Report Code: 015_GBP_IIT_SEC_ANL_01_Ver 1_Dec 2011

Trends in Agriculture and Agricultural Practices in Ganga Basin

An Overview

GRB EMP : Ganga River Basin Environment Management Plan

by

Indian Institutes of Technology


IIT Bombay


IIT Delhi


IIT Guwahati


IIT Kanpur


IIT Kharagpur


IIT Madras


IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Framework for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialogue in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

DrVinod Tare
Professor and Coordinator
Development of GRBMP
IIT Kanpur

The Team

BhagirathBehera, IIT Kharagpur	*bhagirath@hss.iitkgp.ernet.in*
C Kumar, IIT Roorkee	*c.kumar803@gmail.com*
D K Nauriyal, IIT Roorkee	*dknarfhs@iitr.ernet.in*
N C Nayak, IIT Kharagpur	*ncnayak@hss.iitkgp.ernet.in*
P M Prasad, IIT Kanpur	*pmprasad@iitk.ac.in*
Prema Rajgopalan, IIT Madras	*prema@iitm.ac.in*
Pulak Mishra, IIT Kharagpur	*pmishra@hss.iitkgp.ernet.in*
Pushpa L Trivedi, IIT Bombay	*trivedi@hss.iitb.ac.in*
Rajat Agrawal, IIT Roorkee	*rajatfdm@iitr.ernet.in*
S P Singh, IIT Roorkee	*singhfhs@iitr.ernet.in*
Seema Sharma, IIT Delhi	*seemash@dms.iitd.ac.in*
T N Mazumder, IIT Kharagpur	*taraknm@arp.iitkgp.ernet.in*
V B Upadhyay, IIT Delhi	*upadhyay@hss.iitd.ac.in*
Vinay Sharma, IIT Roorkee	*vinayfdm@iitr.ernet.in*
Vinod Tare, IIT Kanpur	*vinod@iitk.ac.in*

Contents

1. Introduction

The Ganga River, being a perennial source of water, facilitates both surface and groundwater irrigation in the basin area. However, high population growth, rising per capita income and increase in standard of living of people, have encouraged the farmers to diversify agriculture towards high water intensive crops such as sugarcane, paddy and wheat which put more stress on the water resources. For the effective and sustainable management of the basin, among others, an understanding of growth and composition of population, sectoral composition of workforce, change in land and water use patterns, settlement patterns, livelihood patterns and their possible impact on the river water resources is imperative. Ganga River Basin (GRB) managementneeds to be viewed as a part of the broader environment and in relation to socio-economic demands and potentials, acknowledging the political and cultural context, as water is not only an economic resource but is also a socio-cultural and environmental resource. The Ganga Basin constitutes 26 percent of the country's land mass and supports about 43% of population (448.3 million as per 2001 census). Agriculture is the major livelihood activity of majority of rural population in the basin area. It is, therefore, necessary to study the dynamics of agriculture with a view to understand the nature and extent of dependency on it and suggest alternative livelihood options to augment income of rural workforce and reduce the stress on river water resources. Keeping these aspects in view, this report attempts topresent the status of agriculture in the basin and its implications for the river basin management. For this purposethe entire basin has beendivided into several parts. The three most significant parts from the point of view of agriculture and irrigation are Upper Ganga Basin (mostly in Uttarakhand), Middle Ganga Basin (mostly in Uttar Pradesh) and Lower Ganga Basin (mostly in Bihar and West Bengal).

It may be pertinent to mention here that this report is designed to prepare a comprehensive overview of the status and prospects of agriculture in the basin area in order to study its implications for water-use, and point/non-point[1] sources of pollution that flows/seeps into river, posing a danger to all forms of life that is dependent on the river water. The information provided is expected to be useful in suggesting(i) ways and means to optimize the use of river water per se, and (ii) modifications in agricultural practices.

2. Scope

This series of reports is envisaged to document the following aspects and issues of agriculture in the Ganga River Basin:

- Agriculture land-use and cropping patterns, size of land holdings
- Crop-diversification
- Sources of irrigation, area irrigated and status of ground water in the basin area

[1] It has been observed that in many a places, river beds have been encroached to grow cucurbetaceous crops known as “Pallaze” where a fair amount of chemical fertilizers and pesticides are used. These chemicals eventually get washed into the river water and thus becoming diffused or non-point source of pollution.

- Use of fertilizers, pesticides, and other inputs
- Agricultural production, productivity, costs and returns in agriculture
- Agricultural practices having an implication for water-use.
- Implications for River Basin

3. General Relevant Information

The Ganga River Basin – which also extends into parts of Nepal, China and Bangladesh – accounts for 26 per cent of India's landmass, 30 per cent of its water resources and more than 40 per cent of its population. The Ganga river basin is one of the most densely populated and fertile river basins in the world. It supports about 300 million people over an area of approximately 80000 sq. km of which some 100 million are directly dependent on the river and its tributaries. Thus Ganga basin supports one of the world's highest densities of population. If one accounts for the entire reach, including all small tributaries of river Ganga, the basin area comprises the part of 11 states including 236 districts within the national administrative boundary.

The states (in order of maximum districts involved) included in the Basin area are Uttar Pradesh (70), Bihar (37), Madhya Pradesh (33),Rajasthan (20), Jharkhand (17), West Bengal (16), Haryana (14), Uttarakhand (13), Delhi (9), Chhattisgarh (4),andHimachal Pradesh (3). However, the Ganga with its main tributaries flows mainly across the Uttarakhand, Uttar Pradesh, Bihar, and West Bengal. The Ganga River Basin has 1949 cities and towns, with an estimated population of 125 million. Average population density in the Ganga River Basin is 520 persons per square km as compared to 312 for India (2001 census). Considering the trend, pattern, influence, ascendancy, problems, and prospects etc. of the Ganga River Basin area, this report focuses only on three parts mostly covering four states of India, i.e. Uttarakhand, Uttar Pradesh, Bihar, and West Bengal (Figure1). A brief account of the four states is given in following sections for ready reference.

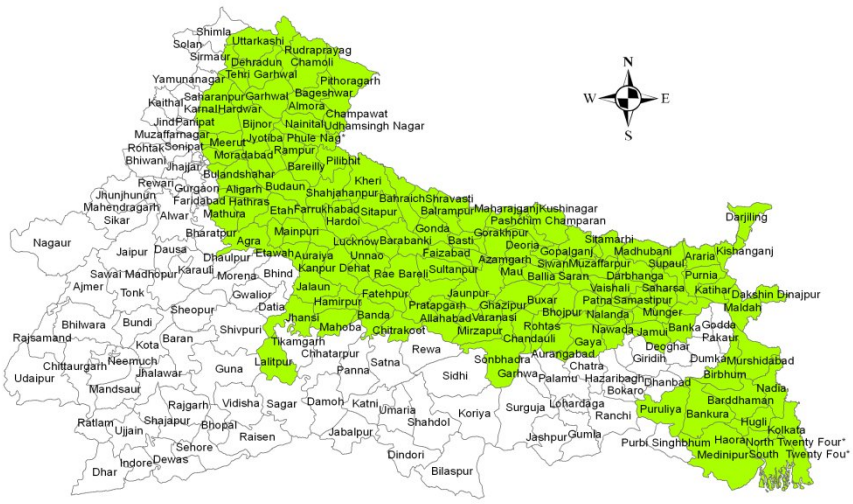

Figure 1: Geographical Delineation of the Portion of Ganga River Basin Considered Significant from Agriculture and Irrigation

3.1. Uttarakhand

Uttarakhand Statewas carved out of parent State of Uttar Pradesh on 9th November 2000, and became 27th State of the Republic of India. In January 2007, the name of the State was changed to Uttarakhand from its earlier name Uttaranchal. The Statehas a total geographical area of 53,483 square kilometer (sq. kms) of which 93 percent is mountainous. About 34,650 sq. kms area is under forest cover. The recorded forest area constitutes 64.79 percent of the total reported area, though the actual cover based on remote sensing and satellite imagery information is only 44 percent[2]. As per the 2001 census, population density is 159 persons per square kilo metres. More importantly, with over fifteen important rivers and over a dozen glaciers in the State, Uttarakhand is a valuable fresh water reserve. The average annual rainfall of the state, as recorded is 1,547 mm. For the administrative purposes, the State has been divided into two sub-divisions, i.e., Kumaon and Garhwal divisions. Kumaon division includes six districts, namely, Almora, Bageshwar, Champawat, Nainital, Pithoragarh, and Udham Singh Nagar; while *Garhwal division* consists of seven districts, viz., Dehradun, Haridwar, Pauri, Rudraprayag, Tehri and Uttarkashi. The State has 78 tehsils, 95 development blocks, 671 NyayaPanchayats, 7,227 Gram Panchayats and 15,761inhabited villages.[3]

According to Census 2001, the State accounts for 8.48 million population with 4.32 million males and 4.16 million females. Out of total 8.48 million population of the State, SC and ST constitute 1.51 million and 0.25 million respectively. The decadal growth rate of the population of the State has declined from 24.23% during 1981-91 to 19.20% during 1991-2001. It has sex ratio of 962 and has a literacy rate of 71.6 percent with 83.3 percent literacy among males and 59.6 percent among females. Literacy rates among SC and ST are relatively lower at 63.4 percent and 63.2 percent respectively.

The workforce constitutes 36.57 percent of total population, of which 27 percent are main workers and 9.57 percent marginal workers. Out of the total workforce, 1.56 million are cultivators (including main and marginal cultivators), 0.25 million are agricultural labourers, 0.06 million people work in household industries and 1.23 million people are engaged in other activities.

The major source of livelihood of the population in the state is agriculture. Almost 70 percent of the population is engaged in agriculture. Out of the total reported area, only 14 percent is under cultivation and over 55 percent of the cultivated land in the state is rain-fed with cropping intensity at 161 percent. Agriculture covers 7.81 lakh hectares of land, out of which 4.43 lakh hectares appear to be under Hill regions which is around 56.8 percent of the

[2]Uttarakhand State: Perspective and Strategic Plan 2008-2027, Watershed Management Directorate, Dehradun, Uttarakhand.
[3]UTTARAHKAND: at a Glance 2008-09, http://gov.ua.nic.in/uaglance

total agricultural land while the plain region constitutes 3.37 lakh hectares (43.2%). Irrigated areas in the Hills are around 10 percent whereas it is around 85 to 90 percent in the plain areas. The average size of land holding is around 0.68 hectare in the hills and 1.77 hectare in the plains. Of the total 9.26 lakh farmers in the state, small and marginal farmers constitute around 88 percent. The subsistence nature of agriculture in the hill districts provides nothing but a low and unstable annual income to the people, causing a sizeable out-migration of male members from the family, leaving behind a large number of female-headed households. As per the BPL survey 2008, about 36.5 percent of the population of the state lives below poverty line.

3.2. Uttar Pradesh

Uttar Pradesh is one of the most populated States of India. As per the 2001 Census, there were about 22.3 million households in the State of which about 18 million were rural households and 4.3 million urban households. The State comprises 16 percent of the country's population and 7.3% of the area. In 2001, Uttarakhand was created as a new State comprising 13 districts of the hilly region of the State. The creation of Uttarakhand has led to significant loss to the State in terms of loss in forest area, geographical area and tourism revenue as most of the holy places of pilgrims are located within the hilly region. The State, though gifted with fertile soil and rivers, is one of the poorest States of India (Govt of UP, 2002).

The state is organized into 17 divisions, 70 districts, 300 Tehsils and 813 development blocks. It has 52,028 Gram Panchayats, covering 97,134 inhabited villages and 689 towns (Kumar, 2005). It is divided into four economic regions, namely, Western Region (WR), Central Region (CR), Bundelkhand Region (BKR) and Eastern Region (ER). In terms of socio-economic development, there exists a vide disparity across regions. For example, population and area of WR and ER are almost same but there is a marked difference in their levels of socio-economic development. The ER and BKR are more backward as compared to WR and CR. The ER is largest among all the regions. It commands over nearly 36 percent of the State's geographical area and a little over 40 percent of the total population. Next to it is WR which comprise one-third of the State's area and about 37 percent of population. These two regions together constitute 68.7 percent of the total area and over three-fourth of the total population of the State. Other two regions - CR and BKR are relatively smaller both in terms of area and population. Density of population varies significantly across regions. It is highest in the ER (776 per sq. km), followed by WR (765 per sq. km.). It is lowest in BKR (280 per sq. km.). Decadal growth of population (1999-2001) is also observed highest in the ER and lowest in the BKR. Urbanisation in the State is lesser than the national average. As against 27.78 percent population living in urban areas in India, only 20.78 percent of the state resides in the urban areas. The percentage of urbanisation also varies significantly across the regions. It is as high as 28.3 percent in WR and as low as 11.6 percent in ER. The highest population density and lowest urban population in the ER imply that there is very

high dependence of population on rural area, especially on the farm sector. This makes the ER relatively poorer than the WR and CR regions.

Figure 2 shows region-wise percentage distribution of rural and urban population in the State. The percentage of rural population marginally declined from 80.3% in 1991 to 79.2% in 2001. This reveals that there is 1.1 percentage point decadal increase in the share of urban population. If the region-wise distribution of population is looked at, it is noticed that urbanization is highest (28.25 percent) in WR, followed by CR (25.11 percent) and BKR (22.46 percent). The ER does not evince any increase in the share of urban population.

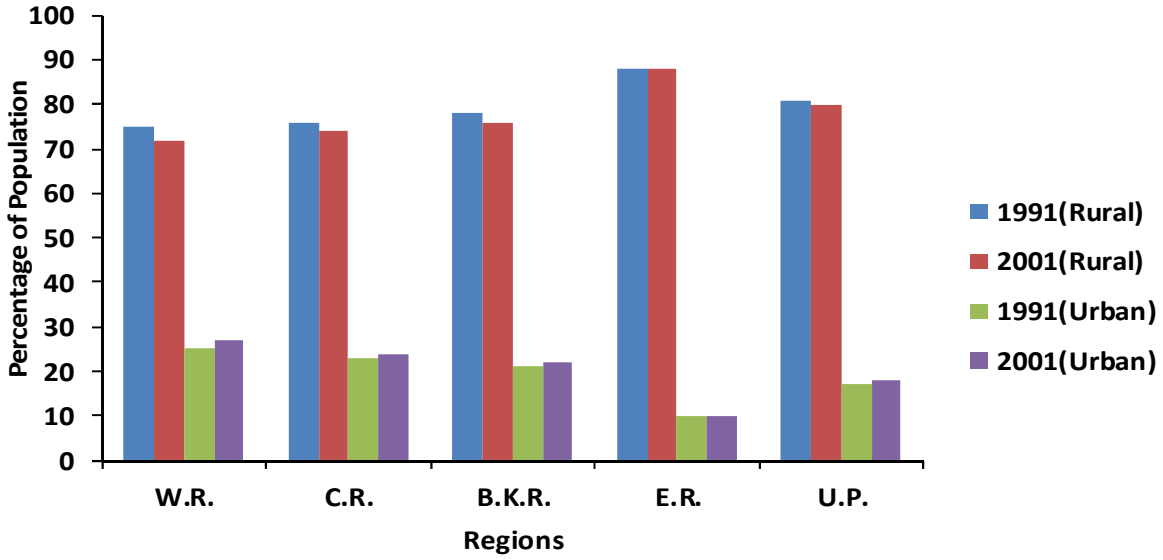

Figure 2: Region-wise Percentage Distribution of Rural and Urban Population of Uttar Pradesh

The State is well known for its success in the green revolution and is the highest producer of food grains and sugarcane in the country; however average yields of most crops are lower as compared to neighboring states Punjab and Haryana. The State shares 16.3 percent of total cropped area and 20.7 percent of total production of food grains of India (GOI, Ministry of Agri, 2007). The State economy is still dependent on the agriculture for its livelihood with industry and services constituted 5.6 percent and 28.5 percent of total workforce, respectively, in 2001 (Figure 3). Agriculture constituted 65.89% of total workforce of the State whereas the corresponding percentage for all-India was only 58.4, indicating that the economy of the State is largely rural and agricultural based. As per the Agricultural Census 2000-01, average size of holdings in Uttar Pradesh was only 0.83 hectare while the All-India average was 1.32 hectare. About 77 percent of the total operational holdings were below 1.0 hectare and 91 percent were below two hectare (GOI, Ministry of Agriculture, 2007). Forest cover of the State declined drastically from 5.2 million hectares to 1.69 millions hectares due to creation of Uttarakhand. The State has about 75 percent of net sown area under irrigation, with relatively higher percentage share of groundwater irrigation through tube wells (Govt. of Uttar Pradesh, HDR 2003).

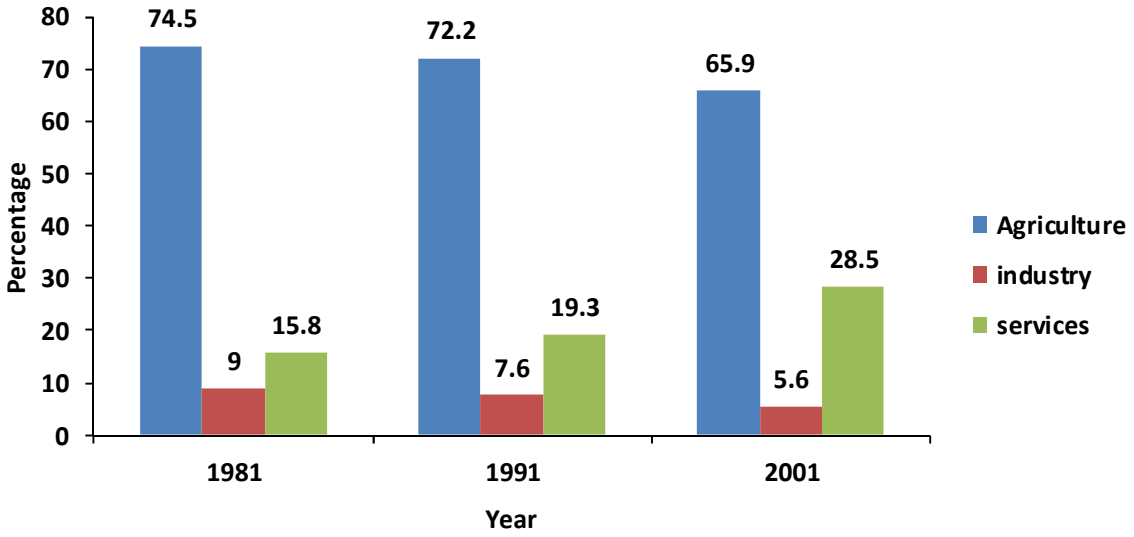

Figure 3: Trends in Structure of Employment in Uttar Pradesh

In terms of other socio-economic indicators too, the State is far behind from many other States. Although literacy rate has increased from 42 percent in 1991 to 57 percent in 2001, it is much below the all-India average of 65 percent. Female literacy, at 43 percent, is also below the all-India average of 54 percent. Maternal mortality is high at 7.07 deaths per 1000 live births compared to 4.08 in India. The infant mortality rate (IMR) is 85 per 1000 live births, which is among the highest in India. IMR is considered the most important measure of how well the government distributes available resources for health, education, status of women and public spending. In rural areas, it is nearly twice as high as in the urban areas. Children in the rural areas have 80 percent higher risk of dying before their fifth birthday than urban children. About 71 percent of UP's population (85 percent in rural and 19 percent in urban) do not have access to sanitary toilets (Government of Uttar Pradesh, 2005). Uttar Pradesh continues to languish at a low level of human development and is in the lowest cluster of States, along with Bihar, Madhya Pradesh, Rajasthan and Orissa. As per the National Human Development Report 2001, HDI of the State was 0.388 as against the all-India 0.472. It ranked 13 among the 15 major Indian States, just above Bihar and Assam (Government of India, HDR 2001).

3.3. Bihar

Bihar has been an agrarian economy and 90 percent of its population lives in rural areas (Economic Survey, 2010-11). The state is located in the fertile Gangetic Plains. Bihar is the ninth largest state of India in terms of its area and the second largest in terms of population. It is bounded by Nepal on the north, Orissa on the south, west Bengal on west and Uttar Pradesh on the east. Bihar lies mid-way between the humid West Bengal in the east and the sub humid Uttar Pradesh in the west. The Bihar plain is divided into two unequal halves by the river Ganga which flows through the middle from west to east. The total area covered by the state of Bihar is 94,163 sq. km. Bihar is mainly a vast stretch of very fertile flat land. It

has several rivers namely Ganga, Son, Bagmati, Kosi, BudhiGandak, and Falgu. Central parts of Bihar have some small hills, for example the Rajgir hills. The Himalayan Mountains are to the north of Bihar, in Nepal. Chota Nagpur plateau lies towards the south of Bihar.

In 1936, Bihar was separated from Orissa. Later in November 2000, Bihar was bifurcated and a new state Jharkhand was made by transferring 13 districts to the new state. The remaining 29 districts have been reorganized into 38 districts. Hence, currently Bihar is divided into 38 districts and 9 divisions for administrative purposes. After the bifurcation of Bihar in 2000, the industrial and mineral-rich zone has gone to Jharkhand and Bihar was left with fertile land water resources. Bihar is richly endowed with water resources, both at the ground water resource and the surface water resource. Bihar has substantial water from rainfall as well as the rivers which flow within the territory of the State. The river Ganga flows right across it from west to east. North Bihar is extremely fertile, the land being watered by the rivers Sarayu, Gandak and Ganga. Twelve districts of Bihar fall on bank of river Ganga. The other rivers are the Sone, Poonpoon, Falgu, Karmanasa, Durgawati, Kosi, Ghaghara etc.

The economy of Bihar is mainly based on agricultural and trading activities. The soil of Bihar is extremely fertile which makes it ideal for agriculture. Agriculture is the vital source of wealth in Bihar. 76% of its population is engaged in agricultural pursuits. Paddy, wheat, maize and pulses are the principal food crops of Bihar. Main cash crops are sugarcane, potato, tobacco, oilseeds, onion, chillies and jute. Bihar is the third largest producer of vegetables and fourth largest producer of fruits in the country. It is the largest producer of litchi, makhana, guava, lady's finger and honey in the country. However, with improved methods and better management, State's contribution in food grain, fruit,vegetables, spices and flowers can be increased manifold. The major agro based industries of Bihar are of rice, sugar, edible oil.

Though endowed with good soil, adequate rainfall and good ground water availability, Bihar has not yet realized its full agricultural potential. Its agricultural productivity is one of the lowest in the country, leading to rural poverty, low nutrition and migration of labour. Based on soil characterization, rainfall, temperature and terrain, three main agro-climatic zones in Bihar have been identified. These are: Zone-I, North Alluvial Plain, Zone-II, north East Alluvial Plain,and Zone-III comprising of Zone-IIIA South East Alluvial Plain and Zone-IIIB South West Alluvial Plain, each with its own unique prospects.

3.4. West Bengal

West Bengal, one of the major states in the eastern part of the country, has predominantly an agrarian economy. It is endowed with rich natural resources and climatic conditions favorable for agriculture. These include large areas of good alluvial soil, abundant surface water and groundwater resources, and good rainfall. The climate of the region (other than in the hill regions) is tropical, hot and humid. Annual rainfall is between 1,300 mm and 1,750 mm. Despite these favourable conditions, the State has witnessed wide fluctuations in the growth of agricultural production (Rawal and Swaminathan, 1998). In line with the changing

trend across the country, West Bengal has experienced a structural shift in output front as the share of agriculture in the State's GDP is recorded to have come down from about 33 percent in 1999-2000 to about 25 percent in 2007-08.

The river Ganga is considered the life line of West Bengal. It is a perennial source of water to the plains of West Bengal for irrigation as well as human and industry consumptions. The river is navigable and it acts as a major transport system in the State with heavy traffic flow. The entire State of West Bengal, except four districts namely Darjeeling, Cooch Behar, Jalpaiguri and Purulia fall under the lower Gangetic Plains region. The Ganges and its numerous distributaries have resulted in highly fertile soils in this region. Accordingly, agriculture has become the key to the economy of the State. A large section of the population derives their livelihood from agriculture. This region also covers many major tributaries of the Ganga.

The agro-climatic zone in West Bengal can be divided into four sub-zones, viz., Barind Plains, Central Alluvial Plains, Alluvial Coastal Saline Plains, and Rarh Plains. The zone of Barind plains that covers two districts namely West Dinajpur and Malda has a relatively high rainfall. It has high NSA but the irrigation facilities are not developed. The zone, central alluvial plains, on the other hand, is the largest sub-zone in the lower Gangetic plains covering around 3.5 million hectares i.e. about 40 percent of the total land. It covers the districts of Murshidabad, Nadia, Burdwan, Hooghly, Howrah and Medinipur. About 68 percent of the land of this zone is cultivated and over 60 percent of the cultivated land is irrigated resulting in a reasonably high cropping intensity. The alluvial coastal saline plains cover the districts of North and South 24-Parganas along with the metropolitan city of Calcutta. Only about 26 percent of the NSA of this is irrigated. The rarh plains that include Birbhum and Bankura districts are mostly rural and poorly developed. About two-thirds of the land in this zone is cultivated with 23 percent falling under forest cover. Poor irrigation facilities in this zone have resulted in a very low cropping intensity.

The seven districts of West Bengal which is part of the Ganga River Basin are 24 Pargana South, 24 Pargana North, Hoogli, Howrah, Kolkota, Maldah, and Medinipur. In all, out of around 42,630,182 people that reside in the Ganga River Basin of this state, about 9,293,861 people live in major towns like Maheshtala, RajpurSonarpur, Serampore, Hugli-Chinsurah, Chandannagar, Haora, Kolkota, Bhatpara, South Dum Dum and so on. Bengal has 160 towns and cities, out of which 27 are class I and 27 are class II cities.

4. Data Sources

District-wise data for different states have been taken from 'Statistical Abstracts' published by these four states for different years. These abstracts were procured from the respective State Planning Commissions and divisional headquarters. The State-wise and district-wise data (for 125 districts) in the Ganga River basin Catchment Area were taken from the following Study: *Bhalla G. S. and Gurmail Singh, 2010, 'Growth of Indian Agriculture: A*

*District Level Study' Final Report on Planning Commission Project, CSRD, JNU, New Delhi.*Most of the data were available in the form of published documents.

5. Data Limitations

In general, in any kind of study based on temporal and spatial growth trends and patterns, there always remain some sorts of limitations due to variations in the units of measurement, definition of certain variables, period of data collection, etc. Such variations may pose problems with regard to comparability of the data. In addition, the data suffers from a few other limitations specific to the agricultural indicators. One of such a major problem pertains to the mixed crops where along with a cereal crop, other crops such as rapeseed/mustard, sesamum and castorseed are also grown. In such case, it becomes difficult to estimate the area in which they are grown. Another major limitation arises out of the fact that most of the states in India do not maintain data for a long period. However, in case of the state of UP, data on almost all major aspects of economic sectors and other Census based information are available for a long time span.

6. Agriculture in Basin Area

Thissection provides an overview of the state of agriculture in the Ganga River Basin area ataggregate level following the levels and growth of selected agricultural indicators over a period of four decades. The main discussion revolves around the level and growth of crop output, crop yield, gross and net sown area, cropping intensity, gross and net irrigated area, fertilizer consumption, use of important power-based agricultural equipments, and the human resources involved in the agriculture in the basin area.At gross level, mainly two types of statistics have been used: one, the district-level average value of selected agricultural indicators in the Ganga River Basin area during the period 1962-65, 1970-73, 1980-83, 1990-93, and 2003-06; and the other, level and growth of selected indicators at state level.

It is important to mention here that although districts in Ganga River Basin area here actually mean the districts which are part of the aforementioned four states, nevertheless, a few adjustments have been made to account for reshuffling of administrative boundaries at district and to some extent, at the state levels. Consequently,there were71 composite districtunits constituted by combining 130 districts (in the four states of the basin area) during 1990-93 and 2003-06 in order to make them comparable with the initial district units of the "sixties", the "seventies" and the "eighties". Appendix I gives details about the formation of the 71 district units. However, the figures for the states are at aggregate level, and the figures represented by Uttar Pradesh and Bihar include Uttarakhand and Jharkhand respectively. The main source of the agricultural statistics presented in a different perspective in the present report originates from the Planning Commission report on the Growth of Indian Agriculture, submitted by Bhalla and Singh (2010).

6.1. Level and Growth of Selected Agricultural Indicators

6.1.1. Crop Output

The new Borlaug seed-fertilizer technology introduced in the mid-sixties made a major impact on raising yield and output levels of some crops and of aggregate crop output in India (Bhalla and Singh, 2010). The average value of crop output in the districts of Ganga

River Basin area reflects an almost four-fold growth from Rs. 1.97 billion during 1962-65 to Rs. 5.24 billion during 2003-06 at 1990-93 prices (Figure 4).

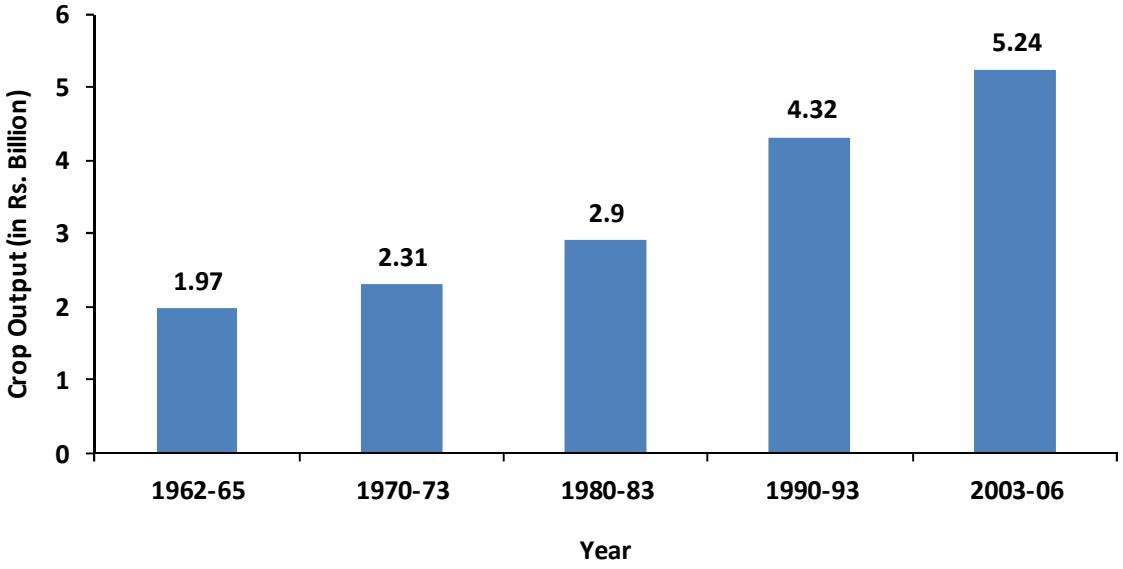

Figure 4: Average value of Crop Output (in Rs Billion) per district in GRB, 1962-65 to 2003-06

Average value of the crop output during 1970-73 is statistically not significantly different than that in 1962-65. This suggests that there was hardly any difference in the level of output value during the initial period of Green revolution (1962-65 to 1970-73) across the districts in the basin area. It is worth mentioning here that the estimation of value level of crop output is based on 35 crops at 1990-93 constant prices (Bhalla and Singh, 2010).

Figure 5 illustrates the level of crop output value across the states in the Ganga River Basin area. In absolute terms, although Uttar Pradesh recorded the maximum output value, yet the production growth indicates that West Bengal has had edge over Uttar Pradesh and Bihar. The period 1980-83 to 1990-93 marks a turning point in India's agricultural development for the reason that during this period, green revolution spread to larger areas and more crops due to 'wider technology dissemination'. At all-India level, the growth rate of crop output accelerated from 2.24 per cent per annum during 1962-65 to 1980-83 to 3.37 per cent per annum during 1980-83 to 1990-93. An interesting feature of the eighties was that agricultural growth permeated to all regions in India. However, comparing the statistics in Ganga river Basin, it can be observed that during the period 1980-83 to 1990-93, the growth in output value of West Bengal was more than doubled and rose almost by 63% for UP, while there was no significant improvement in the production in Bihar. Major contribution in the agricultural output came from faster rise in the rice yield which went from 1.5 per cent during 1967-68 and 1980-81 to 3.3 per cent during 1981-82 to 1991-92. The major jump was seen for the West Bengal during this period arising out of tenancy reforms undertaken in the state after 1977-78 and provision of adequate public supply of credit and other inputs to small farmers (Ramchandran*et al.,*2003).

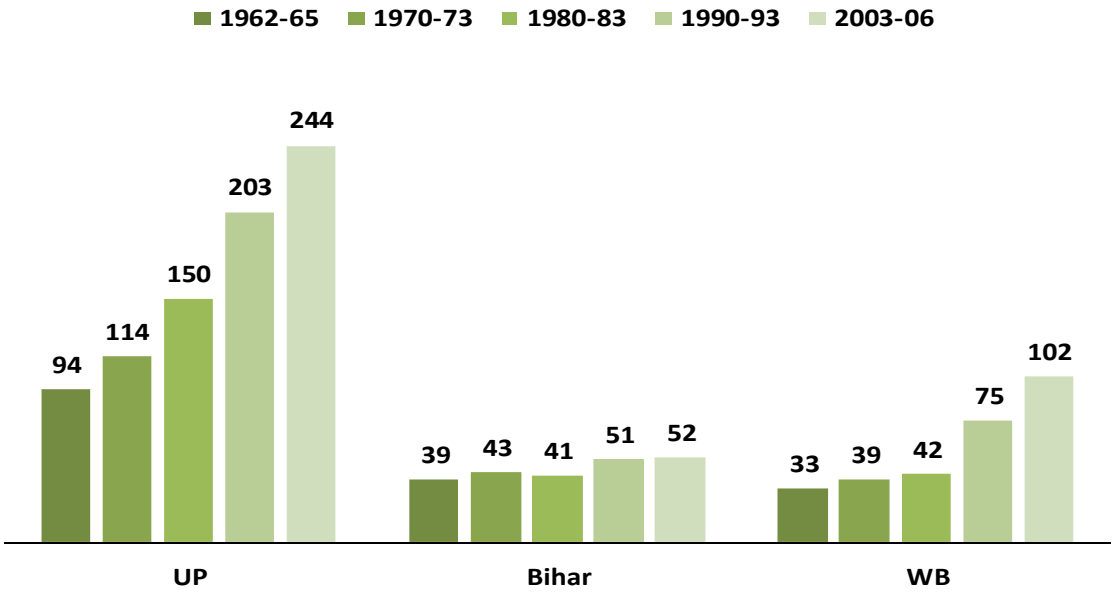

Figure 5: Value of Crop Output (in Rs. Billion) across States in GRB, 1962-65 to 2003-06

The agricultural revolution that swept West Bengal during this period is further corroborated by the data presented in Figure 6.

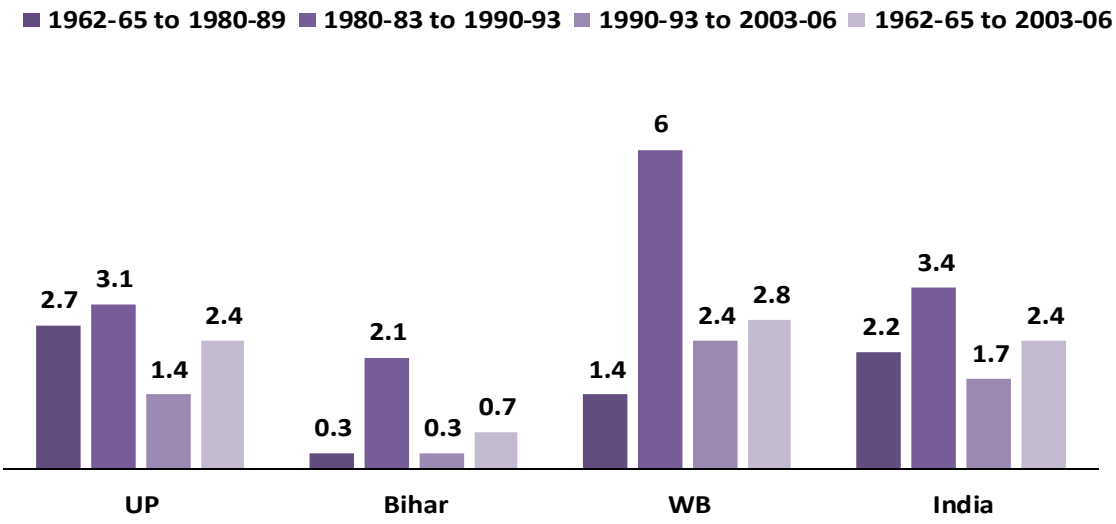

Figure 6: Annual Compound Growth Rate (%) of Crop Value across States in GRB

6.1.2. Crop Yield

Figure 7highlights an increase in the crop yield (in monetary terms)across the districts of the Ganga River Basin area, which grew from a level of Rs. 4,300 per hectare of gross cropped area during the period 1962-65 to Rs.9,900 per hectare during 2003-06 at 1990-93 prices.

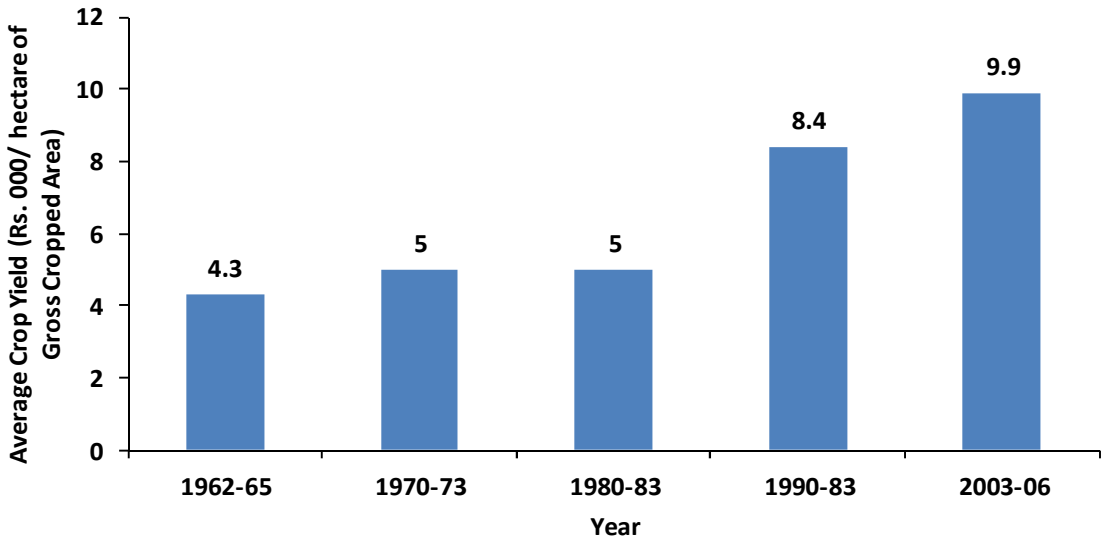

Figure 7: **Average Crop Yield (Rs. 000/ hectare of Gross Cropped Area) per district in GRB, 1962-65 to 2003-06**

In terms of crop yield during the period 1962-65 to 2003-06, the growth rate has been recorded almost similar for Uttar Pradesh and West Bengal i.e. slightly more than 2%, besides the higher rate (4.8%) of growth shown by West Bengal as compared to Uttar Pradesh (3.7%) during 1980-83 to 1990-93 (Figure 8). Bihar has shown the very modest rate of 1% annual compound growth rate of crop yield during the overall period (1962-65 to 2003-06).

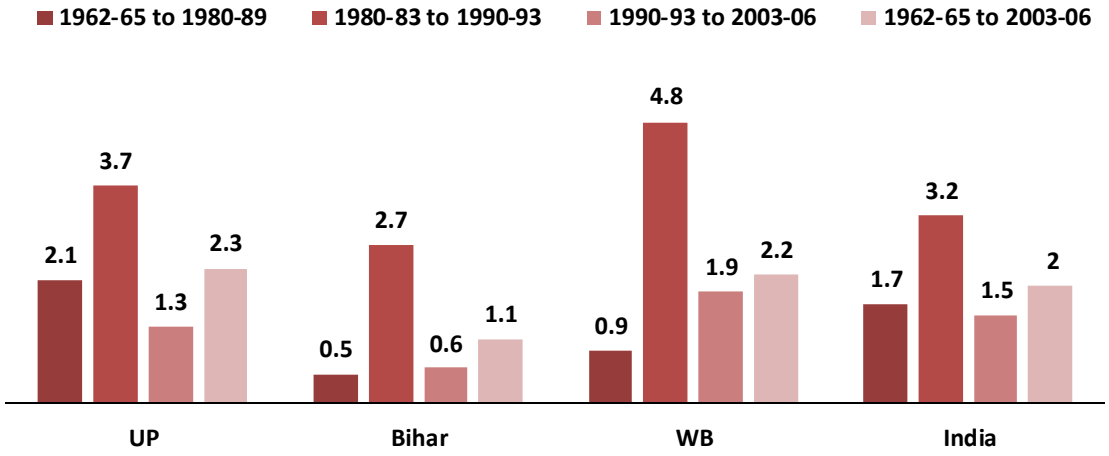

Figure 8: **Annual Compound Growth Rate (%) of Crop Yield across States in GRB**

6.1.3. Net Sown Area

Due to competing demands on area available for cultivation from increase in rural habitations, forestation, urbanization and industrialization, the net sown area throughout the country has registered a rapid deceleration in its growth over time. Figure 9, which

illustrates the average net sown area in the Ganga River basin, clearly indicates that there were no substantial differences in the average level during 1962-65 to 2003-06.

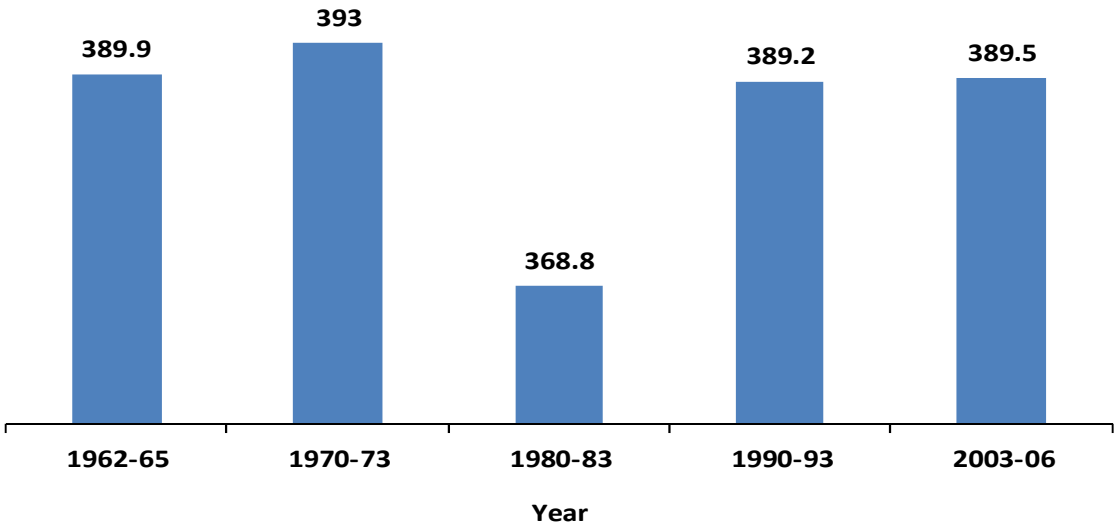

Figure 9: Average Net Sown Area (Thousand hectares) per district in GRB, 1962-65 to 2003-06

At state level, the average net sown area as illustrated in Figure 10 indicates that the states in the Ganga river basin area have either registered a decline or a constant pattern during 1962-65 to 2003-06. Bihar and West Bengal have registered a slight decline during the period, while Uttar Pradesh has had a very negligible annual compound growth rate of around 0.02 percent during the period 1962-65 to 2003-06.

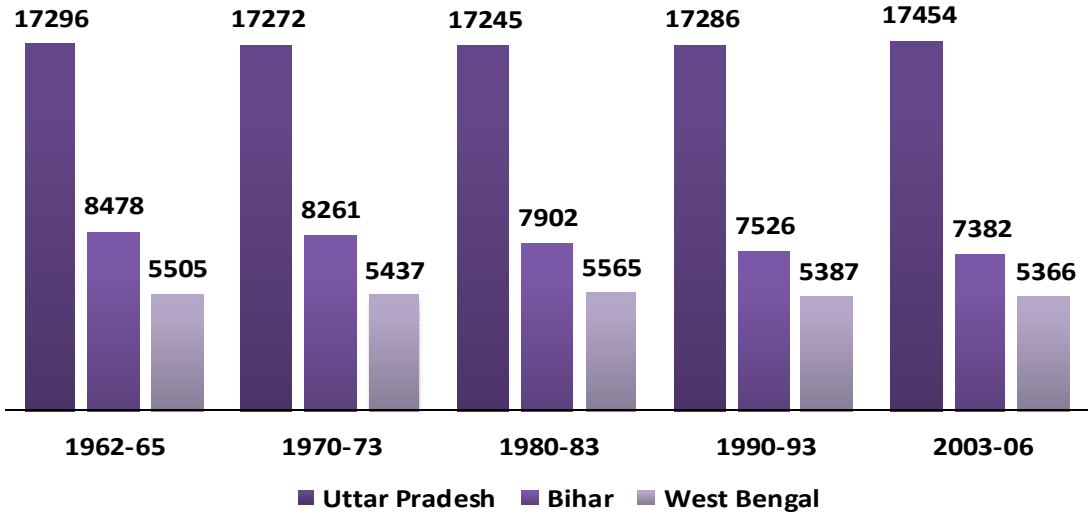

Figure 10: Average Net Sown Area (thousandhectares) across states in GRB, 1962-65 to 2003-06

The growth rates in net area sown across the states in the Ganga River Basinduring the period 1962-65 to 2003-06 (with decadal growth rate as well) are well illustrated in Figure 11.

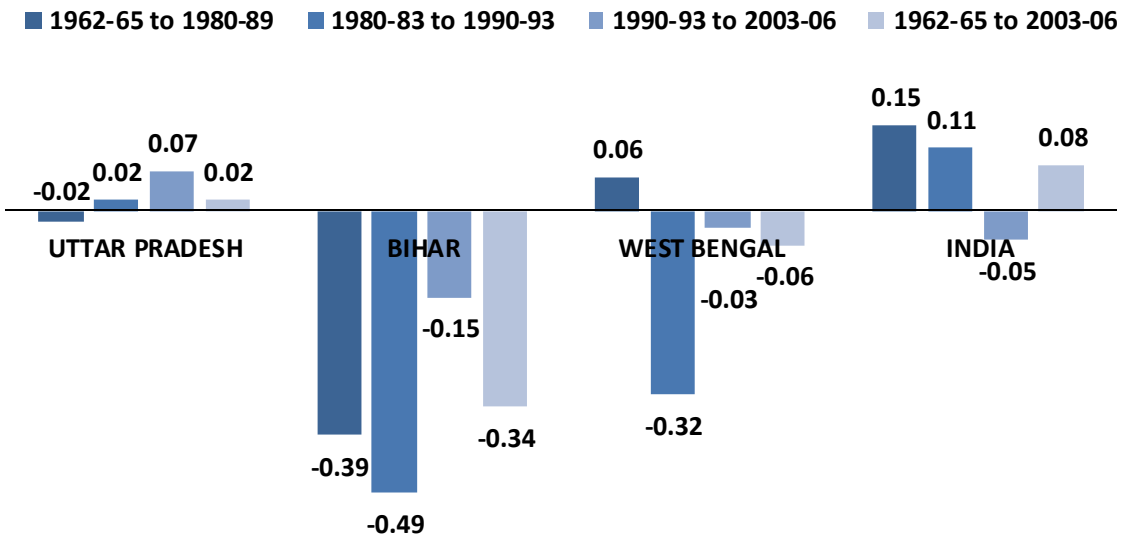

Figure 11: Annual Compound Growth Rate (%) of Net Sown Area across States in GRB

6.1.4. Gross Cropped Area

Notwithstanding the fact that yield growth has become the dominant contributor to growth of output after the advent of green revolution, growth of gross cropped area continues to be an important source of growth of output. The average gross cropped area in the Ganga River Basin area grew from 501.7 thousand hectare during 1962-65 to 598.9 thousand hectare during 2003-06(Figure 12). Though, there has been a growth of more than 19 percent in the average gross cropped area in the districts of the Ganga River Basin, there was minimumgrowth (less than 4%)registered in the average gross cropped area across the districts in the initial period of the green revolution (during 1962-65 and 1970-73).

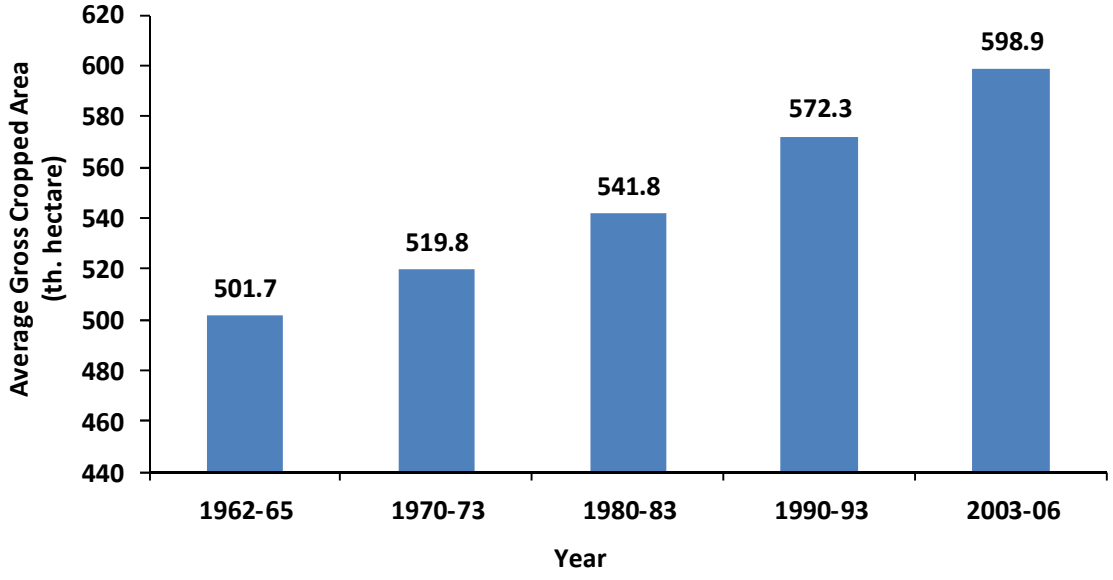

Figure 12: Average Gross Cropped Area (thousand hectares) per district in GRB, 1962-65 to 2003-06

At the state level, the growth in the gross cropped area was almost 6 times higher in West Bengal as compared to Uttar Pradesh during 1962-65 to 2003-06, while Bihar had a continuous decline in the gross cropped area throughout the period (Figure13).

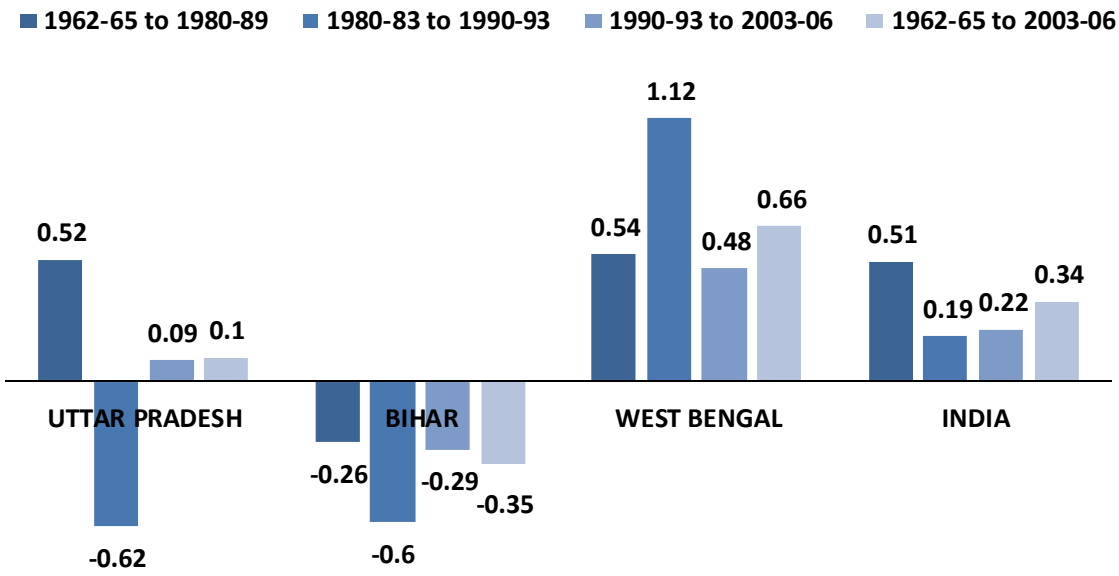

Figure 13: Annual Compound Growth Rate (%) of Gross Cropped Area across States in GRB

Area under crops can grow either through increase in net area sown or through increase in intensity of cultivation. Since a limit has reached with regard to the possibility of increasing net sown area on a substantial scale, hence, the only method of increasing gross cropped area was through increased intensity of cultivation brought about through irrigation and through the introduction of short duration crops.

6.1.5. Cropping Intensity

As discussed above, despite registering a decline of around 0.06% in net sown area during the period 1962-65 to 2003-06, West Bengal managed to record a six-times growth in the gross cropped area as compared to Uttar Pradesh during the same period which can be attributed to the tenancy reforms and adequate provisions for farm related credits.It had registered a substantial growth in the cropping intensity i.e. the number of crops grown from the same land in a year, during 1990-93 (160%) and 2003-06 (176%) as can be seen from Figure 14. The cropping intensity in West Bengal grew from a level of 118% during 1962-65 to 176% during 2003-06 compared to the respective figures of Uttar Pradesh as 128% and 150%. However, the lower cropping intensity in Uttar Pradesh is observed due to some measurement problem, as the cultivation of sugarcane, a major crop, in Uttar Pradesh is an annual crop and should be considered equivalent to two crops (Kharif + Rabi) when it comes to measuring cropping intensity.

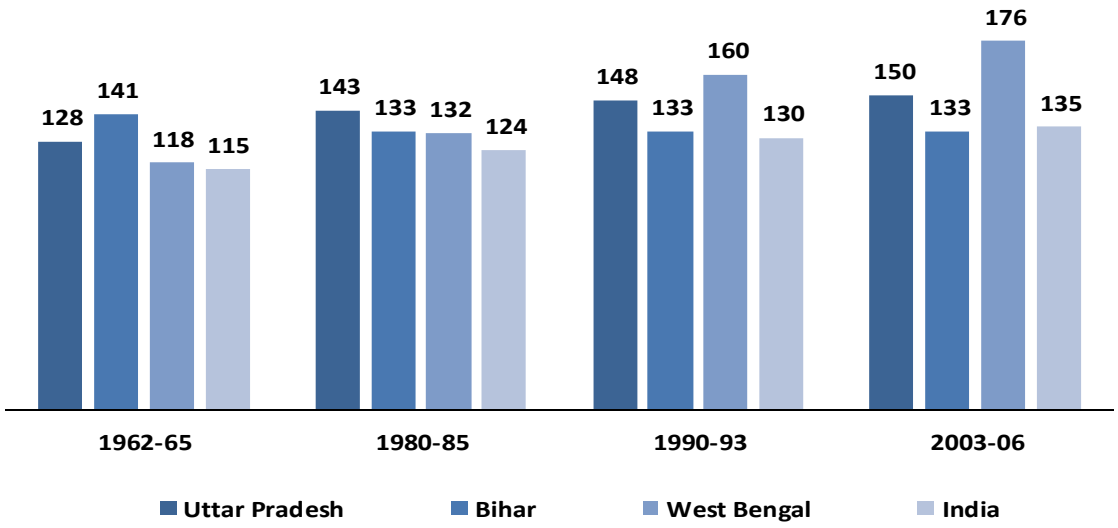

Figure 14: Cropping Intensity (%) across States in GRB, 1962-65 to 2003-06

6.1.6 Trends in Net and Gross Irrigated Area

The improvement in irrigation facilities over the period has had a very important role to play in the spectacular increase in the growth of output in agriculture in the Ganga River Basin area. Construction of canals along Ganga and other small rivers, increasing use of mechanized equipments to exploit the ground water as well as to divert stored surface water in ponds or wells at desired place in the agricultural fields, and other small sources of irrigation like temporary drainage etc. have facilitated a tremendous growth in the proportion of irrigated area in the basin, similar to other areas in the country. Figure 15 indicates the growth of average net irrigated area in theGanga River Basin area. The average net irrigated area in the basin has grown from the level of 89.6 thousand hectare during 1962-65 to 243.6 thousand hectare during 2003-06.

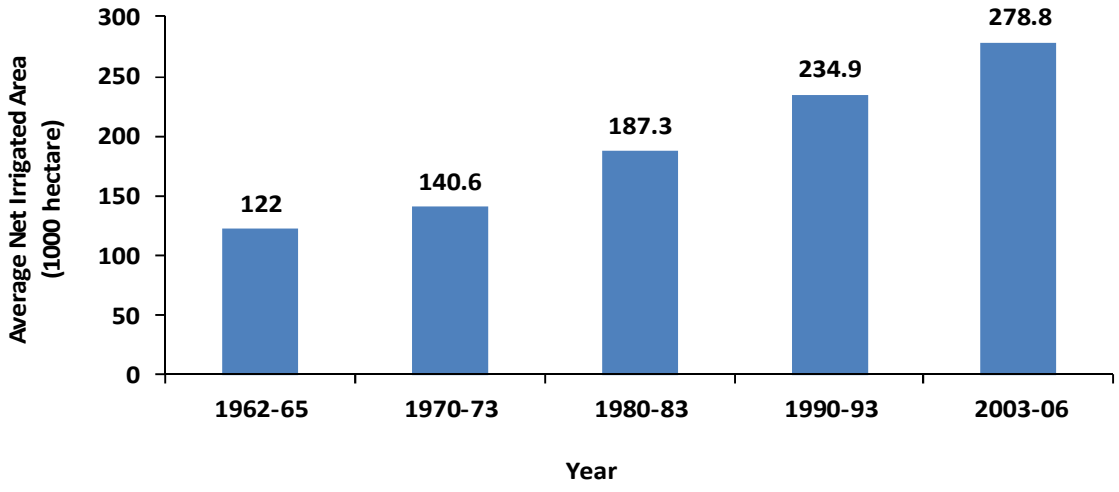

Figure 15: Average Net Irrigated Area (thousandhectare) per district in GRB, 1962-65 to 2003-06

Figure 16 shows the average gross irrigated area in the basin area, which indicates that during the period 1962-65 to 2003-06, there has been anincreaseof more than 200 percent in the average gross irrigated area in the basin.

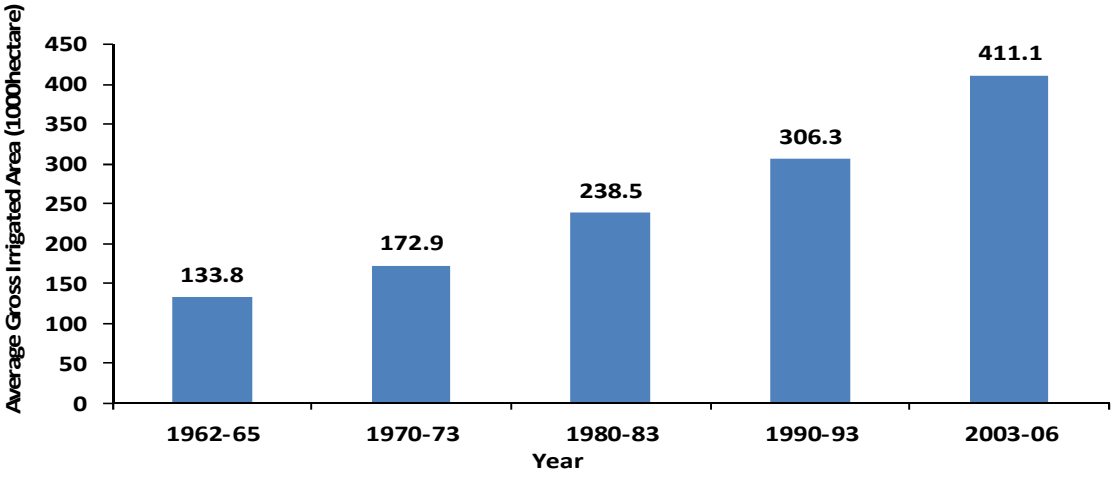

Figure 16: Average Gross Irrigated Area (1000 hectare) per district in GRB, 1962-65 to 2003-06

The average gross irrigated area per district which was recorded at a level of 133.8 thousand hectares during 1962-65 grew to a level of 411.1 thousand hectaresduring the period 2003-06.At the state level, Uttar Pradesh has registered a tremendous increase of around 159 percent in the gross irrigated area during the period 1962-65 to 2003-06 (Figure 17). Uttar Pradesh, which also includes Uttarakhand, recorded a level of only 27 percent irrigated area during early 60's and then managed to get 70 percent of the total cropped area irrigated during 2003-06. On the other hand, having maintained one fourth of the total cropped area irrigated during the period 1962-65 to 1980-83, West Bengal registered a growth of more than 115 percent in GIA during the period 1980-83 to 1990-93, which recorded a little decline during the period 1990-93 to 2003-06. Needless to say, Bihar also registered a tremendous growth (more than 150 percent) in the proportion of irrigated area from the level during 1962-65 (18%) to 2003-06 (48%).

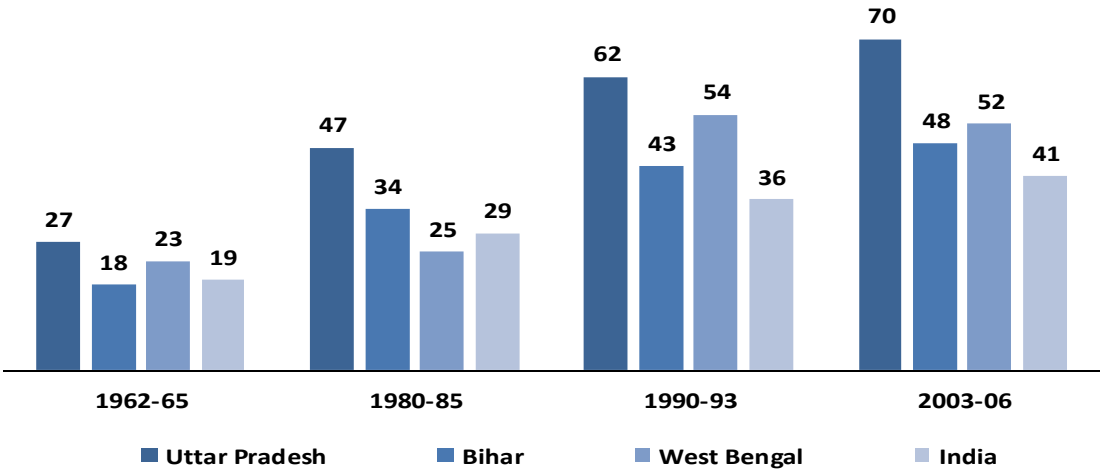

Figure 17: Trends in GIA across States in GRB, 1962-65 to 2003-06

The information provided in Table 1 suggests that UP and Uttarakhand together accounts for the largest net irrigated area from all sources and that it has the highest net irrigated to net sown area.

Table 1: State-wise Irrigation Intensity in the Ganga River Basin (1999-2008)*

State	Net Irrigated Area from All Sources, km^2	Gross Area Irrigated from All Sources, km^2	Net Area Sown, km^2	Net Irrigated to Net Sown Area (Percent)
Bihar and Jharkhand	36460	48820	70920	51%
Uttar Pradesh and Uttarakhand	134260	196960	171820	78%
West Bengal	31360	36610	52960	59%
India	630990	764430	1408610	44%

**Source: Ministry of Agriculture, 2008, Quoted on page 32Environmental and Social Management Framework (ESMF) Volume I - Environmental and Social Analysis, January 2011, Prepared by The Energy and Resources Institute, Delhi for National Ganga River Basin Authority (NGRBA),Ministry of Environment and Forests, Government of India.*

Different sources of water have been used to provided irrigation facilities to the farmland. Although there is a good network of canals especially in Uttar Pradesh, nevertheless canal water meets only 24% of the irrigation requirement of the agriculture in this state. The highest contribution of canals to the irrigation can be seen in case of Bihar and Jharkhand where canals water caters to 39% of the total irrigation requirement. Wells, however, provide the nearly twice that amount, especially in Uttar Pradesh and Uttarakhand (73%), West Bengal (59%), and Bihar and Jharkhand (49%). The detailed information in this regard is provided in Table 2.

Table 2: State/Source-wise net area irrigated (2000-2001) in the Ganga River Basin*

State	Canals,km^2	Tank,km^2	Wells,km^2	Other Sources,km^2	Total Area, All Sources,km^2
Bihar	11360	1550	20930	2410	36250
Uttar Pradesh	30910	820	93840	2590	128160
West Bengal	2610	1730	13970	5230	23540
India	159890	25240	332770	28920	546820

**Source: Water Data- Complete Book, Central Water Commission, GoI, 2005; Quoted on page 33 Environmental and Social Management Framework (ESMF) Volume I - Environmental and Social Analysis, January 2011, Prepared by The Energy and Resources Institute, Delhi for National Ganga River Basin Authority (NGRBA), Ministry of Environment and Forests, Government of India.*

Although ground water is, by and large, used for irrigation purposes, it also provides water for the domestic and industrial uses, as highlighted in Table 3. In fact, throughout the alluvial area of the GangaRiver Basin, the major urban water supply schemes are dependent upon groundwater resources. Similarly, a large number of industries also withdraw significant amounts of groundwater, especially from the easily accessible aquifers in the alluvial zone. The highest availability of the ground water is also found to be in Uttar Pradesh (Table 3).

Table 3: State-wise Groundwater Usage Pattern in the Ganga River Basin States*

State	Annual Groundwater Draft (BCM per year)			Net Annual Groundwater Availability (BCM/Year)
	Irrigation	Domestic and Industrial Uses	Total	
Bihar	9.39	1.37	10.77	27.42
Uttar Pradesh	45.36	3.42	48.78	70.18
Uttarakhand	1.34	0.05	1.39	2.1
West Bengal	10.84	0.81	11.65	27.46
India	212.37	18.05	230.41	398.7

**Source: Central Groundwater Board, 2008 and Central Water Commission, 2008)*

6.1.7 Fertilizer Consumption

Since the very inception of green revolution, the seed-fertilizer technology was the main catalyst to boost up the growth of Indian agriculture. Figure 18 very clearly points out the increasing trend in fertilizer consumption. From the period during 1962-65, when the average level of fertilizer consumption was recorded at just 1.7 thousand tones per district in the GangaRiver Basin area, the average level of fertilizer consumption grew up tremendously to a level of 102.6 thousand tones during 2003-06.This issue needs to be looked at very seriously for the reason that increasing use of chemical fertilizer has become the non-point source of ground and river water pollution. It also puts a big question mark on the sustainability of agricultural growth.

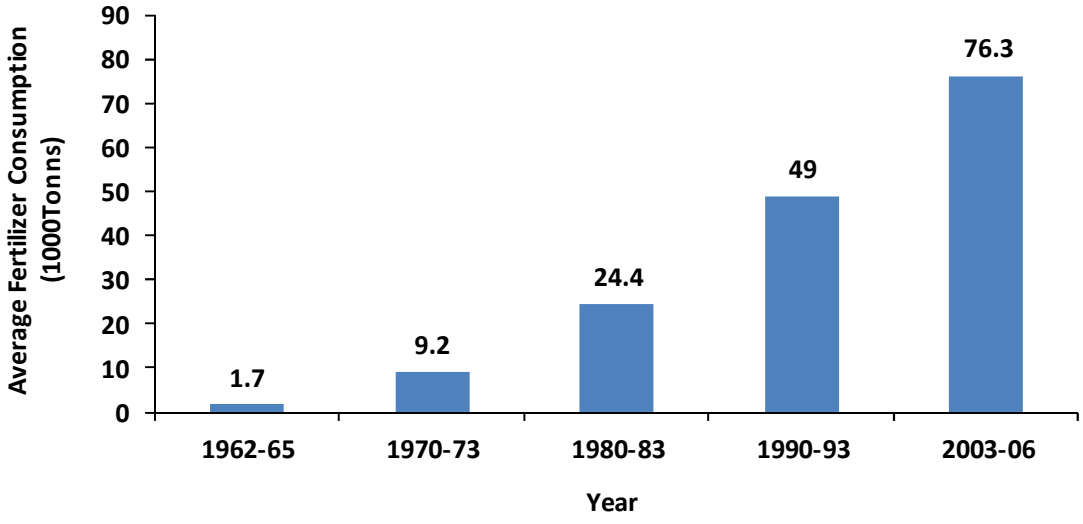

Figure 18: Average Fertilizer Consumption (thousand tonnes) per district in GRB, 1962-65 to 2003-06

If one observes the trend in fertilizer consumption across states in the basin area, West Bengal seems to have registered a tremendous growth in the use of chemical fertilizers from the level of only 5 kg/hectare during 1962-65 to a level of 226 kg/hectare during 2003-06. Uttar Pradesh also followed, more or less, the same level of growth throughout the period

with a level of only 4 kg/hectare during 1962-65 to 205 kg/hectare during 2003-06 (Figure 19). Comparatively, Bihar has registered a modest growth in the fertilizer consumption.

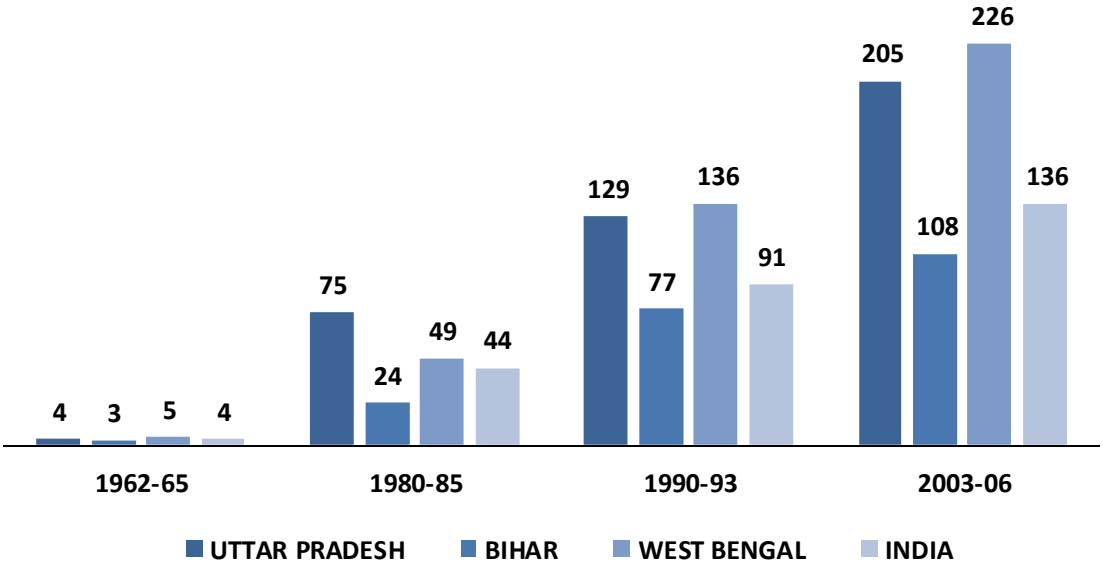

Figure 19: Fertilizer Consumption (kg/hectare) across States in GRB, 1962-65 to 2003-06

It may be mentioned here that the Ganga basin states comprising Bihar, Haryana, Himachal, Jharkhand, Madhya Pradesh, Rajasthan, UP, Uttarakhand, and West Bengal, consume nearly 10 million tones of chemical fertilizers per year, which constitutes 45 percent of the total chemical fertilizer consumption in the country. Of this, Uttar Pradesh alone consumes 38% of the fertilizer used. Such an intensive use of fertilizer may lead to disposal of high levels of nitrogen and phosphorus as part of the agricultural runoff into surface water bodies. As per available estimates, 0 to 15 per cent of the nutrients added to the soils through fertilizers eventually find their way to the surface water systems. Runoff from arable lands may contain nitrogen up to 70 mg/l and phosphorus ranging from 0.05 to 1.1 mg/l, with potential to raise the nutrient level to a considerable degree in stream waters. Similarly, pesticide consumption in the Ganga basin states is about 21,000 tones per year (47.6% of the total pesticide consumption in the country). Pesticides, being highly toxic and chemically more stable than the fertilizer residues, do have much bigger a potential for polluting the surface and ground water and consequently causing harm to the human health and aquatic fauna [*Environmental and Social Management Framework (ESMF) Volume I - Environmental and Social Analysis, January 2011, Prepared by The Energy and Resources Institute, Delhi for National Ganga River Basin Authority (NGRBA), Ministry of Environment and Forests, Government of India. p.127].*

6.1.8 Mechanization and Power Resources

Agriculture in the basin area has been successfully powered by the increasing use of time-saving, labour-saving and efficient equipments replacing the cumbersome wood and iron age of traditional Indian agriculture. The very successful replacement of traditional plough by the tractors provided a very efficient manner to dig out and shuffle the soil to keep the

content of the soil rich and refreshing. So was the relief provided by the increasing use of diesel-based/electric pump-sets to take out the ground water, especially when the rain water falls deficient.

In this regard, it would be interesting to have a look at the growth of these power-based equipments in the Ganga River Basin area. Figures 20 and 21 demonstrate the growth pattern in the average use of tractors and pump-sets per district in the basin area. As could be discerned, the use of tractors grew tremendously from the level of only 1 tractor per thousand hectare of NSA (on an average) per district during 1962-65 to an average level of 33 tractors per thousand hectare of NSA per district in the basin. The significant increase in the use of tractors was registered since the period 1980-83.

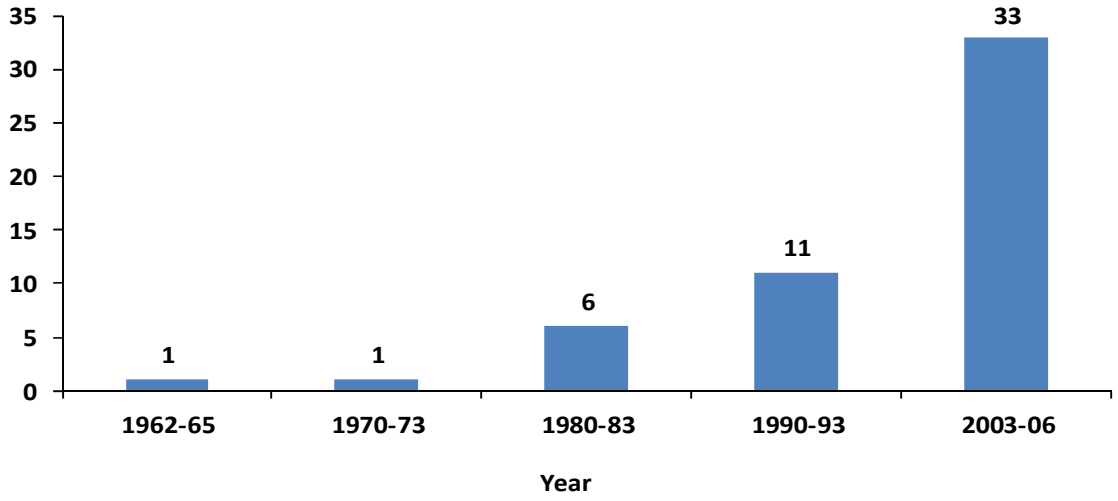

Figure 20: **Average use of tractors (per thousand hectare of net sown area) per district in GRB, 1962-65**

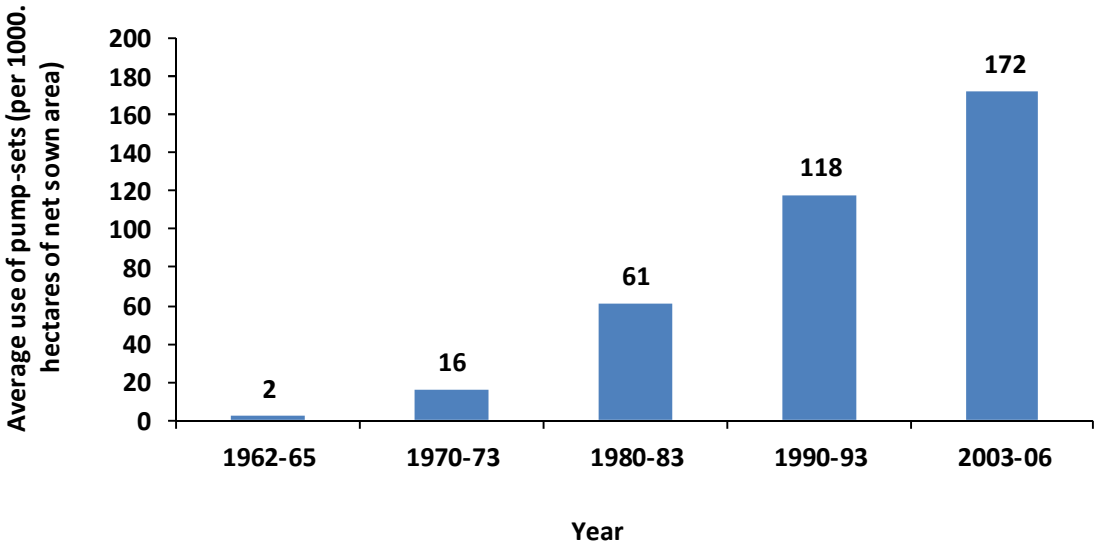

Figure 21: **Average use of pump-sets (per thousand hectares of net sown area) per district in GRB, 1962-65 to 2003-06**

Similarly, since the period 1980-83, the average use of pump-sets per thousand hectare of NSA grew from a level of 61 pump-sets per thousand hectares to an average level of 172 pump-sets per thousand hectare of NSA during 2003-06; a substantial increase of more than 200 percent. The increasing use of pump sets signifies the increasing utilization of the ground water which might sometime exceed the replenishment rate.

6.1.9 Agriculture as a Main Source of Livelihood

The one of the most peculiar characteristics of the Ganga River Basin is the dependence of larger number of its population on agriculture for their livelihood. Figure 22 illustrates clearly that even after increasing use of efficient and power-based agricultural equipments, the use of agricultural workers per 10 hectares of NSA continued to increase substantially since the period 1980-83.

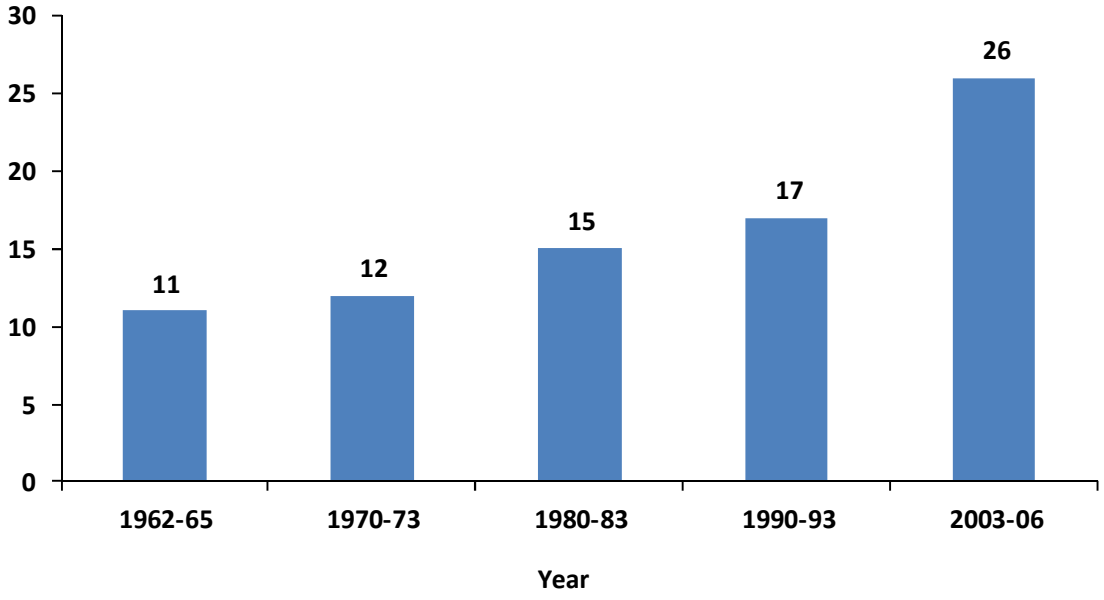

Figure 22: Average Male Agricultural Workers (per 10 hectare of NSA) per district in GRB, 1962-65 to 2003-06

The average male agricultural workers who were employed per 10 hectares of NSA in Ganga River Basin was recorded as 11 during the period 1962-65, grew up to a level of around 26 male agricultural workers per 10 hectares of NSA during the period 2003-06.

7. Summary Remarks

Following summary remarks can be made based on the review of selected agricultural input and output indicators in the Ganga River Basin.

- Crop output, in the basin area, has increased tremendously during last four decades albeit at varying rates across the states.
- The area under agriculture, as illustrated by the declining or the constant rate of growth in the net and gross cropped area, has declined over time as an impact of growing industrialization and urbanization.

- The uses of other inputs like fertilizer and modern agricultural equipments have increased massively over the period.
- Due to improvement in the irrigation facilities, the dependence on the monsoon has declined, which resulted into intensive cultivation (more than one crop a year) as well as crop diversification in the basin area. The green revolution brought a significant change in the agricultural practices in mid sixties, the result of which reflects in the growth pattern during 1980-83 to 1990-93.
- Uttar Pradesh, especially the Western Uttar Pradesh, cashed a major benefit from the green revolution, while the eastern part including Bihar and West Bengal evidenced a relatively slow agricultural growth.
- The decomposition of growth brings to the fore that almost half of growth in output is contributed by modern inputs, namely fertilizer, tractors and tube-wells, about 12-14 per cent by increased use of traditional inputs, namely land and labour, 5-8 per cent by growth of rural infrastructure, and remaining about one-third by the total factor productivity growth in Indian agriculture (Bosworth and Collins, 2008).

References

Bhalla, G. S. and Gurmail Singh (2010). *Growth of Indian Agriculture: A District Level Study*, Final Report on Planning Commission Project, CSRD, JNU, New Delhi.

Bosworth, B. and Collins,S. M. (2008), "Accounting for Growth: Comparing China and India", *Journal of Economic Perspective*, Vol. 22 No 1, pp 45-66.

Ramchandran, V.K., Swaminathan, M. and Rawal, V. (2003), 'Agricultural Growth in West Bengal' Paper presented in the All India Conference on *Agriculture and Rural society in Contemporary India*, Barddhman, Dec. 17-20.