and oilseeds. Overall in the dominantly humid states, expansion in irrigation has resulted in a movement away from the water intensive crop of rice, along with relatively low water requirement crops like oilseeds and pulses, towards somewhat higher value low water-requirement crops like fruits and vegetables. In contrast,, the semi arid regions with high or expanding irrigation facilities has moved towards a water intensive crop regime like rice wheat and sugarcane. Wheat, though not a particularly water-intensive crop, when grown along with rice in the same agricultural year, represents one of the more water intensive crop cycles. The states with low or moderate irrigation facilities and located predominantly in the semi arid regimes have moved away from coarse cereals and shifted towards oilseeds in most cases, pulses in some others, and 'other crops' which includes horticultural crops. The point to note is that expansion in irrigation over time is tending to reverse the traditional cropping cycles, tipping the balance more in favour of water intensive crops in the semi arid zones, and somewhat less water intensive crop in the dominantly humid states. Rice however still remains the most important crop in the latter group of states. (Please see Appendix 3.1, table A-3.3 and A- 3.4)

3.5 CHANGES IN CROPPING PATTERNS AND SOURCES OF IRRIGATION IN INDIA

3.5 (a) Spatial Distribution of Area under Tube Well Irrigation in India

Table - 3.6

Percentage Share of Tube well Irrigation (1991-2006)				Changes in Share (in Percentage)		
States	Tube Well 1991	Tube Well 2001	Tube Well 2006	Tube well 1991-2001	Tube Well 2001-2006	Tube Well 1991-2006
A.P	6.55	23.54	31.89	16.99	8.35	25.34
Assam	0.00	1.18	6.43	1.18	5.25	6.43
Bihar	41.46	59.48	61.83	18.01	2.36	20.37
Gujarat	19.53	34.46	28.84	14.93	-5.62	9.30
Haryana	43.96	49.59	55.75	5.64	6.16	11.79
H.P	3.52	7.94	12.50	4.42	4.56	8.98
J & K	0.17	0.32	0.32	0.15	0.00	0.16
Karnataka	8.21	20.39	32.42	12.18	12.02	24.21
Kerala	19.71	30.45	3.06	10.74	-27.38	-16.64
M.P	8.06	19.44	28.17	11.38	8.73	20.11
Orissa	14.41	14.33	14.33	-0.08	0.00	-0.08
Punjab	56.71	76.13	72.44	19.41	-3.68	15.73
Rajasthan	9.53	20.77	31.16	11.24	10.39	21.63
T.Nadu	7.16	7.89	13.60	0.74	5.71	6.45
U.P	62.26	71.67	71.49	9.41	-0.18	9.24
W.Bengal	36.03	52.80	52.80	16.77	0.00	16.77
India	30.05	40.71	39.63	10.67	-1.08	9.58

Sources: Computed by

(a). Directorate of Economic and Statistics, Ministry of Agriculture, 2001

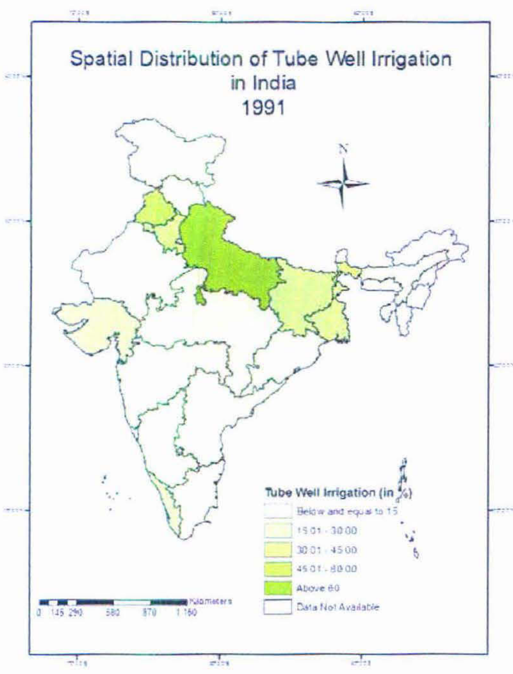
(b). Statistical Abstract of India, 1981 to 2006

The share of tube well irrigation is highest in Punjab followed by Uttar Pradesh, Bihar, Haryana and West Bengal. While States like Assam, Kerala, Jammu and Kashmir, Orissa and Tamil Nadu comprise insignificant Proportion in tube well irrigation. Other sources of Irrigation like tank and other are predominantly high in these states.

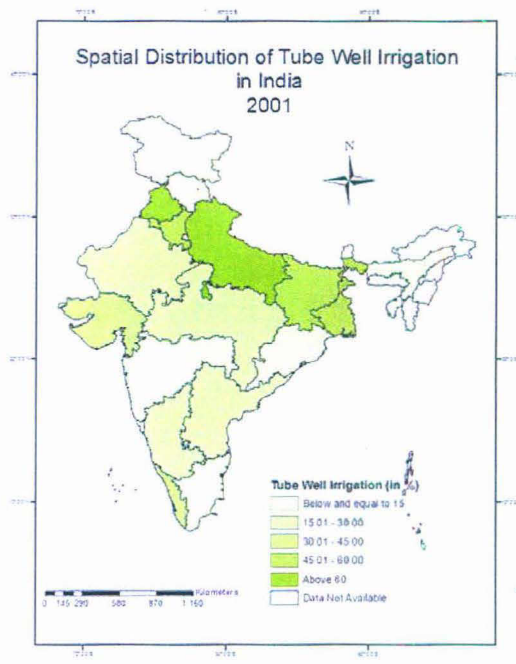
Percentage of change in share of tubewell irrigation is observed high in the semi arid and arid states like Andhra Pradesh, Karnataka and Rajasthan. Whereas the states like Kerala, Uttar Pradesh, Gujarat and Punjab have noticed negative growth in share of area under tube well irrigation.

Spatial and Temporal Variations under the Area of Tube Wells Irrigation in India

Map Numbers: 3.9



Map Numbers: 3.10



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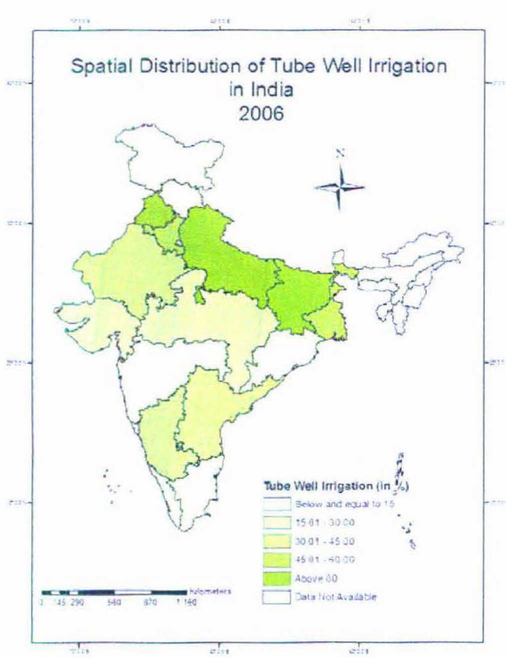

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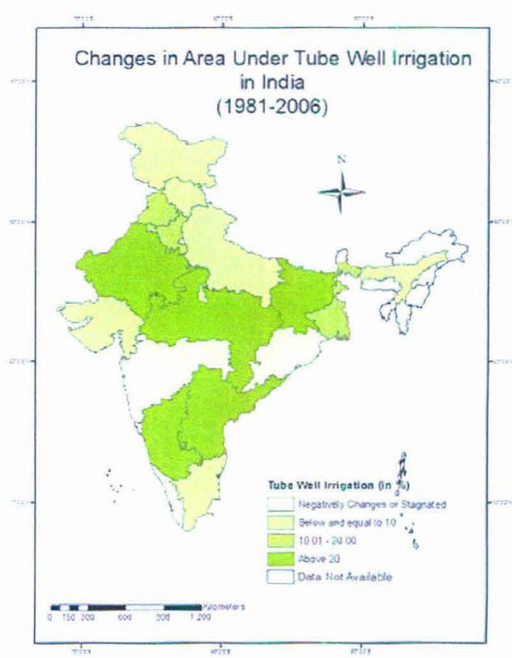


There is clear pattern emerging with concentration of tubewell irrigation in the northern India in the 1991 and it has shifted to Western, central and southern India by 2001

Table - 3.7

Growth Rate of Tube-Wells Irrigation (in %) (1981-2006)			
States	**1991-2001**	**2001-2006**	**1991-2006**
Andhra Pradesh	278.1	33.21	403.72
Assam	0.0	900.00	900.00
Bihar	54.0	-3.79	48.17
Gujarat	101.0	1.03	103.03
Haryana	28.4	13.63	45.90
Himachal Pradesh	185.7	30.00	271.43
Jammu & Kashmir	100.0	0.00	100.00
Karnataka	210.7	77.18	450.43
Kerala	76.6	-89.66	-81.74
Madhya Pradesh	186.1	102.61	479.64
Orissa	-0.6	0.00	-0.61
Punjab	38.6	-5.07	31.60
Rajasthan	174.0	98.63	444.23
Tamil Nadu	34.3	72.37	131.45
Uttar Pradesh	39.2	4.58	45.57
West Bengal	80.5	0.00	80.54
India	56.7	14.38	79.27

Source: Computed by

(a).Directorate of Economic and Statistics, Ministry of Agriculture. 2001

(b). Statistical Abstract of India, 1981 to 2006.

Area under tube well irrigation has increased significantly in the semi arid and arid region like Madhya Pradesh, Rajasthan, Karnataka, and Andhra Pradesh.

Table: 3.8

Tube Well Irrigation Development in India (1991-2006)			
Below 10 %	**10 to 15 %**	**15.1 to 20%**	**Above 20 %**
Humid States			
Kerala		West Bengal	Bihar
Orissa			
Assam			
Semi Arid States			
Tamil Nadu	Haryana	Punjab	Madhya Pradesh
Himachal Pradesh			Karnataka
Uttar Pradesh			Andhra Pradesh
Gujarat			
Jammu & Kashmir			
Maharashtra			Rajasthan

Sources: Same as Table Number: 3.16

When we over view the growth and increases in percent share in area under tube well irrigation, we can summarize that states like Bihar, Madhya Pradesh, Karnataka, Andhra Pradesh and Rajasthan, witnessed very high increase in area under tube well irrigated area, over the period of time.

Table Number: 3.9

Levels on the Basis of Existing Share of Area under Tube Well Irrigation (in %) (2006)					
High		**Moderate**		**Low**	
Punjab	72.44	Karnataka	32.42	Orissa	14.33
Uttar Pradesh	71.49	Andhra Pradesh	31.89	Tamil Nadu	13.60
Bihar	61.83	Rajasthan	31.16	Himachal Pradesh	12.50
Haryana	55.75	Gujarat	28.84	Assam	6.43
West Bengal	52.80	Madhya Pradesh	28.17	Kerala	3.06

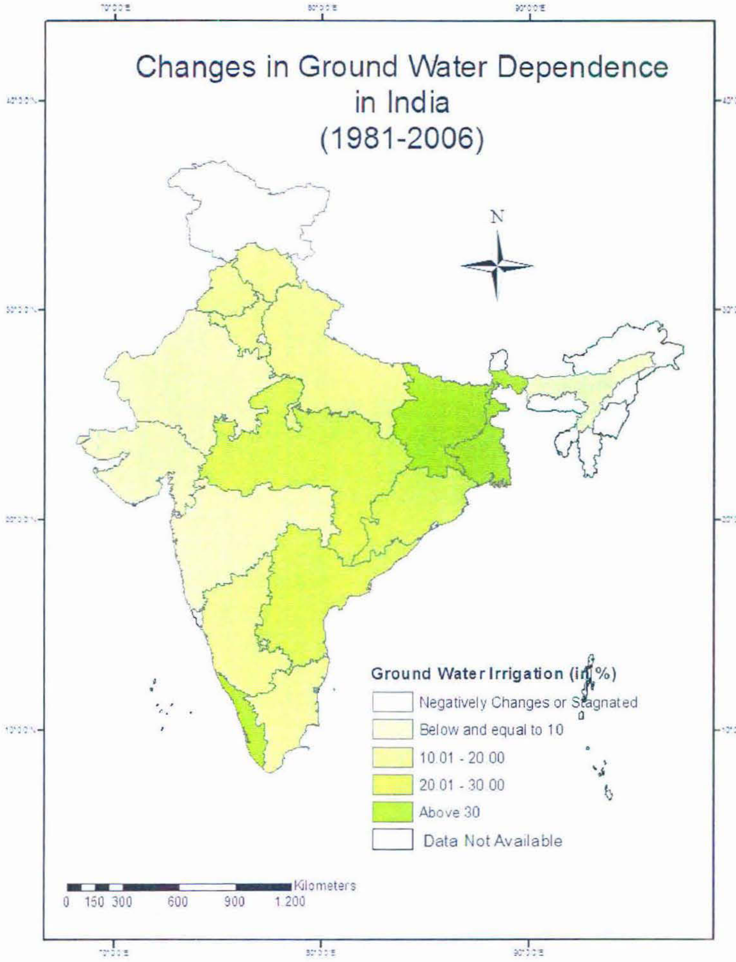
Sources: Computed by

(a). Directorate of Economic and Statistics, Ministry of Agriculture, 2001

(b). Statistical Abstract of India, 1981 to 2006

Tube well irrigation is dominant and played a significant role in crop out put, in the Punjab, followed by Uttar Pradesh, Bihar, Haryana and West Bengal where its level is on significantly level.

Map Number: 3.13



In Humid region, Bihar has witnessed very substantial increase in area under ground water irrigation followed by West Bengal; growth in changes in share of area under ground water irrigation has increased substantially for these states. While irrigation facilities have increased by wells in Kerala

In semi arid states, Gujarat has predominantly higher irrigation area under by ground water followed by Uttar Pradesh, Punjab, Madhya Pradesh and Maharashtra. Irrigation by wells is also dominant here. Ground water dependency is quite high in these regions.

So area under irrigation by ground water irrigation has witnessed substantial increase in India, over the study period. All these led to severe ecological imbalances in over extracted regions especially in Punjab (Vaidyanathan,,A, 1996) .

3.6 TUBE WELL IRRIGATION AND GROWTHS OF MORE WATER INTENSIVE CROPS AND LESS WATER INTENSIVE CROPS

Correlations between Area under Tube Well Irrigation with different Crops and Crop groups

In 1990, when tube well irrigation had introduced, only two crops such as wheat and sugarcane were positively significant correlated at 95 percent significance level. But till 2006, only wheat is positively correlated with tube well irrigation. On the other hand there is negative correlation between less water intensive crops such as coarse cereals, total pulses and total oilseeds with tubewell irrigation. As area under tubewell irrigation has been increasing, area under less water crops have been declining at all the time. (Please see Appendix 3.1, Table A-3.16 to A-3.20)

Correlation between Irrigation Extent and different Crops

Like tubewell irrigation, there are positive interrelationship between water intensive crops and irrigation extent whereas less water intensive crops are negatively correlated with irrigation extent. (Please see Appendix 3.1, Table A-3.16 to A-3.20)

MAJOR FINDINGS AND CONCLUSION

This chapter largely points out to irrigation extent and its impact on cropping patterns changes. The major findings of the chapters are:

It has been experienced that there is wide heterogeneity in terms of irrigation extent across the different states of India. Its variedness is visible as we go to the regional level with different agro climatic regions. The high water intensive crops are significantly higher in areas with high level of irrigation extent.

The proportion of area under tube well irrigation and area under ground water irrigation has increased remarkably in India. Its pace is relatively higher in semi arid and arid states as compare to the humid states. As dependence of area under tube well irrigation increased, the extension of irrigation has also increased in high and low irrigated regions in India at the cost of dependence of area under surface irrigation and other sources which have gone down in all India.

The states with growth in terms area of area under tube well irrigation also noticed increases in proportion of water intensive crops such as rice and sugarcane. This study reveals that states which have been experienced the dominance of area under tube well irrigation or states where dependence of ground water irrigation is higher they also experiencing high growth rate of water intensive crops such as rice, sugar cane and wheat.

Rice and wheat comprises major share in all these high irrigated states and tube well irrigation also playing significant role to accelerate it. Whereas in moderate and low irrigated regions, degree of diversification of crops is also high and less water intensive crops such as total pulses and total oilseeds accounted significant share there. So irrigation extent have been largely affected the direction of cropping patterns across the different agro climatic regions in India especially for the states of semi arid high and moderate irrigated states where level of water intensive crops have been increased, they are tend towards more water intensive crops with the increase of irrigation extent.

Chapter IV

Water Productivity in India

Chapter 4

WATER PRODUCTIVITY IN INDIA

4.1 a. INTRODUCTION

Water is a precious and finite resource. Although it covers three quarters of the earth, only a small fraction is accessible as fresh water. Of the total amount of water withdrawn, almost 70 percent is needed to produce the food that fuels human activity. It is the most critical input for agricultural productivity. Population is increasing and consumption patterns are also diversifying towards high value crops with high water requirements (Kumar et al.2003; Joshi et al.2004), so production will have to increase significantly to meet additional food and food grain demand. But with increasing water demand for high-value crops, and from other sectors, food grain production will face stiff competition for scarce water resource. Improving water productivity is one option for coping with water scarcity (Amarasinghe et al., 2007).

Though land is another natural resource along with water, but water can improve or destroy its productivity with proper or improper management. Water can cause salinity, silting, degradation, gullies, ravines, etc on the soil. The soil is dependent on water, which is an independent resource. Soil management and improvement depends upon water. Serious imbalances like excess rainfall in northeast and deficient rainfall in most other parts have led to problems like floods in excess rainfall areas and drought in deficient rainfall areas with reversal trends.1

So proper water quantity (proper rainfall) and distribution (distribution of rainfall) is a key factor and is an issue to raise the water productivity in India, however more water use resulting in higher production may not always be true (ibid). So there should be an optimum balance between water quantity and rainfall distribution. A shift in the paradigm from land productivity to water productivity is being witnessed at the dawn of the new

[1] *Reddy, P .R.,(2002) "Paradox of deficit and surplus water: impact on food security", intensive agriculture, I.A.R.I, New Delhi.*

century the world over. Conservation and efficient use of every drop of water for enhancing food crop production is water productivity (kg. / hectare mm).

4.1 b GENERAL BACKGROUND OF WATER PRODUCTIVITY

The concept of water productivity is based on "more crop per drop" or "producing more food from the same water resources" or "producing the same amount of food from less water resources". In a broad sense, productivity of water is related to the value or benefit derived from the use of water. Definitions of water productivity are not uniform and change with the background of the researcher or stakeholder involved. For example, obtaining more kilograms dry matter production per unit of transpiration is a key issue for plant breeders. At a basin scale, economists wish to maximize the economical value from water used. There are several definitions of water productivity, so we have to ask ourselves *which crop* and *which drop* are we referring to (see Table 4.1)[2].

Table 4.1

Some examples of stakeholders and definitions in the water productivity framework

Stakeholders	**Definition**	**Scale**	**Target**
Plant physiologist	Dry matter / transpiration	Plant	Utilize light & water
Nutritionist	Calorie / transpiration	Field	Healthy food
Agronomist	Yield/evapotranspiration	Field	Sufficient food
Farmer	Yield / supply	Field	Maximize income
Irrigation engineer	Yield / irrigation supply	Irrigation scheme	Proper water allocation
Groundwater policy maker	$ / groundwater extraction	Aquifer	Sustainable extraction
Basin policy maker	$ /evapotranspiration	River Basin	Maximize profits

Source: Bastiaanssen, W.G.M., Van Dam ,J.C. and Drooger , P., (2003) "Water productivity of irrigated crops in Sirsa district, India, Integration of remote sensing, crop and soil models and geographical information systems.

[2] *Bastiaanssen, W.G.M., Van Dam ,J.C. and Drooger , P., (2003) "Water productivity of irrigated crops in Sirsa district, India, Integration of remote sensing, crop and soil models and geographical information systems.*

The productivity then can be expressed as total dry matter production or as actual yield as a harvestable product. Productivity expressed in kg is less useful if we want to compare different crops or different regions and under these circumstances, a definition based on economic value is more appropriate. These economic values can be based on simple gross value, so kg yield multiplied by market prices, but it can include also a complete economic evaluation to get the net benefits.

4.2. FOCUS AND OBJECTIVES OF THIS CHAPTER

In this chapter, an attempt has been made to analyze the interrelationship between water productivity of different crops and their land productivity. Whether crops' water productivity is positively correlated with land productivity for selected crops or there is no relation between them.

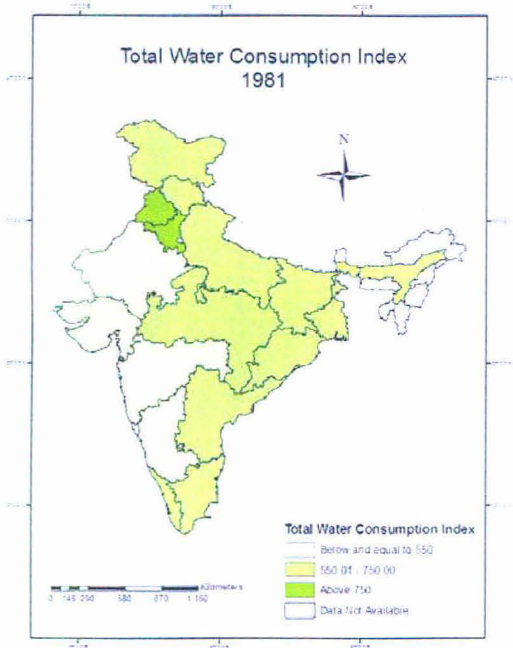
1) Is there a convergence between the variations of land productivity and water productivity?
2) Does the aggregate water productivity in a region decline with increase in irrigation extent?
3) Is the aggregate water productivity of crops higher in dominantly tube well irrigated area compared to other irrigated areas?

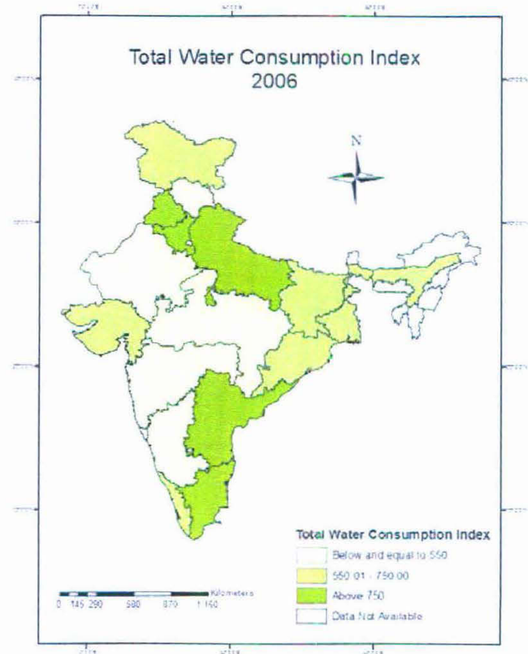
4.3 TOTAL WATER CONSUMPTION INDEX

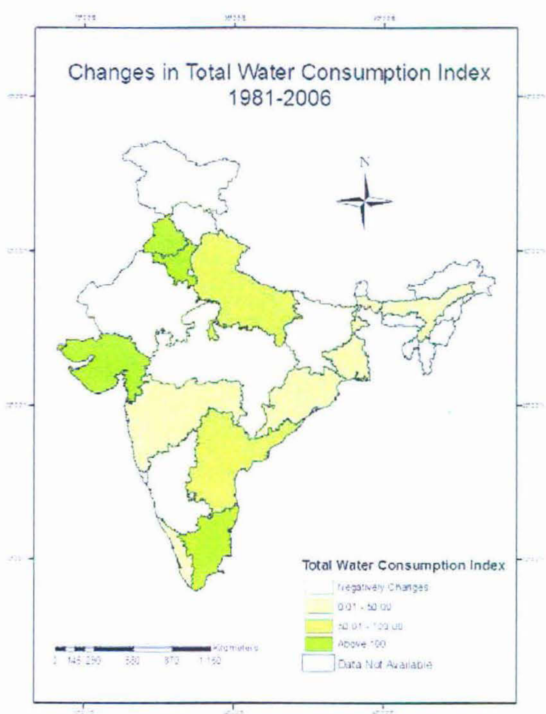
Total water consumption index refers to the variations in the area under different crops such as more water intensive crops and less water intensive crops with respect to their GCA as well as their varying water requirement in different agro climatic set up. It has been observed that higher the area under water intensive crops higher would be the total water consumption index value.

Total Water Consumption of Different Crops across different States in India

Map: 4.1 **Map: 4.2**







Map: 4.3

Maps 4.1 and 4.2 show that all the western states which have been diversified have low level of water consumption of crops in reverse of that states which have been highly irrigated by tube well irrigation, they have high water consumption level. States like Punjab, Haryana, Uttar Pradesh, Andhra Pradesh and Tamil Nadu have high irrigation extent and their major crop combinations are also from highly water intensive crops.

All the highly irrigated semi arid states tend to move towards higher water intensive crops whereas there is no major changes can be seen for all the humid states.

Total water consumption index has increased remarkably in Gujarat. Gujarat is state where ground water dependence is highest.

4.4 Spatial Distribution of Land and Water Productivity across different Agro Climatic Regions in India on the basis of Irrigation Extent

a. Aggregate Land Productivity

Table 4.2

	Aggregate Land Productivity in India (Rs.Lakh/hectare) (1980-83-2005-06)			
Regions/States	**LP_80-83**	**LP_90-93**	**LP_00-03**	**LP_05-06**
Humid				
Moderately Irrigated States	113.95	169.13	190.66	160.00
Less Irrigated States	328.79	569.56	602.77	737.39
Semi Arid				
Highly Irrigated States	247.26	354.10	421.62	407.59
Moderately Irrigated States	246.04	312.82	333.83	326.79
Less Irrigated States	205.03	326.51	349.19	377.79
Arid	30.69	49.89	51.65	54.51

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

4.4 b. Aggregate Water Productivity

Table 4.3

	Aggregate Water Productivity in India (Rs.Lakh/hectare mm) (1980-83-2005-06)			
Regions/States	**WP_80-83**	**WP_90-93**	**WP_00-03**	**WP_05-06**
Humid				
Moderately Irrigated States	174.81	260.48	294.19	247.38
Less Irrigated States	465.15	800.49	833.07	1009.03
Semi Arid				
Highly Irrigated States	319.78	420.17	465.47	456.99
Moderately Irrigated States	355.43	446.09	436.05	423.14
Less Irrigated States	385.32	624.79	622.72	751.01
Arid	71.07	117.57	120.24	127.15

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Result of the above tables (4.2 and 4.3)::

1. Water productivity of different crops is relatively higher where the land productivity has been increased over the time. (for individual crops please see Appendix 4.1 Table A-4.3,4.4,4.5,4.6,4.7,4.8)
2. Though Aggregate water is increasing with the land productivity but in case of semi arid high and moderately irrigated states, the gap between the land and water productivity is much sharper and increasing as compared to less irrigated states which is the questionable issue for the sustainability of these regions.

4.5. SPATIAL CONVERGENCES BETWEEN LAND AND WATER PRODUCTIVITY IN INDIA BY AGRO-CLIMATIC REGIONS

a. Spatial Convergence between Land and Water Productivity for Water Intensive Crops

This section analyses that, whether there is a convergence between land and water productivity of water intensive crops such as rice, wheat and sugarcane with at different levels of for instance for rice in 1980-83 it is (high from above 1500, moderate between 1000 to 1500 and low below 1000) of land and water productivity across the different states in India, likewise for rest of the others. (Please see Appendix A-4.3, 4.4, 4.5, 4.6, 4.7, 4.8).

Rice

Table: 4.4 Spatial Convergences between Land and Water Productivity of Rice in 1980-83

			Rice Land Productivity (in Kg./hectare) 1980-83			
			1.00 (<1000)	2.00 (1000-1500)	3.00 (>1500)	Total
Rice Water Productivity (inKg/hectare mm) 1980-83	1.00 (<1000)	Count	3	1	0	4
		% within RWP_1980	75.0%	25.0%	.0%	100.0%
	2.00 (1000-1500)	Count	2	3	1	6
		% within RWP_1980	33.3%	50.0%	16.7%	100.0%
	3.00 (>1500)	Count	0	1	6	7
		% within RWP_1980	.0%	14.3%	85.7%	100.0%
Total		Count	5	5	7	17
		% within RWP_1980	29.4%	29.4%	41.2%	100.0%

Where, 1 refers to Low level, 2 for Moderate level and 3 for High level of land and water productivity respectively and RWP for Rice Water Productivity.

Table: 4.5 Spatial Convergences between Land and Water Productivity of Rice in 2005-06

			Rice Land Productivity (in Kg./hectare) 2005-06			
			1.00 (<2000)	**2.00 (2000-3000)**	**3.00 (>3000)**	Total
Rice Water Productivity (inKg/hectare mm) 2005-06	**1.00 (<2000)**	Count	5	1	1	7
		% within RWP_2005	**71.4%**	**14.3%**	**14.3%**	100.0%
	2.00 (2000-3000)	Count	1	4	1	6
		% within RWP_2005	**16.7%**	**66.7%**	**16.7%**	100.0%
	3.00 (Above 3000)	Count	0	2	2	4
		% within RWP_2005	**.0%**	**50.0%**	**50.0%**	100.0%
Total		Count	6	7	4	17
		% within RWP_2005	35.3%	41.2%	23.5%	100.0%

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Rice

Tables 4.1 and 4.2 shows a strong convergence between water and land productivity of rice at low, moderate and high all three levels, in 1980-83. There were four states where a level of water productivity was low, out of which three states had low level of land productivity. Apart from this, most of the states with high level of water productivity also had high land productivity around 85.7. On the other hand, in 2005-06, the picture is quite different unlike 1980-83; now seven states have low level of water productivity and low level of land productivity. It has been observed that during the considered period the returns in terms of yield have been gone down since only 4 states have high level of water productivity out of which only two states have recorded high (50 percent) land productivity while two states have shown moderate land productivity. The comparison of 1980-83 and 2005-06 shows that in 1980-83 the states with low water productivity had low land productivity, whereas in 2005-06 only 2 states have high land and water productivity which indicates that it is not necessary that higher the amount of water consumption would produce the same amount of land productivity however during this time period, some states have shifted their levels according to their water dependence.

Wheat

Table: 4.6 Spatial Convergences between Land and Water Productivity of Wheat in 1980-83

			Wheat Land Productivity (in Kg./hectare) 1980-83			
			1.00 (<1000)	**2.00 (1000-2000)**	**3.00 (>2000)**	Total
Water Productivity of Wheat (in Kg/hectare mm) 1980-83	**1.00 (<1500**	Count	6	0	0	6
		% within WWP_1980	**100.0%**	**.0%**	**.0%**	100.0%
	2.00 (1500-3000)	Count	1	4	0	5
		% within WWP_1980	**20.0%**	**80.0%**	**.0%**	100.0%
	3.00 (>3000)	Count	0	4	2	6
		% within WWP_1980	**.0%**	**66.7%**	**33.3%**	100.0%
Total		Count	7	8	2	17
		% within WWP_1980	41.2%	47.1%	11.8%	100.0%

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Table: 4.7 Spatial Convergences between Land and Water Productivity of Wheat in 2005-06

			Land Productivity of Wheat (in Kg/hectare) 2005-06			
			1.00 (<2000)	2.00 (2000-3000)	3.00 (>3000)	Total
Water Productivity of Wheat (in Kg/hectare mm) 2005-06	1.00 (<3000)	Count	8	0	0	8
		% within WWP_2005	**100.0%**	**.0%**	**.0%**	100.0%
	2.00 (3000-5000)	Count	1	2	0	3
		% within WWP_2005	**33.3%**	**66.7%**	**.0%**	100.0%
	3.00 (>5000)	Count	0	3	3	6
		% within WWP_2005	**.0%**	**50.0%**	**50.0%**	100.0%
Total		Count	9	5	3	17
		% within WWP_2005	52.9%	29.4%	17.6%	100.0%

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Wheat

In case of wheat, changes can be seen for the higher level. In 1980-83 there were six states which had higher level of water productivity but they had moderate level of yield whereas in 2005-06 in front of higher water productivity level, land productivity has increased from moderate to high level which shows that the positive relationship between land and water productivity. It has increased for the six states which have higher level of water productivity of wheat.

Table 4.8 Spatial Convergences between Land and Water Productivity of Sugarcane in 1980-83

			Sugar cane Land Productivity (in Kg./hectare) 1980-83			
			1.00(<50000)	**2.00(50000-100000)**	**3.00 (>100000)**	Total
Water Productivity of Sugar cane (in Kg/hectare mm) 1980-83	**1.00 (<30000)**	Count	5	2	0	7
		% within SWP_1980	**71.4%**	**28.6%**	**.0%**	100.0%
	2.00 (30000-50000)	Count	1	4	0	5
		% within SWP_1980	**20.0%**	**80.0%**	**.0%**	100.0%
	3.00 (>50000)	Count	0	1	4	5
		% within SWP_1980	**.0%**	**20.0%**	**80.0%**	100.0%
Total		Count	6	7	4	17
		% within SWP_1980	35.3%	41.2%	23.5%	100.0%

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Table 4.9 Spatial Convergences between Land and Water Productivity of Sugarcane in 2005-06

			Land Productivity of Sugar cane (in Kg/hectare) 2005-06			
			1.00 (<60000)	**2.00 (60000-100000)**	**3.00 (>100000)**	Total
Water Productivity of Sugar cane (in Kg/hectare mm) 2005-06	**1.00 (<30000)**	Count	4	4	0	8
		% within SWP_2005	**50.0%**	**50.0%**	**.0%**	100.0%
	2.00 (30000-50000)	Count	2	2	1	5
		% within SWP_2005	**40.0%**	**40.0%**	**20.0%**	100.0%
	3.00 (Above 50000)	Count	0	2	2	4
		% within SWP_2005	**.0%**	**50.0%**	**50.0%**	100.0%
Total		Count	6	8	3	17
		% within SWP_2005	**35.3%**	**47.1%**	**17.6%**	**100.0%**

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Sugarcane

For sugarcane in 2005-06, changes can be observed at different levels of water productivity. Majority of the states (eight states) have low level of water productivity and at the same level, four states have shown an increase in the yield level but not in the water productivity level, whereas there are two states which have moderate level of water productivity but yield level is low which shows an inverse relationship between water and land productivity.

Same situation observed at higher level, out of four states, two states have recorded a moderate increased the yield of sugarcane and two states have increased high level. So same for sugarcane, it is observed that it is not necessary that higher the level of water productivity or water consumption would increase the same amount of yield; here it is varying across the states.

4.5 b. Spatial Convergence between Aggregate Land and Water Productivity

Table 4.10 Spatial Convergences between Aggregate Land and Water Productivity in 1980-83

			Aggregate Land Productivity (RsLakh/hectare) 1980-83			
			1.00 (<50)	**2.00 (50-100)**	**3.00 (>100)**	Total
Aggregate Water Productivity (RsLakh/hectare mm) 1980-83	**1.00 (<100)**	Count	6	5	0	11
		% within AWP_1980_	54.5%	45.5%	.0%	100.0%
	2.00 (100-200)	Count	0	4	1	5
		% within AWP_1980_	.0%	80.0%	20.0%	100.0%
	3.00 (>200)	Count	0	0	1	1
		% within AWP_1980_	.0%	.0%	100.0%	100.0%
Total		Count	6	9	2	17
		% within AWP_1980_	35.3%	52.9%	11.8%	**100.0%**

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Table 4.11 Spatial Convergences between Aggregate Land and Water Productivity of in 2005-06

			Aggregate Land Productivity (RsLakh/ hectare) 2005-06			Total
			1.00(<100)	2.00 (100-150)	3.00 (>150)	
Aggregate Water Productivity (Rs Lakh/hectare mm) 2005-06	1.00 (<150)	Count	7	3	0	10
		% within AWP_2005	70.0%	30.0%	.0%	100.0%
	2.00 (150-200)	Count	2	2	1	5
		% within AWP_2005	40.0%	40.0%	20.0%	100.0%
	3.00 (>200)	Count	1	0	1	2
		% within AWP_2005	50.0%	.0%	50.0%	100.0%
Total		Count	10	5	2	17
		% within AWP_2005	58.8%	29.4%	11.8%	**100.0%**

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

In the case of Aggregate land and water productivity, in 1980-83, out of 17 states, 11 states had low level of water productivity, out of which six states had low level of yield and rest of the five states such as West Bengal, Assam, Haryana, Uttar Pradesh and Himachal Pradesh have shown a moderate increase in the level of aggregate land productivity but from low level of water productivity. Punjab had moderate water productivity but aggregate land productivity was high, which shows that land productivity has been increasing at the cost of water productivity. Kerala was the only state which had optimum balance between high level of water productivity and high level of land productivity.

Major changes can be observed in 2005-06 where majority of the states have low level of water productivity having low level of yield.

Out of ten states, in seven states, the aggregate land productivity was low as against water productivity but three states such as West Bengal, Haryana, Andhra Pradesh have shown an increase in the level of yield to moderate level from same low level of water productivity, so land productivity is increasing but water productivity is not increasing which would be a problematic situation. In two states such as Himachal Pradesh and Karnataka, aggregate water productivity is moderate but land productivity has decreased and got low level and in reverse of that Punjab experienced increasing in yield but not increase in water productivity level. Gujarat is only single state which has high level of water productivity but yield level is low.

4.6. COMPARATIVE ANALYSIS OF AGGREGATE LAND AND WATER PRODUCTIVITY IN INDIA BY AGRO-CLIMATIC REGIONS

This section compares the land and water productivity in different agro-climatic regions between 1980-83 and 2005-06. For this purpose the 17 major states of India are divided into 3 broad agro-climatic regions namely: a) humid region, b) semi arid region and c) arid region which comprises 5, 11 and 1 states respectively. Humid region is further divided into moderate and low irrigated regions while semi arid region has three sub divisions viz. highly irrigated, moderately irrigated and less irrigated regions. Both the indices have divided by 1 to make a comparable.

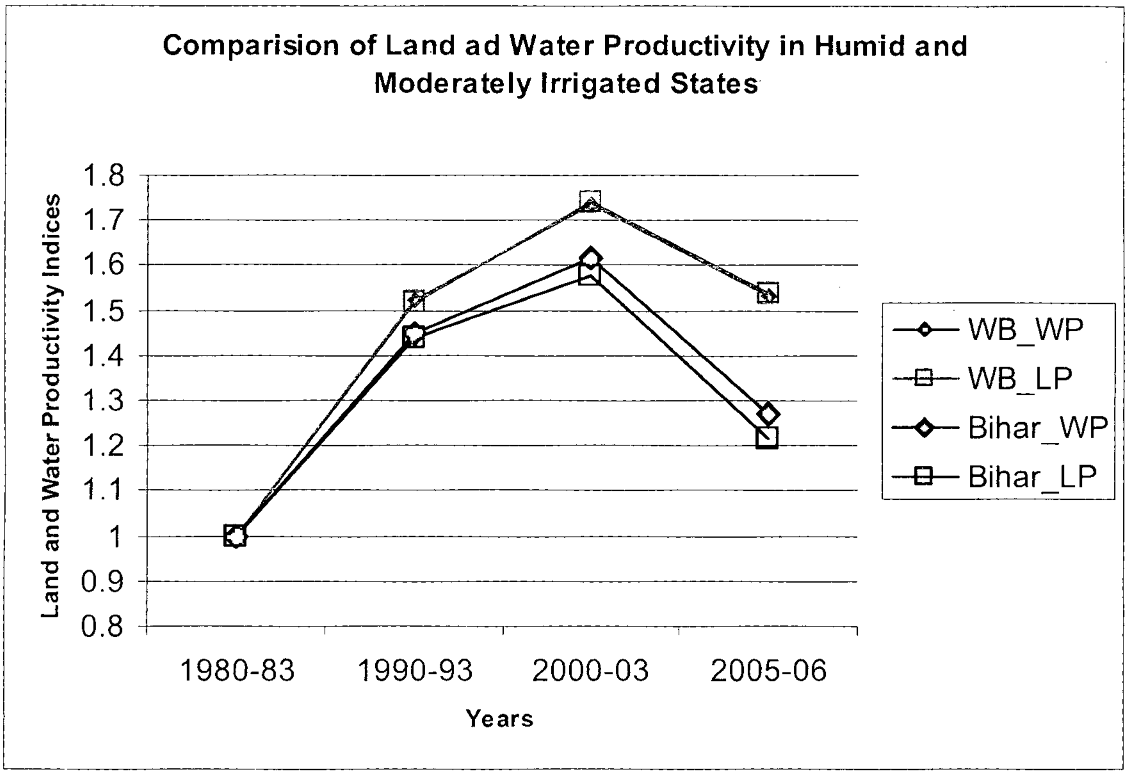


Figure: 4.1 Comparisons of Aggregate Land and Water Productivity Indices in Humid Moderately Irrigated States.

Figure 4.1 shows the aggregate land and water productivity from 1980-83 to 2005-06 for moderately irrigated humid states viz. West Bengal and Bihar. Here it is clearly visible that both have shown a similar trend. During the considered period both land and water productivity have increased sharply between 1980-83 and 1990-93 then they showed a moderate increase followed by a decline in both. In West Bengal, the land and water productivity have been almost same whereas in case of Bihar, the water productivity were same in the 1980-83, since then the gap between water and land productivity has been increasing with water productivity being higher than the land productivity. This trend shows a positive indication for the sustainability of both the resources in this state.

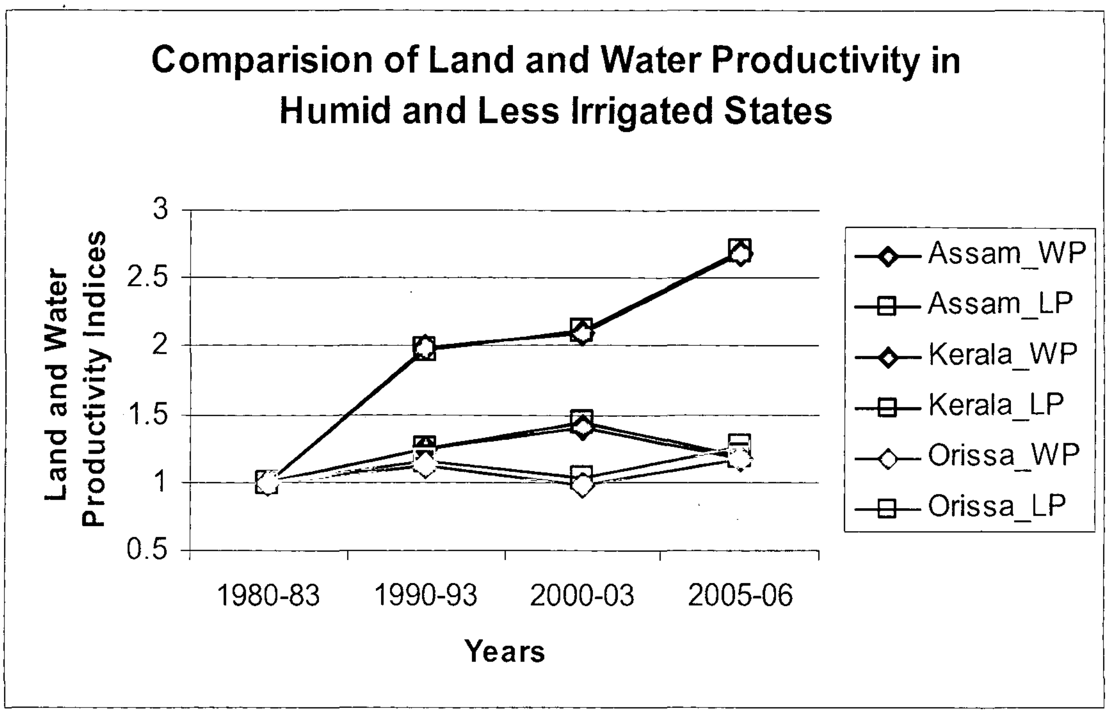


Figure: 4.2 Comparison of Aggregate Land and Water Productivity Indices in Humid Less Irrigated States.

Lesser irrigated humid region comprises Assam, Kerala and Orissa. It can be observed that land and water productivity are highly correlated in all three states showing different trends. Kerala is the leading state showing higher land and water productivity with increasing trend, while Assam has shown a marginal increase from 1980-83 to 2000-03 followed by a decline. On the other hand Orissa does not show any trend.

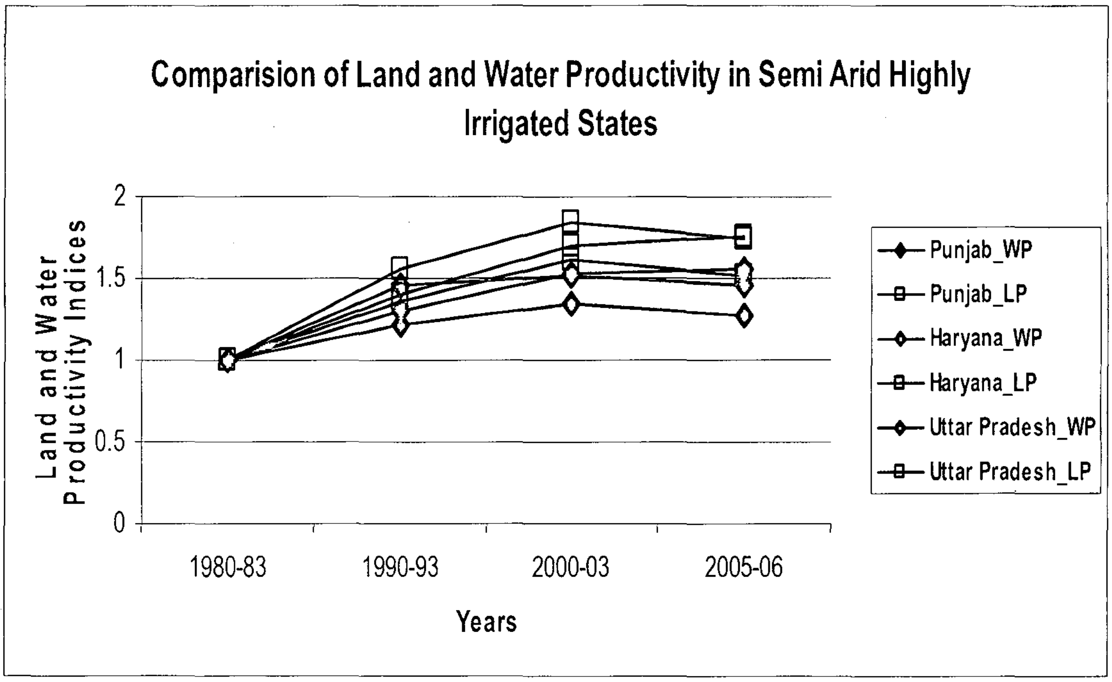


Figure: 4.3 Comparison of Aggregate Land and Water Productivity Indices Semi arid Highly Irrigated States.

The semi arid highly irrigated region (Punjab, Haryana and Uttar Pradesh) has shown presents a completely different picture it shows that land and water productivity in these states were same in 1980-83, which have moderately increased till 200-03 then showed a marginal decline. An important observation is that the gap between land and water productivity is increasing with land productivity being higher than the water productivity. These are the states which have been extracting their ground water resources for a long period of time which led to an increase in the land productivity at the cost of higher water consumption.

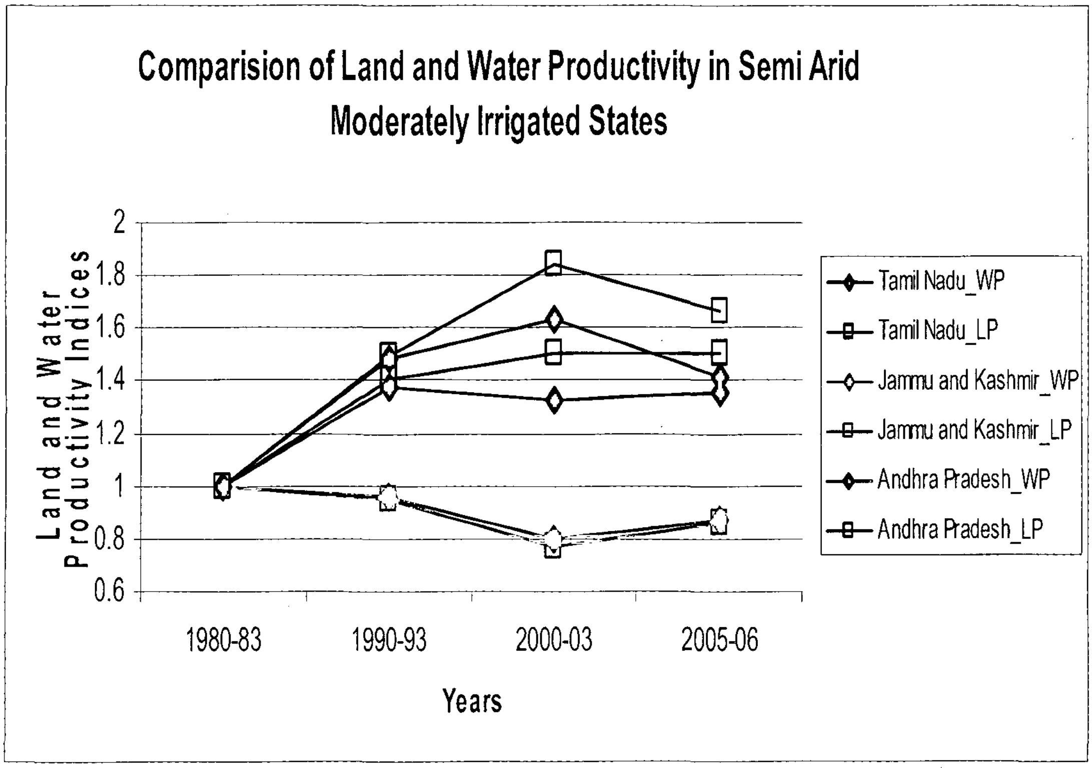


Figure: 4.4 Comparison of Aggregate Land and Water Productivity Indices in Semi arid Moderately Irrigated States.

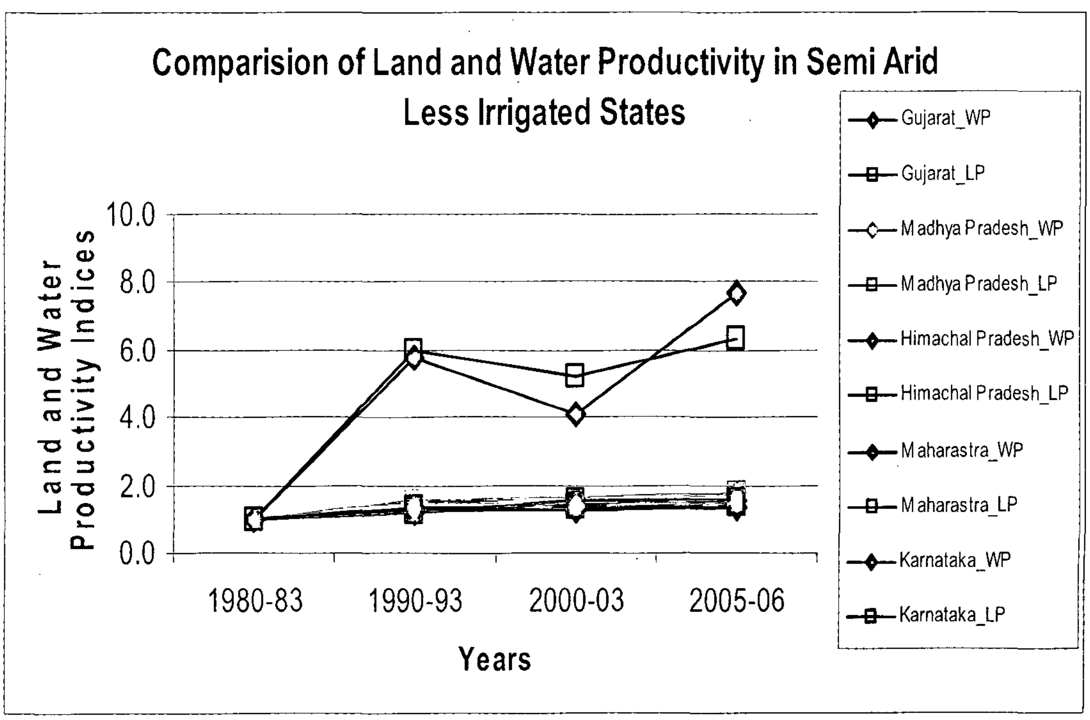


Figure: 4.5 Comparison of Aggregate Land and Water Productivity Indices in Semi arid Less Irrigated States.

In the case of moderately irrigated semi arid region, two states namely Tamil Nadu and Andhra Pradesh have shown a trend similar to the highly irrigated region. A declining trend is observed in both land and water productivity for Jammu and Kashmir.

Aggregate Land and Water Productivity in Semi Arid and Less Irrigated States

In case of less irrigated semi arid region it is observed that four (Madhya Pradesh, Himachal Pradesh, Maharashtra and Karnataka) out of five states have a similar trend where land and water productivity both are relatively higher than other regions. Land productivity has shown marginal increase during the considered period. Only state is Gujarat has shown a sharp increase in both land and water productivity between 1980-83 and 2000-03 than again showed an increase. Equally important to note is that the increase in water productivity is much sharper than the land productivity. This region has shown an efficient utilization of both the resources which can be attributed to their distinct cropping pattern which is less water intensive as discussed in previous chapter.

Aggregate Land and Water Productivity in Arid Region

Rajasthan is the only arid state which shows a similar trend as shown by semi arid less irrigated states. It has almost same water and land productivity and both have been increasing during the considered period.

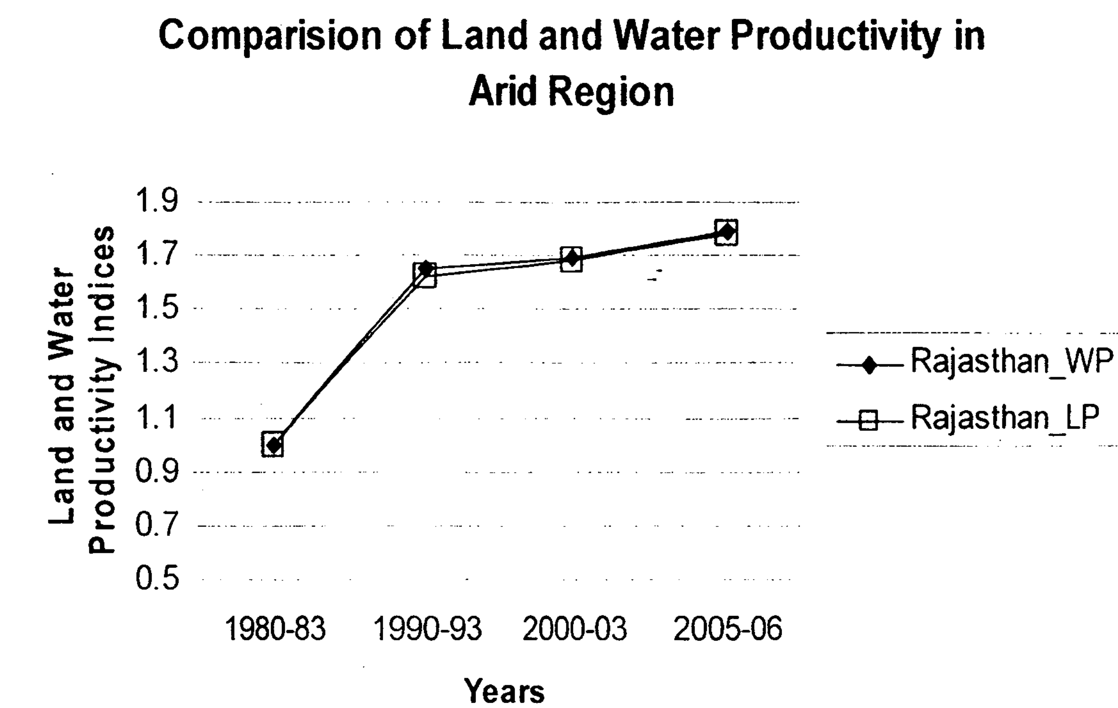


Figure: 4.6 Comparisons of Aggregate Land and Water Productivity Indices in Arid Region.

4.7: AGGREGATE WATER PRODUCTIVITY, IRRIGATION EXTENT AND IRRIGATION INTENSITY

Table Number: 4.12 Correlations between Aggregate Water Productivity and Irrigation Extent

		Aggregate Water Productivity	**Percentage of Irrigation Extent**
Aggregate Water Productivity 1981	Pearson Correlation	1	-.013
	Sig.(2-tailed)	.	.959
	N	17	17
Percentage of Irrigation Extent 1981	Pearson Correlation	-.013	1
	Sig.(2-tailed)	.959	.
	N	17	17
Aggregate Water Productivity 1991	Pearson Correlation	1	-.171
	Sig.(2-tailed)	.	.512
	N	17	17
Percentage of Irrigation Extent 1991	Pearson Correlation	-.171	1
	Sig.(2-tailed)	.512	.
	N	17	17
Aggregate Water Productivity 2001	Pearson Correlation	1	-.116
	Sig.(2-tailed)	.	.657
	N	17	17
Percentage of Irrigation Extent 2001	Pearson Correlation	-.116	1
	Sig.(2-tailed)	.657	.
	N	17	17
Aggregate Water Productivity 2006	Pearson Correlation	1	-.184
	Sig.(2-tailed)	.	.479
	N	17	17
Percentage of Irrigation Extent 2006	Pearson Correlation	-.184	1
	Sig.(2-tailed)	.479	.
	N	17	17

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

Table 4.10 has shown that there is a negative but not significant interrelationship between aggregate water productivity and irrigation extent because 'r' value between these two variables is insignificant that correlation is general but shows negative trend that means irrigation extent is increasing the aggregate water productivity is decreasing. The entire semi arid highly irrigated states and humid states as well experienced the same trend.

Thus it can be stated that aggregate water productivity declining with increase in irrigation extent.

Table Number: 4.13 Correlations between Aggregate Water Productivity and Irrigation Intensity.

		Aggregate Water Productivity	Irrigation Intensity
Aggregate Water Productivity 1981	Pearson Correlation	1	.470
	Sig.(2-tailed)	.	.057
	N	17	17
Irrigation Intensity 1981	Pearson Correlation	.470	1
	Sig.(2-tailed)	.057	.
	N	17	17
Aggregate Water Productivity 1991	Pearson Correlation	1	-.111
	Sig.(2-tailed)	.	.672
	N	17	17
Irrigation Intensity 1991	Pearson Correlation	-.111	1
	Sig.(2-tailed)	.672	.
	N	17	17
Aggregate Water Productivity 2001	Pearson Correlation	1	-.167
	Sig.(2-tailed)	.	.521
	N	17	17
Irrigation Intensity 2001	Pearson Correlation	-.167	1
	Sig.(2-tailed)	.521	.
	N	17	17
Aggregate Water Productivity 2006	Pearson Correlation	1	-.275
	Sig.(2-tailed)	.	.286
	N	17	17
Irrigation Intensity 2006	Pearson Correlation	-.275	1
	Sig.(2-tailed)	.286	.
	N	17	17

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

In case of Irrigation Intensity in 1980-83, though there was positive but not significant interrelationship between aggregate land and water productivity but afterwards it has been found negative but not significant interrelationship because 'r' value between these two variables became negative with and becoming more negative till 2005-06. It shows that as irrigation intensity is increasing the aggregate water productivity is declining.

4.8: AGGREGATE WATER PRODUCTIVITY AND TUBE WELL IRRIGATION

Table 4.10 shows that till 2001, there was a positive but not a strong relationship between the aggregate water productivity and tube well irrigation, but in 2006 it has become negative. In recent period of time, mostly all the states having larger proportion of tubewell irrigation, ground water has been exploited in most of the semi arid highly irrigated states, though land productivity is increasing but aggregate water productivity is not increasing because water productivity has increased up to certain level after that the excessive use of water can lead a serious consequences like alkalization and land salinization.

There is strong positive relationship between tube well irrigation and aggregate water productivity for semi arid highly irrigated states but it is not strong as for less irrigated semi arid states and it reverse of that there is negative relationship for humid states for all the time.

That indicates over the time period factors other than tubewell irrigation seems to have changing the importance I terms of their contribution to crop productivity.

Table Number: 4.14 Correlations between Aggregate Water Productivity and Tube Well Irrigation

		Aggregate Water Productivity	**Percentage of Tube Well Irrigation**
Aggregate Water Productivity 1991	Pearson Correlation	1	0.47
	Sig.(2-tailed)	.	.859
	N	17	17
Percentage of Tube Well Irrigation 1991	Pearson Correlation	0.47	1
	Sig.(2-tailed)	.859	.
	N	17	17
Aggregate Water Productivity 2001	Pearson Correlation	1	.106
	Sig.(2-tailed)	.	.687
	N	17	17
Percentage of Tube Well Irrigation 2001	Pearson Correlation	.106	1
	Sig.(2-tailed)	.687	.

	N	17	17
Aggregate Water Productivity 2006	Pearson Correlation	1	-.237
	Sig.(2-tailed)	.	.360
	N	17	17
Percentage of Tube Well Irrigation 2006	Pearson Correlation	-.237	1
	Sig.(2-tailed)	.360	.
	N	17	17

Source: Computed by Central Statistics of Organisation, Department of Planning and Programme Implementations, Government of India

4.9 INTERRELATIONSHIP BETWEEN LAND AND WATER PRODUCTIVITY

a. Interrelationship between Aggregate Land and Water Productivity

There is positive high significant interrelationship between the different land and water productivity of selected crops and correlation results have shown that there is a significantly high positive interrelationship at 0.01 significant levels between high aggregate land productivity and aggregate water productivity. (Please see Appendix 4.1 Table no; A-4.9 onwards) However it does vary between highly irrigated and less irrigated states across different agro climatic regions in India.

b. Interrelationship between Land and Water Productivity of more Water intensive crops

There is significant positive interrelationship between Land and water productivity of water intensive crops at 99 percent of significance level (2-tailed) for all the time. Coefficient 'r' value is satisfactory. By the time period interrelationship between land and water productivity of wheat is increasing but in reverse of that 'r'-value is marginally decrease in the case of rice and sugarcane, though still land and water productivity have significantly correlated for these crops.

Conclusion

- The correlation of land and water productivity is significant for all periods of time, though the strength of the association is more for the aggregate land and water productivity than the individual crops.
- Over a period of time, the comparison of indices of land and water productivity reveals an interesting trend. The water productivity in less irrigated semi arid regions and the dominantly humid states have increased faster or at the same rate as land productivity. On the other hand, in case of the highly or moderately irrigated semi arid states, the aggregate land productivity has increased faster than the water productivity.
- The above has happened because of movement towards a highly water intensive cropping pattern in the semi-arid irrigated states and a movement away from rice albeit to a lesser extent in the humid states.

Chapter V

Conclusion

Chapter 5

5.1 Conclusion and major findings

The study was undertaken to examine the extent and nature of changes in cropping pattern in India over last 26 years. This study intends to identify to what extent crop areas are shifting and what crops are emerging as more important crops in India in recent times. This study provides an insight of its implication with the crop diversification scenario in different states of India. The first chapter of this study observed the analysis of cropping pattern which reveals that in India crop area shifts has taken place in favour of rice, wheat, total oilseeds and some non-food crops. However, regional trends throw up interesting points. Most of the states having primarily humid agro-climatic regime, which are also the traditional growers of rice, have experienced a reduction in the relative share of rice in their respective cropping patterns.

On the other hand, the states having dominantly a semi-arid agro-climatic regime are moving towards rice, and in many cases, towards a rice-wheat cropping cycle, which is highly water intensive. These two crops are replacing broadly two categories of crops, which are coarse cereals, and pulses which are the least water intensive crops. The analysis suggests that proportion of these less water intensive crops have been significantly declined over the time.

This trend has been a cause for concern. Though the irrigated semi-arid states have been the more productive states in terms of yield levels; previous studies reveal that in many of these states the growth rate of production, more particularly the yield has been stagnating in these states, for crops that are water intensive.

Analysis of crop diversification study reveals that Western region is highly diversified than Southern, South-Eastern & Central region, followed by the north western region and the hilly state of Himachal Pradesh, while the eastern states are highly specialized states. It can be stated that south & western region were moving towards diversification while northern & eastern region is moving towards specialization.

Actually these regions were moving towards more & more food grains especially rice and wheat which is high water intensive crop.

So, it is clear that such cropping pattern shifts can be explained only by expansion of irrigation .An analysis of data in chapter three provides the evidence. It is noticed that there is wide heterogeneity in terms of irrigation extent across the different states in India. The variation is visible when we go to the regional level with different agro climatic regions. The high water intensive crops are significantly higher in areas where high level of irrigation extent.

The proportion of area under tube well irrigation and area under ground water irrigation has increased remarkably in India. Its pace is relatively higher in semi arid and arid states as compare to the humid states. As dependence of area under tube well irrigation increased, the extension of irrigation has also increased in high irrigated and low irrigated regions in India at the cost of dependence of area under surface irrigation and other sources which have gone down in all India.

The states exhibiting growth in terms area of area under tube well irrigation also noticed increase in proportion of water intensive crops such as rice and sugarcane. This study reveals that states which have been experienced the dominance of area under tube well irrigation or states where dependence of ground water irrigation is higher and experiencing high growth rate of water intensive crops such as rice, sugar cane and wheat.

Rice and wheat which are dynamic crops comprises major share in all these high irrigated states and tube well irrigation also playing significant role to accelerate it. Whereas in moderate and low irrigated regions, degree of diversification of crops is also high and less water intensive crops such as total pulses and total oilseeds accounted significant share there.

Analysis regarding difference in cropping patterns in irrigated and less irrigated regions suggests that mostly all highly and moderately semi arid states are tending towards more water intensive crops such as rice and wheat whereas less semi arid states have been shifted their cropping patterns according to their efficiency of water availability.

A negative relationship can be seen for tube well irrigation and area under less water intensive crops such as coarse cereals and total oilseeds. With increasing tubewell irrigation, the majority of the states are moving towards water intensive crops than the less water intensive crops, which affects the water consumption level of concerned states. The study has clearly revealed that many of the semi arid moderately irrigated states has experienced increase in the water consumption of different crops .Contrary to this situation, land productivity has increased marginally or become stagnated and level of water productivity is low as well. At all India level, the status of aggregate water productivity in terms of relationships between productivity growth and rise in water consumption is positive for 1991 as well as 2001. The relationship was relatively stronger in 1991 than in 2001, which suggests that the relative impact on water consumption on productivity growth of different crops have declined over time .It does not justify with the increase in irrigation extent with aggregate water productivity at present time (see Appendix 4.9, 10).this could be a result of rise in relative importance of factors other than irrigation in the growth.

For semi arid highly irrigated states, although land productivity have increased by the virtue of progress in tube well irrigation but the gap between land and water productivity has have been increasing with land productivity being higher than the water productivity. These are the states like Punjab, Haryana, and Uttar Pradesh which have been extracting their ground water resources for a long period of time which led to an increase in the land productivity at the cost of higher water consumption because the productivity per unit of water tapped is much higher in the case of ground water compared to surface irrigation because ground water irrigation involves much less waste by way of conveyance and application losses and farmers have much greater flexibility to adjust timings and the quantum of water application to the crop needs. So finally it can be concluded by the following point:

- The correlation of land and water productivity is significant for all periods of time, though the strength of the association is more for the aggregate land and water productivity than the individual crops.
- Over a period of time, the comparison of indices of land and water productivity reveals an interesting trend. The water productivity in less irrigated semi arid regions and the dominantly humid states have increased faster or at the same rate as land productivity. On the other hand, in case of the highly or moderately irrigated semi arid states, the aggregate land productivity has increased faster than the water productivity.

The above has happened because of movement towards a highly water intensive cropping pattern in the semi-arid irrigated states and a movement away from rice albeit to a lesser extent in the humid states.

The semi arid highly irrigated states where tubewell irrigation is predominant, a farmer is getting higher returns from the land productivity but water productivity is becoming low which is threatening for sustainability of both the resources and further there is no such impact can be seen by the increase of tube well irrigation on aggregate water productivity. In fact it is declining with increase in irrigation extent. Contrary to this, in semi arid less irrigated states and arid states the increase in water productivity is much sharper than the land productivity. This region has shown an efficient utilization of both the resources which can be attributed to their distinct cropping pattern which is less water intensive and all these states in this region have become diversified rapidly from high water intensive crops towards low water intensive crops. So in India in most of semi arid irrigated states, there is a trend that with the increase in irrigation extent or by progress in tube well irrigation, cropping patterns have been changing towards water intensive crops, but there has been increasing the gap between land and water productivity which is a questionable issue for the sustainability of both the precious natural resources.

So water plays very significant role to increase the yield and water productivity. A combination of better water and other input management would contribute to this yield increase. Highly irrigated states can benefit from water management, which can conserve water with only a marginal loss of yield. Saved water can then be used for additional crop water requirements for multiple cropping systems and would increase the more crop water productivity.

5.2 Emerging Issues and suggestions

1. There is a rising gap between aggregate land and water productivity level for the states where irrigation extent is relatively high or moderate level.

2. Most of the semi arid states, which are getting high and moderate level of irrigation extent, the excessive use of ground water dependence would lead the serious consequences by ground water depletion (Vaidyanathan, A, depletion of ground water: some issues) and ecology by which soil and water levels are deteriorating.

3. Like Punjab, the rural electricity has not been subsidized equally for all the states.

4. Equitable distribution of water to the fields and adoption of proper water application methods have great bearing on the benefits by way of returns pr unit of water delivered to each hectare of land irrigated.

Experience has however shown that many farmers, now knowing the implications to their fields, suffer by way of low production and also cause damage to their lands. They also deprive other farmers whose lands are situated in tail reaches, therefore there is need has been felt to ensure equitable, timely and efficient water utilization in the tertiary system below the outlet by organizing irrigation scheduling and coordinated water delivery plan (Hazra,2002)

5. Augmenting access to water resources to all farmers including small and marginal is the need of the day. This can be achieved by creating and empowering regulatory bodies meant to restrict unwanted and indiscriminate use of water without proper permission and regulating the use of water from the surface as well as tube wells.
6. In drought prone regions, drought tolerant crops can be selected where water is very scarce or unreliable.
7. By better matching crops to climatic conditions and to see whether the quality of water available or not and breeding more water efficient crop varieties in order to sustainable management.

So by the optimal cropping patterns, better irrigation management, conjunctive use of water is very essential for present day scenario of water productivity in India, because now more water use resulting in higher production may not always be true. There is a need of proper water management to enhance the more crop output by per drop of water use otherwise it will be a big threaten for the sustainability of both the precious resources such as land and water productivity .

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Appendix 2.1

Table No. A 2.1	CROP GCA RATIO (during 1980-83)						
States	Rice	Wheat	Coarse Cereals	Total Oilseeds	Total Pulses	Sugar	Cotton
Andhra Pradesh	29.04	0.13	23.42	15.31	11.50	1.26	3.51
Assam	65.66	2.98	0.59	7.36	3.40	1.41	0.12
Bihar	49.07	16.32	8.26	2.33	12.44	1.16	0.00
Gujarat	4.46	6.17	24.47	23.70	3.57	0.78	14.13
Haryana	8.84	28.71	18.61	4.22	14.90	2.46	6.27
Himachal Pradesh	10.21	37.53	30.27	2.16	5.52	0.32	0.05
Jammu and Kashmir	27.20	20.68	29.73	5.47	5.14	0.08	0.06
Karnataka	10.23	2.97	24.78	12.13	13.61	1.57	8.86
Kerala	27.66	0.00	0.06	0.91	1.13	0.27	0.20
Madhya Pradesh	22.29	15.70	14.60	9.49	22.16	0.20	2.74
Maharashtra	7.47	5.36	41.03	9.97	13.48	1.46	13.31
Orissa	48.06	0.76	2.46	9.22	20.04	0.58	0.05
Punjab	18.28	42.59	5.82	3.14	4.21	1.36	9.97
Rajasthan	0.79	10.07	37.57	6.85	19.38	0.19	2.09
Tamil Nadu	33.94	0.01	14.90	16.50	9.66	2.88	3.36
Uttar Pradesh	20.26	31.12	10.72	13.98	11.62	6.17	0.14
West Bengal	69.26	3.47	0.72	4.61	6.01	0.31	0.00

Table No. A-2.2	CROP GCA RATIO (during 1990-93)						
States	Rice	Wheat	Coarse Cereals	Total Pulses	Total Oilseeds	Sugar	Cotton
Andhra Pradesh	28.70	0.08	11.96	12.36	25.17	1.42	5.80
Assam	65.67	1.99	0.48	2.94	8.22	0.98	0.05
Bihar	47.82	20.61	7.34	10.76	2.32	1.36	0.00
Gujarat	5.51	4.69	18.80	8.37	27.38	1.17	10.60
Haryana	12.16	33.43	12.24	7.79	11.50	2.36	9.30
Himachal Pradesh	8.46		31.95	4.06	2.19	0.23	0.01
Jammu and Kashmir	25.55		28.93	3.49	7.07	0.03	0.01
Karnataka	10.63	1.77	22.76	13.56	23.86	2.28	4.80
Kerala	17.42	0.00	0.17	0.78	0.73	0.22	0.36
Madhya Pradesh	21.63	15.85	10.11	19.85	20.22	0.19	2.12
Maharashtra	7.46	3.30	37.91	15.54	12.29	1.92	12.29
Orissa	46.75	0.14	1.36	17.12	7.57	0.25	0.05
Punjab	27.84	43.40	2.62	1.36	2.52	1.31	8.49
Rajasthan	0.73	10.51	38.22	16.51	18.31	0.13	2.55
Tamil Nadu	31.17	0.00	23.02	11.54	19.10	3.32	3.59
Uttar Pradesh	21.25	34.73	9.15	11.29	6.79	7.26	0.05
West Bengal	66.79	3.20	0.60	3.29	6.29	0.16	0.00

Table No. A-2.3	CROP GCA RATIO during 2001						
States	Rice	Wheat	Coarse Cereals	Total Pulses	Total Oilseeds	Sugar	Cotton
Andhra Pradesh	28.76	0.10	9.89	15.64	19.64	3.09	7.75
Assam	64.14	1.76	0.50	2.83	7.60	0.68	0.05
Bihar	50.53	21.69	7.39	8.15	1.93	1.09	0.00
Gujarat	6.26	4.02	17.52	6.60	26.96	2.44	15.99
Haryana	16.18	37.47	11.28	2.56	8.35	2.67	9.22
Himachal Pradesh	8.60	38.21	31.59	3.35	1.72	0.32	0.00
Jammu and Kashmir	22.13	23.91	31.12	2.52	6.55	0.00	0.00
Karnataka	11.17	2.15	22.76	16.91	15.57	3.35	4.27
Kerala	10.87	0.00	0.07	0.39	0.13	0.11	0.12
Madhya Pradesh	20.75	13.37	6.56	19.77	21.41	0.30	1.99
Maharashtra	6.83	3.44	31.22	15.76	11.11	2.62	13.48
Orissa	52.41	0.20	2.17	7.61	8.49	0.34	0.52
Punjab	32.15	43.00	2.12	0.66	1.10	1.75	6.45
Rajasthan	0.66	10.79	29.97	14.15	13.09	0.05	2.37
Tamil Nadu	29.64	0.00	8.38	10.98	11.65	4.70	2.15
Uttar Pradesh	22.33	35.63	7.72	10.22	3.14	8.02	0.02
West Bengal	60.99	4.45	0.35	2.69	5.92	0.23	0.01

Table No. A-2.4	CROP GCA RATIO during 2006						
States	Rice	Wheat	Coarse Cereals	Total Pulses	Total Oilseeds	Sugar	Cotton
Andhra Pradesh	29.80	0.08	9.60	13.33	21.87	1.72	7.73
Assam	64.87	1.34	0.51	2.69	6.52	0.63	0.04
Bihar	48.39	21.65	8.81	9.01	1.75	1.11	0.00
Gujarat	5.89	8.10	13.67	6.87	26.82	1.74	16.86
Haryana	16.17	35.42	10.70	2.92	11.29	1.95	8.96
Himachal Pradesh	8.45	38.14	31.46	2.93	1.61	0.28	0.01
Jammu and Kashmir	23.76	22.75	30.76	2.46	0.58	0.02	0.00
Karnataka	11.40	1.94	22.16	15.21	21.93	1.68	3.17
Kerala	9.24	0.00	0.08	0.30	0.13	0.23	0.09
Madhya Pradesh	21.32	14.97	6.81	20.65	23.55	0.24	2.45
Maharashtra	6.72	4.14	29.47	15.22	16.17	2.22	12.75
Orissa	51.39	0.04	0.87	9.28	3.81	0.19	0.65
Punjab	32.68	42.89	1.89	0.40	1.01	1.04	6.89
Rajasthan	0.49	9.79	30.21	15.87	24.23	0.04	2.17
Tamil Nadu	33.99	0.00	9.96	8.71	11.77	5.56	2.33
Uttar Pradesh	22.30	36.25	7.37	10.66	4.20	8.56	0.02
West Bengal	60.66	3.85	0.55	2.33	6.73	0.16	0.02

Table Number: A-2.5

Changes in Relative Share in Crop GCA Ratio in different Agro Climatic Regions in India

Region	States	Years	Rice	Wheat	Coarse cereal	Com. crops	T. Pls.	T.Ols.
Humid	ASM	1981-1991	0.01	-0.99	-0.12	-1.41	-0.46	0.85
		1991-2001	-1.53	-0.23	0.02	-0.94	1.32	-0.62
		2001-2006	0.73	-0.42	0.01	1.48	-0.14	-1.08
	WB	1981-1991	-2.47	-0.27	-0.12	-1.25	-2.72	1.68
		1991-2001	-5.80	1.25	-0.25	0.80	-0.60	-0.37
		2001-2006	-0.33	-0.60	0.20	5.80	-0.36	0.80
	ORS	1981-1991	-1.30	-0.62	-1.09	-0.59	-2.92	-1.65
		1991-2001	5.66	0.06	0.80	0.46	-9.56	0.92
		2001-2006	-1.02	0.16	-1.29	0.01	1.67	-4.68
	BHR	1981-1991	-1.25	4.29	-0.92	0.18	-1.68	0.0
		1991-2001	2.71	1.08	0.05	-0.17	6.07	-0.39
		2001-2006	-2.14	-0.04	1.42	1.42	0.86	-0.18
	KRL	1981-1991	10.24	0	0.11	0.10	-0.36	-0.18
		1991-2001	-6.55	0	-0.10	-0.34	-0.39	-0.60
		2001-2006	-1.63	0	0.02	0.09	-0.09	0.0
Semi Arid	AP	1981-1991	-0.34	-0.06	-11.46	2.45	0.86	9.85
		1991-2001	0.07	0.03	-2.07	3.62	3.28	-5.53
		2001-2006	0.76	-0.67	-1.28	-1.38	-2.31	2.23
	GUJ	1981-1991	1.04	-1.48	-5.56	-3.14	4.81	3.68
		1991-2001	0.76	-0.67	-1.28	6.69	-4.52	-0.42
		2001-2006	-0.37	4.08	-3.86	0.18	0.28	-0.14
	HAR	1981-1991	3.32	4.72	-6.37	2.92	-7.11	7.28
		1991-2001	4.02	4.04	-0.96	0.23	-5.19	-3.15
		2001-2006	-0.01	-2.04	-0.58	-0.97	0.36	2.94
	HP	1981-1991	-1.75	0.69	1.67	-0.14	-145	0.03
		1991-2001	0.15	-0.01	-0.36	0.08	-0.71	-0.47
		2001-2006	-0.16	-0.07	-0.13	-0.03	-0.43	-0.11
	J & K	1981-1991	-1.65	2.35	-0.81	-0.10	-1.65	1.60
		1991-2001	-3.42	0.89	2.19	-0.14	-0.97	-0.52
		2001-2006	1.63	-1.16	-0.36	0.02	-0.06	-5.97
	KTK	1981-1991	0.40	-1.20	-2.02	-3.36	-0.06	11.73
		1991-2001	0.54	0.38	-0.01	0.55	3.35	-8.29
		2001-2006	0.23	-0.20	-0.59	-2.77	-1.70	6.36
	MP	1981-1991	-0.66	0.15	-4.49	-0.62	-2.13	10.73
		1991-2001	-0.88	-2.48	-3.54	-0.02	-0.08	1.19
		2001-2006	0.57	1.60	0.25	0.41	0.88	2.14

	MAH	**1981-1991**	-0.01	-2.06	-3.12	-0.56	2.07	2.31
		1991-2001	-0.64	0.14	-6.69	1.89	-6.69	1.89
		2001-2006	-0.11	0.70	-1.75	-1.13	-0.55	5.07
	PUN	**1981-1991**	9.56	0.81	-3.20	-1.53	-2.85	0.62
		1991-2001	4.31	-0.41	-0.50	-1.61	0.70	-1.42
		2001-2006	0.53	-0.10	-0.23	-0.27	-0.26	-0.09
	TN	**1981-1991**	-2.77	-0.01	-4.07	0.66	1.88	2.60
		1991-2001	-1.53	0.00	-2.45	-0.55	-0.56	-7.44
		2001-2006	4.34	0.00	1.58	1.04	-2.28	0.11
	UP	**1981-1991**	0.99	3.61	-1.57	0.96	-0.32	-7.91
		1991-2001	1.08	0.91	-1.44	0.73	-1.07	-3.65
		2001-2006	-0.03	0.62	-0.34	0.54	0.44	1.06
Arid	**RAJ**	**1981-1991**	-0.05	0.44	-4.65	0.41	-2.87	11.47
		1991-2001	-0.07	0.28	-2.95	-0.26	-2.36	-5.21
		2001-2006	-0.17	-1.00	0.24	-0.21	1.72	11.31

Appendix: 3.1

Table No. A-3.1	Percentage of Irrigation Extent			
States	1981	1991	2001	2006
Andhra Pradesh	32.24	39.06	40.74	41.44
Assam	21.54	21.14	6.22	3.75
Bihar	35.51	43.45	39.03	45.29
Gujarat	20.92	26.01	29.72	34.39
Haryana	59.24	72.71	83.89	83.85
Himachal Pradesh	16.08	17.07	21.93	19.22
Jammu and Kashmir	42.52	40.80	41.58	41.09
Karnataka	13.75	20.36	25.39	28.03
Kerala	10.92	14.84	17.27	18.39
Madhya Pradesh	12.47	22.06	26.35	32.25
Maharashtra	10.53	11.31	16.78	16.89
Orissa	19.82	30.68	33.16	32.17
Punjab	80.70	92.72	94.70	94.93
Rajasthan	19.54	23.84	30.93	38.58
Tamil Nadu	47.95	42.54	54.46	55.09
Uttar Pradesh	54.89	60.94	69.26	74.96
West Bengal	26.76	35.83	43.46	59.23
India	27.66	33.15	38.78	42.73

Table No. A-3.2	Irrigation Intensity during (1981-2006)				
States	1981	1991	2001	2006	1981-2006
Andhra Pradesh	1.25	1.25	1.31	1.36	0.11
Assam	1.00	1.00	1.27	1.44	0.44
Bihar	1.23	1.25	1.33	1.36	0.13
Gujarat	1.17	1.18	1.19	1.21	0.05
Haryana	1.55	1.63	1.80	1.82	0.27
Himachal Pradesh	1.70	1.68	1.44	1.77	0.07
Jammu and Kashmir	1.29	1.46	1.44	1.49	0.20
Karnataka	1.23	1.23	1.24	1.22	-0.01
Kerala	1.60	1.15	1.13	1.17	-0.43
Madhya Pradesh	1.05	1.03	1.04	1.26	0.21
Maharashtra	1.31	1.22	1.30	1.31	0.01
Orissa	1.41	1.20	1.32	1.46	0.05
Punjab	1.71	1.80	1.90	1.93	0.23
Rajasthan	1.26	1.19	1.25	1.23	-0.03
Tamil Nadu	1.28	1.22	1.21	1.15	-0.14
Uttar Pradesh	1.20	1.40	1.43	1.39	0.19
West Bengal	1.03	1.30	1.56	1.57	0.54
India	1.28	1.33	1.38	1.36	0.08

Table Number: A-3.3

Pre Existing Cropping Pattern Crop Area % to Gross Crop Area (1981)				
	Region	**Highly Significant level**	**Significantly level**	**Moderately level**
Irrigation Extent	**Humid**	**More than 30 %**	**10 % to 30%**	**2% to 10%**
Moderate	Bihar	RC	WT, T.PLS	CCL, T.OLS
	W.Bengal	RC		JT, T.PLS, T.OLS, WT
Low	Kerala		RC	
	Orissa	RC	T.PLS	T.OLS,CCL
	Assam	RC		T.OLS, JT, T.PLS,WT
	Semi Arid			
High	Punjab	WT	RC, CTN	CCL, T.PLS, T.OLS
	U.P	WT	RC,T.OLS,T.PLS,CCL	SCN
	T.Nadu	RC	T.OLS, CCL (JW)	T.PLS, CTN , SCN
	Haryana		WT, CCL, T.PLS	RC, CTN, SCN, T.OLS
	J&K		CCL,RC,WT	T.OLS,T.PLS
Moderate	A.P		RC,CCL,T.OLS, T.PLS	JT

Table Number: A-3.4

Existing Cropping Pattern Crop Area % to Gross Crop Area (2006)				
	Regions	**Highly Significant level**	**Significantly level**	**Moderately level**
Irrigation Extent	**Humid**	**More than 30 %**	**10 % to 30%**	**2% to 10%**
High	Bihar,	RC,	WT, CCL	TPLS
	W.Bengal	RC,		T.OLS, JT,WT,T.PLS
Moderate	Orissa	RC,		T.PLS, T.OLS
Low	Assam	RC,		T.OLS, T.PLS
	Kerala			RC
	Semi Arid			
High	Punjab	WT, RC		CTN
	U.P	WT	RC,T.PLS	SCN, CCL,T.OLS
	T.Nadu	RC,	T.OLS	CCL, T.PLS, SCN, CTN
	Haryana	WT	RC, T.OLS, CTN CCL.	T.PLS
Moderate	A.P		RC,T.OLS,T.PLS	CCL, CTN
	Gujarat		T.OLS, CTN, CCL (BJ)	WT, T.PLS,RC
	J & K	CCL (MZ)	RC, WT	T.PLS
	M.P		T.OLS,RC,T.PLS,WT	CCL, CTN
	Karnataka		CCL(JW) ,T.OLS,T.PLS,RC	CTN
Low	H.P	WT,CCL (MZ)	RC	T.PLS
	M.H		CCL,T.OLS,T.PLS,CTN,SCN	RC,WT
	Arid			
Moderate	Rajasthan	CCL (BJ)	T.PLS, T.OLS	WT, CTN

Low	Gujarat		CCL, T.OLS,CTN	WT,RC,T.PLS
	H.P	WT, CCL	RC	T.PLS,T.OLS
	M.H	CCL(JW)	CTN ,T.PLS, T.OLS	RC,WT
	M.P		RC,T.PLS,WT,CCL	T.OLS, CTN
	Karnataka		CCL,T.PLS, T.OLS, CTN, RC	WT
	Arid			
Low	Rajasthan	CCL(BJ)	T.PLS, Wheat	T.OLS, CTN

Table Number: A-3.5

Changes in Share of Irrigation Extent (in %) (1981-2006)				
Humid Region	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
West Bengal	9.07	7.63	15.77	32.47
Bihar	7.93	-4.42	6.26	9.78
Orissa	10.86	2.48	-1.00	12.35
Kerala	3.92	2.43	1.12	7.47
Assam	-0.40	-14.92	-2.47	-17.79
Semi Arid				
Haryana	13.46	11.18	-0.04	24.60
Uttar Pradesh	6.05	8.32	5.69	20.06
Madhya Pradesh	9.59	4.29	5.90	19.78
Karnataka	6.61	5.03	2.64	14.28
Punjab	12.02	1.98	0.23	14.24
Gujarat	5.09	3.71	4.67	13.47
Andhra Pradesh	6.82	1.67	0.70	9.20
Tamil Nadu	-5.41	11.92	0.63	7.14
Maharashtra	0.78	5.47	0.11	6.36
Himachal Pradesh	0.99	5.63	-3.48	3.14
Jammu & Kashmir	-1.72	0.78	-0.49	-1.43
Arid				
Rajasthan	4.30	7.09	7.65	19.05
India	5.49	5.63	3.95	15.06

Table Number: A-3.6

Dependence on Ground Water Irrigation (in %) (1981-2006)								
Percentage Share of Ground Water Irrigation					**Changes in Share**			
States	**1981**	**1991**	**2001**	**2006**	**81-91**	**91-01**	**01-06**	**81-06**
Humid States								
Assam	0.00	0.00	1.18	7.86	0.00	1.18	6.68	7.86
Bihar	33.73	45.39	61.68	64.12	11.66	16.29	2.44	30.39
Kerala	0.00	19.71	30.45	32.14	19.71	10.74	1.70	32.14
Orissa	17.04	38.32	40.04	40.04	21.29	1.72	0.00	23.00
West Bengal	1.14	37.25	59.35	59.35	36.11	22.10	0.00	58.20
S.Arid States								
Gujarat	79.33	79.58	86.74	80.79	0.25	7.16	-5.96	1.45
Uttar Pradesh	61.36	65.77	75.15	77.32	4.41	9.38	2.18	15.97
Punjab	57.33	57.12	76.13	72.44	-0.22	19.01	-3.68	15.11
Maharashtra	56.93	55.57	64.62	64.62	-1.36	9.05	0.01	7.69
Madhya Prad.	42.32	49.75	55.11	65.92	7.42	5.36	10.81	23.60
Haryana	45.31	48.00	49.59	55.75	2.69	1.59	6.16	10.44
Tamil Nadu	41.52	44.61	50.17	54.21	3.09	5.56	4.03	12.69
Karnataka	26.82.	33.77	38.52	45.04	6.95	4.75	6.53	18.23
Andhra Prad.	22.41	30.27	43.15	46.55	7.85	12.89	3.40	24.14
Himachal Prd.	2.17	3.82	11.11	15.38	1.65	7.29	4.27	13.21
J & K	1.32	0.44	0.64	0.32	-0.88	0.21	-0.32	-0.99
Arid State								
Rajasthan	62.82	59.97	70.78	70.52	-2.85	10.81	-0.26	7.70
India	45.70	51.01	61.60	59.25	5.31	10.58	-2.35	13.55

Table Number: A-3.7

Ground Water Dependence Growth Rate (in %) (1981-2006)				
States	**1981-91**	**1991-01**	**01-06**	**1981-06**
Humid				
Bihar	52.50	14.2	-7.59	114.06
Orissa	258.07	6.8	0.00	273.91
West Bengal	4087.06	641.5	0.00	8117.65
Semi Arid				
Andhra Pradesh	67.94	265.1	6.74	167.14
Gujarat	23.38	100.1	21.01	72.25
Haryana	29.03	-71.6	13.63	72.39
Himachal Pradesh	90.00	219.0	5.00	700.00
Jammu & Kashmir	-67.50	125.0	-100.00	-75.00
Karnataka	95.51	199.4	54.84	263.56
Madhya Pradesh	117.45	187.6	134.21	347.72
Maharashtra	3.15	69.0	-0.26	73.84
Punjab	15.17	38.6	-5.07	50.49
Tamil Nadu	-0.80	71.7	68.44	46.77
Uttar Pradesh	19.54	59.1	76.42	77.88
Arid				
Rajasthan	24.92	198.6	102.82	144.45
India	36.37	71.9	22.97	114.11

Table Number: A-3.8

Dependence on Surface Irrigation (in %) (1981-2006)								
Percentage Share of Surface Irrigation					**Changes in Share**			
States	**1981**	**1991**	**2001**	**2006**	**81-91**	**91-01**	**81-06**	**81-06**
Humid								
Assam	63.29	63.37	87.06	25.71	0.09	23.68	-61.34	-37.57
Bihar	40.30	36.01	31.31	30.71	-4.29	-4.70	-0.60	-9.59
Kerala	67.65	47.06	40.68	38.01	-20.59	-6.38	-2.67	-29.64
Orissa	82.96	61.68	60.01	60.01	-21.29	-1.66	-60.01	-22.95
West Bengal	84.82	51.30	18.44	18.44	-33.52	-32.86	-18.44	-66.39
Semi Arid								
Jammu & Kashmir	94.41	94.13	92.28	94.17	-0.28	-1.85	1.89	-0.23
Andhra Pradesh	74.90	65.89	52.47	49.97	-9.01	-13.41	-2.51	-24.93
Tamil Nadu	57.55	54.80	49.24	45.45	-2.75	-5.56	-3.79	-12.10
Karnataka	62.45	52.14	46.42	41.48	-10.31	-5.72	-4.94	-20.97
Haryana	54.40	51.45	49.93	43.78	-2.96	-1.52	-6.15	-10.63
Maharashtra	36.43	44.43	35.38	35.38	8.00	-9.05	-0.01	-1.05
Madhya Pradesh	50.17	39.26	31.76	19.48	-10.92	-7.49	-12.28	-30.69
Punjab	42.28	39.06	23.82	27.31	-3.23	-15.23	3.49	-14.97
Rajasthan	35.30	39.40	28.37	28.23	4.10	-11.03	-0.13	-7.07
Uttar Pradesh	35.38	31.28	22.90	21.62	-4.10	-8.38	-1.28	-13.75
Gujarat	20.37	20.27	12.94	18.48	-0.10	-7.34	5.54	-1.89
Himachal Pradesh	2.17	24.82	2.38	2.88	22.65	-22.44	0.50	0.71
India	47.65	42.79	33.24	28.57	-4.86	-9.55	-4.67	-19.08

Table Number: A-3.9

Dependence on Other Sources of Irrigation (in %) (1981-2006)								
Percentage Share of Other Source's Irrigation					**Changes in Share**			
States	**1981**	**1991**	**2001**	**2006**	**81-91**	**91-01**	**01-06**	**81-06**
Humid								
Assam	36.71	36.63	11.76	66.43	-0.09	-24.86	54.66	29.72
Kerala	32.35	33.23	28.87	29.59	0.88	-4.36	0.72	-2.76
West Bengal	14.04	11.45	22.22	22.22	-2.59	10.77	0.00	8.18
Bihar	25.97	18.61	7.01	5.17	-7.37	-11.59	-1.84	-20.80
Semi Arid								
H.P.	95.65	71.36	84.92	82.69	-24.30	13.56	-2.23	-12.96
Karnataka	10.73	14.09	15.02	13.48	3.36	0.93	-1.54	2.75
M.P.	7.50	11.00	13.13	14.60	3.49	2.13	1.47	7.09
J&K	4.28	5.43	7.07	5.83	1.16	1.64	-1.25	1.55
A.P.	2.69	3.85	4.35	3.46	1.16	0.50	-0.89	0.77
Uttar Pradesh	3.27	2.95	1.95	1.05	-0.31	-1.01	-0.90	-2.22
Rajasthan	1.88	0.64	0.86	1.25	-1.24	0.22	0.39	-0.63
Punjab	0.38	3.83	0.05	0.25	3.45	-3.78	0.20	-0.14
Tamil Nadu	0.93	0.59	0.55	0.31	-0.34	-0.04	-0.24	-0.62
Haryana	0.28	0.55	0.47	0.47	0.27	-0.08	-0.01	0.19
Gujarat	0.30	0.15	0.29	0.74	-0.15	0.14	0.45	0.44
India	6.65	6.20	5.16	12.18	-0.45	-1.04	7.02	5.53

Table – A- 3.10

Growth of Rice (in %) (1981-2006)				
States	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
Andhra Pradesh	4.65	-5.9	9.70	8.00
Assam	10.31	2.4	-6.00	6.22
Bihar	-4.90	3.5	-8.94	-10.35
Gujarat	17.32	14.9	2.01	37.54
Haryana	36.61	49.1	5.62	115.13
Himachal Pradesh	-14.11	-1.9	-2.93	-18.20
Jammu & Kashmir	2.00	-10.9	6.42	-3.30
Karnataka	11.22	7.9	9.84	31.83
Kerala	-31.36	-40.2	-15.61	-65.34
Madhya Pradesh	5.75	7.2	-1.86	11.27
Maharashtra	4.24	-3.1	-0.08	0.88
Orissa	7.95	-1.4	1.74	8.29
Punjab	63.60	23.8	3.91	110.41
Rajasthan	-6.14	-1.9	-18.35	-24.79
Tamil Nadu	-6.50	-8.1	8.75	-6.60
Uttar Pradesh	4.84	4.1	2.61	12.05
West Bengal	12.98	0.7	0.01	13.78

A-3.11

Growth rate of Sugar cane (in %) (1981-2006)				
States	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
Andhra Pradesh	15.28	20.3	3.31	43.21
Assam	-22.74	-29.3	-12.47	-52.21
Bihar	16.91	-23.6	-3.07	-13.40
Gujarat	43.75	52.1	6.22	132.31
Haryana	8.31	11.3	-22.72	-6.85
Himachal Pradesh	-26.09	27.9	-10.34	-15.22
Jammu & Kashmir	-54.17	-63.6	50.00	-75.00
Karnataka	57.85	47.3	-45.56	26.61
Kerala	-5.51	-52.9	94.29	-13.56
Madhya Pradesh	-3.34	33.6	11.53	44.07
Maharashtra	48.12	34.2	-13.92	71.11
Orissa	-28.24	-60.9	16.43	-67.36
Punjab	14.59	29.5	-39.57	-10.32
Rajasthan	-25.21	-58.4	-27.30	-77.36
Tamil Nadu	22.85	30.8	12.09	80.06
Uttar Pradesh	17.67	15.2	4.08	41.11
West Bengal	-34.80	44.4	-30.12	-34.21

A-3.12

Growth of Wheat (in %) (1981-2006)				
States	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
Andhra Pradesh	-44.40	37.8	-15.38	-35.17
Assam	-24.37	-9.7	-29.08	-51.58
Bihar	15.51	10.0	-5.11	20.61
Gujarat	-13.41	-31.4	130.58	36.97
Haryana	17.84	23.3	-0.14	45.09
Himachal Pradesh	4.70	-2.9	-1.20	0.44
Jammu & Kashmir	21.43	5.7	-5.13	21.81
Karnataka	-36.73	24.6	-1.86	-22.61
Madhya Pradesh	7.68	-3.5	6.76	10.92
Maharashtra	-32.49	5.0	22.23	-13.34
Orissa	-63.50	-71.6	-51.47	-94.97
Punjab	11.51	4.3	1.97	18.55
Rajasthan	6.78	9.5	-0.41	16.42
Tamil Nadu	-62.96	-90.0	-100.00	-100.00
Uttar Pradesh	7.97	10.2	-0.29	18.60
West Bengal	3.42	60.3	-13.06	44.14

A-3.13

Growth of Coarse Cereals (in %) (1981-2006)				
States	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
Andhra Pradesh	-45.62	-22.82	2.79	-56.86
Assam	-6.14	3.61	-5.32	-7.92
Bihar	-19.47	5.85	13.80	-2.98
Gujarat	-18.80	-27.90	-0.57	-41.79
Haryana	-26.94	-7.71	0.29	-32.38
Himachal Pradesh	8.76	-4.25	-1.38	2.71
Jammu & Kashmir	6.92	9.31	-2.01	14.53
Karnataka	5.04	-4.49	5.45	5.78
Kerala	186.00	-58.04	25.00	50.00
Madhya Pradesh	-20.33	-30.34	-2.21	-45.73
Maharashtra	-3.46	-12.88	-4.16	-19.40
Orissa	-20.37	-60.79	15.09	-64.06
Punjab	-51.37	-14.12	-8.42	-61.75
Rajasthan	-3.23	-10.02	10.61	-3.68
Tamil Nadu	-17.63	-32.82	12.70	-37.63
Uttar Pradesh	-15.36	-12.06	-5.97	-30.02
West Bengal	6.15	-40.25	54.90	-1.76

A-3.14

Growth of Total Pulses (in %) (1981-2006)				
States	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
Andhra Pradesh	12.28	21.72	-9.74	23.35
Assam	-4.88	0.27	-11.40	-15.50
Bihar	-16.65	-24.33	5.02	-33.76
Gujarat	41.03	-24.82	12.98	19.79
Haryana	-35.63	-70.23	20.38	-76.93
Himachal Pradesh	-24.18	-20.12	-13.79	-47.78
Jammu & Kashmir	-25.92	-26.40	-3.25	-47.24
Karnataka	12.68	19.18	-0.96	33.02
Kerala	-27.52	-50.28	-23.93	-72.59
Madhya Pradesh	-1.40	-0.75	10.75	8.38
Maharashtra	18.28	9.35	-2.08	26.64
Orissa	-3.61	-62.29	30.05	-52.73
Punjab	-59.53	-55.23	-37.71	-88.71
Rajasthan	-4.81	-24.30	37.15	-1.18
Tamil Nadu	31.54	-18.67	-19.19	-13.55
Uttar Pradesh	-0.51	-7.70	3.41	-5.05
West Bengal	-34.97	-11.00	-12.82	-49.54

A-3.15

Growth of Total Oilseeds (in %) (1981-2006)				
Total Oilseeds	**1981-1991**	**1991-2001**	**2001-2006**	**1981-2006**
Andhra Pradesh	71.20	-24.5	17.92	52.37
Assam	22.30	-3.5	-20.02	-5.58
Bihar	-4.01	-16.7	-14.01	-31.27
Gujarat	-79.15	-4.3	7.83	-78.48
Haryana	192.45	-22.7	42.93	223.08
Himachal Pradesh	4.44	-23.6	-7.75	-26.42
Jammu & Kashmir	40.43	-5.1	-91.25	-88.34
Karnataka	119.78	-36.7	55.16	115.93
Kerala	-14.62	-81.9	-2.78	-84.96
Madhya Pradesh	130.45	7.3	16.65	188.48
Maharashtra	25.84	-2.2	47.72	81.87
Orissa	-7.64	-4.5	-52.16	-57.83
Punjab	-11.78	-54.3	-5.62	-61.96
Rajasthan	187.01	-33.9	126.19	329.34
Tamil Nadu	27.66	-47.6	2.92	-31.14
Uttar Pradesh	-49.77	-51.7	32.62	-67.82
West Bengal	60.98	3.3	14.35	90.19

A- 3.16 Correlations between area under tube well irrigation with different crops and crop groups

		RICE	WHEAT	Coarse Cereals	T.OILSEEDS	TOTAL PULSES	SUGAR	COTTON	IrriExt_81
RICE	Pearson Correlation	1	-.350	-.741(**)	-.229	-.200	-.092	-.578(*)	-.019
	Sig. (2-tailed)	.	.168	.001	.377	.442	.725	.015	.943
	N	17	17	17	17	17	17	17	17
WHEAT	Pearson Correlation	-.350	1	.087	-.379	-.096	.253	.005	.610(**)
	Sig. (2-tailed)	.168	.	.740	.134	.715	.328	.986	.009
	N	17	17	17	17	17	17	17	17
Coarse Cereals	Pearson Correlation	-.741(**)	.087	1	.246	.249	-.115	.429	-.223
	Sig. (2-tailed)	.001	.740	.	.341	.334	.659	.085	.389
	N	17	17	17	17	17	17	17	17
T.OILSEEDS	Pearson Correlation	-.229	-.379	.246	1	.109	.340	.468	-.078
	Sig. (2-tailed)	.377	.134	.341	.	.678	.182	.058	.765
	N	17	17	17	17	17	17	17	17
TOTAL PULSES	Pearson Correlation	-.200	-.096	.249	.109	1	.056	-.029	-.170
	Sig. (2-tailed)	.442	.715	.334	.678	.	.830	.911	.513
	N	17	17	17	17	17	17	17	17
SUGAR	Pearson Correlation	-.092	.253	-.115	.340	.056	1	.033	.506(*)
	Sig. (2-tailed)	.725	.328	.659	.182	.830	.	.901	.038
	N	17	17	17	17	17	17	17	17
COTTON	Pearson Correlation	-.578(*)	.005	.429	.468	-.029	.033	1	.061
	Sig. (2-tailed)	.015	.986	.085	.058	.911	.901	.	.817
	N	17	17	17	17	17	17	17	17
IrriExt_81	Pearson Correlation	-.019	.610(**)	-.223	-.078	-.170	.506(*)	.061	1
	Sig. (2-tailed)	.943	.009	.389	.765	.513	.038	.817	.
	N	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

A- 3.17 Correlations between area under tube well irrigation with different crops and crop groups

		RICE	WHEAT	Coarse Cereals	TOTAL PULSES	OILSEEDS	SUGAR	COTTON	TW_91
RICE	Pearson Correlation	1	-.230	-.702(**)	-.264	-.364	-.128	-.501(*)	.126
	Sig. (2-tailed)	.	.375	.002	.305	.151	.626	.041	.630
	N	17	17	17	17	17	17	17	17
WHEAT	Pearson Correlation	-.230	1	.105	-.289	-.462	.247	.011	.573(*)
	Sig. (2-tailed)	.375	.	.688	.260	.062	.338	.967	.016
	N	17	17	17	17	17	17	17	17
Coarse Cereals	Pearson Correlation	-.702(**)	.105	1	.284	.290	-.066	.324	-.473
	Sig. (2-tailed)	.002	.688	.	.270	.259	.801	.205	.055
	N	17	17	17	17	17	17	17	17
TOTAL PULSES	Pearson Correlation	-.264	-.289	.284	1	.566(*)	.150	.147	-.238
	Sig. (2-tailed)	.305	.260	.270	.	.018	.566	.572	.358
	N	17	17	17	17	17	17	17	17
OILSEEDS	Pearson Correlation	-.364	-.462	.290	.566(*)	1	.074	.464	-.385
	Sig. (2-tailed)	.151	.062	.259	.018	.	.777	.061	.128
	N	17	17	17	17	17	17	17	17
SUGAR	Pearson Correlation	-.128	.247	-.066	.150	.074	1	.119	.500(*)
	Sig. (2-tailed)	.626	.338	.801	.566	.777	.	.648	.041
	N	17	17	17	17	17	17	17	17
COTTON	Pearson Correlation	-.501(*)	.011	.324	.147	.464	.119	1	.044
	Sig. (2-tailed)	.041	.967	.205	.572	.061	.648	.	.867
	N	17	17	17	17	17	17	17	17
TW_91	Pearson Correlation	.126	.573(*)	-.473	-.238	-.385	.500(*)	.044	1
	Sig. (2-tailed)	.630	.016	.055	.358	.128	.041	.867	.
	N	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

A- 3.18 Correlations between area under tube well irrigation with different crops and crop groups

		Rice	Wheat	Coarse Cereals	Cotton	Sugarcane	Total Pulses	Total Oilseds	TW_01
Rice	Pearson Correlation	1	-.156	-.680(**)	-.448	-.165	-.304	-.294	.160
	Sig. (2-tailed)	.	.549	.003	.071	.527	.235	.252	.540
	N	17	17	17	17	17	17	17	17
Wheat	Pearson Correlation	-.156	1	.142	-.088	.151	-.365	-.481	.523(*)
	Sig. (2-tailed)	.549	.	.588	.736	.563	.150	.051	.031
	N	17	17	17	17	17	17	17	17
Coarse Cereals	Pearson Correlation	-.680(**)	.142	1	.269	-.056	.282	.193	-.471
	Sig. (2-tailed)	.003	.588	.	.296	.830	.273	.458	.056
	N	17	17	17	17	17	17	17	17
Cotton	Pearson Correlation	-.448	-.088	.269	1	.227	.208	.582(*)	.015
	Sig. (2-tailed)	.071	.736	.296	.	.381	.423	.014	.955
	N	17	17	17	17	17	17	17	17
Sugarcane	Pearson Correlation	-.165	.151	-.056	.227	1	.291	.091	.333
	Sig. (2-tailed)	.527	.563	.830	.381	.	.257	.728	.191
	N	17	17	17	17	17	17	17	17
Total Pulses	Pearson Correlation	-.304	-.365	.282	.208	.291	1	.634(**)	-.267
	Sig. (2-tailed)	.235	.150	.273	.423	.257	.	.006	.300
	N	17	17	17	17	17	17	17	17
Total Oilseds	Pearson Correlation	-.294	-.481	.193	.582(*)	.091	.634(**)	1	-.312
	Sig. (2-tailed)	.252	.051	.458	.014	.728	.006	.	.223
	N	17	17	17	17	17	17	17	17
TW_01	Pearson Correlation	.160	.523(*)	-.471	.015	.333	-.267	-.312	1
	Sig. (2-tailed)	.540	.031	.056	.955	.191	.300	.223	.
	N	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

A- 3.19 Correlations between area under tube well irrigation with different crops and crop groups

		Rice	Wheat	Coarse Cereals	Cotton	Sugar cane	Total pulses	Total oilseed	TW_06
Rice	Pearson Correlation	1	-.185	-.649(**)	-.427	-.078	-.293	-.427	.168
	Sig. (2-tailed)	.	.477	.005	.087	.766	.253	.087	.520
	N	17	17	17	17	17	17	17	17
Wheat	Pearson Correlation	-.185	1	.154	-.033	.184	-.306	-.398	.558(*)
	Sig. (2-tailed)	.477	.	.556	.899	.479	.232	.114	.020
	N	17	17	17	17	17	17	17	17
Coarse Cereals	Pearson Correlation	-.649(**)	.154	1	.163	-.093	.281	.263	-.349
	Sig. (2-tailed)	.005	.556	.	.532	.721	.274	.308	.169
	N	17	17	17	17	17	17	17	17
Cotton	Pearson Correlation	-.427	-.033	.163	1	.064	.152	.573(*)	.032
	Sig. (2-tailed)	.087	.899	.532	.	.808	.559	.016	.903
	N	17	17	17	17	17	17	17	17
Sugar cane	Pearson Correlation	-.078	.184	-.093	.064	1	.165	.002	.335
	Sig. (2-tailed)	.766	.479	.721	.808	.	.528	.995	.189
	N	17	17	17	17	17	17	17	17
Total pulses	Pearson Correlation	-.293	-.306	.281	.152	.165	1	.722(**)	-.036
	Sig. (2-tailed)	.253	.232	.274	.559	.528	.	.001	.890
	N	17	17	17	17	17	17	17	17
Total oilseed	Pearson Correlation	-.427	-.398	.263	.573(*)	.002	.722(**)	1	-.067
	Sig. (2-tailed)	.087	.114	.308	.016	.995	.001	.	.800
	N	17	17	17	17	17	17	17	17
TW_06	Pearson Correlation	.168	.558(*)	-.349	.032	.335	-.036	-.067	1
	Sig. (2-tailed)	.520	.020	.169	.903	.189	.890	.800	.
	N	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

A- 3.20 Correlations between area under tube well irrigation with different crops and crop groups

		Rice	Wheat	Coarse Cereals	Cotton	Sugar cane	Total pulses	Total oilseed	IrriExt_06
Rice	Pearson Correlation	1	-.185	-.649(**)	-.427	-.078	-.293	-.427	.080
	Sig. (2-tailed)	.	.477	.005	.087	.766	.253	.087	.761
	N	17	17	17	17	17	17	17	17
Wheat	Pearson Correlation	-.185	1	.154	-.033	.184	-.306	-.398	.603(*)
	Sig. (2-tailed)	.477	.	.556	.899	.479	.232	.114	.010
	N	17	17	17	17	17	17	17	17
Coarse Cereals	Pearson Correlation	-.649(**)	.154	1	.163	-.093	.281	.263	-.264
	Sig. (2-tailed)	.005	.556	.	.532	.721	.274	.308	.306
	N	17	17	17	17	17	17	17	17
Cotton	Pearson Correlation	-.427	-.033	.163	1	.064	.152	.573(*)	.105
	Sig. (2-tailed)	.087	.899	.532	.	.808	.559	.016	.689
	N	17	17	17	17	17	17	17	17
Sugar cane	Pearson Correlation	-.078	.184	-.093	.064	1	.165	.002	.401
	Sig. (2-tailed)	.766	.479	.721	.808	.	.528	.995	.111
	N	17	17	17	17	17	17	17	17
Total pulses	Pearson Correlation	-.293	-.306	.281	.152	.165	1	.722(**)	-.222
	Sig. (2-tailed)	.253	.232	.274	.559	.528	.	.001	.393
	N	17	17	17	17	17	17	17	17
Total oilseed	Pearson Correlation	-.427	-.398	.263	.573(*)	.002	.722(**)	1	-.181
	Sig. (2-tailed)	.087	.114	.308	.016	.995	.001	.	.487
	N	17	17	17	17	17	17	17	17
IrriExt_06	Pearson Correlation	.080	.603(*)	-.264	.105	.401	-.222	-.181	1
	Sig. (2-tailed)	.761	.010	.306	.689	.111	.393	.487	.
	N	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Total Water requirements of different crops across states

	Rice	Wheat	Cotton	Oilseeds	pulses	coarse cereals	Sugarcane
Andhra Pradesh	1200	650	740	510	320	250	2700
Assam	750	400	740	510	320	250	1200
Bihar	750	400	740	510	320	250	1200
Gujarat	1448	678	740	510	320	250	2726
Haryana	1759.172	757.533	740	510	320	250	3087.119
Himachal Pradesh	1200	650	740	510	320	250	2700
Jammu & Kashmir	1200	650	740	510	320	250	2700
Karnataka	1054.32	569.0587	740.35	510	320	250	2213.782
Kerala	750	400	740	510	320	250	1200
Madhya Pradesh	898.5	482.5	740	510	320	250	1695
Maharashtra	1105.5	597.5	740	510	320	250	2385
Orissa	750	400	740	510	320	250	1200
Punjab	1967	587.5	740	510	320	250	2325
Rajasthan	1525	712.5	740	510	320	250	2925
Tamil Nadu	1087.5	587.5	740	510	320	250	2325
Uttar Pradesh	1016	548	740	510	320	250	2085
West Bengal	750	400	740	510	320	250	1200

Table A-4.1

	Aggregate Land Productivity in India (Rs.Lakh/hectare)			
Regions/States	**LP_80-83**	**LP_90-93**	**LP_00-03**	**LP_05-06**
Humid				
Moderately Irrigated States				
West Bengal	67.05	101.76	116.61	103.01
Bihar	46.90	67.36	74.04	56.99
Less Irrigated States				
Assam	52.83	66.03	75.65	63.39
Kerala	225.84	445.91	475.38	610.86
Orissa	50.12	57.62	51.75	63.14
Semi Arid				
Highly Irrigated States				
Punjab	105.68	143.89	170.94	160.56
Haryana	74.07	115.52	136.09	128.81
Uttar Pradesh	67.51	94.70	114.60	118.22
Moderately Irrigated States				
Tamil Nadu	86.48	129.12	159.04	143.68
Jammu and Kashmir	88.30	83.34	67.46	76.00
Andhra Pradesh	71.26	100.36	107.32	107.11
Less Irrigated States				
Gujarat	13.11	78.90	67.91	83.44
Madhya Pradesh	35.49	53.07	55.93	61.61
Himachal Pradesh	56.02	65.88	84.98	82.99
Maharashtra	43.16	56.40	58.38	61.73
Karnataka	57.25	72.26	81.99	88.02
Arid				
Rajasthan	30.69	49.89	51.65	54.51

A-4.2

	Aggregate Water Productivity in India (Rs.Lakh/hectare mm) (1980-83-2005-06)			
Regions/States	**WP_80-83**	**WP_90-93**	**WP_00-03**	**WP_05-06**
Humid				
Moderately Irrigated States				
West Bengal	96.83	147.54	168.12	148.44
Bihar	77.97	112.94	126.07	98.94
Less Irrigated States				
Assam	76.29	95.54	107.52	89.45
Kerala	308.88	615.06	647.38	825.39
Orissa	79.98	89.90	78.17	94.19
Semi Arid				
Highly Irrigated States				
Punjab	121.60	147.05	164.11	155.46
Haryana	98.53	143.25	149.59	145.65
Uttar Pradesh	99.65	129.86	151.78	155.87
Moderately Irrigated States				
Tamil Nadu	117.05	174.17	190.68	165.21
Jammu and Kashmir	134.18	128.84	107.67	117.13
Andhra Pradesh	104.21	143.07	137.70	140.81
Less Irrigated States				
Gujarat	26.15	151.27	107.28	200.04
Madhya Pradesh	64.53	99.27	102.41	113.31
Himachal Pradesh	99.14	120.91	155.26	151.80
Maharashtra	88.10	113.11	111.21	118.61
Karnataka	107.40	140.23	146.56	167.24
Arid				
Rajasthan	71.07	117.57	120.24	127.15

A-4.3

	Land Productivity of Rice in India (Rs.Lakh/hectare) (1980-83-2005-06)			
Regions/States	**LP_80-83**	**LP_90-93**	**LP_00-03**	**LP_05-06**
Humid				
Moderately Irrigated States	2047.87	2973.10	4981.15	4734.00
Less Irrigated States	3619.74	4559.92	4819.83	5283.00
Semi Arid				
Highly Irrigated States	6737.14	7826.38	10059.89	10859.00
Moderately Irrigated States	6226.01	7479.46	7592.34	7635.00
Less Irrigated States	5499.51	7346.73	7925.57	11344.00
Arid	889.76	1089.38	997.36	1425.00

A-4.4

	Water Productivity of Rice in India (Rs.Lakh/hectare mm) (1980-83-2005-06)			
Regions/States	**WP_80-83**	**WP_90-93**	**WP_00-03**	**WP_05-06**
Humid				
Moderately Irrigated States	2730.49	3964.13	6641.53	6312.00
Less Irrigated States	4826.32	6079.90	6426.45	7044.00
Semi Arid				
Highly Irrigated States	4563.75	5476.14	7645.54	8151.97
Moderately Irrigated States	5368.14	6501.45	6588.34	6581.98
Less Irrigated States	5104.51	6580.05	7251.93	10400.70
Arid	452.35	553.83	507.05	724.45

A-4.5

	Land Productivity of Wheat in India (Rs.Lakh/hectare) (1980-83-2005-06)			
Regions/States	**LP_80-83**	**LP_90-93**	**LP_00-03**	**LP_05-06**
Humid				
Moderately Irrigated States	3292.64	3915.35	6004.31	5066.00
Less Irrigated States	3024.68	2810.90	2590.67	2438.00
Semi Arid				
Highly Irrigated States	7189.53	9575.81	13091.65	12283.00
Moderately Irrigated States	2100.27	2610.52	2328.90	2608.00
Less Irrigated States	4022.34	6972.80	8129.22	9344.00
Arid	1687.82	2393.08	2634.57	2762.00

A-4.6

	Water Productivity of Wheat in India (Rs.Lakh/hectare mm) (1980-83-2005-06)			
Regions/States	**WP_80-83**	**WP_90-93**	**WP_00-03**	**WP_05-06**
Humid				
Moderately Irrigated States	8231.61	9788.36	15010.79	12665.00
Less Irrigated States	7561.71	7027.26	6476.67	6095.00
Semi Arid				
Highly Irrigated States	10641.43	14088.91	19959.77	18713.35
Moderately Irrigated States	3306.48	4098.01	3637.47	4012.31
Less Irrigated States	6941.86	11669.93	14079.36	15916.43
Arid	2116.39	3000.73	3303.54	3463.32

A-4.7

	Land Productivity of Sugar cane in India (Rs.Lakh/hectare) (1980-83-2005-06)			
Regions/States	**LP_80-83**	**LP_90-93**	**LP_00-03**	**LP_05-06**
Humid				
Moderately Irrigated States	104306.98	110624.14	153323.98	126002.00
Less Irrigated States	122630.78	169466.77	174367.36	237838.41
Semi Arid				
Highly Irrigated States	247719.91	168650.63	234756.88	241200.00
Moderately Irrigated States	224990.28	213352.72	177607.38	185436.00
Less Irrigated States	561892.68	298176.12	297030.46	288320.00
Arid	95144.71	47613.54	43747.43	61088.61

A-4.8

	Water Productivity of Sugar cane in India (Rs.Lakh/hectare mm) (1980-83-2005-06)			
Regions/States	**WP_80-83**	**WP_90-93**	**WP_00-03**	**WP_05-06**
Humid				
Moderately Irrigated States	86922.48	92186.79	127769.98	105001.67
Less Irrigated States	102192.31	141222.31	145306.13	198198.68
Semi Arid				
Highly Irrigated States	106682.23	64461.66	95007.21	97686.65
Moderately Irrigated States	88423.53	85239.36	71740.78	74932.75
Less Irrigated States	248810.43	128473.97	128842.33	126694.09
Arid	29447.45	14736.47	13539.90	18907.03

Where WP refers for Water Productivity and LP for Land Productivity

Correlations between Aggregate Land and Water Productivity (1980-83 to 2005-06)

Table Number: A -4.9

		WP 80 83	**WP 90 33**	**WP 00 03**	**WP 05 06**	**LP 80 83**	**LP 90 33**	**LP 00 03**	**LP 05 06**
WP_80_83	Pearson Correlation	1	.915(**)	.932(**)	.889(**)	.979(**)	.933(**)	.927(**)	.932(**)
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000	.000
	N	17	17	17	17	17	17	17	17
WP_90_33	Pearson Correlation	.915(**)	1	.990(**)	.994(**)	.897(**)	.982(**)	.964(**)	.988(**)
	Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000	.000
	N	17	17	17	17	17	17	17	17
WP_00_03	Pearson Correlation	.932(**)	.990(**)	1	.982(**)	.915(**)	.980(**)	.976(**)	.988(**)
	Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	.000
	N	17	17	17	17	17	17	17	17
WP_05_06	Pearson Correlation	.889(**)	.994(**)	.982(**)	1	.864(**)	.966(**)	.946(**)	.980(**)
	Sig. (2-tailed)	.000	.000	.000	.	.000	.000	.000	.000
	N	17	17	17	17	17	17	17	17
LP_80_83	Pearson Correlation	.979(**)	.897(**)	.915(**)	.864(**)	1	.948(**)	.950(**)	.935(**)
	Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.000	.000
	N	17	17	17	17	17	17	17	17
LP_90_33	Pearson Correlation	.933(**)	.982(**)	.980(**)	.966(**)	.948(**)	1	.993(**)	.996(**)
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.000	.000
	N	17	17	17	17	17	17	17	17
LP_00_03	Pearson Correlation	.927(**)	.964(**)	.976(**)	.946(**)	.950(**)	.993(**)	1	.989(**)
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.	.000
	N	17	17	17	17	17	17	17	17
LP_05_06	Pearson Correlation	.932(**)	.988(**)	.988(**)	.980(**)	.935(**)	.996(**)	.989(**)	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.
	N	17	17	17	17	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

Table Number: A -4.10

Total Water Consumption Index (1981-2006)

States	TWCI_81	TWCI_91	TWCI_01	TWCI_06	Changes(1981-2006)
Andhra Pradesh	683.84	701.44	779.39	760.68	76.84
Assam	692.50	691.11	703.59	708.67	16.17
Bihar	601.46	596.45	587.31	576.05	-25.42
Gujarat	501.43	521.56	633.00	632.12	130.69
Haryana	751.67	806.41	909.75	884.39	132.72
Himachal Pradesh	565.02	544.85	547.33	546.70	-18.32
Jammu & Kashmir	658.08	646.87	626.53	648.87	-9.20
Karnataka	533.09	515.31	559.42	526.30	-6.79
Kerala	731.16	724.98	734.31	740.09	8.93
Madhya Pradesh	550.06	534.60	546.09	543.67	-6.40
Maharashtra	489.88	498.63	524.98	520.44	30.56
Orissa	626.69	641.00	661.99	670.31	43.62
Punjab	869.05	978.48	1041.60	1032.76	163.72
Rajasthan	431.74	424.32	429.55	428.65	-3.08
Tamil Nadu	738.82	741.34	834.09	869.69	130.87
Uttar Pradesh	677.50	729.18	755.05	758.44	80.95
West Bengal	692.40	689.72	693.63	693.94	1.54

Table Number: A -4.11

Correlations between Rice Water Productivity with Rice Land Productivity

		RWP_1980-83	RLP_1980-83	RWP_2005-06	RLP_2005-06
RWP_1980-83	Pearson Correlation	1	.779(**)	.518(*)	.471
	Sig. (2-tailed)	.	.000	.033	.056
	N	17	17	17	17
RLP_1980-83	Pearson Correlation	.779(**)	1	.174	.598(*)
	Sig. (2-tailed)	.000	.	.504	.011
	N	17	17	17	17
RWP_2005-06	Pearson Correlation	.518(*)	.174	1	.710(**)
	Sig. (2-tailed)	.033	.504	.	.001
	N	17	17	17	17
RLP_2005-06	Pearson Correlation	.471	.598(*)	.710(**)	1
	Sig. (2-tailed)	.056	.011	.001	.
	N	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

- Correlation is significant at the 0.05 level (2-tailed).

Table Number: A -4.10

Total Water Consumption Index (1981-2006)

States	TWCI_81	TWCI_91	TWCI_01	TWCI_06	Changes(1981-2006)
Andhra Pradesh	683.84	701.44	779.39	760.68	76.84
Assam	692.50	691.11	703.59	708.67	16.17
Bihar	601.46	596.45	587.31	576.05	-25.42
Gujarat	501.43	521.56	633.00	632.12	130.69
Haryana	751.67	806.41	909.75	884.39	132.72
Himachal Pradesh	565.02	544.85	547.33	546.70	-18.32
Jammu & Kashmir	658.08	646.87	626.53	648.87	-9.20
Karnataka	533.09	515.31	559.42	526.30	-6.79
Kerala	731.16	724.98	734.31	740.09	8.93
Madhya Pradesh	550.06	534.60	546.09	543.67	-6.40
Maharashtra	489.88	498.63	524.98	520.44	30.56
Orissa	626.69	641.00	661.99	670.31	43.62
Punjab	869.05	978.48	1041.60	1032.76	163.72
Rajasthan	431.74	424.32	429.55	428.65	-3.08
Tamil Nadu	738.82	741.34	834.09	869.69	130.87
Uttar Pradesh	677.50	729.18	755.05	758.44	80.95
West Bengal	692.40	689.72	693.63	693.94	1.54

Table Number: A -4.11

Correlations between Rice Water Productivity with Rice Land Productivity

		RWP_1980-83	**RLP_1980-83**	**RWP_2005-06**	**RLP_2005-06**
RWP_1980-83	Pearson Correlation	1	.779(**)	.518(*)	.471
	Sig. (2-tailed)	.	.000	.033	.056
	N	17	17	17	17
RLP_1980-83	Pearson Correlation	.779(**)	1	.174	.598(*)
	Sig. (2-tailed)	.000	.	.504	.011
	N	17	17	17	17
RWP_2005-06	Pearson Correlation	.518(*)	.174	1	.710(**)
	Sig. (2-tailed)	.033	.504	.	.001
	N	17	17	17	17
RLP_2005-06	Pearson Correlation	.471	.598(*)	.710(**)	1
	Sig. (2-tailed)	.056	.011	.001	.
	N	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

- Correlation is significant at the 0.05 level (2-tailed).

Table Number: A -4.12

Correlations between Wheat Water Productivity with Wheat Land Productivity

		WWP_1980-83	**WLP_1980-83**	**WWP_2005-06**	**WLP_2005-06**
WWP_1980-83	Pearson Correlation	1	.865(**)	.698(**)	.553(*)
	Sig. (2-tailed)	.	.000	.002	.021
	N	17	17	17	17
WLP_1980-83	Pearson Correlation	.865(**)	1	.684(**)	.758(**)
	Sig. (2-tailed)	.000	.	.002	.000
	N	17	17	17	17
WWP_2005-06	Pearson Correlation	.698(**)	.684(**)	1	.897(**)
	Sig. (2-tailed)	.002	.002	.	.000
	N	17	17	17	17
WLP_2005-06	Pearson Correlation	.553(*)	.758(**)	.897(**)	1
	Sig. (2-tailed)	.021	.000	.000	.
	N	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Correlations Table Number: A -4.13

Correlations between Sugarcane Water Productivity with Sugarcane Land Productivity

		SWP_1980-83	**SLP_1980-83**	**SWP_2005-06**	**SLP_2005-06**
SWP_1980-83	Pearson Correlation	1	.915(**)	.306	.483(*)
	Sig. (2-tailed)	.	.000	.233	.049
	N	17	17	17	17
SLP_1980-83	Pearson Correlation	.915(**)	1	.083	.446
	Sig. (2-tailed)	.000	.	.751	.073
	N	17	17	17	17
SWP_2005-06	Pearson Correlation	.306	.083	1	.807(**)
	Sig. (2-tailed)	.233	.751	.	.000
	N	17	17	17	17
SLP_2005-06	Pearson Correlation	.483(*)	.446	.807(**)	1
	Sig. (2-tailed)	.049	.073	.000	.
	N	17	17	17	17

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table- A 4.14

Correlation between Aggregate Water Productivity with Tube well Irrigation for Semi arid highly irrigated states.

		WP_90_33	WP_00_03	WP_05_06	Tw_91	Tw_01	Tw_06
WP_90_33	Pearson Correlation	1	.561	-.340	-.574	-.153	-.258
	Sig. (2-tailed)	.	.621	.779	.611	.902	.834
	N	3	3	3	3	3	3
WP_00_03	Pearson Correlation	.561	1	.588	.356	.732	.655
	Sig. (2-tailed)	.621	.	.600	.768	.477	.545
	N	3	3	3	3	3	3
WP_05_06	Pearson Correlation	-.340	.588	1	.965	.981	.996
	Sig. (2-tailed)	.779	.600	.	.168	.123	.055
	N	3	3	3	3	3	3
Tw_91	Pearson Correlation	-.574	.356	.965	1	.897	.939
	Sig. (2-tailed)	.611	.768	.168	.	.291	.223
	N	3	3	3	3	3	3
Tw_01	Pearson Correlation	-.153	.732	.981	.897	1	.994
	Sig. (2-tailed)	.902	.477	.123	.291	.	.068
	N	3	3	3	3	3	3
Tw_06	Pearson Correlation	-.258	.655	.996	.939	.994	1
	Sig. (2-tailed)	.834	.545	.055	.223	.068	.
	N	3	3	3	3	3	3

Table- A 4.15

Correlation between Aggregate Water Productivity with Tube well Irrigation for Semi arid moderately irrigated states.

		WP_80_83	WP_90_33	WP_00_03	WP_05_06	I.EXT_1981	I.EXT_1991	I.EXT_2001	I.EXT_2006
WP_80_83	Pearson Correlation	1	.639	.995	.506	.980	.914	.794	.876
	Sig. (2-tailed)	.	.559	.062	.662	.128	.266	.416	.320
	N	3	3	3	3	3	3	3	3
WP_90_33	Pearson Correlation	.639	1	.561	-.340	.779	.896	.975	.931
	Sig. (2-tailed)	.559	.	.621	.779	.431	.293	.143	.239
	N	3	3	3	3	3	3	3	3
WP_00_03	Pearson Correlation	.995	.561	1	.588	.956	.870	.731	.825
	Sig. (2-tailed)	.062	.621	.	.600	.190	.328	.478	.382
	N	3	3	3	3	3	3	3	3
WP_05_06	Pearson Correlation	.506	-.340	.588	1	.324	.113	-.122	.028
	Sig. (2-tailed)	.662	.779	.600	.	.790	.928	.922	.982
	N	3	3	3	3	3	3	3	3
I.EXT_1981	Pearson Correlation	.980	.779	.956	.324	1	.977	.900	.955
	Sig. (2-tailed)	.128	.431	.190	.790	.	.138	.288	.192
	N	3	3	3	3	3	3	3	3
I.EXT_1991	Pearson Correlation	.914	.896	.870	.113	.977	1	.973	.996
	Sig. (2-tailed)	.266	.293	.328	.928	.138	.	.150	.054
	N	3	3	3	3	3	3	3	3
I.EXT_2001	Pearson Correlation	.794	.975	.731	-.122	.900	.973	1	.989
	Sig. (2-tailed)	.416	.143	.478	.922	.288	.150	.	.095
	N	3	3	3	3	3	3	3	3
I.EXT_2006	Pearson Correlation	.876	.931	.825	.028	.955	.996	.989	1
	Sig. (2-tailed)	.320	.239	.382	.982	.192	.054	.095	.
	N	3	3	3	3	3	3	3	3

Table A-4.16 Correlation between Aggregate Water Productivity with Tube well Irrigation for Semi arid less irrigated states.

		Tw_91	Tw_01	Tw_06	WP_90_33	WP_00_03	WP_05_06
Tw_91	Pearson Correlation	1	.976(**)	.726	.651	-.320	.714
	Sig. (2-tailed)	.	.001	.102	.161	.536	.111
	N	6	6	6	6	6	6
Tw_01	Pearson Correlation	.976(**)	1	.856(*)	.587	-.267	.643
	Sig. (2-tailed)	.001	.	.030	.221	.610	.168
	N	6	6	6	6	6	6
Tw_06	Pearson Correlation	.726	.856(*)	1	.335	-.044	.350
	Sig. (2-tailed)	.102	.030	.	.516	.935	.496
	N	6	6	6	6	6	6
WP_90_33	Pearson Correlation	.651	.587	.335	1	.246	.959(**)
	Sig. (2-tailed)	.161	.221	.516	.	.639	.002
	N	6	6	6	6	6	6
WP_00_03	Pearson Correlation	-.320	-.267	-.044	.246	1	.241
	Sig. (2-tailed)	.536	.610	.935	.639	.	.645
	N	6	6	6	6	6	6
WP_05_06	Pearson Correlation	.714	.643	.350	.959(**)	.241	1
	Sig. (2-tailed)	.111	.168	.496	.002	.645	.
	N	6	6	6	6	6	6

Table A-4.17 Correlation between Aggregate Water Productivity with Tube well Irrigation for humid irrigated states.

		WP_90_33	WP_00_03	WP_05_06	Tw_91	Tw_01	Tw_06
WP_90_33	Pearson Correlation	1	.999(**)	.999(**)	-.018	.047	-.434
	Sig. (2-tailed)	.	.000	.000	.977	.940	.465
	N	5	5	5	5	5	5
WP_00_03	Pearson Correlation	.999(**)	1	.997(**)	.000	.070	-.410
	Sig. (2-tailed)	.000	.	.000	1.000	.911	.493
	N	5	5	5	5	5	5
WP_05_06	Pearson Correlation	.999(**)	.997(**)	1	-.045	.017	-.462
	Sig. (2-tailed)	.000	.000	.	.943	.978	.433
	N	5	5	5	5	5	5
Tw_91	Pearson Correlation	-.018	.000	-.045	1	.991(**)	.890(*)
	Sig. (2-tailed)	.977	1.000	.943	.	.001	.043
	N	5	5	5	5	5	5
Tw_01	Pearson Correlation	.047	.070	.017	.991(**)	1	.876
	Sig. (2-tailed)	.940	.911	.978	.001	.	.051
	N	5	5	5	5	5	5
Tw_06	Pearson Correlation	-.434	-.410	-.462	.890(*)	.876	1
	Sig. (2-tailed)	.465	.493	.433	.043	.051	.
	N	5	5	5	5	5	5