To meet the high demand of food, fiber and fuel to an ever increasing population of the country, it is necessary to bring more land under cultivation or to increase production per unit area from presently available land and water. Due to rising pace of urbanization and a reluctance to disturb environment, it seems to be a difficult task to bring more area under farming. The effect of climate change on agriculture is adversely affecting the Indian agriculture, making food availability scarce. The existing production levels barely manage to keep pace with the growing population. Thus, the only option available with us is to optimize production with efficient management of available natural resources like land and water. Keeping the above facts in mind the present book "Optimal Crop Planning and Resource Use Management" has been written and scope to enhance income of the farming community is being worked out. The book will serve as guide to policy maker, planner as well as researchers in formulating policies to tackle food security and strengthening economic conditions of farming community of the state in particular and nation in general.

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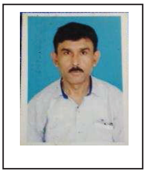

Dedicated

To

Farming Community

Authors

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PREFACE

To meet the high demand of food, fiber and fuel to an ever increasing population of the country, it is necessary to bring more land under cultivation or to increase production per unit area from presently available land and water. Due to rising pace of urbanization and a reluctance to disturb environment, it seems to be a difficult task to bring more area under farming. The effect of climate change on agriculture is adversely affecting the Indian agriculture, making food availability scarce. The existing production levels barely manage to keep pace with the growing population. Thus, the only option available with us is to optimize production with efficient management of available natural resources like land and water. The supply of land and water for irrigation at right time and right quantity for production of various crops is an essential part for agricultural production. Therefore, the need of the hour is a comprehensive strategy to tackle the growing menace of food and nutritional insecurity. In a country of continental dimensions with vast disparities, it is pertinent to note here that developmental efforts be directed in specific directions and in specific areas for optimum utilization of resources. Optimization of agricultural production to meet the nutritional requirement of the rising population and judicious use of resources would be helpful in the present situation.

Agricultural growth is not keeping pace with the growth in other sectors of economy. It is lagging far behind than that of the manufacturing and service sectors. The share of agriculture in GDP has fallen steeply over years but overall dependence on agricultural sector for livelihood remains quite high. About 40% of farm households have a keen desire to quit agriculture but they remain in it because of limited opportunities outside of it. It is disheartening that farmers are not getting due credit for their contribution towards making the state as well as the country self sufficient in food grains production in spite of the fact that farmers' income are very low. State Government is also trying to re-orient agriculture through diversification policy and other measures.

Agriculture is the single largest private sector occupation in Bihar. The goal of the agriculture production system is to maximize income of land owing and landless rural populace to improve their livelihoods.

It is with this background, the Government of India has set a policy target of doubling farmers' income by 2022. The shift from production to income has various implications in evolving strategies, identifying options and exploring innovative institutional mechanisms. It requires a new strategy at state as well as on national level and implementation plans at ground level. Several options may be available for increasing farmers' incomes. Some includes, increase in crop area through intensification, lowering yield gaps and raise yields, reduction in cost of cultivation by improving production efficiency, agricultural diversification towards more remunerative commodities, such as horticulture, livestock and fish, increasing prices of food commodities, value addition, packaging and branding to the agricultural produce, reducing the transaction cost by improving the supply chain, and providing job opportunities outside agriculture sector. The task is not easy to execute any option. It requires complete revamping and re-orientation of agri-food system, and strengthening of infrastructure and institutions in terms of new production systems, and farmers' access to remunerative markets, credit, inputs, information and technologies. There are number of examples within state which demonstrate that farmers with limited land are fetching significantly higher incomes than those with similar landholdings. However, such examples are few. We can also learn lessons from south and Southeast Asian countries where landholdings are small and policy focus is more on farmers' income security than production.

Keeping the above facts in mind the present book **"Optimal Crop Planning and Resource Use Management"** has been written and scope to enhance income of the farming community is being worked out. The book will serve as guide to policy maker, planner as well as researchers in formulating policies to tackle food security and strengthening economic conditions of farming community of the state in particular and nation in general

Authors

BRIEF SUMMARY

The book "Optimum Crop Planning and Resource Use Management" is based on the outcome of the Social Science Network project of ICAR-NIAP ***"Regional Crop Planning for Improving Resource Use Efficiency and Sustainability",*** which was undertaken in the state of Bihar with a view to maximize the income of farming community of the state through optimum utilization of resources available in the state. In the backdrop of the prevalence of climate change (global warming) situation resulting in erratic monsoon and declining groundwater table in the state, in particular, and at the national level in general, the study was considered as of the prime importance towards making efforts for raising the income of the agrarian masses. The objectives of the study are:

1. To study the existing land use, cropping pattern and resources use efficiency in the state.
2. To estimate the cost and returns of important crops grown in the state considering the market prices, economic prices and natural resource valuation technique.
3. To examine current status of natural resource base in different regions of the state
4. To examine the scope for revising the crop plan at zonal level as well as for the state as a whole.
5. To develop optimum crop plan for the state for better resource use efficiency, sustainability and maximizing net farm income across production environments.

The study was based on both time series as well as primary level data. The study was carried out in three agro-climatic zones of the state viz., Agro-climatic zone-I, Agro-climatic zone-II and Agro-climatic zone-III. In order to examine the changes in cropping pattern, the diversification was measured using the formula developed by Chand and Sonia, 2002. To measure the changes in land use pattern, location coefficient (L) was worked out. The primary level data i.e. input-output data for different crops under the study were obtained from Comprehensive Cost of Cultivation Scheme running in the Department of Agricultural Economics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur for the block period ,2008-11.

The cost and net returns analysis for different crops grown in the state of Bihar were evaluated under alternative scenarios viz., market prices (MP), economic prices (EP) and natural resource valuation (NRV). Lastly, the optimization of crop model using linear programming was followed for three agro-climatic zones of the state as well as for the state as a whole, separately. Two constraints such as land as well as groundwater were used for this optimization analysis.

Changes in land use pattern in the state has shown a remarkable change in the area under non-agricultural uses as it has stepped up from 11.38% to as high as 18.20% during the period under study. The total unculturable land has gone up from 37.64% (TE-1973) to 42.81% during the year TE-2013. The area under miscellaneous tree crops and groves as well as current fallow has also jumped up during the same period. The net sown area has constantly declined over the period under study (TE-1973 to TE-2013). The reason for decline in net sown area may be attributed probably due to putting of more agricultural land under non-agricultural uses, more fallow lands as well as rise in area under miscellaneous tree crops and groves. The trend of land use pattern of different activities from sample data also confirmed the trend share of the secondary data for the state as whole.

Changes in irrigation pattern in the state depicted the fact that the percentage of available surface water in the state has, by and large, declined throughout the study period as it was observed as high as 43.91% in TE-1973, which decreased to only 28.82% in TE-2013. A sharp decline in surface water in the state was probably due to poor management of canals (siltation) climate change from green house gas (GHG) emission as well as rapid deforestation.). Subsequently, there is only option with the cultivators to use the more and more groundwater in order to raise the crop productivity and augment the agricultural production. The percentage of groundwater utilization in the state escalated to as large as 67.60% in TE-2013 as compared to only 28.83% in TE-1973.

From examination of cropping pattern of the state, it was observed that there was continuous decline in the gross cropped area from 8519 thousand hectares in TE-1973 to only 7520 thousand hectares in TE-2013. Among cereals, wheat and maize crops have shown rising trend in its area, whereas it was observed declining trend in case of rice and barely throughout the period under study. The area under pulse crops was found decreasing and a sharp decline in its area may be due to reasons of low productivity of the pulses crops, generally grown on marginal/ un-irrigated land, incidence of insects and pests as well as infestation by the animals. The area under oilseed crops, revealed, by and large, declining trend during the study period. But, in case of sugarcane and potato, the picture was encouraging as the percentage area under both crops showed upward trend throughout the study period. A similar pattern was also observed in case of cropping pattern from sample data for the state as whole like that of cropping pattern from time series data.

Analysis of decadal change in yield of major crops in the state has revealed the increase in productivity of cereal crops i.e. nearly more than two times increase during 40 years of time period viz., 9.51 q/ha in TE-1973 to 24.69 q/ha in TE-2013. In case of paddy, wheat, barley and ragi, it was found rising trend in yield, by and large, by more than two folds, whereas it rose by more than 4 folds in case of maize during the study period. It was, further, observed that the yield of most of the pulse crops such as gram, lentil, pea, moong, urad and khesari remained below 11.0 q/ha except for arhar crop which produced 18.60 q/ha during investigation period. So far as oilseeds are concerned, the yield of rapeseed and mustard, linseed and sunflower crops were observed to be up by more than two times during the period, TE-1973 to TE-2013. The yield of potato and sugarcane had also improved during the period under investigation.

The diversification index for the overall period (TE-2013 to TE-1973) was estimated to be 20.46, this emphasized the pace of diversification during the study period. Rise in diversification index supports the dependence of farming community on market dynamics.

In order to examine the dynamics of various categories of land, location coefficients were worked out for different periods of time and it was observed that in the state, large concentration of land was found to be lopsided to miscellaneous tree crops and groves, followed by the land put to non-agricultural uses, current fallow lands and net sown area.

Resource use efficiency for paddy and wheat were found to be very low, being only 0.38 and 0.41, respectively. The mean level of economic efficiency revealed that the farmers could reduce the current cost of produce, on an average; by 62% and 59% to achieve the potential minimum cost of production relative to the efficient farmer's given current output level of paddy and wheat farms, respectively. These efficiencies suggest that there is considerable potential for decreasing input and thus reducing the cost of production in case of paddy and wheat. In other crops like rabi maize, lentil, rapeseed & mustard, potato, brinjal and chilli, there is also scope to raise the resource use efficiency and thus to produce a given output level at minimum cost in the state.

The maximum subsidy was used for rabi maize (5106.28/ha) and next on wheat (Rs. 4673.41/ha), barley (Rs. 4301.69) and paddy (2664.96/ha). In total subsidy, the NPK found a major share as compared to the seed and irrigation. Larger groundwater irrigation subsidy was given on rabi maize, followed by wheat. Seed subsidy was higher in case of wheat. Among pulse crops, a large subsidy was put in the cultivation of khesari, followed by gram and pea. Among oilseeds, rapeseed and mustard accounted for larger subsidy. The use of subsidy was observed comparatively more in case of potato as compared to other vegetable crops under study.

Regarding biological nitrogen fixation, it was observed comparatively high in case of arhar, followed by gram, urad, moong, lentil and pea. On the other hand, green house gas (GHG) emission was evaluated comparatively higher in case of paddy (Rs. 1838/ha), followed by wheat (Rs. 182.50/ha), for both seasons maize (Rs. 158.50/ha) and ragi (Rs. 111.50). In case of pulse crops, it was observed Rs. 235/ha for pea and Rs. 97/ha for rest of the other pulse crops under study. The emission was recorded comparatively higher in sunflower (Rs. 144.50), followed by Rs. 114.50/ ha for each of rapeseed & mustard and linseed.

Cost and returns analysis for cereal crops at market prices revealed that comparatively larger cost was found in case of rabi maize (Rs. 15889.83/ha), followed by barely, wheat and ragi. Net returns over variable costs were estimated to be comparatively high in rabi maize (Rs. 30908.69/ha), followed by barely, wheat and paddy. Among pulses, per hectare net return at market prices was obtained comparatively larger for arhar (Rs. 28108.37/ha), followed by lentil, gram, urad and so on. Rapeseed & mustard among oilseeds and tomato among vegetables recorded comparatively high net returns at market prices. Cost and returns at economic prices recorded comparatively higher net returns for rabi maize among cereals, arhar in case of pulses, rapeseed & mustard among oilseeds and onion among vegetable crops under study. Chilli fetched comparatively higher net income among cash crops. The net returns based on natural resource valuation (NRV) among cereal crops was evaluated comparatively large for rabi maize (Rs. 25643.92/ha), followed by barely, wheat and paddy. This is also fact that GHG emission in paddy and wheat are much larger as compared to other crops. The net returns at NRV was found comparatively high in arhar among pulses, rapeseed & mustard among oilseeds, onion among vegetables and chilli among cash crops under study.

Analysis of optimum crop model for Bihar revealed that from the point of view of optimum area allocation for crops grown in the state with existing ground water use at 10.26 BCM, it was observed that the area under kharif maize, rabi maize, arhar, kulthi, gram, lentil, khesari, moong, urad, pea, rapeseed and mustard, linseed, potato, cabbage, brinjal, cauliflower, okra, tomato, onion, sugarcane and chilli tend to increase at all the three price scenarios as compared to existing area of the above crops. On the other hand, the area under crops such as paddy, wheat, barley, ragi, sunflower and jute showed decline in its area at all the three said prices, may probably be due to maximization of income at existing water condition. The optimum gross cropped area (GCA) was estimated only 7283.48 thousand hectare in all the three prices conditions as compared to existing cropped area being at higher level i.e. 7388.0 thousand hectares. The optimum profit would be earned about 101.10 hundred crores from the optimum model.

When groundwater use is increased to 12.83 BCM in the state, the optimum area allocation for almost all crops included in the model revealed positive direction of change in all the three price scenarios. Further, it was observed that the gross cropped area (GCA) too rose to the level of 8550.50 thousand hectares as compared to the existing GCA, being only 7388.00 thousand hectares. If the cropping pattern is followed in accordance with the optimum crop plan in the state, the profit to the level of 110.90 hundred crores would be obtained out of this model, provided that the groundwater development is enhanced with cheap sources of irrigation facilities.

From the optimum crop model, the expected net gains to the cultivators were estimated 9.57, 9.32 and -0.81 hundred crores at three business scenarios in case of existing groundwater use at 10.26 BCM. When the groundwater use was raised to 12.83 BCM, the expected net gains to the cultivators could be assessed 24.94, 24.94 and 13.60 hundred crores at MP, EP and NRV. Thus the gains are positive in all the three prices scenarios.

Hence, crop models as discussed above may be used for the optimization of income of the farming community provided that the groundwater development is enhanced as well as means of irrigation are made available by the government to the cultivators of the state. Renewal sources of energy may be popularized for use with a view to reduce the expenditure burden on usual diesel irrigation and protecting the society from ill effect of air pollution generated through the use of diesel. Infrastructural development with regard to uninterrupted supply of electricity and solar energy may be expanded for better adoption and acceptability of the optimal models by the farming community in order to enhance their income and thus raise the poor standard of living conditions of mass peasantry of the state.

From the foregoing discussion, the following policy implications may be confronted so as to optimize the income of the farming community

POLICY IMPLICATIONS

- Reduction of fallow land.
- Special emphasis on increasing the area and production of pulses and oilseeds.
- Expansion of surface irrigation to augment groundwater irrigation and reduce cost of irrigation
- Assured supply of low cost energy source (electricity) for agricultural operations.
- Emphasis on diversification of agriculture.
- Enhancing resource use efficiency.
- Accountability of financial institution
- Improved marketing infrastructure
- Consolidation of holding.

Chapter-I

AGRO-CLIMATIC PROFILE OF BIHAR AND RATIONALE OF THE STUDY

The state of Bihar is being talked about as a sleeping giant of Indian Agriculture. The National Commission on Farmers has concluded that Bihar and eastern India present uncommon opportunities for becoming another “Fertile Crescent”, even as the present Fertile Crescent (Punjab, Haryana and western Uttar Pradesh) have reached a state of economic and ecological distress. Water, the life line of agriculture, is abundant in Bihar and the real issue is not availability but management.

Bihar, with its bountiful natural resources of fertile soil, abundant water, varied climate and rich cultural and historical heritage, is one of the most fascinating states of India. The farmers are intelligent and hard working. Therefore, agriculture has been described as the core competence of Bihar.

Agriculture is considered as backbone of the economy of Bihar. The percentage of population, employed in agricultural production system in Bihar, is estimated 77 per cent, which is much higher than the national average. Nearly 22 percent of GDP of the state during 2010-14 (Economic Survey, Government of Bihar, 2014-15) has been from agricultural sector including forestry and fisheries. The state has attained self sufficiency in food grains production, however, barring maize and pulses productivity, various farm produces in Bihar is much below the national average. The area under cultivation is shrinking, even though there is tremendous scope for income generation by improving productivity. Adverse climatic conditions, like drought and floods, do play a role in decreasing production but these adverse conditions can be overcome to some extent by irrigation, flood control and drainage scheme. The agricultural production can further be enhanced to the extent through raising cropping intensity, change in cropping pattern, further, genetic improvement in seeds of high yielding varieties, cultivation practices and with availability of better post harvest technology etc.

Bihar with geographical area of about 94.2 thousand square Kms is divided by river Ganga into two parts, the north Bihar with an area of 53.3 thousand square KMs and the south Bihar having an area of 40.9 thousand square Kms. Based on soil characterization, rainfall, temperature and terrain, the state was classified districts of Bihar into three comprehensive agro-climatic zones.

Table 1: Name of the districts under each Agro-Climatic Zones

Sl.No.	Agro-climatic zone	Districts
1.	**Agro- climatic zone- I (North-West Alluvial Plains)**	West Champaran, East Champaran, Siwan, Saran, Sitamarhi, Sheohar, Muzaffarpur, Vaishali, Madhubani, Darbhanga, Samastipur, Gopalganj, Begusarai
2.	**Agro-climatic Zone- II ((North-East Alluvial Plains)**	Purnea, Katihar, Saharsa, Supaul, Madhepura, Khagaria, Araria, Kishanganj.
3.	**Agro-climatic zone- III (South Alluvial Plains)**	Sheikhpura, Munger, Jamui, Lakhisarai, Bhagalpur & Banka. Rohtas, Bhojpur, Buxar, Bhabhua, Arwal, Patna, Nalanda, Nawada, Jehanabad, Aurangabad, Gaya.

Table 2: Important physiographic features of the Agro-climatic zones

Sl. No.	Agro-climatic zone	Soil	pH	Organic Matter (%)	Available Nitrogen (Kg./ha.)	Available Phosphorus (Kg./ha.)	Available Potash (Kg./ha.)
1.	**Agro- climatic zone-I (North-West Alluvial Plains)**	Sandy loam, loam	6.5–8.4	0.2-1.0	150-350	5-50	100-300
2.	**Agro-climatic Zone-II ((North-East Alluvial Plains)**	Sandy loam, Clay loam	6.5–7.8	0.2-1.0	150-300	10-35	150-250
3.	**Agro-climatic zone-III (South Alluvial Plains)**	Sandy loam, Clay loam, loam, Clay	6.8–8.0	0.5-1.0	200-400	10-100	150-350

Sl. No.	Agro-climatic zone	Total Rainfall (mm)	Temperature (^{0}C)	
			Max.	Min.
1.	Agro- climatic zone I (Northern West)	1040 – 1450 (1245.00)	36.6	7.7
2.	Agro-climatic Zone II (Northern East)	1200 – 1700 (1450.00)	33.8	8.8
3.	Agro-climatic zone III (Southern East & West)	990 – 1240 (1115.00)	37.1	7.8

Zone- I (North-West Alluvial Plains)

The northern plains include Saran, Siwan, Gopalganj, E. Champaran, W. Champaran, Sheohar, Sitamarhi, Madhubani, Darbhanga, Muzaffarpur, Vaishali, Samastipur and Begusarai districts. The sub-zone is at foot of Himalaya and receives 1275mm rainfall. The climate is dry to moist sub-humid and soil type is heavy textured sandy loam to clayey, medium acidic. Over 70 per cent of land in this sub zone is arable and about 42 % of this is irrigated. Intensity of cropping in this zone is 142.43%

Zone- II (North-East Alluvial Plains)

Supaul, Khagaria, Saharsa, Madhepura, Purnea, Katihar, Kisangunj, Araria, Naugachhia districts of Bihar constitute this sub-zone. Being at the end of mid-Gangetic valley, drainage and management of floods and seasonal rushes are problem in the region. A little over 60 per cent of land is cultivated and 44 % of this is irrigated. The region receives

1224 mm of rainfall and the climate is similar to other sub-zones in Bihar plain, dry to moist sub-humid. Cropping intensity in this zone is high (150.10%) relative to the other sub-zone in Bihar; however, the land productivity is low.

Zone- III (South Alluvial Plains)

The south Bihar plains cover Patna, Nalanda, Bhojpur, Rohtas, Bhabhua, Gaya, Jahanabad, Arwal, Nawada, Aurangabad district in zone- III-B and Sheikhpura, Lakhisarai, Jamui, Banka, Munger and Bhagalpur district in zone-III-A. The region is well irrigated over 75% of the cropped area, covered by irrigation, which is mostly through a network of canals. However, the proportion of net sown area is relatively low at 54% and the cropping intensity is also relatively low at 133.88 %, about 13 % of the land is under forest cover.

The gross and net sown area in the State is estimated at 80.26 lakh ha and 56.38 lakh ha, respectively. The intensity of cropping is 142 per cent. The principal crops are paddy, wheat, pulses, maize, potato, sugarcane, oilseeds and jute. Rice, wheat and maize are the major cereal crops. The average yield of rice and wheat are 1.45 and 2.19 t/ha, respectively, as against the production potential (Experimental yield at research farm as well as realized in front line demonstration) of 4.5 and 5.0 t/ha. Similarly, the average maize yield of the state is about 2.38 t/ha as against its yield potential of 5 t/ha. While, winter maize is a success story, the farmers have realized yield level of 6-8 t/ha. Similarly, boro-rice (summer rice) has the realization of 6-8 t/ha. Even though, the state is rich in soil and water resources, the average yield of rice, wheat, maize and sugarcane in the state is only about 32, 44, 40 and 38 % of the potential yield, respectively.

Distribution of Operational Holdings

There are around 1.47 crore landholdings in the State of which around 91.06 percent are marginal (<1 ha). With around 90 percent of the total population living in rural areas, agriculture as the primary feeder of rural economy continues to operate not only on margins of land but also on the margins of human enterprise. Without increasing returns to these margins, not much can be done realistically to develop the agricultural sector. Thus, agriculture continues to define both the potentialities and constraints to development in Bihar.

Table 3: Distribution of holdings by size class

Category of farmers	No. of holdings	Operational holding (In ha.)
Marginal (0-1ha.)	1,47,44,098 (91.06%)	36,68,727.64 (57.43%)
Small (1-2 ha.)	9,48,016 (5.85%)	11,85,695.24 (18.56%)
Semi medium (2-4 ha.)	4,14,664 (2.56%)	10,72,969.00 (16.80%)
Medium (4-10 ha.)	81,484 (0.50%)	4,14,941.12 (6.50%)
Large (10-above ha.)	3129 (0.03%)	45,227.71 (0.71%)
Total	**1,61,91,391 (100%)**	**63,87,560.71 (100%)**

Source : Agricultural Census (2010-11), Ministry of Agriculture, New Delhi

In Bihar, there are only three main cropping seasons viz. kharif (July-October), rabi (Oct-March) and zaid crops (grown between March and July). Due to diverse range of agro-climatic situations and available water resources, a large number of crops are grown in the state. However, cropping pattern of the state being dominated by rice-wheat rotation is unleashing serious degradation to huge natural resource base of the state, scaling up the incidence of nutrients/ micronutrient deficiency in the soil, insect- pest attack on crops as well as erstwhile environmental deteriorations are also further buttressing a major threats to productivity, food grains production and sustainability of agriculture. It is the demand of present scenario that the diversification of cropping pattern of state should be directed towards high valued crops ensuring its suitability across the regional environment and quality output.

The state zone-I is moderately flood affected area, zone-II is the most flood affected as well as zone-III is considered as water scarce area. The conditions in these zones differ to each other, therefore, it seems to be an essential and utmost task to have a suitable crop planning for different regions so as to maximize the net income of the farming community through putting their costly resources under optimum use. In fact, the macro-economic policies such as supply of both free and highly subsidized power, water and fertilizers have affected resource use efficiency in agriculture. It is also felt that the current land use pattern is not based on the principle of comparative advantage/ economic criteria/natural resource valuation coupled with serious conditions of misallocation of resources, efficiency loss and indiscriminate use of natural resources. Thus in the backdrop of the above facts and conditions prevailing in the state, a study was formulated accordingly and thus the project on “Regional crop planning for improving resource use efficiency and sustainability was carried out with the following objectives:

1. To study the existing land use, cropping pattern and resources use efficiency in the state.
2. To estimate the cost and returns of selected crops grown in Bihar based on market prices, economic prices and natural resource valuation techniques.
3. To examine the current status of natural resource base in different regions of the state
4. To examine the scope for revising the crop plan at zonal level as well as state level as a whole.
5. To develop optimum crop plan for the state for better resource use efficiency, sustainability and maximizing net farm income across production environments.

Chapter-II

LAND USE AND CROPPING PATTERN

Land Use Pattern

There are considerable regional variations in the general land use of area because of diversities in landforms and rainfall. It is essential to shift from generalities to particularities in the study region, where agriculture is the only means of livelihood for majority of the people. Such studies are fundamental for future planning. Studies on land use pattern have received a good deal of attention from researchers in the past and continue to draw their attention. Presently the patterns are being minutely investigated at the regional or micro regional rather than at the national level.

Land is gift given by the nature to the mankind hence it is the basic resource of human society. Land use is the surface utilization of all developed and vacant land on a specific point at a given time and space. This leads one back to the village farm and the farmer to the fields, garden pastures, fallow lands and forests and to the isolated farm steam (Freeman T.W. 1968). The study of land use is important not only in agriculturally dominated, over populated developing regions but throughout the world because of its relationship with different human phenomena. Its importance also increased during the population pressure and decreasing man and land ratio, increasing demand for food and raw materials the need for optimum utilization of land in an integrated manner has assumed greater relevance. Therefore, scientific regional, intensive and proper use of every parcel of land has become essential. Lands' planning on micro level, based on land use surveys is the first step in putting our lands to the maximum use. The nature and intensity of land use is closely related to the technology adopted by man. Extension of agricultural land with the help of technology may cause considerable changes in land use. Geography deals with the spatial relationship between these aspects and planning. This is because land use changes to meet available demands of the land by the society in its new ways and conditions of life. The demands for new uses of land may be inspired by a technological change or by a change in the size composition and requirements of a community. Some changes are short linked whereas other presents a more constant (Jackson J.N; 1963)

Some of the past works done by the researchers on land use cropping pattern and resource uses are essential and relevant to cite here to make our investigation more scientific and factual.

Briassoulis (2000) in her study indicated that since time immemorial humans used land to meet their material, social and cultural needs. In this process, they modified land resources in various ways, often with detrimental effects on the environment and human well-being. Land cover may change under the influence of biophysical conditions only but, most frequently; it results from human-induced land use change.

C. Ramasamy *et al.,* (2005) in their study conducted in Tamil Nadu analyzed the factors affecting other fallow land. The other fallow lands in the state have much higher growth rate than the current fallow land. The other fallow lands registered a significant positive growth rate during the last two decades as well as during 40 years period between 1960 and 2000. Further, other fallow lands are that lands which remain fallow for more than one year and hence, growth in other fallow lands pose serious causes in stabilizing the net sown area. He further, investigated that labour scarcity, measured by the wage differential between lean and peak season with the differences in labour availability and labour demand during different seasons may be the causes of increasing other fallow lands in the state

Mohanty (2009) studied the trend of urbanization, socio-economic development and changes in land use highlighted the extent to which land under forest has declined over the time and across states of India. Urbanization which is considered as an indicator of development is likely to be associated with increased land utilization for non-agricultural purposes. The study revealed that there was a phenomenal increase in population and urbanization. The population increase has taken place even in relatively land abundant semi-arid states such as Rajasthan and Gujarat. The level of urbanization in India is also on rise and it has to deal with problems of land intrusions on productive agricultural lands. This is because urban land uses persistently compete with rural land uses on the basis of more favourable land rent free market.

Malik (2012) in his investigation in changing land use pattern in Haryana from 1995-98 to 2002-05 revealed that marginal changes have occurred in all land use categories except proportion of area under forest which has drastically declined from 2.575 percent in 1995-98 to 1.02 percent 2002-05. Proportion of net sown area to total area has slightly declined from 82.12 percent in 1995-98 to 80.16 percent in 2002-05, while area under non-agricultural uses has recorded positive change which increased from 8.69 percent in 1995-98 to 10.14 percent in 2002-05.

Premakumara and Seema (2013) in their studies on land use pattern revealed the comparison of growth rate and ratio of net sown area and horticultural area in India and Karnataka. The area of horticulture has significantly increased when compared with that of the net area sown in India as well as in Karnataka. The net sown area has increased in Karnataka significantly higher than all India average and on the other hand, the horticulture area has been increased in India significantly higher than Karnataka. The ratio of horticultural area to net sown is more in Karnataka as compared to India

Crop Diversification

K. Palanisami *et al.,* (2009) in their study diversification of agriculture in coastal district of Tamil Nadu found that socio-economic systems of coastal areas are more vulnerable to impact of climatic changes. There exits wide spatio-temporal disparity in crop diversification in the coastal districts of Tamil Nadu, India. They suggested that those regions which are more vulnerable to climatic change, attempt should be made for more crop diversification to avoid risk of crop failure and loss of income and employment to the rural people.

Pal and Kar (2012) in their study in Malda district used different methods of measuring crop diversification for a uniform data set of Malda district. They also studied the status and changing pattern of crop diversification in different blocks of Malda district with a comparative outlook of district and state level status. Herfidahl index and Simpson index are widely used for measure of crop diversification but as per output scale of resolution, Gini's coefficient and Entropy measures are to be considered as better. As per the way of calculation, Entropy index, Modified entropy index and ogive index are more effective. District level status is far ahead the state level and blocks level status good. Monotonization in crop diversification is going on which was reflected through forward and backward shifting crop diversification into a single class in between 2001 to 2008. Peasants are still addicted with cereals instead of high value crops.

Rehima, M. *et al.,* (2013) studied the factors affecting farmer's crops diversification in Ethiopia described crop diversification a strategy for management of risks and an important step for transition from subsistence to commercial agriculture. The factors that affected crop diversification were gender, education and trade experience, membership in cooperatives, resource ownership, feature of land owned, access to extension services and transaction costs. They recommended that government should promote female participations, invest in formal and informal education of the farmers, provide incentive for extension workers and improve extension services. Furthermore, the government and stakeholder should strengthen agricultural inputs and agricultural research particularly; generating agro-ecology based technologies and disseminates them. Transaction cost need strengthening rural urban infrastructure to link crop diversification with markets.

Methodological Framework and Analytical Tools

In the beginning of the study of Regional Crop Model (RCP), the changes in land utilization pattern, cropping pattern as well as resource use efficiency of different inputs viz., seed, fertilizers labours etc for different agro-climatic regions as well as for the state as a whole i.e. for Bihar were studied. The secondary data, related to land use statistics and cropping pattern since 1970-71 to till date for the different district as well for Bihar state were obtained from Directorate of Statistics and Evaluation, Govt. of Bihar. The different published books from Directorate of Statistic and Evaluation, Govt. of Bihar were also consulted for collection of concerning data.

Changes in Cropping Pattern

In order to study the changes in cropping pattern in the state, the extent of **diversification** at a given point of time was used. The diversification was measured in terms of change in the level of land allocated to different production activities as a proportion of total land used for the purpose, using the following formula (Chand and Sonia, 2002).

$$\mathrm{DIV_{mk}} = [0.5\sum \mathrm{ABS}(\mathrm{A_{im}} - \mathrm{A_{ik}})/\mathrm{TCA}]$$

Where,

DIV_{mk}= diversification in cropping pattern between year m & k.

A_{im}= area under i^{th} crop in m^{th}year.

A_{ik}= area under i^{th} crop in k^{th} year.

TCA= total cropped area.

ABS ( ) is a function in excel, which always returns the positive value.

The measure of diversification as above gives the extent of total cropped area where diversification took place. It is the sum of absolute deviation in area under crop ‘ i’ between the two periods. As the shift in the area in proposed formula gets counted twice, from i to j and j to i; the sum is multiplied by 0.5.

Changes in Land Use Pattern

In order to measure the changing land use pattern, Location Coefficient (L) method was used.

Location coefficient (L) was used to identify the pattern of distribution of a given category of lands across different regions of the state as well as for the state as a whole

$$L = \frac{L_{ij}/L_i}{L_j/L_s}$$

Where,

L_{ij}= area of j[th] category of land in i[th] state /region.

L_i= area of all categories of land in the state /region.

L_j= area of j[th] category of land in the country.

L_s= area of all categories of land in the country.

A higher value of location coefficient for a state or region indicates the higher concentration of that particular category of land in that state or region.

Changes in land use

An analysis of changes in land use pattern in Bihar presented in Table 1 revealed that the steady changes in forest area have occurred over the periods under analysis. The area under forest cover has increased right from 596.77 thousand ha (6.38% of geographical area) in TE-1973 to as much as 621.64 thousand ha.(6.64% of geographical area) in TE-2013 in the state. The table has also reported a remarkable change in area under non-agricultural uses i.*e.* for the purpose of the human settlement, recreation grounds, establishment of factories as well as construction of roads and transports etc. As it is evidenced from the fact that the area put to non- agricultural uses has stepped up from 11.38% (of geographical area) to as high as 18.20% (of geographical area). A decline in area with regard to barren and uncultivable land has been reported and in percentage term, it declined from 5.08% in TE-1973 to 4.61% in TE-2013.

But, on the other, there has been a sharp rise in the category of area put to not available for cultivation (unculturable land), that is from only 3522.87 thousand ha (TE-1973) to as much as 4007.08 thousand ha (TE-2013). Total unculturable land includes different categories of land such as forests, barren and unculturable land, permanent pastures, miscellaneous tree crops and groves, cultivable waste lands and fallow lands. The share of total unculturable land was 37.64% of geographical area in the year TE1973, which went up to 42.81% over the year TE-2013. The area under miscellaneous tree crops and groves has also increased from 196.55 thousand ha in TE-1973 to 245.10 thousand ha in TE-2013 i.e. during 43 years period of the study, the rise in area under tree crops and groves may probably be due to changes in weather conditions resulting in decline of water table, costly diesel irrigation for crops etc., thus engulfing the margin of crop profits. The current fallow land has jumped up many folds since TE-2003 (5.83%) to TE-2013 (8.79%). The reason for this may be the same as stated above. .The analysis has further indicated that net sown area has constantly declined over the periods under study (TE-1973 to TE-2013) as it was evidenced from the fact that it registered 5836.83 thousand ha in the year TE-1973, which downsized to 5352.49 thousand ha.

The reasons for decline in net sown area may probably be attributed to putting of more agricultural land under non-agricultural uses, more fallow lands as well as rise in area under miscellaneous trees crops & groves. The reasons for increase in non-agricultural uses, current fallow and miscellaneous tree crops & groves have already been explained above.

Land use pattern of Agro-climatic zone-I

Land use pattern in agro-climatic zone-I has been analyzed and presented in Table 1A. Perusal of the table revealed that the land put to non-agricultural uses, has gone up from only 436.67 thousand ha in TE-1973 to as much as 703.28 thousand ha during 43 years time period. This category of land is rising at a pace of 0.13 percent compound growth rate during 2003-2013. Land under miscellaneous tree crops & groves showed upward trend at 0.16 percent growth rate during the period 2003 to 2013. Further, it was also observed that the current fallow lands set the rising trend at 0.98 per cent annual growth rate during the period 2003-2013. The enhanced trend in above categories of land may be attributed to erratic monsoon causing decline in water table, costly diesel irrigation system, scarcity of labour due to migration of labour to other cities/towns for better employment opportunity and also transfer of labour to MNREGA. The higher pace of rise in non-agricultural uses of land may be assigned to the settlement of ever-rising population as well as set up of different factories, construction of roads, buildings, recreation grounds etc. On the other hand, it was observed that the net sown area has registered declining trend as it was found 69.07% in TE-1973 which fell down to only 67.93% of geographical area.

It infers that it is very challenging task for policy makers to increase the income per unit reduced net sown area. On the other hand, rising trend of current fallow lands also put questions before the planners to look for the solutions so as to discourage/denounce the rising tendency of current fallows.

Land use pattern of Agro-climatic zone-II

Land use pattern in agro-climatic zone-II of the state was analyzed and presented in Table 1B and revealed that the area under non-agricultural uses, land under miscellaneous tree crops and groves and fallow lands other than current fallows and current fallow lands have been estimated to go up at annual compound growth rates of 0.18%, 0.11% 0.28% and 1.19%, respectively during the period 2003-13. The other categories of land indicated the declining trend. During the same period of study, it was also observed that there has been reduction in the net sown area at the rate of -0.03% compound growth rate. It is important to mention here that net sown area showed increasing trend since TE-1973 i.e 1008.10 thousand ha to 1167.66 thousand ha in TE-2003 and thereafter, since TE-2003, it fell down to 1134.53 thousand ha in TE-2013.

Since zone-II is the most flood prone area and due to recurring floods, the farmers put their land as fallows and on the other hand, due to climate change and erratic rainfall, costly diesel irrigation system, scarcity of labour, the cultivators prefer to keep some part of their land as fallow. Hence in this zone, both current fallow as well as other than current fallow lands had shown rising trend.

Table 1: Land use pattern in Bihar

(000'ha)

Sl.No.	Particulars	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR (2003-13)
1.	Geographical area	9359.70 (100.00)	9359.70 (100.00)	9359.70 (100.00)	9359.70 (100.00)	9359.70 (100.00)	9359.70 (100.00)	-
2.	Forests	596.77 (6.38)	610.27 (6.52)	616.45 (6.59)	619.91 (6.62)	621.64 (6.64)	621.64 (6.64)	0.00
3	Barren and unculturable land	475.63 (5.08)	443.17 (4.73)	437.87 (4.68)	436.46 (4.66)	431.71 (4.61)	431.71 (4.61)	-0.06
4	Land put to non agricultural uses	1065.30 (11.38)	1222.47 (13.06)	1452.20 (15.52)	1641.05 (17.53)	1694.66 (18.11)	1703.50 (18.20)	0.20
	(a). Land area	852.24 (9.11)	981.01 (10.48)	1165.37 (12.45)	1278.98 (13.66)	1337.51 (14.29)	1346.77 (14.39)	0.27
	(b). Permanent water area	139.55 (1.49)	157.40 (1.68)	186.98 (2.00)	207.39 (2.22)	207.39 (2.22)	207.39 (2.22)	0.00
	(c). Temporary water area	73.51 (0.79)	84.05 (0.90)	99.85 (1.07)	154.68 (1.65)	149.76 (1.60)	149.02 (1.59)	-0.18
5	Culturable waste land	105.73 1.13	88.67 (0.95)	66.87 (0.71)	46.22 (0.49)	45.29 (0.48)	45.15 (0.48)	0.09
6	Permanent pasture	44.93 (0.48)	34.80 (0.37)	25.88 (0.28)	17.77 (0.19)	15.74 (0.17)	15.67 (0.17)	-0.66
7	Land under misc. trees & groves	196.55 (2.10)	205.92 (2.20)	211.90 (2.26)	234.21 2.50	244.19 (2.61)	245.10 (2.62)	0.16
8	Fallow land other than current fallow	214.40 (2.29)	199.60 (2.13)	188.10 (2.01)	134.21 (1.43)	121.90 (1.30)	121.59 (1.30)	-0.43
9	Current fallow	823.55 (8.80)	836.87 (8.94)	736.99 (7.87)	545.86 5.83	888.91 (9.50)	822.72 (8.79)	2.21
10	Total unculturable land(2 to 9)	3522.87 (37.64)	3641.75 (38.91)	3736.26 (39.92)	3675.70 (39.27)	4092.74 (43.73)	4007.08 (42.81)	0.41
11	Net area sown	5836.83 (62.36)	5718.08 (61.09)	5607.93 (59.92)	5683.87 (60.73)	5266.83 (56.27)	5352.49 (57.19)	-0.29

Figures in parentheses indicate percentage value, ***Source: Statistical abstract of Bihar, different issues.***

Table 1A: Land use pattern of **Agro-Climatic Zone-I** in Bihar

Sl. No.	Particulars	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR (2003-13)
1.	Geographical area	3261.50 (100.00)	3261.50 (100.00)	3261.50 (100.00)	3261.50 (100.00)	3261.50 (100.00)	3261.50 (100.00)	-
2	Forests	84.53 (2.59)	92.00 (2.82)	91.86 (2.82)	91.86 (2.82)	91.86 (2.82)	91.86 (2.82)	0.00
3.	Barren and unculturable land	96.23 (2.95)	85.50 (2.62)	99.76 (3.06)	101.37 (3.11)	100.00 (3.07)	100.00 (3.07)	-0.08
4.	Land put to non agricultural uses	436.67 (13.39)	489.53 (15.01)	596.81 (18.30)	685.05 (21.00)	699.27 (21.44)	703.28 (21.56)	0.13
	(a). Land area	355.45 (10.90)	411.21 (12.61)	485.51 (14.89)	526.64 (16.15)	542.76 (16.64)	547.33 (16.78)	0.20
	(b). Permanent water area	58.95 (1.81)	64.13 (1.97)	80.41 (2.47)	88.85 (2.72)	88.85 (2.72)	88.85 (2.72)	0.00
	(c). Temporary water area	21.83 (0.67)	24.96 (0.77)	30.89 (0.95)	69.57 (2.13)	67.66 (2.07)	66.95 (2.05)	-0.22
5.	Culturable waste land	12.13 (0.37)	12.47 (0.38)	10.79 (0.33)	5.47 (0.17)	5.16 (0.16)	5.11 (0.16)	-0.30
6	Permanent pasture	13.30 (0.41)	7.83 (0.24)	9.48 (0.29)	5.84 (0.18)	5.40 (0.17)	5.35 (0.16)	-0.41
7.	Land under misc. trees & groves	127.85 (3.92)	130.46 (4.00)	140.24 (4.30)	144.64 (4.43)	149.61 (4.59)	150.48 (4.61)	0.16
8.	Fallow land other than current fallow	46.17 (1.42)	41.17 (1.26)	38.68 (1.19)	25.37 (0.78)	23.44 (0.72)	23.14 (0.71)	-0.42
9.	Current fallow	191.82 (5.88)	123.07 (3.77)	195.43 (5.99)	112.87 (3.46)	136.74 (4.19)	154.43 (4.73)	0.98
10.	Total unculturable land(2 to 9)	1008.70 (30.93)	982.03 (30.11)	1183.06 (36.27)	1172.47 (35.95)	1211.48 (37.14)	1233.66 (37.82)	0.19
11.	Net area sown	2252.73 (69.07)	2279.47 (69.89)	2252.64 (69.07)	2276.63 (69.80)	2237.62 (68.61)	2215.44 (67.93)	-0.10

Figures in parentheses indicate percentage values. ***Source: Directorate of Economics and Evaluation, Govt. of Bihar, Patna***

Table 1B: Land use pattern of **Agro-Climatic Zone-II** in Bihar

Sl. No.	Particulars	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR (2003-13)
1.	Geographical area	1648.90 (100.00)	1648.90 (100.00)	1648.90 (100.00)	1648.90 (100.00)	1648.90 (100.00)	1648.90 (100.00))	-
2.	Forests	1.63 (0.10)	3.50 (0.21)	3.08 (0.19)	3.09 (0.19)	3.09 (0.19)	3.09 (0.19)	0.00
3.	Barren and unculturable land	99.90 (6.06)	89.27 (5.41)	103.43 (6.27)	100.13 (6.07)	99.16 (6.01)	99.16 (6.01)	-0.06
4.	Land put to non agricultural uses	179.73 (10.90)	220.40 (13.37)	300.70 (18.24)	323.64 (19.63)	331.99 (21.13)	335.28 (20.33)	0.18
	(a). Land area	125.81 (7.63)	160.89 (9.76)	220.87 (13.40)	241.30 (14.63)	249.81 (15.15)	252.97 (15.34)	0.24
	(b). Permanent water area	37.74 (2.29)	39.67 (2.41)	54.21 (3.29)	58.81 (3.57)	58.81 (3.57)	58.81 (3.57)	0.00
	(c). Temporary water area	16.18 (0.98)	19.84 (1.20)	25.62 (1.55)	23.53 (1.43)	23.36 (1.42)	23.48 (1.42)	0.01
5.	Culturable waste land	26.07 (1.58)	16.40 (0.99)	10.44 (0.63)	6.56 (0.40)	6.06 (0.37)	6.01 (0.36)	-0.42
6	Permanent pasture	9.03 (0.55)	7.77 (0.47)	4.53 (0.27)	2.90 (0.18)	2.47 (0.15)	2.45 (0.15)	-0.86
7.	Land under misc. trees & groves	45.01 (2.73)	46.33 (2.81)	51.34 (3.11)	59.84 (3.63)	61.58 (3.73)	61.79 (3.75)	0.11
8.	Fallow land other than current fallow	60.47 (3.67)	52.30 (3.17)	52.82 (3.20)	33.90 (2.06)	33.26 (2.02)	33.41 (2.03)	0.28
9.	Current fallow	218.89 (13.28)	165.83 (10.06)	155.44 (9.43)	100.39 (6.09)	134.47 (8.15)	122.40 (7.42)	1.19
10.	Total unculturable land(2 to 9)	640.73 (38.86)	601.80 (36.50)	681.79 (41.35)	630.46 (38.24)	710.23 (43.07)	663.59 (40.24)	0.07
11.	Net area sown	1008.10 (61.14)	1047.10 (63.50)	1116.35 (67.70)	1167.66 (70.81)	1087.88 (65.98)	1134.53 (68.81)	-0.03

Figures in parentheses indicate percentage values. ***Source: Directorate of Economics and Evaluation, Govt. of Bihar, Patna***

Land use pattern of Agro-climatic zone-III

Land use pattern in zone-III of the state are presented in Table 1C. Perusal of the table revealed that a similar pattern of change in different categories of land have been observed like that of zone-I and zone-II. The only difference is that the growth of non-agricultural uses of land in this zone was estimated to be larger i.e. 0.27 percent per annum. The fast pace of growth of this category of land may probably be due to the fact that this zone is capital of the state, and thus, the expansion of industries networks, educational institutions and residential buildings etc are taking place on a large scale.

Zone –III is actually water scarce zone, very low water table, comparatively costly water draft due to diesel operated devices and scarcity of labour, these compel the cultivators to put their land as fallow, since the current fallow land was found to rise at 2.84% growth rate during the period under study. Further, it was noticed that the net sown area too went on declining at -0.62% growth rate during the study period (2003-13).

Land use pattern (Sample data)

Analysis of land use pattern from sample data in the state of Bihar has been presented in Table 2 and it was revealed that annual or seasonal crops accounted for 97.04% of reporting area, followed by current fallow land (1.62%), tree crops (1.10%), non-agricultural uses was (0.15%) and so on. It is observed that the trend of share of different activities in sample data confirms the trend share of secondary data for the state as a whole.

Land use pattern in zone-I from sample data (presented in Table 2A) consisted of 95.96% of annual or seasonal crops, followed by tree crops (2.77%), current fallows (1.0%), culturable waste land (0.16%). Land pattern in zone II has been given in Table 2B and it was observed from the table that seasonal/annual crops shared about 86.10 percent of reporting area, followed by current fallow as much as 7.76%, non-agricultural uses (6.14%), comparatively larger share of current fallows in zone-II may probably be on account of this zone being acute flood affected area. Similarly the land use pattern in Agro-climatic Zone-III has been shown in Table 2C. Perusal of the table indicated the share of annual/seasonal crops to the level of 97.41 percent, followed by current fallows (2.59%).

Table 1C: Land use pattern of **Agro-Climatic Zone-III** in Bihar

Sl. No.	Particulars	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR (2003-13)
1.	Geographical area	4449.43 (100.00)	4449.43 (100.00)	4449.43 (100.00)	4449.43 (100.00)	4449.43 (100.00)	4449.43 (100.00)	0.00
2.	Forests	510.60 (11.48)	514.77 (11.57)	521.50 (11.72)	524.95 (11.80)	526.68 (11.84)	526.68 (11.84)	0.00
3.	Barren and unculturable land	279.50 (6.28)	268.40 (6.03)	234.67 (5.27)	234.96 (5.28)	232.57 (5.23)	232.55 (5.23)	-0.06
4	Land put to non agricultural use	448.90 (10.09)	512.53 (11.52)	554.69 (12.47)	632.36 (14.21)	655.34 (14.73)	664.94 (14.94)	0.27
	(a). Land area	360.69 (8.11)	419.07 (9.42)	458.99 (10.32)	511.04 (11.49)	536.75 (12.06)	546.47 (12.28)	0.35
	(b). Permanent water area	51.20 (1.15)	53.18 (1.20)	52.36 (1.18)	59.73 (1.34)	59.73 (1.34)	59.73 (1.34)	0.00
	(c). Temporary water area	37.01 (0.83)	40.28 (0.91)	43.34 (0.97)	61.58 (1.38)	58.86 (1.32)	58.59 (1.32)	-0.22
5.	Culturable waste land	67.53 (1.52)	59.80 (1.34)	45.63 (1.03)	34.19 (0.77)	34.12 (0.77)	34.03 (0.76)	0.00
6.	Permanent pasture	22.60 (0.51)	19.20 (0.43)	11.87 (0.27)	9.04 (0.20)	7.91 (0.18)	7.87 (0.18)	-0.76
7.	Land under misc. trees & groves	20.02 (0.45)	21.36 (0.48)	20.32 (0.46)	29.73 (0.67)	32.56 (0.73)	32.84 (0.74)	0.23
8.	Fallow land other than current fallow	107.77 (2.42)	106.13 (2.39)	96.60 (2.17)	74.94 (1.68)	65.33 (1.47)	65.04 (1.46)	-0.77
9.	Current fallow	398.74 (8.96)	543.44 (12.21)	386.12 (8.68)	332.60 (7.48)	539.79 (12.13)	545.88 (12.27)	2.84
10.	Total unculturable land(2 to 9)	1855.67 (41.71)	2045.63 (45.98)	1871.41 (42.06)	1872.77 (42.09)	2094.30 (47.07)	2109.83 (47.42)	0.66
11.	Net area sown	2593.77 (58.29)	2403.80 (54.02)	2238.94 (50.32)	2239.59 (50.33)	2018.05 (45.36)	2002.52 (45.01)	-0.62

Figures in parentheses indicate percentage values. ***Source: Directorate of Economics and Evaluation, Govt. of Bihar, Patna***

Table 2: Land use pattern in Bihar from sample data TE-2011

Particulars	TE-2010-11 (ha)	% Share
Reporting area	1186.03	100
Annual/seasonal crops	1150.94	97.04
Current fallow land	19.23	1.62
Trees crops	13.01	1.10
Miscellaneous permanent crops	0.27	0.02
Culturable waste land	0.75	0.06
Non-agricultural uses	1.82	0.15

Table 2A: Land use pattern of **Agro-Climatic Zone-I** in Bihar from sample data TE-2011

Particulars	TE-2010-11 (ha)	% Share
Reporting area	470.39	100.00
Annual/seasonal crops	451.39	95.96
Current fallows	4.70	1.00
Tree crops	13.01	2.77
Miscellaneous permanent crops	0.27	0.06
Culturable waste land	0.75	0.16
Non-agricultural uses	0.27	0.06

Table 2B: Land use pattern of **Agro-Climatic Zone-II** in Bihar from sample data TE-2011

Particulars	TE-2010-11 (ha)	% Share
Reporting area	195.83	100.00
Annual/seasonal crops	168.60	86.10
Current fallows	15.19	7.76
Non-agricultural uses	12.03	6.14

Table 2C: Land use pattern of **Agro-Climatic Zone-III** in Bihar from sample data TE-2011

Particulars	TE-2010-11 (ha)	% Share
Reporting area	557.97	100
Annual/seasonal crops	543.5	97.41
Current fallows	14.47	2.59

Irrigation Pattern in Bihar

Irrigation is considered as the vital input for crop production. Productivities of different crops largely depend on irrigation water. Irrigation water may be categorised as surface water and ground water.

Changes in irrigation pattern in the state has been presented in Table 3 which depicted that the net irrigated area was observed around 2145.00 thousand hectares in TE-1973, which raised to the tune of 3450.92 thousand ha in TE-2003 but its rising trend turned down to the level of 3045.00 thousand hectares in TE-2013. The scale down in the net irrigated area since TE-2013 may be due to declining trend of net sown area as well as declining water table during the study period. A similar trend like that of net irrigated area was repeated in case of percentage irrigation coverage as its coverage was estimated as 56.90% in the TE-2013.

Table 3: Irrigation Pattern in Bihar

Particulars	**TE-1973**	**TE-1983**	**TE-1993**	**TE-2003**	**TE-2011**	**TE-2013**
Net irrigated area (000 ha)	2145.00	2442.85	3130.88	3450.92	3210.00	3045.00
Irrigation coverage (%)*	36.75	42.72	55.83	60.71	60.95	56.90
Surface water (%)	43.91	43.52	33.46	31.24	29.21	28.82
Groundwater (%)	28.83	36.14	50.65	64.18	67.60	67.51
Other sources	27.25	20.33	15.89	4.58	3.19	3.58

Data source: Statistical Abstract, Various issues
***Irrigation Coverage (%)=(NIA/NSA)*100**

The percentage of available surface water in the state revealed, by and large, declining trend throughout the study period as it was observed as high as 43.91% in TE1973, which decreased to only 28.82% in TE2013. A sharp decline in surface water in the state may probably be due to climate change resulted from green house gas (GHG) emission, deforestation/felling of more and more trees as well as poor management of canals (siltation). Alternatively, there was only option left to harvest/use the more and more groundwater in order to raise the crop productivity and augment the food grains production. As a result, the percentage of ground water utilization in the state escalated to as large as 67.60% in TE-2013 as compared to only 28.83% in TE-1973.

Zone-wise irrigation pattern

Irrigation pattern of Agro-climatic zone-I in the state is presented in Table 3A. In zone-I, the net irrigated area has toned up as high as 1205.86 thousand ha in TE-2013 from only 447.77 thousand ha in TE-1973. Similarly, the irrigation coverage has also been found uprise to the level of 54.43% in the year TE-2013 as compared to only 19.88% in TE-1973. Further, it was also observed that surface irrigation water has diminished to 23.32% in TE-2013 with respect to 32.61% in TE-1973. However, the percentage of surface water has improved during the fag end of the study period (the present decade of present century), probably on account of repairing and better management of canal irrigation system. Just reverse to the trend of surface irrigation, the groundwater irrigation has gone up to 76.19% in TE-2003 from only 56.55% in TE-1973 but suddenly it dipped to as low as 74.49% in TE-2013. The other source of irrigation covers *ahar, payens*, *rainwater collected in ditches/pits* etc.

Table 3A: Irrigation pattern of **Agro-Climatic Zone-I** in Bihar

Particulars	**TE-1973**	**TE-1983**	**TE-1993**	**TE-2003**	**TE-2011**	**TE-2013**
Net irrigated area (000 ha)	447.77	703.72	999.43	1128.82	1202.31	1205.86
Irrigation coverage (%)	19.88	30.87	44.38	49.58	53.73	54.43
Surface water (%)	32.61	42.63	24.67	20.49	20.30	23.32
Groundwater (%)	56.55	48.98	66.96	76.16	77.69	74.49
Other sources	10.84	8.39	8.37	3.35	2.01	2.19

Analysis of irrigation pattern in Agro-climatic zone-II of the state is given in Table 3B and it pointed out that the irrigation coverage has enhanced from 12.170% in TE-1973 to the level of 57.80% in TE-2011 and it turned down to the level of 45.23% in TE-2013. On the other hand, there has been tremendous decline in surface irrigation water, since it reduced from as high as 68.34 in TE-1973 to mere 14.70% in TE-2011 and again, it rose to 20.35% probably due to revival of the canal irrigation system in the zone. Contrary to the trend of surface water, the share of groundwater in the zone upheld to as much as 83.24% in TE-2011 from only 23.87% in TE-1973 and thereafter, it went down to 78.39% in TE-2013 due to rise in the percentage of surface water during the last period of investigation.

Table 3B: Irrigation pattern of **Agro-Climatic Zone-II** in Bihar

Particulars	**TE-1973**	**TE-1983**	**TE-1993**	**TE-2003**	**TE-2011**	**TE-2013**
Net irrigated area (000 ha)	128.05	213.19	432.85	591.02	626.58	513.20
Irrigation coverage (%)	12.71	20.36	38.77	52.18	57.60	45.23
Surface water (%)	68.34	51.56	26.47	15.09	14.70	20.35
Groundwater (%)	23.87	36.93	61.38	81.74	83.24	78.39
Other sources	7.79	11.52	12.15	3.17	2.06	1.26

Investigation of irrigation pattern in Agro-climatic zone-III of the state has been laid down in Table 3C. Zone-III is regarded as the water scarce (drought prone) area as it was observed that the coverage of irrigation scaled up to the level of 77.29% in TE-2003 from only 60.48% in TE-1973, however, it declined substantially to the level of 66.22% in TE-2013. A substantial decline in irrigation coverage during the last period of the study may be attributed to the fact that of erratic monsoon, declining water table and declining net sown area in the zone. Further, it was found that the trend of surface water in the zone remained, by and large, constant, the share of ground water increased by more than two fold during the study period as the figure reveals the rise in groundwater from 21.32% in TE-1973 to 51.90% in TE-2013. There has been a rapid decrease in other source of irrigation during the study period. In this zone, the share of surface and ground water was observed as 50:50 basis.

Table 3C: Irrigation pattern of ***Agro-Climatic Zone-III*** in Bihar

Particulars	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013
Net irrigated area (000 ha)	1568.66	1525.94	1698.60	1731.08	1381.09	1325.97
Irrigation coverage (%)	60.48	63.48	75.87	77.29	68.44	66.22
Surface water (%)	45.15	42.81	40.42	43.77	39.83	42.79
Groundwater (%)	21.32	30.11	38.31	50.37	55.45	51.90
Other sources	33.53	27.08	21.27	5.86	4.72	5.31

Irrigation pattern (Sample data)

Irrigation pattern for the state as whole for sample data (TE-2010-11) is presented in Table 4. The irrigation coverage for the state as a whole was observed to be 62.68%. Sample data study showed that out of total irrigated area the share of groundwater irrigated area was found 90.29% and the surface irrigation area, accounted for only 9.71%. Thus, it is inferred that the groundwater is considered as the major source of irrigation for growing of crops in the state.

Table 4: Irrigation pattern in Bihar from sample data

Particulars	TE-2010-11
Net irrigated area (ha)	1081.56
Irrigation coverage (%)	62.68
Surface irrigated area (%)	9.71
Groundwater irrigated area (%)	90.29

Zone-wise analysis of sample data for irrigation pattern has been presented in Table 4A, 4B and 4C. Perusal of the tables pinpointed the fact that irrigation coverage was observed comparatively large i.e. 70.17 per cent in Zone-I, followed by 60.41% in zone-II and 58.82% in zone-III.

Table 4A: Irrigation pattern of **Agro-Climatic Zone-I** in Bihar from Sample data

Particulars	TE-2010-11
Net irrigated area (ha)	467.41
Irrigation coverage (%)	70.17
Surface irrigated area (%)	23.21
Groundwater irrigated area (%)	76.79

Table 4B: Irrigation pattern of **Agro-Climatic Zone-II** in Bihar from sample data

Particulars	TE-2010-11
Net irrigated area (ha)	160.26
Irrigation coverage (%)	60.41
Surface irrigated area (%)	-
Groundwater irrigated area (%)	100.00

Table 4C: Irrigation Pattern of **Agro-Climatic Zone-III** in Bihar from Sample data

Particulars	TE-2010-11
Net Irrigated area (ha)	467.11
Irrigation Coverage (%)	58.82
Surface irrigated area (%)	22.44
Groundwater Irrigated area (%)	77.56

Further, it was revealed that cent percent (100%) irrigated area in zone-II was covered under groundwater irrigation, followed by 77.56% groundwater irrigation in zone-III and 76.79% in zone-I.

Thus, it is opined that the cost of irrigation becomes comparatively higher on account of diesel pump irrigation. The canal system as the cheap source of irrigation is on declining trend in the state.

Cropping pattern in Bihar

Cropping pattern may be defined as the proportion of area under different crops in a given period of time. The gross cropped area for the state as a whole has revealed declining trend as it was 8519 thousand hectares in TE-1973 which receded to 7949 thousand hectares in TE-2003 and further declined to 7520 thousand hectares in TE-2013.

Analysis of the Table 5 indicated that among cereal crops, the area under wheat jumped up from 15.42% in TE-1973 to 28.59% in TE-2013 of the respective gross cropped area. Similar trend was observed in case of maize, its area has gone up from 8.20% in TE-1973 to as much as 9.06 in TE-2013. However, the area under total cereals declined from 6336 thousand ha (TE-1973) to 6027 thousand ha (TE-2013), the decline may probably be due to decrease in area under rice and barely.

It was further examined that the area under total pulses was found to be 14.48% of gross cropped area in TE-1973 and further it decreased to as much as 7.01% of gross cropped area in TE-2013. A sharp decline in its area may probably be on account of low productivity of pulses crops, growing in marginal lands/ un-irrigated lands, incidence of insects & pests as well as infestation by animals (Nilgai and wild pigs etc.). The area under total food grains was estimated at 7569 thousand ha in TE-1973 which went down to 6554 thousand ha in TE-2013, however, in percentage term, it maintained, by and large constant throughout the study period i.e. 88.84% in TE-1973 to 87.16% in TE-2013 of grossed cropped area.

While discussing the area under oilseeds, it was observed that its area has increased from 148 thousand ha in TE-1973 to the level of 172 thousand ha in TE-1993 and afterward, its area scaled down to the tune of 136 thousand ha in TE-2013. On the other hand, the area of jute in the cropping pattern has picked up from 136 thousand ha in TE-1973 to 142 thousand ha in TE-2003 and further stuck down to 127 thousand ha in TE-2013. But, in case of sugarcane and potato, the picture was encouraging as the percentage area under both crops showed rising trend throughout the study period. The area under sugarcane and potato has stepped up from 1.90% and 0.98% in TE-1973 to further 3.19% and 2.07%, respectively of gross cropped area in TE-2013.

Cropping pattern of Agro-climatic zone-I

Cropping pattern in zone-I of the state has been depicted in Table 5A. Perusal of the table has laid emphasis that the gross cropped area (GCA) has explicitly shrinked to 3155 thousand ha in TE-2013 from the level of 3311 thousand ha in TE-1973. In other words, the compound growth rate of GCA has indicated a marginal rise in GCA during the period 2003-13. Indepth analysis of the table revealed that among cereal crops, paddy and barely stuck negative growth values i.e. -0.21 & -2.52 percent, respectively in its area during the investigation periods (2003-13), indicating thereby decline in area of both crops. So far as the case of wheat and maize is concerned, the compound growth rate of area of both crops could be estimated 0.20 & 0.29%, respectively during the period 2003-13, thus indicating the rising trend in area of both crops under study. The other crops viz., sugarcane, potato & oilseeds could also reveal positive compound growth rates of area at 3.66%, 0.47% and 0.12% per annum, respectively. The rest other crops included in the table registered negative growth rates per annum during 2003-13.

Cropping pattern in Zone-II

Cropping pattern in agro-climatic zone-II of the state has been analyzed and presented in Table 5B. Zone-II is popular for rabi maize production as this preposition was approved by positive and larger compound growth of area of maize crop as evidenced by 1.37% growth rate per annum during 2003-13. The growth in area of wheat (-0.74%) pinpointed the fact the area of wheat was replaced by rabi maize crop during the period under investigation (2003-13). Further, it was also investigated that the area under sugarcane crop has increased at 9.22% annual growth rate during 2003-13.

Table 5: Cropping pattern in **Bihar**

(Area '000 ha)

Year	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR(2003-13)
Paddy	3563 (41.83)	3570 (44.52)	3471 (43.78)	3597 (45.26)	3155 (42.70)	3165 (42.08)	-0.43
Wheat	1314 (15.42)	1515 (18.89)	1903 (24.00)	2112 (26.57)	2107 (28.51)	2150 (28.59)	0.21
Barley	208 (2.44)	92 (1.15)	38 (0.48)	22 (0.28)	12 (0.16)	11 (0.15)	-3.25
Maize	699 (8.20)	645 (8.04)	488 (6.15)	609 (7.67)	641 (8.67)	681 (9.06)	0.48
Total cereal	6336 (74.37)	5953 (74.24)	6055 (76.37)	6366 (80.09)	5933 (80.30)	6027 (80.15)	-0.13
Gram	205 (2.41)	156 (1.94)	128 (1.61)	72 (0.90)	59 (0.79)	59 (0.78)	-1.22
Masoor	166 (1.94)	157 (1.96)	167 (2.10)	177 (2.22)	176 (2.38)	167 (2.22)	-0.19
Khesari	686 (8.06)	319 (3.98)	241 (3.04)	151 (1.90)	81 (1.10)	73 (0.97)	-3.04
Arhar	85 (1.00)	60 (0.74)	53 (0.66)	41 (0.52)	27 (0.36)	23 (0.31)	-2.60
Pea	59 (0.69)	40 (0.50)	32 (0.40)	26 (0.32)	21 (0.28)	19 (0.25)	-1.26
Total Pulses	1233 (14.48)	891 (11.11)	700 (8.83)	703 (8.84)	555 (7.51)	527 (7.01)	-1.29
Total food grains	7569 (88.84)	6844 (85.35)	6754 (85.20)	7069 (88.93)	6488 (87.81)	6554 (87.16)	-0.34
Oilseeds	148 (1.73)	163 (2.03)	172 (2.17)	143 (1.80)	141 (1.90)	136 (1.81)	-0.09
S/cane	162 (1.90)	117 (1.45)	130 (1.64)	105 (1.32)	145 (1.96)	240 (3.19)	3.68
Potato	84 (0.98)	107 (1.34)	127 (1.60)	144 (1.82)	148 (2.00)	156 (2.07)	0.42
Tobacco	15 (0.18)	13 (0.16)	16 (0.20)	15 (0.18)	9 (0.13)	10 (0.13)	-2.33
Jute	136 (1.59)	138 (1.73)	142 (1.79)	142 (1.79)	125 (1.69)	127 (1.68)	-0.84
Gross sown area	8519 (100)	8019 (100)	7928 (100)	7949 (100)	7388 (100)	7520 (100)	-0.14

Figures in parentheses indicate percentage values

Recently the cultivators of this zone consider sugarcane cultivation as more profitable than rabi maize crop because of their perception that sugarcane cultivation requires comparatively less labour as compared to rabi maize as well as sugar factory of the zone is also ensuring payment into their account. Hence, the cultivators of the zone are tempting towards sugarcane cultivation. The rest other crops consisting in cropping pattern showed negative compound growth rates per annum during 2003-13.

Cropping pattern of Agro-climatic zone-III

Analytical picture of cropping pattern of region-III is presented in Table 5C and it was observed that the gross cropped area has diminished at -0.19 per cent growth rate during the period under study (2003-13). Among cereal crops, the only wheat crop showed rising trend in its area at 0.61% annual growth rate whereas the rice (-0.57%), maize (-1.00%) and barely (-3.46%) revealed declining trend during the period under study. It is obvious that area under maize might have shifted to wheat crop. The area under rabi pulses have also probably shifted to wheat crop. Among pulses, only lentil crop showed marginal rise in its area (0.05% growth rate), whereas on the other hand, oilseed crops also revealed increasing trend at 0.22% growth rate during the period 2003-13. In this zone, further it was examined that sugarcane and potato ascertained positive compound growth rates being 2.60% and 0.61%, respectively during the investigation period (2003-13). This zone is considered as traditional and popular producer of potato. It is also important to mention here that when the data of area of different crops was compared; it was found that the area of only three crops viz., wheat, lentil and potato accounted for rising trend throughout the study period since TE-1973 to TE-2013.

Cropping pattern (Sample data)

Analysis of cropping pattern in Bihar from sample data has been presented in Table 6. The table clearly revealed that the total cereal crops accounts for 85.48% of the sample gross cropped area for the state as whole during TE-2010-11. The total pulses shares nearly 9.48% and thus total foodgrains area in the state comprises as much as 94.97% of the sample gross cropped area in TE-2010-11. Oilseeds, vegetables and cash crops altogether occupy very meagre share i.e. 0.99%, 2.56% and 1.47%, respectively of sample gross cropped area during the study period. It is an important to notice here that the only three crops viz. paddy, wheat and maize dominate in the cropping pattern and these three occupy as much as 84.83% of the sample GCA.

Table 5A: Cropping pattern of **Agro-Climatic Zone-I** of Bihar

(Area '000 ha)

Crops	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR(2003-13)
Paddy	1351 (40.10)	1403 (46.21)	1418 (44.46)	1360 (44.69)	1320 (41.64)	1260 (39.92)	-0.21
Wheat	467 (14.10)	590 (19.43)	809 (25.38)	914 (30.04)	954 (30.09)	928 (29.43)	0.20
Barely	110 (3.33)	40 (1.31)	98 (3.07)	4 (0.15)	2 (0.07)	2 (0.06)	-2.52
Maize	327 (9.86)	338 (11.13)	219 (6.88)	279 (9.16)	288 (9.10)	301 (9.55)	0.29
Total cereals	2487 (75.12)	2386 (78.57)	2576 (80.78)	2567 (84.35)	2573 (81.16)	2498 (79.17)	-0.02
Gram	22 (0.)	21 (0.69)	13 (0.40)	1 (0.03)	1 (0.02)	2 (0.05)	-5.93
Masoor	35 (1.12)	38 (1.26)	38 (1.18)	43 (1.41)	45 (1.43)	40 (1.28)	-0.40
Khesari	94 (2.85)	73 (2.40)	29 (0.89)	11 (0.37)	5 (0.16)	4 (0.12)	-5.66
Arhar	52 (1.57)	38 (1.26)	25 (0.79)	26 (0.86)	15 (0.46)	11 (0.35)	-4.02
Peas	14 (0.42)	8 (0.25)	9 (0.27)	4 (0.13)	4 (0.14)	4 (0.14)	-0.14
Total pulses	311 (9.39)	234 (7.71)	288 (9.04)	183 (6.03)	152 (4.80)	140 (4.44)	-1.35
Total food grains	2798 (84.51)	2620 (86.28)	2864 (89.82)	2750 (90.38)	2725 (85.95)	2638 (83.60)	-0.10
Oilseeds	50 (1.50)	48 (1.58)	57 (1.77)	55 (1.82)	57 (1.79)	54 (1.71)	0.12
Sugarcane	113 (3.43)	101 (3.33)	111 (3.47)	96 (3.16)	132 (4.16)	220 (6.97)	3.66
Potato	34 (1.01)	38 (1.25)	70 (2.18)	66 (2.18)	68 (2.15)	75 (2.36)	0.47
Tobacco	9 (0.28)	64 (2.12)	14 (0.43)	13 (0.44)	9 (0.29)	10 (0.31)	-1.23
GCA	3311 (100.00)	3036 (100.00)	3189 (100.00)	3043 (100.00)	3170 (100.00)	3155 (100.00)	0.08

Figures in parentheses indicate percentage values

Table 5B: Cropping pattern of **Agro-Climatic Zone-II** in Bihar

(Area '000 ha)

Crops	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR(2003-13)
Paddy	679 (47.05)	668 (45.65)	650 (43.89)	795 (44.48)	682 (40.72)	698 (40.97)	-0.59
Wheat	144 (9.97)	165 (11.27)	290 (19.59)	378 (21.16)	313 (18.69)	318 (18.67)	-0.74
Barely	22 (1.55)	11 (0.75)	27 (1.81)	1 (0.08)	0.0 (0.00)	0 (0.00)	-1.88
Maize	90 (6.26)	112 (7. 65)	126 (8.54)	190 (10.62)	260 (15.51)	280 (16.41)	1.37
Total cereals	1062 (73.52)	980 (66.94)	1137 (76.80)	1395 (78.07)	1259 (75.24)	1301 (76.38)	-0.29
Gram	6 (0.42)	10 (0.66)	6 (0.39)	4 (0.25)	1 (0.06)	1 (0.05)	-7.68
Masoor	11 (0.76)	12 (0.82)	16 (1.05)	15 (0.86)	10 (0.62)	10 (0.57)	-1.93
Khesari	47 (3.28)	41 (2.82)	33 (2.20)	20 (1.12)	10 (0.60)	8 (0.49)	-3.72
Arhar	3 (0.20)	2 (0.16)	1 (0.10)	1 (0.08)	1 (0.04)	1 (0.03)	-5.14
Peas	5 (0.36)	4 (0.25)	6 (0.37)	5 (0.28)	3 (0.18)	3 (0.16)	-3.48
Total pulses	76 (5.28)	138 (9.42)	123 (8.33)	138 (7.75)	121 (7.21)	114 (6.70)	-1.76
Total foodgrains	1138 (78.80)	1118 (76.36)	1260 (85.13)	1534 (85.82)	1380 (82.44)	1415 (83.08)	-0.43
Oilseeds	33 (2.27)	35 (2.38)	37 (2.53)	38 (2.14)	44 (2.64)	41 (2.41)	-0.62
Sugarcane	2 (0.11)	3 (0.18)	2 (0.11)	1 (0.04)	2 (0.14)	5 (0.31)	9.22
Potato	11 (0.75)	1 (0.07)	24 (1.59)	36 (2.02)	39 (2.32)	37 (2.16)	-0.12
Jute	86 (5.98)	135 (9.20)	134 (9.08)	141 (7.88)	125 (7.44)	127 (7.43)	-0.80
GCA	1444.00 (100.0)	1464 (100.00)	1480 (100.00)	1787 (100.00)	1674 (100.00)	1703 (100.00)	-0.46

Figures in parentheses indicate percentage values

Table 5C: Cropping pattern of **Agro-Climatic Zone-III** in Bihar

(Area '000 ha)

Crops	TE-1973	TE-1983	TE-1993	TE-2003	TE-2011	TE-2013	CGR(2003-13)
Rice	1466 (38.94)	1476 (44.31)	1453 (46.34)	1425 (50.09)	1153 (45.35)	1208 (45.04)	-0.57
Wheat	700 (18.60)	760 (22.83)	786 (25.07)	809 (28.45)	840 (33.03)	904 (33.70)	0.61
Barely	58 (1.53)	40 (1.21)	83 (2.64)	15 (0.54)	9 (0.37)	9 (0.33)	-3.46
Maize	265 (7.04)	195 (5.86)	78 (2.49)	125 (4.40)	92 (3.60)	101 (3.75)	-1.00
Total cereals	2727 (72.46)	2527 (75.88)	2486 (79.29)	2364 (83.11)	2101 (82.60)	2229 (83.13)	-0.15
Gram	165 (4.38)	126 (3.77)	108 (3.46)	65 (2.27)	56 (2.22)	57 (2.12)	-0.87
Masoor	109 (2.90)	106 (3.18)	118 (3.76)	118 (4.16)	119 (4.69)	117 (4.36)	0.05
Khesari	476 (12.64)	230 (6.92)	166 (5.28)	120 (4.22)	66 (2.58)	61 (2.26)	-2.79
Arhar	30 (0.80)	20 (0.60)	15 (0.49)	13 (0.44)	11 (0.44)	12 (0.44)	-0.49
Peas	24 (0.63)	16 (0.49)	12 (0.38)	15 (0.53)	11 (0.45)	12 (0.44)	-0.31
Total pulses	846 (22.48)	519 (15.59)	445 (14.19)	348 (12.23)	282 (11.11)	273 (10.18)	-1.06
Total food grains	3184 (94.94)	3046 (91.47)	2931 (93.48)	2712 (95.34)	2383 (93.71)	2502 (93.31)	-0.26
Oilseeds	65 (1.73)	68 (2.05)	66 (2.09)	41 (1.44)	40 (1.56)	41 (1.53)	0.22
Sugarcane	34 (0.91)	20 (0.60)	14 (0.44)	8 (0.29)	10 (0.41)	15 (0.55)	2.60
Potato	39 (1. 03)	48 (1.44)	35 (1.12)	42 (1.48)	41 (1.61)	44 (1.63)	0.61
GCA	3764 (100.00)	3330 (100.00)	3135 (100.00)	2845 (100.00)	2543 (100.00)	2681 (100.00)	-0.19

Figures in parentheses indicate percentage values

Table 6: Cropping pattern in ***Bihar*** from sample data TE-2010-11

Particulars	n (number of observation)	Area (ha)	% of sample GCA
Paddy	3186	732.61	42.46
Wheat	2833	639.13	37.04
Maize	473	91.93	5.33
Ragi	12	6.35	0.37
Barely	8	5.05	0.29
Total cereals	-	**1475.07**	**85.48**
Gram	148	37.79	2.19
Lentil	486	100.85	5.84
Arhar	21	3.13	0.18
Kulthi (Horse gram)	8	2.75	0.16
Pea	7	3.14	0.18
Moong	13	3.1	0.18
Khesari	24	9.76	0.56
Urad	12	3.31	0.19
Total pulses	-	**163.82**	**9.48**
Total food crops	-	**1638.90**	**94.97**
R& M	127	12.70	0.74
Linseed	8	1.5	0.09
Sunflower	14	3.00	0.17
Oilseeds	-	**17.20**	**0.99**
Cabbage	7	2.9	0.17
Brinjal	19	4.4	0.25
Cauliflower	20	5.9	0.34
Okra (Bhindi)	16	2.44	0.14
Potato	98	15.38	0.89
Tomato	15	5.2	0.30
Onion	20	7.9	0.46
Vegetables	-	**44.12**	**2.56**
Chillies	12	1.65	0.10
Jute	9	6.8	0.39
Sugarcane (planed)	25	6.95	0.40
Sugarcane (ratoon)	30	8.96	0.52
Cash crops	-	**25.36**	**1.41**
GCA	-	1725.57	100.00

GCA-Gross cropped area

Table 6A: Cropping pattern of ***Agro-Climatic Zone-I*** in Bihar from sample data TE-2010-11

Particulars	n(number of observation)	Area (ha)	% of sample GCA
Paddy	1252	275.76	41.63
Wheat	1089	242.49	36.61
Maize	280	42.63	6.44
Barely	8	5.05	0.76
Ragi	8	4.35	0.66
Total cereal	-	**570.29**	**86.09**
Lentil	134	24.79	3.74
Arhar	15	3.27	0.49
Moong	13	4.18	0.63
Pea	7	3.14	0.47
Urad	12	3.31	0.50
Total pulses	**-**	**35.55**	**5.37**
Total food crops	-	**605.84**	**91.46**
Rapeseed & mustard	107	10.98	1.66
Sunflower	4	1.5	0.23
Oilseeds	-	**12.48**	**1.88**
Potato	78	13.73	2.07
Cabbage	3	0.8	0.12
Brinjal	9	1.5	0.23
Okra	6	0.55	0.08
Cauliflower	11	3.1	0.47
Vegetables	-	**19.68**	**2.97**
Chilli	8	0.85	0.13
Sugarcane	55	22.55	3.40
Cash crops	-	**24.4**	**3.53**
GCA	-	662.4	100.00

GCA-Gross cropped area

Table 6B: Cropping pattern of ***Agro-Climatic Zone-II*** in Bihar from sample data TE-2010-11

Particulars	n(number of observation)	Area (ha)	% of sample GCA
Paddy	499	120.3	44.86
Wheat	412	90.6	33.79
Maize	102	39.5	14.73
Lentil	71	8.1	3.02
Total food grains	**-**	**258.5**	**96.40**
Sunflower	10	2.85	1.06
Jute	9	6.8	2.54
GCA	-	268.15	100.00

GCA-Gross cropped area

Table 6C: Cropping pattern of **Agro-Climatic Zone-III** in Bihar from sample data TE-2010-11

Particulars	n(number of observation)	Area (ha)	% of sample GCA
Paddy	1435	327.43	41.30
Wheat	1332	306.08	38.61
Maize	91	9.83	1.24
Ragi	4	2	0.25
Total cereal	-	**645.34**	**81.40**
Gram	148	37.79	4.77
Lentil	281	67.97	8.57
Arhar	6	0.26	0.03
Khesari	24	9.95	1.25
Kulthi	8	2.75	0.35
Total pulses	-	**118.72**	**14.97**
Total foodgrains	-	**764.06**	**96.37**
Rapeseed & mustard	20	1.71	0.22
Linseeds	8	1.5	0.19
Oilseeds	-	**3.21**	0.40
Potato	20	2.07	0.26
Cabbage	4	2.1	0.26
Brinjal	11	2.9	0.37
Okra	10	1.89	0.24
Tomato	15	5.2	0.66
Onion	20	7.8	0.98
Cauliflower	9	2.8	0.35
Vegetables	-	**24.76**	**3.12**
Chilli	4	0.8	0.10
GCA		792.83	100.00

GCA-Gross cropped area

Zone-wise cropping pattern from sample data has been presented in Tables 6A, Table 6B and Table 6C and further perusal of the tables indicated that the area under total foodgrains crops was estimated to be 91.46% in zone-I, followed by 96.40% in zone-II and 96.37% in zone-III of sample gross cropped area during TE-2010-11. The rest other crops like oilseeds, vegetables and cash crops shared about 0.1% to 3.68% among different zones of the state during the investigation period. In the sample data too, the paddy, wheat and maize crops dominated in the cropping pattern of different zones of the state.

Yield of major crops in Bihar

Decadal change in yield of major crops in Bihar has been depicted in Table 7. An examination of the table showed that for cereals for the state as a whole, the productivity has increased more than two times during 40 years of time i.e. 9.51 q/ha in TE-1973 to 24.69q/ha in TE-2013. In case of paddy, wheat, barley and ragi, there has been found upsurge in the yield by and large, by more than two times during 40 years of study period (Since TE-1973 to TE-2013), whereas only in case of maize, it rose by more than four times during the same period as evidenced by 8.46 q/ha in TE-1973 to 36.28 q/ha in TE-2013. The increase in the yield may be attributed to the introduction of green revolution and adoption of new production technology. In case of total pulses, the rise in productivity was very low/slow as it was reflected from the yield figure from 6.3 q/ha in TE-1973 to 9.70 q/ha in TE-2013. It is further observed that the yield of most of the pulses crops such as gram, lentil, pea, moong, urad and khesari persisted below 11.00 q/ha except arhar crop which produced 18.60 q/ha during 40 years of investigation.

Table 7: Trend of yield of major crops in Bihar

(q/ha)

Crops	TE-1973	TE-1983	TE-1993	TE-2003	TE-2013
Cereals	9.51	10.61	14.40	17.33	24.69
Paddy	9.56	8.82	10.97	14.25	20.27
Wheat	14.14	14.60	19.10	18.96	27.57
Maize	8.46	11.17	19.24	23.84	36.28
Barely	6.10	7.79	9.72	11.73	14.43
Ragi	5.46	6.53	5.15	8.79	11.26
Pulses	6.3	6.50	5.49	8.20	9.70
Gram	5.84	8.28	10.13	10.16	12.47
Lentil	5.23	6.77	8.58	8.76	10.35
Arhar	8.35	12.45	12.21	12.20	18.60
Pea	5.86	5.85	6.51	9.37	10.36
Moong	3.79	4.12	5.77	5.93	6.40
Urad	3.59	4.58	4.89	6.82	8.72
Khesari	5.59	6.52	7.99	8.53	11.43
Oilseeds	3.41	5.76	3.95	8.10	12.78
Rapeseed Mustard	5.44	6.88	8.97	6.89	13.73
Linseed	3.12	4.60	4.49	7.6	8.5
Sunflower	4.50	4.73	6.91	7.15	14.28
Sugarcane	349.48	348.33	441.70	442.38	498.68
Potato	72.83	100.70	95.4	147.7	194.32

So far as oilseeds are concerned, the yield of rapeseed & mustard, linseed and sunflower crops were found to increase by more than two times during the study period (TE-1973 to TE-2013). This achievement in oilseed yield may probably be due to adoption of improved technology/varietal change.

In case of potato, the yield has jumped up from 72.83 q/ha in TE-1973 to 194.32 q/ha in TE-2013. The yield of sugarcane has also improved from 349.48 q/ha (TE-1973) to 498.68 q/ha in 2013.

Extent of diversification

Crop diversification indicates the direction of shift from growing of cereal crops (low valued crops) to more remunerative crops (high valued crops), thus ultimately enhancing /raising the level of income of the farming community through revitalizing sustainable agriculture.

In order to ascertain the extent of crop diversification in the state, diversification index was computed for different periods which are presented in Table 8. Perusal of table clearly revealed the diversification index 11.89 during the period of seventies (TE83-TE73), which further scaled down to 5.62% during TE93-TE83 and in the subsequent period (TE-2003-TE-1993), the diversification index scaled up to 7.96. Rise in diversification index supports the dependence of farming community on market dynamics. For recent period TE-2013-TE-2003, diversification index was calculated as 6.31, which was comparatively low as compared to earlier periods as above. It is a matter of serious concern and it clarifies that the pace of diversification has slowed down during the recent period despite having more emphasis on agriculture by the government. The diversification index for the overall period (TE-2013-TE-1973) was computed as 20.46, this emphasizes on the pace of diversification during the study period (40 years of time).

Table 8: Extent of crop diversification in Bihar

Period	Diversification Index (%)
TE-1983-TE-1973	11.89
TE-1993-TE-1983	5.62
TE-2003-TE-1993	7.96
TE-2011-TE-2003	4.66
TE-2013-TE-2003	6.31
TE-2013-TE-1973	20.46

Zone-wise diversification Index

Decade wise extent of crop diversification in different zones of the state has been presented in Table 8A, Table 8B and Table 8C. The tables were further examined and observed that the diversification index (DI) for overall period (TE-2013-TE-1973) was computed 21.5 in ago-climatic zone-I, followed by 25.28 in agro-climatic zone-II as well as 29.55 in agro-climatic zone-III of the state. This indicates that comparatively larger diversification was emphasized in zone-III (being agriculturally developed zone) as compared to Zone-I and zone-II

Table 8A: Extent of crop diversification in **Agro-Climatic Zone-I** in Bihar

Period	Diversification Index (%)
TE-1983-TE-1973	12.05
TE-1993-TE-1983	13.80
TE-2003-TE-1993	7.81
TE-2011-TE-2003	4.69
TE-2013-TE-2003	6.82
TE-2013-TE-1973	21.58

Table 8B: Extent of crop diversification in **Agro-Climatic Zone-II** in Bihar

Period	Diversification Index (%)
TE-1983-TE-1973	12.13
TE-1993-TE-1983	13.45
TE-2003-TE-1993	12.89
TE-2011-TE-2003	10.31
TE-2013-TE-2003	9.95
TE-2013-TE-1973	25.28

Table 8C: Extent of crop diversification in **Agro-Climatic Zone-III** in Bihar

Period	Diversification Index (%)
TE-1983-TE-1973	14.65
TE-1993-TE-1983	7.68
TE-2003-TE-1993	7.39
TE-2011-TE-2003	8.44
TE-2013-TE-2003	8.68
TE-2013-TE-1973	29.55

Location Coefficient

To study the dynamics of various categories of land, location coefficients were worked out for different periods viz., for 1970-71, 1980-81, 1990-91, 2000-01, 2010-13 and 2012-13, as presented in Table 9. Perusal of table revealed that the larger concentration of land was observed lopsided to miscellaneous tree crops and groves, followed by land put to non- agricultural uses, current fallow lands and net sown area as the location coefficient for them being 2.54, 2.12, 1.65 and 1.27, respectively. It was further observed that there has been sharp escalation in area under miscellaneous tree crops and groves and as manifested by location coefficients which stepped up from 1.01 in 1970-71 to 2.54 in the year 2012-13. The location coefficient of area under current fallow was only 1.27 in 2001 which increased to the level of 1.65 in 2012-13. The rise in the concentration of land towards this category may probably be due to erratic monsoon, global warming and declining water table in the state especially from the beginning of the present century. Further examination of table pointed out that the declining trend in net sown area in the state has compelled us to think over this miserable situation as the location coefficient for this category of land declined from as much as 1.39 (1970-71) to 1.27 (2012-13)

Table 9: Location coefficient of different categories land in Bihar

Sl. No.	Year	1970-71	1980-81	1990-91	2000-01	2010-11	2012-13
1	Reporting area	-	-	-	-	-	-
2	Forests	0.31	0.28	0.30	0.29	0.29	0.29
3	Area under non-agri-cultural uses	2.07	1.94	2.23	2.25	2.12	2.12
4	Barren and unculturable land	0.52	0.72	0.74	0.81	0.83	0.83
5	Permanent pastures & other grazing lands	0.11	0.10	0.06	0.05	0.05	0.05
6	Land under misc. tree crops & groves	1.01	1.41	1.78	2.19	2.51	2.54
7	Culturable waste land	0.20	0.20	0.14	0.11	0.12	0.12
8	Fallow lands other than current fallows	0.76	0.63	0.65	0.43	0.39	0.36
9	Current fallows	2.19	1.58	1.56	1.27	2.12	1.65
10	Total unculturable waste land	0.66	0.67	0.74	0.74	0.81	0.78
11	Net sown area	1.39	1.38	1.30	1.31	1.22	1.27

Zone-wise location coefficient

Location coefficients of different categories of land in different agro-climatic zones of the state have been presented in Table 9A, Table 9B and Table 9C.

Table 9A: Location coefficient of different categories of land in ***Agro-Climatic Zone-I*** of Bihar

Sl. No.	Year	1970-71	1980-81	1990-91	2000-01	2010-11	2012-13
1	Reporting area	-	-	-	-	-	-
2	Forests	0.40	0.42	0.41	0.40	0.40	0.40
3	Area under non-agri-cultural uses	1.12	1.12	1.13	1.13	1.12	1.12
4	Barren and unculturable land	0.55	0.52	0.63	0.63	0.63	0.63
5	Permanent pastures & other grazing lands	0.78	0.59	0.34	0.34	0.32	0.32
6	Land under misc.tree crops & groves	2.57	2.29	1.82	1.68	1.66	1.67
7	Culturable waste land	0.33	0.32	0.46	0.32	0.31	0.31
8	Fallow lands other than current fallows	0.73	0.59	0.54	0.51	0.52	0.51
9	Current fallows	0.92	0.66	0.69	0.55	0.48	0.53
10	Total unculturable waste land	0.88	0.82	0.86	0.86	0.82	0.84
11	Net sown area	1.07	1.10	1.09	1.09	1.14	1.11

Perusal of the Table9A, has suggested that the major concentration of land in zone-I is located under land under miscellaneous tree crops and groves, followed by area under non-agricultural uses and net sown area as evidenced by location coefficient being 1.67, 1.12 and 1.11, respectively during the period 2012-13. In zone-II (Table 9B), the estimated location coefficient was found highest 2.0 for miscellaneous tree crops and groves, followed by fallow lands other than current fallow (1.45), area under non-agricultural uses (1.02), barren and unculturable land 1.20, net sown area (1.10), current fallow (0.80) and so on. A larger location coefficient for land under miscellaneous tree crops and groves may have emerged on account of a large scale afforestation programmes and Horticulture Mission run by the government and NGOs. Since the zone is acute flood affected area as well as possessing erratic monsoon behaviour, the cultivators of the area prefer to put their land as fallows and barren & unculturable.

Table 9B: Location coefficient of different categories of land in ***Agro-Climatic Zone-II*** of Bihar

Sl. No.	Year	1970-71	1980-81	1990-91	2000-01	2010-11	2012-13
1	Reporting area	-	-	-	-	-	-
2	Forests	0.02	0.01	0.03	0.03	0.03	0.03
3	Area under non-agri-cultural uses	0.85	0.96	1.07	1.03	1.03	1.02
4	Barren and unculturable land	1.04	1.07	1.23	1.19	1.19	1.20
5	Permanent pastures & other grazing lands	1.01	1.12	0.33	0.33	0.28	0.28
6	Land under misc. tree crops & groves	1.05	0.62	2.59	1.92	1.99	2.00
7	Culturable waste land	2.83	2.45	1.40	0.76	0.70	0.72
8	Fallow lands other than current fallows	1.49	1.35	1.51	1.31	1.41	1.45
9	Current fallows	1.80	1.15	1.28	0.96	0.70	0.80
10	Total unculturable waste land	1.05	0.91	0.98	0.89	0.84	0.87
11	Net sown area	0.97	1.05	1.01	1.07	1.12	1.10

Table 9C examined the data of location coefficients in zone -III and revealed highest concentration of land towards miscellaneous tree crops & groves (4.81, followed by forest (1.93), current fallows (1.48), barren and unculturable land (1.23), fallow lands other than current fallow (1.21), non-agricultural uses (0.89) and net sown area (0.86).

It is of utmost importance to mention here that the location coefficient for land under miscellaneous tree crops and groves was found highest in zone-III (4.81) as compared to zone-II (2.0) and zone-I (1.67). Secondly, the concentration of land towards forest has also high (1.93) as compared to other zones of the state. Thirdly, the concentrations of land towards barren and unculturable land as well as fallow lands (both current fallow and fallow lands other than current fallow) were also observed to be larger in zone-III. A larger concentration of above categories of land in zone-III may probably be on account of erratic monsoon, resulting in declining water table in the area; henceforth the situation compels the cultivators to put their land as fallow.

Table 9C: Location coefficient of different categories of land in ***Agro-Climatic Zone-III*** of Bihar

Sl. No.	Year	1970-71	1980-81	1990-91	2000-01	2010-11	2012-13
1	Reporting area	0	0	0	0	0	0
2	Forests	1.83	1.77	1.92	1.93	1.93	1.93
3	Area under non-agri-cultural uses	0.88	0.86	0.86	0.88	0.89	0.89
4	Barren and unculturable land	1.30	1.27	1.20	1.23	1.23	1.23
5	Permanent pastures & other grazing lands	1.02	1.15	0.37	0.45	0.40	0.39
6	Land under misc.tree crops & groves	0.30	0.29	1.86	3.64	4.74	4.81
7	Culturable waste land	1.29	1.48	0.45	0.34	0.32	0.31
8	Fallow lands other than current fallows	1.01	1.11	1.16	1.27	1.22	1.21
9	Current fallows	1.07	1.13	1.14	1.39	1.57	1.48
10	Total unculturable waste land	1.15	1.14	1.12	1.16	1.22	1.19
11	Net sown area	0.92	0.92	0.92	0.89	0.83	0.86

Chapter-III

RESOURCES USE EFFICIENCY- A DATA ENVELOPMENT ANALYSIS (DEA) APPROACH

Resource Use Efficiency

Efficiency of resource use, which can be defined as the ability to derive maximum output per unit of resource, is the key to effectively addressing the challenges of achieving food security. There are various techniques and methods to examine resource use efficiency such as Data Envelopment Analysis (DEA), Stochastic Frontier (SF) production function etc. In the present study, DEA method has been used which is explained here:

Nargis and Lee (2010) conducted a study to find out technical, allocative, economic, and scale efficiency using field level survey data from a sample of 199 Boro rice farmers in north central Bangladesh using DEA method which is widely used tool to estimate the agricultural efficiency analysis in recent years. The results of the study revealed that on an average, the farms technical, allocative, economic and scale efficiencies were 0.93, 0.82, 0.69 and 0.90, respectively. Their existing inefficiencies were 7%, 18%, 31% and 10%. Although tremendous development has been achieved in crop production in Bangladesh, the evidences suggested that there was still need for full utilization of technological potential. Better supply of electricity, improved seeds may help the farming beneficial to farming community of Bangladesh.

S. Tan *et al.*(2010) assessed the impact of land fragmentation on rice producers' efficiency in South-east China using detailed household, crop and plot level data to investigate the levels and determinants of rice producers' technical efficiency for three villages with different characteristics in a major rice-growing area of south-east China, focusing, in particular on the impact of fragmentation. Empirical results obtained by applying a stochastic frontier model showed statistically significant differences in technology level among villages, with the remotest village having least technology level. Within villages, average technical efficiency was generally high, ranging from 0.80 to 0.91 for the three types of rice that were grown in the region.

Kumar, De and Chattopadhyay (2010) in their study found that for sustainable income and employment in the rural areas seems to be very much dependent on degree of crop diversification of land use towards cultivating various crops. In view of this, crop diversification has been an important issue of agricultural development not only in India, but also in other part of the world. In India, the growth of area under cultivation in different states remained stagnant in the current decade and growth of yield of various crops has rearched the saturation level. Efforts in different parts of India are made to cultivate those crops, which are remunerative and environmental friendly. Their study on nature and extent of crop diversification in West Bengal, a rice growing state of India conducted for the period from 1970 to 2005 suggested that marginal and small farmers play a positive role in crop diversification and that has been supported by growth of various infrastructures network during the period under consideration.

Akighir *et al*., (2011) conducted a study to investigate the efficiency of resource use in rice farming enterprise in Kwande local government area of Benue state in Nigeria. The study was conducted from data collected from 100 rice growing farmers using random sampling technique and the analytical tools used were Cobb Douglas production function and technical efficiency techniques. The study revealed coefficient of elasticity (1.3) using Cobb Douglas production function, which implies that rice farmers in the area are producing in the first stage of production. The technical efficiency estimates revealed that all the marginal physical productivities (MPPs) were higher than the Average Physical Products (APPs) which also suggested that the farmers were producing in the first stage of production. The study concluded that rice farmers were technically efficient in the rice production

Mesfin (2011) in his study on crop diversification in eastern Ethiopia revealed that farmers of the study area employed crop diversification as a self-insuring strategy in order to manage risks of drought, pest and diseases, soil fertility decline and input price variations. He further suggested to promote crop diversification, by providing farm machinery through easy loan and improving access to market information and giving more attention to irrigation facilities.

Ali and Samad (2013) conducted study on resource use efficiency in farming: an application of stochastic frontier production function in Bangladesh to find out technical efficiency in farming. They also characterized farmers into social and economic classes and estimated the cost and returns of farming. The results revealed that fertilizer and planting materials (seeds, seedlings and cuttings) are significant determinants of farm output. Analysis of inefficiency revealed that farmer's personal characteristics did not contribute to farm efficiency. Individual farm technical efficiency scores showed that 76% of the farmers were more than 70% technically efficient. Overall farmers performed at an average technical efficiency of 75% of which only one farmer was between 90% and 100% efficient. In addition, a farmer realized an average gross margin of 61804.64 taka from cultivating one hectare of land. Women were found to be dominant in farming in the study area.

The findings of the study have implications for increased food production in the study area. Attainment of 75% efficiency means that farmers still have room to increase their efficiency to the optimum (100%). This will require those factors, which are constraints to efficiency. Such constraints include the availability of planting materials, and supply of the important inputs in farming will increase efficiency and ultimately, agriculture production in the environment.

Sureshkumar *et al.* (2014) carried out an investigation to estimate the input use, cost structure, return and resource use efficiency in wheat production of south Gujarat division of India. The data was collected from 240 sample farmers for investigation. The results of the study revealed that the average total cost of cultivation was Rs 45784.31. The average net profit over (Cost C_2) was 20017.55. The average cost of production of wheat was found to be about Rs. 128.86 which was lower than the market price of wheat. Functional analysis of wheat crop revealed the regression coefficients for seed, N fertilizer, irrigation, human labour, number of weeding, P fertilizer, FYM, bullock labour and number of spray i.e. 0.511, 0.371, 0.288, 0.188, 0.171, 0.148, 0.059, 0.029 and 0.020, respectively. These were positive and statistically significant, indicated that if expenses made on these resources, this would fetch profitable returns.

Reddy and Reddy (2014) in their study on resource use efficiency of agricultural input factors with reference to farm size conducted in Nellore district of Andhra Pradesh pointed out that farm size is of an extreme interest in agriculture. Since the amount of income is dependent on the size of farm, preponderance in small and tiny holdings, is mainly responsible poor peasantry in the third world counties. The results of the study pointed out that in case of small farm, on the basis of ratios of MVP and MC of the input factors; it was found that the pattern of resource use in small farms needed some modifications, particularly of technological factors. Chemical fertilizers and plant protection methods may be increased, whereas use of HYV seed may be reduced to obtain more output. In case of medium farms, the findings are same as for small farms except expenses on tractor may also be decreased to get the optimum output. In case of large farms, the expenditure on application of HYV seeds and on use of tractors needed to be reduced to get the profitable output with increase in technological knowhow, application of chemical fertilizers and plant protection majors.

Data Envelopment Analysis (DEA) approach

Resource use efficiency under different crop production is estimated on the basis of DEA. DEA is a Linear Programming technique for constructing a non-parametric piece wise linear envelop to a set of observed output and input data. Efficiency is defined as a measure of how efficiency inputs are employed to produce a given level of output producing same level of output with lower level of inputs or more output with the same level of inputs this means higher level of efficiency. The technique of DEA has been used to find the relative efficiency score of each farm in relation to farms with minimum input output ratio for all inputs. The score of the most efficient farms being one, the score of each farm will lie between zero and one.

In the present study, the DEA approach has been used to analyze the data for optimizing the performance measure of each production unit and determining the most preferable ones. Unit level data from Cost of Cultivation Scheme for the block period 2008-2011 from various regions of Bihar have been used. The information obtained included the amount of input costs which were used in crop production such as human labour, fertilizer seed etc. and the yield as an output.

In order to specify the mathematical formulation of model, we assume that we have K farmers Decision Making Units (DMU) using N inputs to produce M outputs. Inputs are denoted by x_{jk} (j=1,2,….. n) and output are represented by Y_{ik} (i=1,2,3…..m) for each farmer k (k=1,2,…. K). The technical efficiency (TE) of the farmers can measured as:

$$\mathbf{TE_k} = \sum_{i=1}^{m} u_i y_{ik} / \sum_{j=1}^{n} v_j x_{jk}$$

Where, $Y_{ik}$is the quantity of i^{th} output produced by k^{th} farmer, x_{jk} is the quantity of j^{th} input used by the k^{th} farmer, u_i and v_j are the output and input weights, respectively. The farmer maximizes the technical efficiency, TE_k subject to

$$\mathbf{TE_k} = \sum_{i=1}^{m} u_i y_{ik} / \sum_{j=1}^{n} v_j x_{jk} \leq 1$$

Where, u_i and $v_j \geq 0$

The above equation indicates that the technical efficiency measure of a farmer cannot exceed one, and the input and output weights are positive. The weights are selected in such a way that the farmer maximizes its own technical efficiency which is executed separately. To select optimal weights, the following linear programming model is specified:

Min TE_k

Subject to

$$\sum_{i=1}^{m} u_i y_{ik} - y_{ik} + \omega \geq 0$$

Where k=1,2,………..k

$$x_{jk} - \sum_{j=1}^{n} v_j x_{jk} \geq 0$$

and u_i and $v_j \geq 0$

The above model shows TE under constant returns to scale (CRS) with an assumption if w=0 and it changes into variable returns to scale (VRS), if w is used unconstrained. In the first case, it leads to technical efficiency (TE) and in second case, pure technical efficiency (PTE) is estimated.

Technical Efficiency (TE) : It can be expressed generally as the ratio of sum of the weighted outputs to sum of weighted inputs. The value of technical efficiency varies between zero and one; where a value of one implies that the DMU is the best performer located on production frontier and has no reduction potential. Any value of TE lower than one indicates that DMU uses inputs inefficiently.

Cost or Economic Efficiency (CE): one can measure both technical and allocative efficiencies to verify the behavioral objectives such as cost minimization or revenue maximization.

Cost minimization DEA is expressed as

$$\mathbf{Min_{YX_k^*}\ w_k'\ X_k^*,}$$

$$\mathbf{Subject\ to\ \ -y_k+YY\geq 0,}$$

$$\mathbf{X_k^*-XY\geq 0,}$$

$$\mathbf{Y\geq 0,}$$

Where w_k is a vector of input prices for the k^{th} farmer and X_k* (which is calculated by LP) is the cost minimizing vector of input quantities for the k^{th} farmer, given the input prices w_k and the output level y_k.

Total cost efficiency (CE) or economic efficiency of the k^{th} farmer can be calculated as

$$\mathbf{CE= w_kX_k^*/w_kX_k}$$

That is the ratio of minimum cost to the observed cost.

While the allocative efficiency (AE) is calculated as the ratio of cost efficiency to technical efficiency

$$\mathbf{AE=CE/TE}$$

DEA is well established approach for measuring the relative efficiency of decision making units (DMUs) that have multiple inputs and outputs. We have used this method to investigate the technical efficiency (TE), allocative efficiency (AE) and cost efficiency or economic efficiency (CE). In this study, we use input-oriented efficiency measures because they reflect local reality where a decrease in scarce resources (inputs) makes use of more relevance.

Efficiency or performance analysis is a relative concept relates to production analysis and measures the production with ratio. TE relates the degree to which a farmer produces maximum output from a given bundle of inputs, or uses the minimum amount of inputs to produce a given level of output when the technology exhibits constant returns to scale but is likely to differ otherwise. These two definitions of TE are known as output-oriented or input-oriented efficiency measures, respectively. AE or price efficiency reflects the ability of a farm to use the inputs in optimal proportions, given their respective price EE or CE is distinct from the other two; even though it is the product of TE and AE and reflects the ability of a production unit to produce a well-specified output at minimum cost. An economically-efficient might be both technically and allocatively efficient.

Resource use efficiency through DEA

Resource use efficiency measures guide/direct the producers to use their production resources efficiently/properly in the production process to maximize income. Efficiency measures such as technical efficiency (TE), allocative efficiency (AE) or price efficiency as well as economic efficiency (EE) or cost efficiency (CE) were worked out using Data Envelopment Analysis (DEA) method and presented in Table 10

It was observed from the table that the mean levels of technical, allocative and economic efficiency scores were 0.62, 0.61 and 0.38, respectively for paddy. The mean score of technical efficiency implied that paddy farmers could decrease the current input by 38.0% to produce the same amount of output with a given technology. The mean allocative efficiency also suggests that cost of production could be reduced by 39%, if the farmers had used the right combination of inputs and output mix relative to input and output prices. On the other hand, the mean level of economic efficiency indicated that farmers could reduce the current cost of produce, on an average, by 62.0% to achieve the potential minimum cost of production relative to the efficient farmers given current output level. Thus, these efficiency results suggest that there is considerable potential for decreasing input and reducing the cost of production in case of paddy.

Table 10: Crop wise resource use efficiency in Bihar TE 2010-11

Crop	N (Sample size)	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency(CE)
Cereal crops				
Paddy	430	0.62	0.61	0.38
Wheat	448	0.69	0.60	0.41
Maize (kharif)	86	0.64	0.68	0.44
Maize (rabi)	66	0.71	0.65	0.46
Barley	8	0.98	0.62	0.61
Ragi	11	0.99	0.75	0.74
Pulse crops				
Gram	49	0.81	0.75	0.61
Arhar	8	0.86	0.85	0.73
Lentil	167	0.55	0.50	0.27
Khesari	11	0.85	0.78	0.66
Urad	4	1.00	0.95	0.95
Kulthi	7	0.99	0.86	0.85
Moong	6	0.98	0.73	0.71
Pea	7	1.00	0.87	0.87
Oilseeds				
Rapeseed & mustard	64	0.71	0.72	0.51
Linseeds	8	1.00	0.76	0.76
Sunflower	10	0.95	0.74	0.70
Vegetables				
Brinjal	17	0.78	0.71	0.55
Cabbage	7	1.00	0.80	0.79
Cauliflower	18	0.84	0.78	0.65
Okra	14	0.87	0.86	0.74
Onion	11	0.92	0.77	0.71
Tomato	10	0.98	0.67	0.66
Potato	49	0.75	0.76	0.56
Cash crops				
Sugarcane (planted)	13	0.81	0.72	0.58
Sugarcane (ratoon)	9	0.97	0.90	0.87
Chilli	12	0.56	0.78	0.44
Jute	3	0.89	0.91	0.82

. In case of wheat, the estimated TE was found to be 0.69 which indicated that producer could decrease the current input by 31.0% to produce the same amount of output. The mean level of AE was estimated 0.60; this directs the farmers to reduce the cost of production by 40.0% considering the right proportion of inputs with their prices. Further, the cost efficiency measure was 0.41 which advised the farmer that the current cost of production could be lessened by 59.0% in order to achieve the given current output level at potential minimum cost of production.

For rabi maize crop, the estimated technical efficiency, allocative efficiency and cost efficiency were 0.71, 0.65 and 0.46, respectively. The mean level of technical efficiency revealed that maize cultivator could reduce the current input by 29.0% in order to produce the same amount of output. In other words, the TE also suggests that the output (maize) could be increased by 29.0% with a given level of current inputs. Allocative efficiency provides guidance to farmer that the cost could be diminished by 35.0% through manipulating the right combination of inputs with their prices. Further, the cost efficiency (CE) hinted that the cost of production of maize crop could be reduced, on an average, by 54.0% in order to arrive at the potential least cost production relative to the surrounding efficient farmers given the current level of output. Thus efficiency measures results that there is considerable scope for decreasing input and reducing cost of production of maize.

In case of ragi crop, the efficiency measures such as TE, AE and CE were estimated as 0.99, 0.75 and 0.74, respectively, where cost of production could be reduced, on an average, by 26.0% by farmer to produce ragi at potential minimum cost of production for a given level of output.

Among pulses, the lentil crop showed comparatively low resource use efficiency, hence there is ample scope to decrease input/ to reduce the cost of production for a given level of output as suggested by the efficiency measures being only 0.55 (TE), 0.50 (AE) and 0.27 (CE). In case of gram, the TE, AE and CE were estimated as 0.81, 0.75 and 0.61, respectively. Arhar accounted for 0.86 (TE), 0.85 (AE) and 0.73(CE), suggesting to reduce input and thus, lessen the cost of production for a given level of output. For urad, kulthi, moong and pea, the TE were estimated at higher side ranging from 0.98 to 1.0, suggesting very low opportunity to reduce the input cost and further these crops revealed considerable potential for improving the allocative and cost efficiency.

Among oilseed crops, rapeseed & mustard is considered as an important crop for which TE, AE and CE were found to be 0.71, 0.72 and 0.51, respectively. The mean level of technical efficiency implied that the farmer could reduce the input by 29.0% to maintain the current level of production. Allocative efficiency also suggests that the cost of production could be reduced by 28.0%, if the farmers used right inputs and output mix relative to input costs and output prices. The mean level of economic efficiency indicates that farmers could reduce current average cost of production by 49.0% to achieve the potential minimum cost of production for a given level of output. In case of linseed and sunflower, there would be considerable opportunity to promote allocative & cost efficiency.

Among vegetable crops, brinjal and potato accounted for comparatively low efficiency measures being 0.78 & 0.75 for TE, 0.71 & 0.76 for AE and 0.55 & 0.56 for CE, respectively. The efficiency measures of the above two crops asserted for considerable potential for improving the TE, AE and CE for a given level of output. The estimated TE, AE and CE of other vegetable crops viz., cabbage, cauliflower, okra, onion and tomato also stressed upon possible potential for improvement in TE, AE and CE.

Regarding sugarcane in cash crops, it was observed that the estimated technical, allocative and cost efficiencies were 0.81, 0.72 and 0.58, respectively. The technical efficiency emphasized that the farmer could decrease the input by 19.0% to produce the current level of output. The allocative efficiency disclosed the fact that cost of production could be lessened by 28.0% by the cultivators through using right input combination and output mix evaluated at input and output prices for a given level of output. The mean level of cost efficiency pointed out that the cost of production, on an average, could be decreased by 42.0% to arrive at potential minimum cost of production in comparison to the efficient farmer for a given level of output. Perusal of the estimated TE, AE and CE of jute and Chilli also came out with the fact that there is ample opportunities/potential for improvement in technical, allocative and economic efficiencies.

Resource use efficiency in zone-I

Results of resource use efficiency in zone-I as presented in Table 10A revealed the fact that among cereal crops, paddy, wheat and rabi maize stated very low cost efficiency being 0.51, 0.57 and 0.45, respectively, suggesting thereby further scope to minimize the cost by 49.0%, (paddy) 43.0% (wheat) and 55.0% (rabi maize), respectively to produce the output of these crops at least cost/ minimum cost. Among pulses crops, the crop masoor (lentil) and moong apprised very low economic efficiency (EE)/cost efficiency (CE) being only 0.28 and 0.71, thus these figures guide the cultivator to maximize his profit by using least cost principle. Oilseed crops such as rapeseed & mustard also showed low economic efficiency i.e. 0.55, thus suggesting the reduction of cost by 45.0% possible through manipulating the technical and allocative efficiency. Among vegetable crops, the potato crop contributed extremely low cost efficiency (0.55), thus advocating ample scope to maximize the income through use of least cost principle in production of the crop.

Table10A: Crop wise resource use efficiency in ***Agro-Climatic Zone-I of*** Bihar TE 2010-11

Crop	n (Sample size)	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Cereal crops				
Paddy	180	0.74	0.69	0.51
Wheat	180	0.75	0.76	0.57
Maize(kharif)	69	0.84	0.74	0.63
Maize (rabi)	21	0.64	0.70	0.45
Barley	8	0.98	0.62	0.61
Ragi	8	0.99	0.83	0.82
Pulse crops				
Arhar	8	0.92	0.81	0.74
Lentil	41	0.45	0.62	0.28
Moong	6	0.98	0.73	0.71
Pea	7	1.00	0.87	0.87
Oilseeds				
Rapeseed & mustard	57	0.69	0.80	0.55
Vegetables				
Brinjal	9	1.00	0.70	0.70
Cauliflower	10	0.90	0.80	0.72
Okra	6	0.92	0.77	0.71
Potato	41	0.72	0.76	0.55
Cash crops				
Sugarcane (planted)	13	0.81	0.72	0.58
Sugarcane (ratoon)	9	0.97	0.90	0.87
Chilli	8	0.99	0.80	0.80

Among cash crops under study, the low economic efficiency/cost efficiency (0.58) was observed in sugarcane (planted), thus, puts the suggestion for maximizing profit through adjustment in available technology and use of optimum combinations of inputs to produce the crop at least cost.

Resource use efficiency in Zone-II

Resource use efficiency for different crops grown in zone-II has been given in Table 10B and interpretation of the result indicated that the resource use efficiency i.e. cost efficiency (CE) of paddy and wheat crops were found to be comparatively low i.e. only 0.63 and 0.57, respectively, these suggest that producer may have the opportunity to reduce the cost of production by 37.0% and 43.0%, respectively in both crops through use of technical expertise and optimum resource combination. Since this zone is popular for maize growing area, therefore, the cost efficiency for rabi maize is observed comparatively larger (i.e. 0.70), this reveals the opportunity even to reduce the cost by 30%. The sunflower & jute crops are majorly grown in this zone; hence its cost efficiency (CE) is on comparatively higher side being 0.70 and 0.82.

Table10B: Crop wise resource use efficiency in ***Agro-Climatic Zone-II of*** Bihar TE 2010-11

Crop	n (Sample size)	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Cereal crops				
Paddy	60	0.92	0.68	0.63
Wheat	70	0.82	0.69	0.57
Maize (rabi)	24	0.76	0.91	0.70
Pulse crops				
Lentil	24	0.96	0.68	0.65
Oilseeds				
Sunflower	10	0.95	0.73	0.70
Cash crops				
Jute	3	0.89	0.91	0.82

Resource use efficiency in zone-III

Crop-wise resource use efficiency in zone-III has been presented in Table 10C and the perusal of the table reported that like that of zone-I, the paddy, wheat and maize revealed lower cost efficiencies being 0.41, 0.42 and 0.45, respectively during the period TE-2010-11.

Among pulses crops grown in this zone, masoor (Lentil) and gram registered comparatively very low cost efficiency i.e. 0.28 and 0.60, this suggests that the producer has opportunity to minimize the cost of production by 72% and 40%, respectively to produce both the crops at least cost.

Table10C: Crop wise resource use efficiency in ***Agro-Climatic Zone-III of*** Bihar TE 2010-11

Crop	n (Sample size)	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Cereal crops				
Paddy	190	0.68	0.60	0.41
Wheat	198	0.74	0.56	0.42
Maize (kharif)	17	0.88	0.84	0.74
Maize (rabi)	21	0.87	0.52	0.45
Pulse crops				
Gram	49	0.82	0.73	0.60
Lentil	102	0.40	0.71	0.28
Khesari	11	0.94	0.86	0.81
Kulthi	7	0.99	0.81	0.80
Oilseeds				
Rapeseed & mustard	7	0.99	0.73	0.72
Linseeds	8	1.00	0.76	0.76
Vegetables				
Brinjal	8	0.85	0.76	0.64
Cauliflower	8	0.94	0.65	0.62
Okra	8	0.94	0.87	0.82
Onion	11	0.92	0.77	0.71
Tomato	10	0.98	0.64	0.63
Potato	8	0.94	0.89	0.82
Cash crops				
Chilli	4	0.98	0.83	0.81

It was further investigated that there is ample scope to minimize the cost of production of some vegetables viz., brinjal, cauliflower and tomato as indicated by cost efficiency estimated as 0.64, 0.62 and 0.63, respectively. The other vegetables like okra & potato achieved/gained comparatively larger technical, allocative and cost efficiencies.

Chapter-IV

COST-RETURN ANALYSIS BASED ON MARKET PRICE, ECONOMIC PRICE AND NATURAL RESOURCE VALUATION TECHNIQUES

The performance of different crops was assessed by computing net returns under alternative scenarios. The alternative scenarios are (i) Market prices (ii) Economic prices net of subsidies; and (iii) Income based on natural resource valuation techniques (Raju *et al.,* 2015). For cost-return analysis of various crops grown in Bihar, the primary data concerning cost and returns for 450 sample farmers were obtained from Comprehensive Cost of Cultivation Scheme for the block year, 2008-11 for the state of Bihar. As the data of cost of cultivation was in binary format it was extracted into excel using SAS package for calculation of cost-returns data from various RTs (Record Types) of CCC Scheme and further the outliers in the extracted data were detected and accordingly corrected and finally used for further analysis.

Besides this, input-output data were also generated through survey of few crops like cabbage, cauliflower, tomato, chilli, sunflower, linseed, barely, ragi, kulthi (horse-gram) and onion for the year 2014-15 and further cost and returns for the above crops were deflated to 2008-11 price level.

Net return at market prices (NR_{MP})

Net returns at market prices is defined as the gross return (value of main product and by product) less variable costs (Cost A_1+ imputed value of family labour) at market prices actually paid and received by the farmer or imputed in some cases.

$$NR_{MP} = GR - VC$$

Where, NR_{MP}- Net return at market prices; GR- Gross Returns; VC-Variable Cost.

Cost A_1 includes

(a). Value of hired human labour

(b). Value of hired bullock labour

(c). Value of owned bullock labour (cost of maintenance and upkeep charges)

(d). Value of owned machinery labour (Upkeep charges)

(e). Hired machinery charges

(f). Value of seed

(g). Value of pesticides

(h). Value of manure

(i). Value of fertilizers (NPK)

(j). Irrigation charges (Canal)

(k). Depreciation of implements and farm buildings

(l). Land Revenue cess and other taxes (Total cess and taxes/GCA)

(m). Interest on working capital (@ 12.5% per annum)

(n). Miscellaneous expenses (other than input costs etc)

Net returns at economic prices (NR_{EP})

Net return at economic prices was defined as the difference between net return or income at market prices and subsidies on inputs like fertilizers, irrigation and seed used in crop production.

i.e. $$NR_{EP} = NR_{MP} - subsidy$$

Thus, subsidy component has been internalized into the model, by covering three aspects viz., fertilizers subsidy, irrigation subsidy and seed subsidy.

Fertilizer subsidy included subsidy on nitrogen, phosphorous and potassium. Fertilizer subsidy per kilogram was estimated at Rs. 19.347 per kg of N; Rs. 42.563 per kg of P& K for TE-2010-11. Quantity of fertilizers application for different crops under CCC Scheme for TE-2010-11 was used for calculation of subsidy on fertilizers.

Total irrigation (Groundwater) subsidy in rupees terms was calculated by taking number of hours pump operated, HP, pump efficiency, water level, friction losses and subsidy rate of diesel for different crops based on CCC Scheme data.

Ground water subsidy was estimated by initially calculating the crop wise ground water use i.e.

Ground water use (cubic meter) = Irrigation hours (hrs/ha) x Groundwater draft (cum/ha)

The irrigation hour (hrs/ha) for each crop was taken from plot wise CCC scheme data. The information of ground water draft was not available in CCC Scheme data. Hence, the groundwater draft was estimated using the formula:

$$Groundwater\ draft \left(\frac{lit}{sec}\right) = \frac{HP * 75 * pump\ efficiency}{Total\ head(m)}$$

The information on HP of the pumps owned by the farmers was available in CCC Scheme data set. Pump efficiency was assumed to be 40 percent. The total head was obtained as per equation:

$$\boldsymbol{Total\ head = Water\ level\ (mbgl) + Draw\ Down\ (m)}$$
$$\boldsymbol{+ Friction\ loss\ (10\%\ of\ water\ level) +\ Draw\ Down}$$

The ground water draft for each crop cultivated by farmers was computed. Further, the groundwater cost was estimated for diesel pump. Thus, the subsidy per hectare of groundwater use was estimated as the product of diesel used in extraction of groundwater and per liter subsidy rates during 2008-11 for diesel pumps (Srivastava *et al,* 2015).

Diesel subsidy @ Rs. 20 per liter in TE-2010-11 was used for calculation of groundwater subsidy.

Net returns based on natural resource valuation (NR_{NRV})

Net return based on Natural Resource Valuation (NRV) technique has taken care of nitrogen fixation by legume crops and Green House Gas (GHG) emission from crop production. As such NR_{NRV} is computed as by adding value of nitrogen fixation by legume crops at economic price of nitrogen and deducting the imputed value of GHG emission cost to the atmosphere.

i.e. $$\boldsymbol{NR_{NRV} = NR_{EP} +\ (value\ of\ N - Cost\ of\ GHG).}$$

Thus, legumes are environment-friendly crops and are different from other food plants because of property of synthesizing atmospheric nitrogen into plant nutrients. As such, the economic valuation has been done by taking into account the positive externality of legume crops by biological nitrogen fixation and negative externality of GHG emission.

The data on contribution of pulses by biological nitrogen fixation and emission of different crops were collected from various published scientific literatures, (Peoples *et al.,*1995, IIPR, 2003, IARI, 2014). The value of GHG emissions in terms of CO_2Kg equivalent was taken at the rate of 10 US dollar per tonne. Biological nitrogen fixation for various crops has been calculated by taking the average value of nitrogen fixed by various legumes and then multiplied with the economic price of nitrogen prevailed in the TE-2010-11.

Crop wise input subsidy in Bihar

Agricultural subsidies are the expenses actually made/paid by the government/nations for the benefit of the cultivators in the form of rebate for purchase of fertilizers, seeds, diesel and electricity etc to be used in production of crops. For the study, subsidies on fertilizers, seed and groundwater draft have been considered and thus, the estimated subsidies on the above items are presented in Table 11.

Perusal of the table revealed that among cereal crops, the maximum subsidy was used for rabi maize (Rs. 5106.28/ha) and the next on wheat (Rs. 4673.41/ha), barely (Rs. 4301.69/ha) and paddy (Rs. 2664.96/ha). In total subsidy, the NPK subsidy formed major share as compared to seed and irrigation subsidy. Larger groundwater irrigation subsidy was given on rabi maize (Rs. 1196.28/ha), followed by wheat (Rs. 801.45/ha), seed subsidy was higher (Rs. 201.94/ha) in case of wheat.

Among pulses crops, a larger amount of subsidy was put in khesari (Rs. 3393.26/ha) followed by gram (Rs. 2340.05/ha) and pea (Rs. 1958.29/ha) and so on. Comparatively higher subsidy regarding fertilizers (Rs. 3393.26/ha) was allocated on khesari followed by gram (Rs. 1839.31/ha) out of pulses under study. Comparatively higher amount of groundwater irrigation subsidy was given on moong (309.23/ha), followed by urad (Rs. 287.73/ha) and gram (Rs. 219.07/ha) and so on. Regarding seed subsidy, gram accounted for Rs. 281.67/ha which is larger.

Regarding oilseed crops under study, it was revealed that the total subsidy was much larger (Rs. 3829.12/ha) in case of rapeseed & mustard than other oilseed crops like linseed and sunflower under investigation.

Further examination of the table revealed that the total amount of subsidy was found relatively higher in case of potato (Rs. 7202.06/ha), followed by brinjal (Rs. 5351.35/ha), onion (Rs. 3910.60/ha), okra (Rs. 3343.07/ha) and so on.

Further, it was revealed that among cash crops, the total subsidy amount evaluated for sugarcane (planted) was found comparatively larger (Rs. 6501.75/ha), followed by ratoon sugarcane (Rs. 4138.05/ha), chilli (Rs. 3042.89/ha) and so on. Sugarcane being the most water consuming crop, it accounted for groundwater irrigation subsidy as Rs.724.0/ha which is higher as compared to Rs. 416.67/ha (Chilli) and Rs. 409.63/ha in sugarcane (ratoon). Comparatively larger amount of fertilizer subsidy was applied in planted sugarcane (Rs. 5777.65/ha).

Table 11: Crop wise input subsidy (Rs/ha) in Bihar

(Rs./ha)

Crop	NPK	Seed	Groundwater	Total subsidy
Cereal crops				
Paddy	2314.61	54.98	295.37	2664.96
Wheat	3670.01	201.94	801.45	4673.41
Maize(kharif)	2221.75	45.11	69.92	2336.78
Maize(rabi)	3833.20	76.80	1196.28	5106.28
Ragi	1802.17	0.00	183.33	1985.51
Barely	3762.80	0.00	538.89	4301.69
Pulses crops				
Gram	1839.31	281.67	219.07	2340.05
Lentil	1584.26	54.40	38.51	1677.17
Arhar	498.02	85.59	19.78	603.39
Kulthi(Horse gram)	1066.66	0.00	0.00	1066.66
Khesari	0.0	0.00	0.00	0.0
Moong	805.44	2.39	309.23	1117.06
Urad	702.94	83.50	287.73	1074.17
Pea	1747.28	54.59	156.43	1958.29
Oilseeds				
Rapeseed & mustard	3058.68	197.92	572.52	3829.12
Linseed	949.86	0.00	202.50	1152.36
Sunflower	1833.14	0.00	688.00	2521.14
Vegetables				
Brinjal	4983.70	0.00	367.65	5351.35
Cabbage	2438.79	0.00	267.00	2705.79
Cauliflower	2339.78	0.00	224.39	2564.17
Okra(Bhindi)	2825.88	0.00	517.19	3343.07
Potato	6093.91	0.00	1108.15	7202.06
Tomato	1150.38	0.00	1177.78	2328.16
Onion	1832.60	0.00	2078.00	3910.60
Cash crops				
Sugarcane(planted)	5777.65	0.00	724.10	6501.75
Sugarcane (ratoon)	3728.42	0.00	409.63	4138.05
Chilli	2626.23	0.00	416.67	3042.89
Jute	2517.97	0.00	277.41	2795.38

. Source: Estimated using unit level CoC data (TE 2010-11)

Notes: # Subsidy Rate @ Rs19.35/Kg of N; Rs 42.56/Kg of P&K combine for TE 2010-11 *Diesel Subsidy rate @20.00 per litre.
$ Seed subsidy on paddy rate @ Rs 7.00/Kg and Pulses Rs 20 .00/ Kg in 2008-09, 2009-10 and 2010-11, respectively

Zone wise input subsidy for crops

Input subsidies for different crops grown in different zones of the state were analyzed and are given in Table 11A, Table 11B and Table 11C.

Table 11A: Crop wise input subsidy (Rs/ha) in ***Agro-Climatic Zone-I*** of Bihar

(Rs./ha)

Crop	NPK	Seed	Groundwater	Total subsidy
Cereal crops				
Paddy	2222.87	22.98	370.79	2616.64
Wheat	4251.52	86.9	830.89	5169.30
Maize (kharif)	943.13	41.97	109.05	1094.15
Maize (rabi)	4081.70	48.89	1290.98	5421.57
Ragi	1985.27	0	287.50	2272.77
Barley	3762.80	0	538.89	4301.69
Pulses crops				
Arhar	369.56	44.88	27.69	442.13
Lentil	1414.43	13.83	0.30	1428.56
Moong	805.44	2.39	309.23	1117.06
Urad	702.94	83.5	287.73	1074.17
Pea	1747.28	54.59	156.43	1958.29
Oilseeds				
Rapeseed & mustard	3458.27	96.38	597.01	4151.66
Vegetables crops				
Brinjal	2685.18	0	300.00	2985.18
Cabbage	2096.29	0	500.00	2596.29
Cauliflower	1852.40	0	253.03	2105.43
Okra(Bhindi)	2601.73	0	666.67	3268.40
Potato	5843.10	0	1132.94	6976.04
Cash crops				
Sugarcane (planted)	5777.65	0.00	724.10	6501.75
Sugarcane(ratoon)	3728.42	0.00	409.63	4138.05
Chilli	2249.33	0	475.00	2724.33

Details of input subsidies in zone-I (Table 11A) indicated that among cereal crops, the farmers of the region utilized the higher subsidy (Rs. 5421.57/ha), in rabi maize followed by wheat (Rs. 5169.30/ha), barely (Rs. 4301.69/ha) and paddy (Rs. 2616.64/ha). Among pulses crops, pea, lentil and moong were identified as larger user of subsidies (Rs. 1958.29/ha, Rs. 1428.56/ha & Rs. 1117.06/ha, respectively) in its cultivation. Among vegetables, potato was considered as heavy consumer of subsidies (Rs.6967.04/ha) than other vegetable crops like okra (Rs. 3268.40/ha), brinjal (Rs. 2985.18/ha) and so on. Among cash crops, it was sugarcane (planted) which required larger amount of subsidy (Rs. 6501.75/ha), followed by ratoon sugarcane (Rs. 4138.05/ha) and so on.

For agro-climatic zone-II, the crop-wise input subsidy has been depicted in Table 11B and explained that similar to that zone-I, among cereal crops, maize accounted for larger subsidy (Rs. 7756.77/ha), followed by wheat (Rs.3769.44/ha) and paddy only Rs. 1546.85/ha. Out of total subsidy, the share of fertilizer subsidy was much higher to that of groundwater and seed. Since this zone is known as the traditional area of sunflower production, thus the total subsidy used by this crop is Rs. 5855.77/ha. The cash crops such as jute, commonly grown this area needs considerably more water in production and processing, subsidy used on this crop has been estimated Rs. 2795.38/ha.

Table 11B: Crop wise input subsidy (Rs/ha) in ***Agro-Climatic Zone-II*** of Bihar

(Rs./ha)

Crop	NPK	Seed	Groundwater	Total subsidy
Cereals crops				
Paddy	1375.381	12.35	159.1201	1546.851
Wheat	3077.649	35.14	656.6499	3769.439
Maize	6530.014	38.24	1188.52	7756.774
Pulses crops				
Lentil	554.0118	3.61	0	557.6218
Oilseeds				
Sunflower	5330.77	0.00	525.00	5855.77
Cash crops				
Jute	2517.971	0	277.4074	2795.378

For zone-III, the Table 11C has illustrated the input subsidy for different crops produced in the zone and depicted that the subsidy on fertilizers was found to be comparatively very high, followed by groundwater subsidy and least on seed subsidy except for onion crop which expended more subsidy on groundwater (Rs. 2078.00/ha), followed by fertilizer (Rs. 1832.60/ha) because the requirement of water in onion cultivation is comparatively high. The other crop tomato in which subsidy on groundwater (Rs. 1177.78/ha) also exceeded the subsidy on fertilizers (Rs. 1150.38/ha).

Table 11C: Crop wise input subsidy (Rs/ha) in ***Agro-Climatic Zone-III*** of Bihar

(Rs./ha)

Crop	NPK	Seed	Groundwater	Total subsidy
Cereals crops				
Paddy	3108.07	20.11	305.51	3433.69
Wheat	3187.26	80.57	819.66	4087.49
Maize(kharif)	3386.30	37.8	0.00	3424.10
Maize(rabi)	5034.40	37.8	657.78	5729.98
Ragi	1217.68	0.00	423.75	1641.43
Pulses crops				
Gram	1839.31	281.67	219.07	2340.05
Lentil	1674.91	36.95	66.46	1778.32
Arhar	0.00	37.58	0.00	37.58
Kulthi(Horse gram)	1066.45	0.00	0.00	1066.45
Khesari	0.00	0.00	0.00	0.00
Oilseeds				
Rapeseed & mustard	766.43	47.56	425.61	1239.60
Linseed	949.8572	0	202.50	1152.36
Vegetables crops				
Brinjal	7280.26	0.00	400.00	7680.26
Cabbage	3189.22	0.00	208.75	3397.97
Cauliflower	2947.98	0.00	208.89	3156.86
Okra(Bhindi)	3222.05	0.00	427.50	3649.55
Potato	7293.50	0.00	978.00	8271.50
Tomato	1150.38	0.00	1177.78	2328.16
Onion	1832.60	0.00	2078.00	3910.60
Cash crops				
Chilli	3284.37	0.00	300.00	3584.37

It was further observed that similar to that earlier both zones (I &II), the expenditure on subsidy was estimated comparatively high on rabi maize (Rs. 5729.98/ha), followed by wheat (Rs. 4087.49/ha) and paddy (Rs. 3433.69/ha). Among pulses crops, gram and lentil crops required and used more subsidies such as Rs. 2340.05/ha and Rs. 1778.32/ha, respectively. Among oilseeds, the subsidy expenditure on rapeseed and mustard was calculated as Rs. 1239.60/ha and linseed (Rs. 1152.36/ha). So far as vegetable crops are concerned, it was assessed that the cultivation of potato required much subsidy i.e. Rs. 8271.50/ha, followed by brinjal (Rs.7680.26/ha), these two crops are heavy feeder of fertilizers, therefore the extent of subsidies on these crops are high. The use of subsidies on other vegetable crops such as okra, cabbage and cauliflower are Rs. 3649.55/ha, Rs. 3397.97/ha and Rs. 3156.86/ha, respectively.

From the above discussion, it may be pointed out here that:

- The use of subsidy on paddy was comparatively larger in zone-III as compared to zone-I and zone-II.
- Subsidy on wheat was found higher in zone-I as compared to zone-III and zone-II.
- Subsidy on rabi maize was observed high in zone-II as compared to zone-III and zone-I
- Subsidy on lentil was high in zone-III as compared to zone-I and zone-II
- Subsidy used in the cultivation of potato was higher in zone-III than that of zone-I.

Nitrogen fixation and GHG emission

It is proven fact that biological nitrogen fixation is generally done by pulses crops and it helps to supplement the requirement of nitrogen for succeeding crops to be grown. Hence, the biological nitrogen fixed by the pulses crops must be taken into account while estimating the cultivation cost of succeeding crops. On the other hand, presently the Green House Gas (GHG) emission has been considered as one of the important source for global warming and environmental pollution and thus, it is considered as social cost for society resulting in health hazard of human beings. Various experimental results have revealed that agricultural crops also emit GHG in the form of CO_2 and CH_4 and ultimately add to the global warming. This factor should also be accounted for in estimating the cultivation cost of different crops in order to ensure the fact that how much does it cost to society? Nitrogen fixation and GHG emission (in value terms) for different crops are presented in Table 12.

Perusal of the table revealed that the biological nitrogen fixation was found comparatively higher for arhar (Rs. 3414/ha), followed by gram (Rs 3140/ha), urad (Rs. 2506/ha), moong (Rs. 2235/ha), lentil (Rs. 1993/ha) and pea (Rs. 1389/ha).

Among cereal crops, the value of GHG emission was evaluated highest in case of paddy (Rs. 1838/ha), followed by wheat (Rs. 182.50/ha), for both seasons maize (Rs. 158.50/ha) and ragi (111.50/ha). In case of pulses crops, comparatively larger value of GHG emission was observed in pea (Rs. 235.00/ha) and Rs 97/ha for rest other pulses crops such as gram, lentil, arhar, kulthi, khesari, moong and urad. Among oilseeds, the value of emission was recorded Rs. 144.50/ha in case of sunflower and Rs.114.50/ha for both rapeseed and mustard and linseed. In case of vegetables, the value of emission of GHG was revealed Rs. 235.00/ha for each vegetables as well as chilli.

Table 12: Crop wise nitrogen fixation and GHG emission (Rs/ha)

SL No.	Crops	Value of Nitrogen fixation (A)	GHG cost (B)	Net NRV effect (A-B)
Cereal crops				
1.	Paddy	0.00	1838.00	-1838.00
2.	Wheat	0.00	182.50	-182.50
3.	Maize(kharif)	0.00	158.50	-158.50
4.	Maize(rabi)	0.00	158.50	-158.50
5.	Ragi	0.00	111.50	-111.50
6.	Barely	NA	NA	NA
Pulse crops				
7	Gram	3140.00	97	3043.00
8.	Lentil	1993.00	97.00	1896.00
9.	Arhar	3414.00	97.00	3317.00
10.	Kulthi(Horse gram)	0.00	97.00	-97.00
11.	Khesari	0.00	97.00	-97.00
12.	Moong	2235.00	97.00	2138.00
13.	Urad	2506.00	97.00	2409.00
14.	Pea	1389.00	235.00	1154.00
Oilseeds				
15.	Rapeseed & mustard	0.00	114.50	-114.50
16.	Linseed	0.00	114.50	-114.50
17.	Sunflower	0.00	144.50	-144.50
Vegetable crops				
18.	Brinjal	0.00	235.00	-235.00
19..	Cabbage	0.00	235.00	-235.00
20.	Cauliflower	0.00	235.00	-235.00
21.	Okra(Bhindi)	0.00	235.00	-235.00
12.	Potato	0.00	235.00	-235.00
23.	Tomato	0.00	235.00	-235.00
24.	Onion	0.00	235.00	-235.00
Cash crops				
26.	Sugarcane(planted)	NA	NA	NA
27.	Sugarcane (ratoon)	NA	NA	NA
28.	Chilli	0.00	235.00	-235.00
29.	Jute	NA	NA	NA

NA- Not available

Cost and returns

(a) Cost and returns of crops at market prices (MP)

Net return is considered as the reward for entrepreneur. Net return or profit is the barometer for the measurement of success or failure of business activity. Variable costs, gross returns and net returns over variable cost have been estimated and presented in Table 13.

An examination of the table revealed that among cereal crops, comparatively larger cost was found in case of rabi maize (Rs 15889.83 per ha), followed by barely (Rs. 15185.34 per ha), wheat (Rs. 14022.78per ha) and ragi (Rs 13564.44 per ha). Net returns over variable costs were estimated to be comparatively higher in rabi maize (Rs 30908.69/ha), followed by barely (Rs 16627.41/ha), wheat (Rs 13707.29/ha) and paddy (Rs 10396.80/ha). It is important to note here that paddy, wheat and maize are the major cereal crops grown in the state of Bihar.

Among pulses crop, the variable costs incurred in the production of pea was calculated Rs. 14028.15 per ha, comparatively higher as compared to other pulse crops such as moong (Rs. 11418.42/ha), gram (Rs.9907.29/ha) and so on. Per hectare net return was obtained comparatively higher for arhar (Rs 28108.37/ha), followed by lentil (Rs. 23416.47/ha), gram (Rs. 15986.13), urad (Rs. 13060.43/ha) and so on.

Among oilseeds, the net income in case of rapeseed & mustard was accounted for Rs. 17618.55/ha over variable cost Rs. 10204.09/ha, whereas in sunflower, it was only Rs. 5263.25/ha over variable cost Rs. 10586.54/ha.

As many types of vegetables are grown in the state because these are more remunerative crops. The cost of cultivation of vegetable crops were estimated and observed relatively larger in tomato (Rs. 40446.81/ha), followed by potato (Rs. 38254.21/ha), onion (Rs. 38116.64/ha), brinjal (Rs. 33422.34/ha) and so on. On the other hand, the profit level to vegetable cultivators was found to be higher in onion (Rs. 102706.29/ha), followed by okra (Rs. 78716.52/ha), brinjal (Rs. 66467.24/ha), cauliflower (Rs. 47887.97/ha, potato (Rs. 41724.26/ha), tomato (Rs. 35216.96/ha) and so on.

While examining the cost and returns of cash crops at market prices, it was studied that the cultivation cost of growing sugarcane (planted), chilli, jute and sugarcane (ratoon) were accounted for Rs. 26652.29/ha, Rs. 23798.47/ha, Rs. 15222.46 and Rs. 12195.75/ha, respectively. The net income in growing sugarcane (planted), chilli and jute were assessed to be Rs. 67728.58/ha, Rs. 64887.21/ha and Rs. 4622.76/ha).

Table 13: Comparative cost and returns of different crops at alternative price scenario in Bihar (TE-2010-11)

(Rs/ha)

Crops	n (No. of observations)	Gross returns	Variable cost	Net returns at market prices	Net returns at economic prices	Net returns at NRV prices
Cereals crops						
Paddy	3186	22902.09	12505.29	10396.80	7731.84	5893.84
Wheat	2833	27730.08	14022.78	13707.29	9033.89	8851.39
Maize(kharif)	142	19352.88	9346.17	10006.70	7669.92	7511.42
Maize(rabi)	331	46798.52	15889.83	30908.69	25802.42	25643.92
Ragi	12	15996.16	13564.44	2431.72	446.22	334.72
Barely	8	31812.76	15185.34	16627.41	12325.72	12325.72
Pulses crops						
Gram	148	26408.34	9907.29	15986.13	13646.08	16689.08
Lentil	486	30187.59	6771.12	23416.47	21739.30	23635.30
Arhar	21	35692.14	7583.77	28108.37	27504.98	30821.98
Kulthi(Horsegram)	8	14654.57	7646.67	7007.90	5941.24	5844.24
Khesari	24	13232.46	6319.48	6912.98	6912.98	6815.98
Moong	13	18974.95	11418.42	7556.52	6439.46	8577.46
Urad	12	22559.40	9498.97	13060.43	11986.26	14395.26
Pea	7	23691.67	14028.15	9663.52	7705.23	8859.23
Oilseeds						
Rapeseed & mustard	127	27822.64	10204.09	17618.55	13789.43	13674.93
Linseed	8	15894.31	9161.05	6733.26	5580.90	5466.40
Sunflower	14	15849.79	10586.54	5263.25	2742.12	2597.62
Vegetable crops						
Cabbage	7	53380.47	25094.16	28286.31	25580.52	25345.52
Brinjal	18	99889.58	33422.34	66467.24	61115.89	60880.89
Cauliflower	20	72075.36	24187.39	47887.97	45323.80	45088.80
Okra(Bhindi)	16	98405.36	19688.83	78716.52	75373.46	75138.46
Potato	98	79978.46	38254.21	41724.26	34522.19	34287.19
Tomato	15	75663.77	40446.81	35216.96	32888.80	32653.80
Onion	20	140822.93	38116.64	102706.29	98795.69	98560.69
Cash crops						
Sugarcane(planted)	25	94380.87	26652.29	67728.58	61226.83	61226.83
Sugarcane (ratoon)	30	43192.66	12195.75	30996.91	26858.86	26858.86
Chilli	12	88685.68	23798.47	64887.21	61844.32	61609.32
Jute	9	19845.23	15222.46	4622.76	1827.39	1827.39

Thus, it was inferred that among cereal crops, rabi maize was proved to be more remunerative crop, while among pulses, arhar, lentil, gram &urad fetched more net income to cultivators. Among oilseeds, rapeseed and mustard was considered as the most profitable enterprise. While discussing vegetables, almost all vegetable crops under study were found to be remunerative to the cultivators. Similarly, cash crops like sugarcane (planted), chillis were observed to be high income growing enterprise.

(b) Net returns based on economic prices (EP)

Net returns by economic prices are worked out by subtracting the total subsidy from the net income at market prices of different crops. Total subsidy includes seed subsidy, fertilizer (NPK) subsidy and irrigation subsidy (diesel subsidy). While estimating the net income at economic prices of different crops, the amount of subsidy must be considered and thus added to the cost structure or deducted from the net income at market prices. The idea behind it is that if the Government had not provided the subsidy that would have been actually paid by the farmers/ cultivators. Subsidies are reckoned as the expenditure made by the nation for the benefit of the people of that nation or in other words, subsidies are the national expenses for the purpose of benefits for nation's people. Analysis of net returns based on economic prices has been presented in Table 13.

Among cereal crops, the net returns by economic prices for different crops were found to be Rs. 25802.42/ha, Rs. 12325.72/ha, Rs. 9033.89/ha and Rs. 7331.84/ha for rabi maize, barley, wheat and paddy, respectively.

Among pulses crop, net return by economic prices came out to be Rs. 27504.98/ha in case of arhar, Rs. 21739.30/ha (lentil), Rs. 13646.08/ha (gram) and Rs. 11986.26/ha for urad.

Regarding oilseeds crop under study, it was revealed that the rapeseed and mustard, linseed and sunflower accounted for net returns Rs. 13789.43/ha, Rs. 5580.90/ha and Rs. 2742.12/ha, respectively at economic prices.

Further examination of the earlier table revealed that the NPK had major share in total subsidy. The trend of net incomes by economic prices was observed to be different from the trend of amount of total subsidy. Comparatively higher net income by economic prices was garnered by onion (Rs. 98795.69/ha), followed by okra (75373.46/ha), brinjal (Rs. 61115.89/ha), cauliflower (Rs. 45323.80/ha), potato (34522.19/ha), tomato (Rs. 32888.80/ha) and cabbage (Rs. 25580.52/ha).

Analyzing the net returns using the economic prices, it was revealed that among the cash crops under study, it was found that the chilli crop fetched comparatively higher income (Rs. 61844.32/ha), followed by sugarcane (planted) (Rs. 61226.83/ha), sugarcane (ratoon) (Rs. 26858.86/ha).

(c) Net return based on natural resource valuation (NRV)

Net returns based on natural resource valuation consists of two components i.e. returns by adding economic value of nitrogen (A) and returns by deducting cost of GHG emissions (B). As it has been revealed by the many researchers that the biological nitrogen fixation is carried out by different pulse crops, which are utilized by the succeeding crops grown. The concept behind it is that the biological nitrogen fixation by pulses are made available to succeeding crops and further, while estimating the net returns of succeeding crops, the biological nitrogen fixation must be taken into account. Another component, GHG emission refers to Green House Gas emission. Many experiments have manifested/proved that GHG in the form of CH_4, CO_2 etc are emitted by different agricultural crops such as paddy, wheat etc., which thus add to environment/climate(stimulates the climate change) and ultimately forms the cost to the society or phrase it as social cost to the nation. Hence, the cost of GHG emission must be taken into account or deducted from the returns by economic prices while estimating the net returns based on NRV. Net returns based on natural resource valuation have been presented in Table 13.

Since the biological nitrogen fixation is done by pulse crops only, hence there were changes in the returns of pulse crops only due to addition of economic value of nitrogen to net returns by economic prices and for rest crops, it remained same as that of the net returns estimated at economic prices. In other words, the net NRV effect (A-B) is added to net return at economic prices to arrive at net return on natural resource valuation (NRV). The values of biological nitrogen fixation are given in Table 12. It was observed that the net returns based on NRV were worked out by deducting the cost of GHG emission and adding economic value of nitrogen to net return at economic prices (EP) of different crops.

Further, the net returns based on NRV among cereal crops were imputed comparatively larger in rabi maize (Rs. 25643.92/ha), followed by barely (Rs. 12325.72/ha), wheat (Rs. 8851.39/ha), and paddy (Rs. 5893.84/ha). This is important to note here that GHG emission by paddy & wheat are much larger as compared to other crops. For barely, the GHG emission was not available.

Among pulses, the net returns (NRV) for arhar, lentil, gram, urad and pea were found to be Rs. 30821.98/ha, Rs. 23635.30/ha, Rs. 16689.08/ha, Rs. 14395.26/ha and Rs.8859.23/ha, respectively.

Regarding oilseeds, the GHG emissions are meagre, henceforth the net returns (NRV) came out as Rs. 13674.93/ha for rapeseed & mustard and Rs. 5466.40/ha in case of linseed.

While discussing the NRV net returns regarding vegetable crops, it was observed that due to less GHG emission, the net returns (NRV) were assessed Rs. 98560.59/ha (onion), Rs.75138.46/ha (Okra), Rs. 60880.89/ha (brinjal), Rs. 45088.80/ha (cauliflower), Rs. 34287.19/ha (potato) and Rs. 32653.80/ha for tomato.

For cash crops, the net income (NVR) for chilli, sugarcane (planted), sugarcane (ratoon) and jute were generated for Rs. 61609.32/ha, Rs. 61226.83/ha, Rs. 26858.86/ha and Rs. 1827.39/ha, respectively. This is to mention here that the GHG emission for jute and sugarcane crops were not available.

Zone-wise cost and returns

Zone wise costs and returns for different crops at alternative prices (i.e. at market price, economic price and NRV price) are presented in Table 13A, Table 13B and Table 13C.

Perusal of the Table 13A revealed that in zone-I, among cereals crops, the net return at NRV was obtained Rs. 14846.60/ha in case of rabi maize, followed by barely Rs. 12325.72/ha and so on during the period TE-2010-11. Among pulses crops, arhar crop fetched the largest income Rs. 29777.75/ha, followed by lentil (Rs. 26463.09/ha), urad (Rs.14395.26/ha) etc. The net income at NRV of rapeseed and mustard crop was assessed Rs. 14667.26/ha in the zone. Further among vegetables, the estimation of profit at NRV for okra was found Rs. 177167.60/ha, followed by cauliflower (Rs.39013.89/ha), potato (Rs. 32686.36/ha) and so on during the period of investigation. Among cash crops, chilli accounted for Rs. 77595.10/ha net income, followed by planted sugarcane crop (Rs. 61226.83/ha) during the period under study.

Table 13B revealed that profitability from different crops at different alternative prices during TE-2010-11 in zone-II which is vulnerable to floods. The net income at NRV for rabi maize was evaluated comparatively high as much as Rs. 47077.69/ha, followed by wheat (Rs. 9374.53/ha) and paddy (Rs.1801.44/ha). The lentil crop showed the net income at NRV being Rs. 24328.50/ha during the period as mentioned above. The net return at NRV in case of sunflower was recorded Rs. 5321.18/ha during the study period. Further, jute crop earned the benefit of Rs. 1827.39/ha during the same period as above.

Table 13A: Comparative cost and returns of different crops at alternative price scenario in ***Agro-Climatic zone-I of*** Bihar (TE-2010-11)

(Rs/ha)

Crops	n (No. of observations)	Gross returns	Variable cost	Net returns at market prices	Net returns at economic prices	Net returns at NRV prices
Cereal crops						
Paddy	1252	21429.61	12573.09	8856.52	6239.88	4401.88
Wheat	1089	28455.29	14319.93	14135.37	8966.06	8783.56
Maize (kharif)	84	12341.03	8280.56	4060.48	2966.33	2807.83
Maize (rabi)	196	35764.52	15337.85	20426.67	15005.10	14846.60
Ragi	8	18231.73	15333.79	2897.93	625.17	513.67
Barley	8	31812.76	15185.34	16627.41	12325.72	12325.72
Pulses crops						
Arhar	15	35798.74	8893.85	26904.89	26462.75	29777.75
Lentil	134	32663.66	6668.02	25995.65	24567.09	26463.09
Moong	13	18974.95	11418.42	7556.52	6439.46	8577.46
Urad	12	22559.40	9498.97	13060.43	11986.26	14395.26
Pea	7	23691.67	14028.15	9663.52	7705.23	8859.23
Oilseeds						
Rapeseed & mustard	107	29929.89	10996.47	18933.42	14781.76	14667.26
Vegetable crops						
Brinjal	9	42975.39	23351.40	19623.99	16638.81	16403.81
Cabbage	3	57343.00	40533.40	16809.60	14213.30	13978.30
Cauliflower	11	63789.74	22435.42	41354.33	39248.89	39013.89
Okra(Bhindi)	6	198712.61	18041.61	180671.00	177402.60	177167.60
Potato	78	76692.16	36794.76	39897.40	32921.36	32686.36
Cash crops						
Sugarcane (planted)	25	94380.87	26652.29	67728.58	61226.83	61226.83
Sugarcane (ratoon)	30	43192.66	12195.75	30996.91	26858.86	26858.86
Chilli	8	105991.37	25436.94	80554.43	77830.10	77595.10

Table 13B: Comparative cost and returns of different crops at alternative price scenario in ***Agro-Climatic zone-II of*** Bihar (TE-2010-11)

(Rs/ha)

Crops	n (No. of observations)	Gross returns	Variable cost	Net returns at market prices	Net returns at economic prices	Net returns at NRV prices
Cereal crops						
Paddy	499	16446.93	11260.64	5186.29	3639.44	1801.44
Wheat	412	27022.59	13696.12	13326.47	9557.03	9374.53
Maize(rabi)	102	72193.64	17200.67	54992.97	47236.19	47077.69
Pulses crops						
Lentil	71	30939.24	8046.11	22893.12	22335.5	24328.50
Oilseeds						
Sunflower	14	23843.75	12552.30	11291.45	5435.68	5321.18
Cash crops						
Jute	9	19845.23	15222.46	4622.76	1827.39	1827.39

Cost returns analysis of different crops in zone-III as presented in Table 13C pointed out that among cereal crops, the highest net return accrued in kharif maize i.e. Rs. 7332.23/ha, followed by paddy (Rs. 6848.21/ha), wheat (6096.90/ha) and ragi (Rs. 3490.64/ha) during the period TE-2010-11. The per hectare net returns at NRV for zone-III was estimated comparatively larger i.e. Rs. 35508.67 for arhar, followed by lentil (Rs. 21411.51 and gram Rs. 16689.08 and so on during the above period. The net income (NRV) in rapeseed & mustard was observed comparatively higher Rs. 6947.53/ha as compared to linseed crop i.e. only Rs 5466.40/ha. Among vegetables, the net income per hectare at natural resource valuation (NRV) during TE-2010-11 was observed comparatively higher as much as Rs. 105642.17 per hectare in case of brinjal, followed by Rs. 98560.69/ha (onion) and so on during the investigation period.

From the foregoing discussion, it may be pointed out that:

- The net income of paddy was higher in zone-III as compared to zone-I and zone-II
- The net income from wheat was recorded comparatively larger in zone-II with respect to zone-I & zone-III.
- Rabi maize accounted for more net income in zone-II followed by zone-I and zone-III.
- Zone-III fetched more net income for kharif maize than that of zone-I.
- Net income from lentil was observed comparatively more in zone-I as compared to Zone-II and Zone-III.
- Per hectare income from rapeseed & mustard was high in zone-I than zone-III.
- Potato was more profitable in zone-III than that of zone-II.
- Chilli fetched more net income in zone-I than zone-III.

Table 13C: Comparative cost and returns of different crops at alternative price scenario in ***Agro-Climatic zone-III of*** Bihar (TE-2010-11)

(Rs/ha)

Crops	n (No. of observations)	Gross returns	Variable cost	Net returns at market prices	Net returns at economic prices	Net returns at NRV prices
Cereal crops						
Paddy	1435	26711.52	14591.63	12119.90	8686.21	6848.21
Wheat	1332	27293.93	16927.04	10366.89	6279.40	6096.90
Maize(kharif)	58	25837.59	14922.76	10914.83	7490.73	7332.23
Maize(rabi)	33	33839.78	25947.78	7892.00	2162.02	2003.52
Ragi	4	13399.97	8156.41	5243.56	3602.14	3490.64
Pulse crops						
Gram	148	26408.34	10422.21	15986.13	13646.08	16689.08
Lentil	281	28816.90	7523.08	21293.83	19515.51	21411.51
Arhar	6	35425.64	3194.39	32231.25	32193.67	35508.67
Kulthi(Horse gram)	8	14654.57	7646.67	7007.90	5941.45	5844.45
Khesari	24	13232.46	6319.48	6912.98	6912.98	6815.98
Oilseeds						
Rapeseed & mustard	20	15179.19	6877.55	8301.63	7062.03	6947.53
Linseed	8	15894.31	9161.05	6733.26	5580.90	5466.40
Vegetable crops						
Brinjal	9	156783.54	43226.11	113557.43	105877.17	105642.17
Cabbage	4	50754.75	25818.63	24936.12	21538.15	21303.15
Cauliflower	9	78198.06	26274.86	51923.20	48766.34	48531.34
Okra(Bhindi)	10	48034.45	20954.65	27079.80	23430.25	23195.25
Potato	20	97231.55	48068.88	49162.67	40891.16	40656.16
Tomato	15	75663.77	40446.81	35216.96	32888.80	32653.80
Onion	20	140822.93	38116.64	102706.29	98795.69	98560.69
Cash crops						
Chilli	4	54028.48	20574.72	33453.75	29869.38	29634.38

Chapter-V

STATUS OF NATURAL RESOURCES AND SCOPE FOR REVISING CROP PLAN

Land degradation

The extent of land degradation in Bihar is depicted in Table 14 and it was indicated that the total degraded land in the state is about 1371 thousand hectares. Out of the total degraded lands, water erosion covered nearly 76.51 percent, secondly the waterlogged and marshy land (permanent) accounted for 9.34% of the total degraded area in the state during TE-2010-11. Further the share of sodic soils was estimated 7.73%, followed by saline soils (3.28%), acidic soils (2.99%) and mining/industrial waste lands.

Table 14: Extent of land degradation in Bihar TE 2010-11

Category of land	Area (000 ha)	Share in total geographical area (%)	Share in total degraded land (%)
Water erosion	1049	11.1	76.51
Acid soils	41.0	0.44	2.99
Wind erosion	-	-	-
Saline soils	45	0.48	3.28
Sodic soils	106	1.13	7.73
Mining/industrial waste lands	2	0.02	0.15
Waterlogged and marshy land (permanent)	128	1.36	9.34
Total degraded land	1371	14.56	100
Total geographical area	9360	100.00	

Source: Report of National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur June-2010

Status of water resources

The existing water resources in the state during the period TE-2010-11 has been given in Table 15. Annual replenishable groundwater resources in the state are constituted by two components such as (i) from rainfall and from (ii) other sources. Further, it was observed that the state consists of annual replenishable groundwater resources equal to 29.34 billion cubic meters (BCM). As much as 22.94 BCM groundwater is annually recharged by rainfall and only 6.39 BCM by other sources. Natural discharge of groundwater was estimated 2.47 BCM and thus 26.86 BCM net annual groundwater is available which may be utilized for irrigation and domestic consumption purposes.

Table 15: Status of water resources in Bihar TE 2010-11

Particulars	**Value (BCM)**
Total available surface water resources (BCM)	-
Annual replenishable groundwater resources#	29.34
From rainfall	22.94
From other sources	6.39
Natural discharge	2.47
Net annual groundwater availability	26.86
Total utilizable water resources (surface + groundwater)	-

Source: Groundwater Scenario of India, 2009-10, Central Groundwater Board, June 2010

Irrigation potential created and utilized

Since irrigation water is considered as the vital input for the crop production. Irrigation water is one of the determinants for change in the productivity of different crops. Hence, ultimate irrigation potential, irrigation potential created and irrigation potential utilized in the state of Bihar are presented in Table 16. Perusal of the table displayed the fact that during Sixth Five Year Plan (1980-85), extent of irrigation potential utilized was 103.16% of total irrigation potential created during the period under study. In case of groundwater, the share of irrigation potential utilized was 137.54% of irrigation potential created during the period under study, whereas of IPU in IPC was found 82.53% in case of surface water. During 10th Five Year Plan, it was observed that overall share of IPU in IPC was accounted for 60.82%. Further, it was studied that in case of surface water, it (share of IPU in IPC) was 62.45%, while in case of groundwater; it claimed 59.59 percent during the period under study

Table16: Ultimate irrigation potential (UIP), irrigation potential created (IPC) and irrigation potential utilized (IPU) in Bihar

Irrigation project	**UIP (000 ha)**	**Share of IPC in UIP (%)**		**Share of IPU in IPC (%)**	
		VI FYP (1980-85)	**X FYP (2002-07)**	**VI FYP (1980-85)**	**X FYP (2002-07)**
Surface	6768	3736 (55.20)	3561.9 (52.63)	3084 (82.53)	2224.5 (62.45)
Groundwater	4120	2232 (54.17)	4486 (108.88)	3070 (137.54)	2670.8 (59.59)
Total	10888	5968 (54.81)	8047.9 (73.92)	6154 (103.16)	4895.3 (60.82)

FYP: Five year plan
Data source: Water and related statistics, CWC 2010

Categorization of blocks based on water development

Various blocks existing in the state were categorized on the basis of water development made so far and have been presented in Table 17.

Table17: Categorization of blocks based on groundwater development 2010-11

Source: Groundwater Scenario of India, 2009-10, Central Groundwater Board, June 2010

Category	Number of blocks	Share of total assessment units(%)
Safe	529	99.0
Semi-critical	4	1.0
Critical	-	-
Over-exploited	-	-
Total assessment units	533	100.0

It was observed from the table that 533 blocks of the state were assessed and it was found that 99 percent blocks were found to have safe groundwater and only 1% blocks were in semi-critical categories.

Scope for Revising Crop Plan

Bihar agriculture is facing many challenges viz., shrinking net sown area non-availability of quality seeds, major irrigation through diesel pump sets (more costly), inadequate storage facilities, inadequate processing industries for agricultural produces, poor marketing infrastructure, scarcity of labour as well as erratic behavior of monsoon etcetera. Extraction of groundwater for irrigating the crops is assessed as very low as compared to the availability of sufficient groundwater in the state.

Table 18: Groundwater resources availability and utilization in Bihar

State/Zones	Groundwater availability (BCM)	Annual Groundwater draft for irrigation (BCM)	Net Groundwater availability for future irrigation (BCM)
Zone-I	10.83	4.44	5.16
Zone-II	5.79	2.12	3.14
Zone-III	9.65	3.70	5.80
Bihar	26.27	10.26	14.10

Source: GWB, Patna 2011

It is reflected by the fact that the groundwater development is only 44% in the state; this means that only 44% of available groundwater is utilized for irrigating the crops. On the other hand, it is noted that the net sown area in the state has shrunken over the time. It has been observed almost stagnation in the productivities of almost crops grown in the state. Due to erratic nature of monsoon mostly during first decade of the present century, the water table is going down in different parts of the state; the most affected zone is agro-climatic zone-III. The areas under almost crops except wheat, maize, sugarcane and potato, have declined over the period under study (TE-1973 –TE-2013). The productions of most of the crops were found to be remaining stagnant over the study periods. Under these conditions, the question here arises ‘how to maximize the income of the farming community of the state out of shrinking net sown area with the use of cheap sources of energy for groundwater extraction i.e. electric or solar energy which are comparatively cheap than diesel energy. Further, repairing and maintenance and expansion of surface irrigation system (canal) are very much essential for augmenting irrigation, recharge of groundwater as well as lessen the dependency on worsening weather situation. Here effort is being made to maximize the income of the cultivators from raising the crops, considering the important constraints viz., land constraints and water constraints. Land constraint uses allocation of the minimum and maximum area for each crop grown in the state, assuming the considerable area under major staple food crops (paddy, wheat and maize etc.) from the food security point of view in the state. Regarding groundwater constraint, two situations of groundwater uses are considered such as income maximization at existing groundwater use and secondly, when the groundwater use is increased more than existing level. However, it is felt that what methods/ devices should be used to draft a desired level of groundwater at minimum cost in order to maximize the cultivator income. The diesel energy used for irrigating the crops is much costlier than electricity and releases CO_2 and in turn also helps to push up surroundings environmental pollution level. The utilization of cheap source of energy such as electricity/solar will certainly raise the income level of farming community in general and on the other hand, the national exchequer also, in particular.

Chapter-VI

OPTIMIZATION OF CROP MODEL

Agriculture sector is a key driver in the development of economic and social condition of not only the nation but of the whole world. Agriculture depends on water and land resources. The supply of land and water for irrigation in right time and right quantity for various crops is the vital requirement for optimum agricultural production. Climate change exacerbates the water allocation for different crops in the country particularly water consuming crops like paddy, wheat, maize and sugarcane etc. Water table is going down day by day. In many parts of the state even in country, people are facing water scarcity for their day to day uses. The population pressure is increasing at rapid speed. Due to urbanization and developmental activities and a reluctance to disturb natural environments there is a difficult task to bring more area under cultivation. In this condition feeding the ever-rising population i.e. food security is the biggest challenge worldwide. The role of optimization of agricultural produces with minimal uses of other resources and thinking for our coming generation is highly emphasized by the international community, in particular developing nations, optimal crop model would be of great importance to struggle in coping with the impact of global climate change and nutritional security and sustainability of the natural resources for future existence of human beings. Many researchers have also found optimal crop plan beneficial and income enhancing measure for the farming community. Some of the reviews about the optimal uses of resources are discussed below:

Dahiphale *et al.,* (2015) in his study on optimal cropping patterns for Jaisamand command of Udaipur district in Rajasthan, India, applied a software LINGO (Linear programming Software) to allocate the area for production maximization and found that the area allocated for different crop activities in 9, 18, 21, 24 and 30 canal running days was obtained. The optimal food production for maize, soyabean, moong, wheat, mustard, gram and barely in 9, 18, 21, 24 and 30 canal running days obtained as 33454.94, 70278.44, 68505.53, 71987.65 and 72082.02 tonnes with investment of 403.00, 773.78, 797.67, 845.09 and 851.22 million rupees, respectively. The net benefit obtained as 219.55, 58.02, 451.89, 456.06 and 455.43 million rupees for 9, 18, 21, 24 and 30 canal running days respectively.

Rani and Rao (2012). Conducted study in RDS Rajoli Banda Diversion scheme area, Mahboobnagar, Andhra Pradesh, India as a case study and applied linear programming for minimizing water uses keeping all other resources such as cultivable land, seeds, fertilizer and human power, pesticides and cash as constraints. The results revealed that optimization approach significantly improved the annual net benefits with optimal area allocation.

Sethi *et al.,* (2006) in their study optimal crop planning and water resources allocation in coastal groundwater basin, Orissa, India. The studies revealed that 40% deviation of the existing cropping pattern was found the optimal and satisfies the minimum food requirement and maintain geo-hydrological balance of the basin. The sensitivity analysis of the conjunctive use of surface and ground water showed that 20% surface water and 30% groundwater availability as the optimum water allocation level. The proposed cropping and water resources allocation policies of the developed models were found to be socio-economically acceptable that maintained the balance of the entire system, considering all the constraints as restrictions imposed.

In the context of the above studies, an attempt has been made in this chapter to formulate and optimal crop model for the state and different agro-climatic zones of Bihar to optimize the production and restrict the natural resources at optimal uses to get maximum benefits to the farming community of the state in particular and nation in general using linear programming. GAMES software is used to arrive at the results.

The Mathematical programming can be used for developing optimum crop or land use planning. It is an easy and flexible method for assessing different ways to use limited resources under variable objective and constraints.

The present study makes an attempt to develop different crop planning strategies by using *Linear Programming (LP).* It develops the crop model which increases the productivity with minimum input cost under the constraints of available resources like water usage and also labour, fertilizers, seeds etc and ultimately getting maximum net benefits. Multi-crop model for two seasons are formulated in LP for maximizing the net returns, minimizing the cost and minimizing the water usage by keeping all other available resources (such as cultivable land, seeds, fertilizers, human labour, pesticides, capital etc.) as constraints.

Mathematical specifications of the model

Mathematical model specification for Bihar are given as under

$$\boldsymbol{Max\ Z = \sum_{c=1}^{n} [\![(Y]\!]_c\, P_c - \ C_c\,)A_c \ldots \ldots (1)}$$

$$\sum_{t}\sum_{c} a_{tc}A_c \leq NS_t - OA_t \dots\dots\dots..(2)$$

$$A_c \geq A_{min_c} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(3)$$

$$A_c \leq A_{max_c} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(4)$$

$$\sum_{c} w_c A_c \leq RGWAA \dots\dots\dots\dots\dots..(5)$$

$$A_c \geq 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(6)$$

Objective function: Maximization of net income (equation 1)

$$\sum_{c=1}^{n} (Y_c P_c - C_c) A_c$$

Let Y_c denotes yield of crop c in one hectare of land, P the price received for the output from crop c, C_c refers to the cost incurred to cultivate crop c in one hectare of land and A_c is the area under cultivation of crop c then RHS of the equation 1 represents sum of net revenue obtained from all the crops considered for optimum model development. The objective is to maximize the net revenue (z) based on the optimum crop plan.

Land constraint

Optimal use of land for each month is required, this can be achieved by having separate constraint equation (Equation 2 is a compact form of 12 equations one for each month as given below). This helps to have separate sown area for each month and ensures that total cultivated area under selected crops in each month should be less than net sown area (NS_t) minus area under orchard (OA_t) crops. Further, crop calendar has to be maintained as per format given in Appendix. Thus a_{tc} in equation 2 refers to the coefficients of crop calendar matrix for t^{th} month and c^{th} crop

$$\sum_{t}\sum_{c} a_{tc}A_c \leq NS_t - OA_t$$

Where, t= Jan, Feb,……….Dec

Minimum and maximum constraints (Equation 3-4)

Crop planning model using LP primarily captures the supply side behavior especially area response based on net returns and resource constraints ignoring the demand aspect. Such models tend to overestimate or underestimate the area allocations for some crops. As a consequence, a single crop may cover infeasible larger area (Overestimation) or null or negligible area (underestimation).

In some modeling solutions, some major crops may drastically lose their relevance and the corresponding area allocation may become negligible. Then, even though estimates are robust and mathematically proven, such allocations may not be desirable and practically possible from the food and livelihood security point of view of the farming community as appropriate changes in policy framework is required only after adoption of the optimum sustainable crop model. Similarly, area for some minor crop may be overestimated ignoring the demand. To overcome such situations assigning values to minimum and maximum area is essential in the model. To eliminate such practically undesirable solutions, concept of min, max constraint is adopted in the model.

Groundwater Constraints

Water is scare natural resource. The groundwater usage should be less than or equal to replenishable groundwater available for agriculture (RGWAA) for making the agriculture sustainable. Data of RGWAA is published by Central Ground Water Board. This can also be estimated by deducting water consumed by industries and other non-farm activities from total replenishable ground water.

Ground water constraint to be used in linear programming (LP model is prescribed as under

$$\sum_{c} \boldsymbol{w_c A_c} \leq \boldsymbol{RGWAA}$$

Where, w_c is actual water drafted for a crop c in the recent year based on cost of cultivation data. A_c indicates the area allocation for a crop c.

Existing land area allocations under different crops are useful to make comparison with optimal crop plan model. The lands under different crops are available in statistical abstract of the state. Further this data is useful for defining min and max area allocation limits for selected crops. Existing area under different crops are the average of three years data under the crop. Min and max area have been decided on the basis of expert advice.

Optimum Crop Model for Bihar

The study makes an attempt to develop different crop plans/model using Linear Programming (LP). The model which increases the productivity with minimum input cost under constraints of available resources like water usage and labour, fertilizers, seeds etc. and ultimately getting maximum net benefits. Multi-crop model for two seasons are formulated in LP for maximizing the net returns, minimizing the cost and minimizing the water usage by keeping all other available resources (such as cultivable land, seeds, fertilizers, human labour, pesticides, capital etc) as constraints. In the state of Bihar, for the sake of practical utility, the land and water were considered as constraint in the background of the fact that water development is only 44% till now. Zone-I is moderately flood prone, zone-II is acute flood prone and zone-III is water scarce area where water table is going down. Since, groundwater is available abundantly in the state, even though the water development is only 44 percent at present. Our objective is to maximize the income of cultivators. Here our proposition is that the further increase in the water development from the existing level will obviously increase the gross cropped area and in turn, would raise the income of farming community. Groundwater development level may be enhanced by raising the irrigation structure such as cheap irrigation devices. Further, the agricultural labour could not be taken as constraints because the season wise quantification of agricultural labour was difficult. Fertilizers availability is also ensured in the state; hence it may not be taken as constraint. Linear programming was used to arrive at optimum crop model using GAMS software and the results for the state as a whole i.e. Bihar are presented in Table 18, 18A and 18B.

Perusal of the Table 19 indicated that from the optimum area allocation for crops grown in state at different alternative prices (existing groundwater use at 10.26 BCM), it was observed that the cropping pattern was observed alike i.e. similar in all the three prices conditions/scenarios. On comparison with exiting cropping pattern, it was noted that the area under kharif maize, rabi maize, arhar, kulthi, gram, lentil, khesari, moong, urad, pea, rapeseed & mustard, linseed, potato, cabbage, brinjal, cauliflower, okra, tomato, onion, sugarcane and chilli tend to increase at all the three prices scenarios as compared to existing area of above crops. On the other hand, the area under crops such as paddy, wheat, barley, ragi, sunflower and jute showed decline in their area at all three prices, may probably be on account of maximization of income at existing water situation.

It was also observed from the table that the optimum gross cropped area (GCA) was estimated to be only 7283.48 thousand ha in all three prices conditions as compared to existing cropped area being 7388.00 thousand ha. The earning of optimum profit would be about 101.10 hundred crores from the optimum crop model.

Perusal of Table 19A revealed that when groundwater use is increased to 12.83 BCM, the optimum area allocation for almost all the crops included in the model showed positive direction of change in all the three prices scenarios.

Table 19: Optimum crop model for Bihar at existing groundwater at 10.26 BCM

Crops	Existing area (000 ha)	Optimum area (000 ha)			Direction of change
		Market price (MP)	Economic price (EP)	Natural resource valuation (NRV)	
Paddy	3156.00	2900.00	2900.00	2900.00	---
Wheat	2106.33	2000.00	2000.00	2000.00	---
Maize (kharif)	232.56	250.00	250.00	250.00	+++
Maize (rabi)	349.69	367.98	367.98	367.98	+++
Ragi	9.90	9.00	9.00	9.00	---
Barely	11.97	10.00	10.00	10.00	---
Arhar (Red gram)	26.67	40.00	40.00	40.00	+++
Kulthi (Horse gram)	10.76	15.00	15.00	15.00	+++
Gram	58.97	70.00	70.00	70.00	+++
Lentil	173.16	200.00	200.00	200.00	+++
Khesari	83.82	85.00	85.00	85.00	+++
Moong (Green gram)	161.31	200.00	200.00	200.00	+++
Urad (Black gram)	18.66	20.00	20.00	20.00	+++
Pea	21.35	24.00	24.00	24.00	+++
Rapeseed & mustard	86.76	110.00	110.00	110.00	+++
Linseed	23.90	25.00	25.00	25.00	+++
Sunflower	18.97	18.00	18.00	18.00	---
Potato	151.00	200.00	200.00	200.00	+++
Cabbage	38.72	40.00	40.00	40.00	+++
Brinjal	55.36	60.00	60.00	60.00	+++
Cauliflower	61.94	70.00	70.00	70.00	+++
Okra	58.31	70.00	70.00	70.00	+++
Tomato	46.57	70.00	70.00	70.00	+++
Onion	52.53	56.00	56.00	56.00	+++
Jute	123.96	120.00	120.00	120.00	---
Sugarcane	159.46	250.00	250.00	250.00	+++
Chilli	3.00	3.50	3.50	3.50	+++
GCA	7388.00	7283.48	7283.48	7283.48	---
Profit (00 crores)				**101.10**	

It was also investigated that the gross cropped area (GCA) too increased to the level of 8550.50 thousand hectares as compared to the existing GCA, being only 7388.00 thousand hectares, which will certainly maximize the income of cultivators, only if groundwater development is enhanced with cheap source of irrigational facilities. The table further reveals that if the cropping patterns in the state are followed in accordance with the optimum crop plan, the profit to the level of 110.90 hundred crores would be obtained out of this

Table 19A: Optimum crop model for Bihar on increasing 25% of existing groundwater use (12.83 BCM)

Crops		Optimum area (000 ha)			Direction of change
	Existing area (000 ha)	Market price (MP)	Economic price(EP)	Natural resource valuation(NRV)	
Paddy	3156.00	3500.00	3500.00	3500.00	+++
Wheat	2106.33	2600.00	2600.00	2600.00	+++
Maize (kharif)	232.56	250.00	250.00	250.00	+++
Maize (rabi)	349.69	400.00	400.00	400.00	+++
Ragi	9.90	12.00	12.00	12.00	+++
Barely	11.97	15.00	15.00	15.00	+++
Red gram	26.67	40.00	40.00	40.00	+++
Kulthi (Horse gram)	10.76	15.00	15.00	15.00	+++
Gram	58.97	70.00	70.00	70.00	+++
Lentil	173.16	200.00	200.00	200.00	+++
Khesari (Lathyrus)	83.82	85.00	85.00	85.00	+++
Moong (Green gram)	161.31	200.00	200.00	200.00	+++
Urad (Black gram)	18.66	20.00	20.00	20.00	+++
Pea	21.35	24.00	24.00	24.00	+++
Rapeseed & mustard	86.76	110.00	110.00	110.00	+++
Linseed	23.90	25.00	25.00	25.00	+++
Sunflower	18.97	25.00	25.00	25.00	+++
Potato	151.00	200.00	200.00	200.00	+++
Cabbage	38.72	40.00	40.00	40.00	+++
Brinjal	55.36	60.00	60.00	60.00	+++
Cauliflower	61.94	70.00	70.00	70.00	+++
Okra (Bhindi)	58.31	70.00	70.00	70.00	+++
Tomato	46.57	60.00	60.00	60.00	+++
Onion	52.53	56.00	56.00	56.00	+++
Jute	123.96	150.00	150.00	150.00	+++
Sugarcane	159.46	250.00	250.00	250.00	+++
Chilli	3.00	3.500	3.500	3.500	+++
GCA	7388.00	8550.50	8550.50	8550.50	+++
Profit (00 crores)				**110.90**	

Expected gain from optimum crop plan/model

Expected gains based on optimum crop model estimated under different prices situations under existing groundwater use at 10.26 BCM with reference to existing cropping pattern are presented in Table 19B. The table explained that under optimum crop model at existing groundwater use to (10.26 BCM), there was decline in the gross cropped area for the state as whole which was measured as only -1.41% with respect to existing GCA. When the groundwater use is increased to 12.83 BCM, then GCA would be pushed up by 15.73% as compared to the existing GCA of the state.

Table 19B: Gain due to optimal crop model over two different GW use scenarios in Bihar

Optimal scenario	Change in GCA%	Existing revenue (00 crores)	Optimal net returns (00 crores)	Change in farmer's revenue (00 crores) (Optimal-Existing $_{MP}$)	Gain to society (00 crores)	Net gain (00 crores)
Groundwater use at existing scenario (10.26 BCM)						
Market price	-1.41	122.15	131.72	9.57	0	9.57
Economic price	-1.41	96.84	106.16	-15.99	25.31	9.32
NRV	-1.41	91.44	101.43	-20.72	19.91	-0.81
Groundwater use increased by 25% of existing GW use (12.83 BCM)						
Market price	15.73	122.15	147.09	24.94	0.00	24.94
Economic price	15.73	96.84	116.85	-5.30	30.23	24.94
NRV	15.73	91.44	110.91	-11.24	24.83	13.60

It was further observed that at existing groundwater scenario (10.26 BCM), optimal net returns were calculated 131.72, 106.16 and 101.43 hundred crores at market price (MP), economic price (EP) and natural resource valuation price (NRV), respectively. Further, the gain to the society was estimated 25.31 and 19.91 hundred crores at EP and NRV. Thus, ultimate net gains to the cultivators were estimated 9.57, 9.32 and -0.81 hundred crores at three business scenarios. The change in farmer's revenue was found positive only at MP i.e. 9.57 hundred crores. However, this positive change is at the cost which is paid by the society in terms of cost of subsidy on fertilizers, seeds and diesel etc.

In case of restricted groundwater scenario at 12.83 BCM, the optimal net returns were worked out 147.09, 116.85 and 110.91 hundred crores and further, gain to the society could be obtained 30.23 and 24.83 hundred crores at EP and NRV. Finally the cultivator's net gain could be assessed 24.94, 24.94 and 13.60 hundred crores at MP, EP and NRV. Thus, the gains are positive in all the three model of business as usual. These gains can only be obtained by pushing up the groundwater development as well as providing appropriate and cheap irrigation devices to the farming community of the state.

CROP PLANS FOR DIFFERENT AGRO-CLIMATIC ZONES

(a) Optimal crop model for Agro-climatic zone-I

The optimal crop model for zone-I is depicted in Table 20 and Table 20A. Perusal the Table 20 indicated that in case of existing groundwater at 4.50 BCM, it was revealed that almost all crops i.e. paddy, wheat, maize, ragi, barely, redgram, lentil, khesari, moong, urad, pea, rapeseed & musratd, linseed, potato, cabbage, brinjal, cauliflower, okra, sugarcane and chilli as included in the model showed positive direction of changes in optimal area allocation in all the three prices scenario i.e. MP, EP and NRV in this zone.

Table 20: Optimum crop model for ***Agro-climatic zone-I*** in Bihar for existing groundwater at 4.50 BCM

Crops	Existing area (000 ha)	Optimum area (000 ha)			Direction of change
		Market price (MP)	Economic price (EP)	Natural resource valuation (NRV)	
Paddy	1320.33	1400.00	1400.00	1400.00	+++
Wheat	954.33	1025.00	1025.00	1025.00	+++
Maize (kharif)	83.45	100.00	100.00	100.00	+++
Maize (rabi)	120.39	150.00	150.00	150.00	+++
Ragi	4.78	6.00	6.00	6.00	+++
Barely	2.00	5.00	5.00	5.00	+++
Arhar (RedGram)	14.67	20.00	20.00	20.00	+++
Lentil	45.33	55.00	55.00	55.00	+++
Khesari (Lathyrus)	5.00	5.00	5.00	5.00	+++
Moong (GreenGram)	82.22	100.00	100.00	100.00	+++
Urad(BlackGram)	18.66	25.00	25.00	25.00	+++
Pea	7.35	11.50	11.50	11.50	+++
Rapeseed & mustard	42.25	60.00	60.00	60.00	+++
Linseed	11.64	15.00	15.00	15.00	+++
Potato	71.66	100.00	100.00	100.00	+++
Cabbage	17.70	20.00	20.00	20.00	+++
Brinjal	25.31	30.00	30.00	30.00	+++
Cauliflower	28.32	35.00	35.00	35.00	+++
Okra (Bhindi)	26.66	30.00	30.00	30.00	+++
Sugarcane	147.46	200.00	200.00	200.00	+++
Chilli	2.00	2.50	2.50	2.50	+++
GCA	3170.00	3395.00	3395.00	3395.00	+++
Profit (00 crores)				**45.24**	

Further, it was observed that at the level of existing GW use the optimal GCA was found to be increased i.e. 3395.00 thousand hectares from existing GCA being only 3170.00 thousand hectares for zone-I.

Table 20A: Gain due to optimal crop model over existing scenario in ***Agro-climatic zone-I*** of Bihar

Optimal scenario	Change in GCA%	Existing revenue (00 crores)	Optimal net returns (00 crores)	Change in farmer's revenue (00 crores) (Optimal-Existing $_{MP}$)	Gain to society (00 crores)	Net gain (00 crores)
Groundwater use at existing scenario (4.45 BCM)						
Market price	7.10	51.23	60.41	9.18	0	9.18
Economic price	7.10	39.94	47.64	-3.59	11.29	7.70
NRV	7.10	37.63	45.24	-5.99	8.97	2.98

Perusal of the Table 20a explained the fact that for existing GW use at 4.50 BCM, the optimal net returns could be assessed 60.41, 47.64 and 45.24 hundred crores at three prices MP, EP and NRV. Finally the net gain to the cultivator was obtained positive at all the three prices i.e 9.18 hundred crores at MP, 7.70 hundred crores at EP and 2.98 hundred crores at NRV prices. Hence, it is opined that even at existing GW use, the net income/return of the cultivators may be optimized by growing the crops as indicated in the optimal model in zone-I.

(b) Optimal crop model for Agro-climatic zone-II

Agro-climatic zone-II is vulnerable to floods and also known as the place for sorrow of Kosi river. The optimal crop models for this zone were also estimated using two different groundwater use scenarios i.e one at 2.12 BCM existing GW use and another groundwater use increased to 2.65 BCM (increased by 25% of existing GW use) and are presented in Table 21 and Table 21A and Table 21B.

Perusal of the Table 21 (existing GW use at of 2.12 BCM) revealed that the positive change in optimal area allocation was found for almost all crops except paddy which showed decline in its area as compared to the existing area in zone-II Further, it was observed increase in optimal GCA as compared to the existing GCA in this region i.e. as much as 1452.90 thousand hectares from existing 1425.04 thousand hectares.

When the GW use was increased to 2.65 BCM, the estimation of optimal model showed positive direction of changes in all the crops under study under zone-II. It also revealed the change in optimal GCA 1618.00 thousand hectares as compared to the existing only 1425.04 thousand hectares.

Table 21: Optimum crop model for ***Agro-climatic zone-II*** of Bihar at existing GW use (2.12 BCM)

Crops	Existing area (000 ha)	Optimum area (000 ha)			Direction of change
		Market price (MP)	Economic price (EP)	Natural resource valuation (NRV)	
Paddy	681.67	584.90	584.90	584.90	---
Wheat	312.00	350.00	350.00	350.00	+++
Maize (rabi)	174.12	200.00	200.00	200.00	+++
Lentil	11.00	15.00	15.00	15.00	+++
Rapeseed & mustard	19.70	20.00	20.00	20.00	+++
Sunflower	18.97	25.00	25.00	25.00	+++
Potato	34.28	40.00	40.00	40.00	+++
Cabbage	8.79	12.00	12.00	12.00	+++
Brinjal	12.57	15.00	15.00	15.00	+++
Cauliflower	14.06	20.00	20.00	20.00	+++
Okra (bhindi)	13.24	20.00	20.00	20.00	+++
Jute	123.96	150.00	150.00	150.00	+++
Chilli	0.68	1.00	1.00	1.00	+++
GCA	1425.04	1452.90	1452.90	1452.90	+++
Profit (00 crores)				**20.87**	

Table 21A: Optimum crop model for ***Agro-climatic zone-II*** of Bihar for GW use at (2.65BCM)

Crops	Existing area (000 ha)	Optimum area (000 ha)			Direction of change
		Market price (MP)	Economic price (EP)	Natural resource valuation (NRV)	
Paddy	681.67	750.00	750.00	750.00	+++
Wheat	312.00	350.00	350.00	350.00	+++
Maize (rabi)	174.12	200.00	200.00	200.00	+++
Lentil	11.00	15.00	15.00	15.00	+++
Rapeseed & mustard	19.70	20.00	20.00	20.00	+++
Sunflower	18.97	25.00	25.00	25.00	+++
Potato	34.28	40.00	40.00	40.00	+++
Cabbage	8.79	12.00	12.00	12.00	+++
Brinjal	12.57	15.00	15.00	15.00	+++
Cauliflower	14.06	20.00	20.00	20.00	+++
Okra	13.24	20.00	20.00	20.00	+++
Jute	123.96	150.00	150.00	150.00	+++
Chilli	0.68	1.00	1.00	1.00	+++
GCA	1425.04	1618.00	1618.00	1618.00	+++
Profit (00 crores)				**21.17**	

On the basis of the above two different GW use scenarios the gain was also calculated and presented in Table 21B.

Table 21B: Gain due to optimal crop model over two different GW use scenario in ***Agro-climatic zone-II*** in Bihar

Optimal scenario	Change in GCA%	Existing revenue (00 crores)	Optimal net returns (00 crores)	Change in farmer's revenue (00 crores) (Optimal-Existing $_{MP}$)	Gain to society (00 crores)	Net Gain (00 crores)
Groundwater use existing scenario (2.12 BCM)						
Market price	1.96	23.36	26.86	3.50	0	3.50
Economic price	1.96	18.92	22.04	-1.31	4.44	3.12
NRV	1.96	17.58	20.87	-2.49	3.10	0.61
Groundwater use increased by 25% of existing GW use (2.65 BCM						
Market price	13.54	23.36	27.71	4.36	0	4.36
Economic price	13.54	18.92	22.64	-0.71	4.44	3.72
NRV	13.54	17.58	21.17	-2.19	3.10	0.91

The picture depicted in the above table indicated that in the first condition, the optimal GCA increased by 1.96% and change in farmers' revenue was evaluated positive (3.50 hundred crores) at market price but it was calculated negative as -1.31 & -2.49 hundred crores at other two business scenarios i.e. economic price and NRV price, respectively. The estimated optimal profit at existing GW use scenario was 20.87 hundred crores at NRV business prices. Further, the net gains from optimal model were estimated to 3.50, 3.12 and 0.61 hundred crores at all alternative business prices, using existing GW scenario.

But, on the basis of the next condition i.e. 2.65 BCM GW use, the change in optimal GCA was computed by 11.53% and changes in farmer's gain was calculated to be positive i.e. 4.36 hundred crores on market price condition, whereas for rest two other prices conditions, the gain was found to be negative i.e. 0.71 and -2.19 hundred crores at their respective economic and NRV prices. It was further revealed that the net gains were accounted for positive in all business scenarios considered in the optimal model in the study.

(c) Optimal crop model for Agro-climatic zone-III

Agro-climatic zone-III is considered as water scarce region of the state however it is agriculturally more developed than other two zones of the state. Optimal crop model for the zone was also worked out on the basis of two groundwater use conditions i.e first at existing GW use (3.70 BCM) and second at (4.63 BCM) GW use and is presented in Table 22, Table 22A and Table 22B.

Perusal of the Table 22 indicated that at existing GW use (3.70 BCM), it was figured out that paddy, kharif maize, ragi, arhar, kulthi, gram, lentil khesari, rapeseed & mustard, linseed, potato, cabbage, brinjal, cauliflower, bhindi, tomato, onion and chilli showed positive direction of change in its optimal area allocation and two crops such as wheat and rabi maize included in the model for this zone showed retarded change in optimal area allocation. Consequently, optimal GCA also depicted positive direction of change, thus the GCA escalated from existing area of 2548.86 thousand hectares to optimum area being 2636.79 thousand hectares.

When the groundwater use was enhanced up to 4.63 BCM, all the crops consisting in the model came out with the positive direction of change under optimal area allocation and thus, the positive change was also accounted for in case of optimal GCA i.e. it would scaled up from 2548.86 thousand hectares to 3152.50 thousand hectares in Agro-climatic zone-III. Consequently the level of profit i.e. 32.51 hundred crores would be obtained from this optimal model.

Table 22: Optimum crop model for ***Agro-climatic zone-III*** of Bihar at existing ground water use at 3.70 BCM

Crops	Existing area (000 ha)	Optimum area (000 ha)			Direction of change
		Market price (MP)	Economic price (EP)	Natural resource valuation (NRV)	
Paddy	1154.00	1189.29	1189.29	1189.29	+++
Wheat	840.00	800.00	800.00	800.00	---
Maize (kharif)	33.31	35.00	35.00	35.00	+++
Maize (rabi)	55.19	50.00	50.00	50.00	---
Ragi	4.16	6.00	6.00	6.00	+++
Arhar (RedGram)	12.00	18.00	18.00	18.00	+++
Kulthi (HorseGram)	3.86	5.00	5.00	5.00	+++
Gram	58.64	70.00	70.00	70.00	+++
Lentil	116.84	150.00	150.00	150.00	+++
Khesari (Lathyrus)	68.49	70.00	70.00	70.00	+++
Rapeseed & mustard	20.85	25.00	25.00	25.00	+++
Linseed	23.90	25.00	25.00	25.00	+++
Potato	40.67	55.00	55.00	55.00	+++
Cabbage	12.43	15.00	15.00	15.00	+++
Brinjal	15.30	20.00	20.00	20.00	+++
Cauliflower	19.88	25.00	25.00	25.00	+++
Okra (Bhindi)	24.55	26.00	26.00	26.00	+++
Tomato	21.47	25.00	25.00	25.00	+++
Onion	22.33	26.00	26.00	26.00	+++
Chilli	1.00	1.50	1.50	1.50	+++
GCA	2548.86	2636.79	2636.79	2636.79	+++
Profit (00 crores)				**29.15**	

Net gain due to optimal area allocation for zone-III is presented in Table 22B. A critical view of the table was pointed out that at existing GW use at 3.70 BCM, optimal net returns were estimated 40.27, 31.00 and 29.15 hundred crores at three different prices (MP, EP and NRV, respectively), but change in farmer's revenue was found positive (3.27 hundred crores) at market price only. Further the net gains were accounted for 3.27 & 3.03 hundred crores at market price and economic price but it (net gain) was found negative (-0.72 hundred crores) at NRV price. Further, it was also observed an increase of 3.45% in optimal GCA as compared to existing GCA of the zone-III.

Table 22A: Optimum crop model for ***Agro-climatic zone-III*** of Bihar by increasing 25% of existing GW use (4.63 BCM)

Crops	Existing area (000 ha)	Optimum Area (000 ha)			Direction of change
		Market price (MP)	Economic price (EP)	Natural resource valuation(NRV)	
Paddy	1154.00	1500.00	1500.00	1500.00	+++
Wheat	840.00	1000.00	1000.00	1000.00	+++
Maize (kharif)	33.31	35.00	35.00	35.00	+++
Maize (rabi)	55.19	55.00	55.00	55.00	+++
Ragi	4.16	6.00	6.00	6.00	+++
Arhar (RedGram)	12.00	18.00	18.00	18.00	+++
Kulthi (HorseGram)	3.86	5.00	5.00	5.00	+++
Gram	58.64	70.00	70.00	70.00	+++
Lentil	116.84	150.00	150.00	150.00	+++
Khesari (Lathyrus)	68.49	70.00	70.00	70.00	+++
Rapeseed & mustard	20.85	25.00	25.00	25.00	+++
Linseed	23.90	25.00	25.00	25.00	+++
Potato	40.67	55.00	55.00	55.00	+++
Cabbage	12.43	15.00	15.00	15.00	+++
Brinjal	15.30	20.00	20.00	20.00	+++
Cauliflower	19.88	25.00	25.00	25.00	+++
Okra (Bhindi)	24.55	26.00	26.00	26.00	+++
Tomato	21.47	25.00	25.00	25.00	+++
Onion	22.33	26.00	26.00	26.00	+++
Chilli	1.00	1.50	1.50	1.50	+++
GCA	2548.86	3152.50	3152.50	3152.50	+++
Profit (00 crores)				**32.51**	

Table 22 B: Gain due to optimal crop model over existing scenario of ***Agro-Climatic zone-III*** in Bihar

Optimal scenario	Change in GCA%	Existing revenue (00 crores)	Optimal net returns (00 crores)	Change in farmer's revenue (00 crores) (Optimal-Existing $_{MP}$)	Gain to society (00 crores)	Net gain (00 crores)
Groundwater use existing scenario (3.70 BCM)						
Market price	3.45	37.00	40.27	3.27	0	3.27
Economic price	3.45	27.97	31.00	-6.00	9.03	3.03
NRV	3.45	26.07	29.15	-7.84	7.13	-0.72
Groundwater use increased by 25% of existing GW (4.63 BCM)						
Market price	23.68	37.00	46.14	9.15	0	9.15
Economic price	23.68	27.97	34.97	-2.03	9.03	6.99
NRV	23.68	26.07	32.51	-4.49	7.13	2.64

When GW use was increased to 4.63 BCM, the optimal crop model exhibited change in optimal GCA by 23.68%. Change in farmers' revenue was found positive only in case of market price but gain to the society at two prices EP and NRV were calculated 9.03 and 7.13 hundred crores, respectively and the final net gain to cultivators were estimated 9.15, 6.99 and 2.64 hundred crores on MP, EP and NRV, respectively under this GW use scenario.

Hence, all crop models as discussed above may be used for the optimization of income of the farming community provided that the groundwater development is created/ enhanced as well as means of irrigation made available by the government to the cultivators of the state. Renewal sources of energy may be popularized for use with a view to reduce the expenditure burden on usual diesel irrigation and protecting the society from ill effect of air pollution generated through the use of diesel. Infrastructural development with regard to uninterrupted supply of electricity and solar energy may be expanded for better adoption and acceptability of the optimal models by the farming community in order to enhance income and raising standard of living conditions of poor peasants of the state.

Chapter-VII

POLICY IMPLICATIONS

The results of this study have important policy implications. In order to make agriculture more remunerative, there is need of multi-pronged approach.

- **Reduction of fallow land.**

Rising trend of fallow land may be discouraged so that these lands may be put under cultivation

- **Special emphasis on increasing the area and production of pulses and oilseeds.**

- **Expansion of surface irrigation to augment groundwater irrigation and reduce cost of irrigation**

Irrigation is one of the most limiting factors for raising the productivity. In the state, with abundant water resources, not much has been done since couple of decades towards expanding surface irrigation. This will also help in recharging ground water in those areas which are away from river catchment.

- **Assured supply of low cost energy source (electricity) for agricultural operations.**

In absence of electricity, most of the agricultural operations are done using diesel operated energy source in the state which increases the cost of crop production as well as post-harvest operations, thus affecting the cultivators' profitability.

- **Emphasis on diversification of agriculture.**

In recent years, diversification of agriculture has slowed down. Expedition of diversification of agriculture from low valued crops to high valued crops will enhance the income of cultivators.

- **Enhancing resource use efficiency.**

Proper utilization of human, machine labour, fertilizers (NPK) and seed and water etc. will maximize the income of farmers.

- **Accountability of financial institution**

In the state about 93% cultivators are small and marginal farmers who remained debarred from the benefits of low interest agricultural credits. Therefore, accountability to bank should be fixed to bring this section of the people in their ambit.

- **Improved marketing infrastructure**

Weak marketing infrastructure is also a barrier to participation in urban markets, where food prices are multiple times higher than the rural markets. Since 2006 APMC in Bihar is repealed. Distance to markets is the main concern for rural people across the state. High transportation costs result in lower farm-gate prices, which in turn, reduce household income. Most of the farmers sell their product to village merchant/itinerary traders at low price.

- **Consolidation of holding.**

Fragmented land increases the labour and transportation cost for inputs as well as also for the produce. Hence, consolidation of holding seems to be an essential for large scale production

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APPENDICES

Appendix A: Crop wise Input Use Efficiency

Input	Actual Use (A)	Optimal Use (O)	Efficiency ((O-A)/A)*100
Paddy			
Human Labour	816.74	304.84	-62.68
NPK	89.00	44.42	-50.09
Seed	57.21	74.78	30.71
Groundwater	5506.66	2623.64	-52.36
Wheat			
Human Labour	460.67	257.14	-44.18
NPK	132.00	104.37	-20.93
Seed	114.63	80.88	-29.44
Groundwater	5604.61	826.24	-85.26
Maize Kharif			
Human Labour	660.25	315.00	-52.29
NPK	85.22	17.17	-79.85
Seed	35.80	7.47	-79.14
Groundwater	0.00	0.00	0.00
Maize Rabi			
Human Labour	672.68	213.49	-68.26
NPK	139.87	94.93	-32.13
Seed	21.79	11.60	-46.78
Groundwater	7955.51	4327.71	-45.60
Ragi			
Human Labour	583.76	56.61	-15.32
NPK	86.47	16.02	-34.53
Seed	21.24	1525.48	-24.58
Groundwater	2454.70	56.61	-37.85
Barely			
Human Labour	360.71	214.41	-40.56
NPK	121.40	112.84	-7.05
Seed	89.27	96.73	8.35
Groundwater	4064.46	1713.45	-57.84
Arhar			
Human Labour	474.09	332.48	-29.87
NPK	13.82	0.00	-100.00
Seed	22.71	14.13	-37.81
Groundwater	1336.27	0.00	-100.00
Kulthi (Horsegram)			
Human Labour	315.16	243.58	-22.71
NPK	58.87	32.01	-45.63
Seed	45.54	51.98	14.15
Groundwater	0.00	0.00	0.00

Appendix A: Crop wise input use efficiency

(Contd…)

Input	Actual use (A)	Optimal use (O)	Efficiency ((O-A)/A)*100
Gram			
Human labour	326.59	240.61	-26.33
NPK	121.49	14.76	-87.85
Seed	69.03	58.20	-15.69
Groundwater	2532.58	998.27	-60.58
Lentil			
Human labour	316.95	97.05	-69.38
NPK	46.07	42.00	-8.83
Seed	48.81	45.53	-6.72
Groundwater	1693.94	0.00	-100.00
Khesari (Lythyrus)			
Human labour	304.30	278.38	-8.52
NPK	0.0	0.0	0
Seed	81.78	71.86	-12.13
Groundwater	0.00	0.00	0.00
Moong (GreenGram)			
Human labour	481.67	397.41	-17.49
NPK	38.98	28.72	-26.31
Seed	20.54	19.75	-3.87
Groundwater	2445.77	0.00	-100.00
Urad (BlackGram)			
Human labour	346.77	343.97	-0.81
NPK	34.01	30.56	-10.13
Seed	20.66	20.57	-0.46
Groundwater	1620.51	1256.50	-22.46
Pea			
Human labour	416.69	285.15	-31.57
NPK	85.19	89.65	5.23
Seed	57.74	57.22	-0.89
Groundwater	1408.57	0.00	-100.00
Rapeseeds & mustard			
Human labour	673.63	393.39	-41.60
NPK	98.72	46.90	-52.49
Seed	6.23	5.42	-12.96
Groundwater	3580.56	921.32	-74.27
Linseed			
Human labour	364.50	196.54	-46.08
NPK	51.24	79.62	55.39
Seed	23.75	20.06	-15.56
Groundwater	1263.39	1031.96	-18.32

Appendix A: Crop wise input use efficiency

(Contd…)

Input	Actual use (A)	Optimal use (O)	Efficiency ((O-A)/A)*100
Sunflower			
Human labour	1427.50	407.86	-71.43
NPK	164.60	95.62	-41.91
Seed	5.32	8.69	63.56
Groundwater	3876.40	3363.55	-13.23
Brinjal			
Human labour	1181.69	573.93	-51.43
NPK	269.67	114.78	-57.44
Seed	510.00	609.11	19.43
Groundwater	1815.79	972.11	-46.46
Cabbage			
Human labour	603.54	497.22	-17.62
NPK	157.66	150.19	-4.74
Seed	526.00	578.69	10.02
Groundwater	1771.81	1208.20	-31.81
Cauliflower			
Human labour	657.18	554.77	-15.58
NPK	123.58	76.30	-38.26
Seed	520.00	495.83	-4.65
Groundwater	1320.12	1211.51	-8.23
Okra (Bhindi)			
Human labour	777.75	731.79	-5.91
NPK	157.51	91.81	-41.71
Seed	10.55	9.47	-10.24
Groundwater	2842.47	1635.54	-42.46
Potato			
Human labour	1104.35	461.45	-58.22
NPK	194.66	49.80	-74.42
Seed	2534.48	1828.42	-27.86
Groundwater	5973.46	2747.41	-54.01
Tomato			
Human labour	1117.89	1142.18	2.17
NPK	70.14	64.38	-8.21
Seed	230.69	131.00	-43.21
Groundwater	6885.17	6744.17	-2.05
Onion			
Human labour	1317.07	955.85	-27.43
NPK	99.31	81.72	-17.71
Seed	9.37	6.15	-34.29
Groundwater	7584.02	7674.21	1.19
Sugarcane (planted)			
Human labour	753.24	374.59	-50.27
NPK	180.15	214.25	18.93
Seed	5761.97	3686.14	-36.03
Groundwater	9171.00	7108.63	-22.49

Appendix A: Crop wise Input Use Efficiency

(Contd…)

Input	Actual use (A)	Optimal use (O)	Efficiency ((O-A)/A)*100
Sugarcane (ratoon)			
Human labour	609.03	504.25	-17.21
NPK	125.75	100.89	-19.77
Seed	0.00	0.00	0.00
Groundwater	9171.00	3685.94	-59.81
Chilli			
Human labour	1242.50	436.99	-64.83
NPK	138.96	88.64	-36.21
Seed	120.00	167.50	39.58
Groundwater	2275.22	831.74	-63.44
Jute			
Human labour	685.90	493.87	-28.00
NPK	138.06	125.37	-9.19
Seed	7.33	7.16	-2.31
Groundwater	2044.77	1584.19	-22.52

Appendix-B : Crop wise input use and output of Bihar TE-2010-11

Crops	N (kg/ha)	P (kg/ha)	K (kg/ha)	NPK (kg/ha)	Ground water draft (cum/ha)	Yield (q/ha)
Cereal crops						
Paddy	63.50	39.16	24.54	89.00	5506.66	25.24
Wheat	83.93	50.01	27.49	132.00	5604.61	23.97
Maize (kharif)	60.55	46.31	19.30	85.22	0.00	19.68
Maize (rabi)	91.32	58.04	24.49	139.87	7955.51	49.28
Ragi	28.61	45.93	27.00	86.47	2454.70	15.13
Barely	58.64	44.90	17.86	121.40	4064.46	32.25
Pulse crops						
Gram	41.85	78.39	13.59	121.49	2532.58	10.29
Arhar (Redgram)	3.89	9.93	0.00	13.82	1336.27	9.80
Lentil	16.22	29.69	12.40	46.07	1693.94	9.55
Khesari (Lythyrus)	0.0	0.0	0.0	0.0	0.00	7.73
Kulthi (Horse Gram)	27.82	41.40	0.00	58.87	0.00	8.16
Moong (green Gram)	10.96	28.02	0.00	38.98	2445.77	5.41
Urad (Black Gram)	9.57	24.45	0.00	34.01	1620.51	5.09
Pea	24.93	37.40	22.86	85.19	1408.57	13.81
Oilseeds						
Rapeseed & mustard	49.25	48.60	32.34	98.72	3580.56	12.01
Linseed	22.60	17.64	11.00	51.24	1263.39	9.03
Sunflower	72.15	60.95	31.50	164.60	3876.40	12.14
Vegetable crops						
Brinjal	120.11	106.23	45.88	269.67	1815.79	315.62
Cabbage	65.90	60.26	31.50	157.66	1771.81	183.71
Cauliflower	50.84	47.32	25.42	123.58	1320.12	213.83
Okra(Bhindi)	76.55	61.14	39.64	157.51	2842.47	79.80
Onion	42.68	30.25	27.70	99.31	7584.02	189.50
Potato	94.38	82.96	41.38	194.66	5973.46	180.82
Tomato	42.18	24.67	37.00	70.14	6885.17	152.25
Cash crops						
Sugarcane(planed)	81.41	82.05	60.33	180.15	5900.67	624.51
Sugarcane(ratoon)	69.95	59.94	0.00	125.75	3270.66	365.90
Chillies	57.53	48.16	36.60	138.96	2275.22	36.28
Jute	64.00	46.00	28.06	138.06	2044.77	12.66

Appendix-B1: Crop wise input use and output in *Agro-Climatic Zone-I* of Bihar TE-2010-11

Crops	N (kg/ha)	P (kg/ha)	K (kg/ha)	NPK (kg/ha)	Ground water draft (cum/ha)	Yield (q/ha)
Cereal crops						
Paddy	56.93	43.25	29.82	89.18	5054.49	23.53
Wheat	82.16	55.65	28.08	143.76	6186.07	24.02
Maize (kharif)	55.82	46.36	0.00	67.22	0.00	14.79
Maize (rabi)	95.32	57.75	27.10	137.36	8802.08	44.62
Ragi	34.63	47.97	27.00	100.23	2454.70	20.04
Barely	58.64	44.90	17.86	121.40	4064.46	33.02
Pulse crops						
Arhar (Redgram)	3.89	9.93	0.00	13.82	1336.27	9.98
Lentil	10.69	27.36	0.00	38.05	227.32	10.16
Moong (Green Gram)	10.96	28.02	0.00	38.98	2445.77	5.35
Urad (Black Gram)	9.57	24.45	0.00	34.01	1620.51	5.09
Pea	24.93	37.40	22.86	85.19	1408.57	13.81
Oilseeds						
Rapeseed & mustard	52.11	48.41	29.51	105.53	3582.07	12.47
Vegetable crops						
Brinjal	63.03	51.37	30.00	144.40	1428.82	136.11
Cabbage	42.00	36.80	30.00	108.80	2323.28	200.00
Cauliflower	41.67	35.96	21.00	98.63	1293.29	215.53
Okra(Bhindi)	78.31	62.43	60.00	149.31	2555.61	69.67
Potato	75.44	71.72	44.72	156.50	6317.84	165.15
Cash crops						
Sugarcane (planed)	96.06	98.70	55.41	228.00	6163.46	624.51
Sugarcane (ratoon)	70.36	59.17	19.20	128.15	3377.13	365.90
Chillies	48.00	42.06	33.00	118.34	2207.12	25.88

Appendix-B2: Crop wise input use and output in *Agro-Climatic Zone-II* of Bihar TE-2010-11

Crops	N (kg/ha)	P (kg/ha)	K (kg/ha)	NPK (kg/ha)	Ground water draft (cum/ha)	Yield (q/ha)
Cereal crops						
Paddy	43.04	52.86	38.01	53.24	4770.346	24.27
Wheat	66.41	49.34	42.47	108.41	4341.847	31.02
Maize	113.52	57.49	44.33	215.34	7646.213	88.75
Pulse crops						
Lentil	24.95	23.00	0.00	26.62	5103.729	12.46
Oilseeds						
Sunflower	64.00	46.00	0.00	110.00	4159	12.3
Cash crops						
Jute	64.00	46.00	28.056	138.06	2044.772	12.66

Appendix-B3: Crop wise input use and output in *Agro-Climatic Zone-III* of Bihar TE-2010-11

Crops	N (kg/ha)	P (kg/ha)	K (kg/ha)	NPK (kg/ha)	Ground water draft (cum/ha)	Yield (q/ha)
Cereal crops						
Paddy	101.59	47.58	16.57	128.43	6325	28.4
Wheat	83.38	43.25	22.33	120.36	5487	23.8
Maize (kharif)	69.48	43.10	18.64	117.46	0	24.4
Maize (rabi)	95.02	58.65	16.44	170.11	3920	35.6
Ragi	16.58	42.36		58.93	0	7.5
Pulse crops						
Gram	26.55	29.70	16.65	57.69	0	10.3
Lentil	18.71	31.09	12.00	49.56	0	9.2
Arhar	0.00	0.00	0.00	0.00	2533	9.4
Khesari	0.00	0.00	0.00	0.00	0.0	7.6
Kulthi (Horse gram)	27.82	41.40	0.00	58.87	0	8.2
Oilseeds						
Rapeseed & Mustard	20.12	26.58	0.00	28.98	3371	6.9
Linseed	22.60	17.64	11.00	51.24	1263.39	9.03
Vegetable crops						
Brinjal	177.18	161.09	63.75	394.93	2590	495.1
Cabbage	71.88	66.13	31.88	169.88	1220	207.8
Okra(Bhindi)	76.12	63.25	38.44	173.53	3416	93.9
Potato	119.14	91.06	30.50	236.34	5617	213.3
Tomato	42.18	24.67	37.00	70.14	1374	151.6
Onion	42.08	29.46	27.89	98.04	6885	194.7
Cauliflower	62.31	61.53	30.94	154.78	12148	200.6
Cash crops						
Chilli	74.20	58.84	42.00	175.04	2411	57.1

Appendix-C: Crop Calendar

Month	Paddy	Wheat	K_maize	R_maize	Ragi	Barely	Arhar	Kulthi	gram	Lentil	khesari	moong	Urad	Pea	Rapeseed	Linseed	Sunflower	Potato	Cabbage	Brinjal	C_flower	Okra	Tomato	Onion	Jute	Scane	Chilli
jan	0	1	0	1	0	1	1	0	1	1	1	0	0	1	1	1	1	0	1	0	1	0	1	1	0	0	0
feb	0	1	0	1	0	1	1	0	1	1	1	0	0	1	1	1	1	0	1	0	0	1	1	1	0	1	0
mar	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0
apr	0	1	0	1	0	1	0.5	0	1	1	0	1	1	0	0	0	1	0	0	0	0	1	0	1	1	1	0
may	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0
jun	0	0	1	0	1	0	0.5	0	0	0	1	1	1	0	0	0	0	1	0	0.5	0	0	0	0	1	1	0
jul	1	0	1	0	1	0	1	0	0	0	1	1	1	0	0	0	0	1	0	1	0	0	0	0	1	1	1
Aug	1	0	1	0	1	0	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	1
sep	1	0	1	0	1	0	1	1	0	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1
oct	1	0	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1
nov	1	0	0	0	0	1	1	1	1	1	0	0	0	0.5	1	1	1	0	1	1	1	0	1	0	0	1	1
dec	0	1	0	1	0	1	1	0	1	1	1	0	0	1	1	1	1	0	1	0	1	0	1	1	0	1	1

Appendix-D: Existing area and Min. Max. area used in LP of Bihar

Crops	Area(000 ha)	Min_A	Max_A
Paddy	3156.00	2900	3500
Wheat	2106.33	2000	2600
Kharif maize	232.56	200	250
Rabi maize	349.69	340	400
Ragi	9.90	9	12
Barely	11.97	10	15
RedGram(Arhar)	26.67	25	40
HorseGram (kulthi)	10.76	10	15
Gram	58.97	60	70
Lentil	173.16	160	200
Lathyrus (Khesari)	83.82	80	85
Green Gram (moong)	161.31	160	200
BlackGram	18.66	15	20
Pea	21.35	19	24
Rapeseed & mustard	86.76	80	110
Linseed	23.90	23	25
Sunflower	18.97	18	25
Potato	151.00	148	200
Cabbage	38.72	35	40
Brinjal	55.36	50	60
Cauliflower	61.94	60	70
Okra	58.31	50	70
Tomato	46.57	40	60
Onion	52.53	50	56
Jute	123.96	120	150
Sugarcane	159.46	160	250
Chilli	3.00	2	3.5
GCA	7388.00		

Appendix-D1: Existing area and Min. Max. area used in LP of Zone-I of Bihar

Crops	Area(000'ha)	MinA	MaxA
Paddy	1320.33	1000	1400
Wheat	954.33	900	1025
Kharif maize	83.45	80	100
Rabi maize	120.39	100	150
Ragi	4.78	4	6
Barely	2.00	2	5
RedGram (Arhar)	14.67	15	20
Lentil	45.33	40	55
Lathyrus (Khesari)	5.00	3	5
Green Gram (moong)	82.22	80	100
BlackGram (urad)	18.66	15	25
Pea	7.35	6	11.5
Rapeseed & mustard	42.25	40	60
Linseed	11.64	10	15
Potato	71.66	70	100
Cabbage	17.70	10	20
Brinjal	25.31	20	30
Cauliflower	28.32	30	35
Okra	26.66	25	30
Sugarcane	147.46	140	200
Chilli	2.00	2	2.5
GCA	3170.00		

Appendix-D2: Existing area and Min. Max. area used in LP of Zone-II of Bihar

Crops	Area(000'ha)	MinA	MaxA
Paddy	681.67	600	750
Wheat	312.00	300	350
Rabi Maize	174.12	175	200
Lentil	11.00	10	15
Rapeseed & mustard	19.70	15	20
Linseed	5.43	5	8
Potato	34.28	30	40
Cabbage	8.79	5	12
Brinjal	12.57	12	15
Cauliflower	14.06	14	20
Okra	13.24	10	20
Jute	123.96	120	150
Chilli	0.68	0.5	1

Appendix-D3: Existing area and Min. Max. area used in LP of Zone-III of Bihar

Crops	Area(000'ha)	MinA	MaxA
Paddy	1154.0	1000	1500
Wheat	840.0	800	1000
Kharif maize	33.3	30	35
Rabi maize	55.2	50	60
Ragi	4.2	4	6
RedGram (Arhar)	12.0	12	18
HorseGram (kulthi)	3.9	3	5
Gram	58.6	50	70
Lentil	116.8	120	150
Lathyrus (khesari)	68.5	60	70
Rapeseed & Mustard	20.8	20	25
Sunflower	6.8	6	8
Potato	40.7	40	55
Cabbage	12.4	10	15
Brinjal	23.3	20	25
Cauliflower	19.9	15	25
Okra	24.5	20	26
Tomato	21.5	20	25
Onion	22.3	20	26
Chilli	1.0	1	2
GCA	2543.0		

Appendix-E: GAMES CODES

```
$setglobal path "C:\Users\user\Desktop\LP\"
Sets
c crops /
$call =xls2gms.exe I=%path%bihar_LP1.xls O=%path%bihar_LP1.inc R=limit!a2:a28
$include %path%bihar_LP1.inc
 / ;
display "crops List Loaded from Excel sheet Limit", c;
set
    t period  /jan,feb,mar,apr,may,jun,jul,aug,sep,oct,nov,dec/
    st stat /Area,Min_A,Max_A,Nreturn,water,EcoPrice,NRV, water_c/ ;
*///Precaution: name of crop should be same in both excel files set c and land(t,c)
parameter land(t,c) ;
$call gdxxrw.exe %path%bihar_LP1.xls par=land rng=data!a1:ab13
*///make the path relative for the gdx files
$GDXIN %path%bihar_LP1.gdx
*$GDXIN  C:\Users\rajni2\Documents\gamsdir\projdir\regional.gdx
$load land
$GDXIN
display "Land Data as loaded from Excel Sheet Data", land;
$call gdxxrw.exe %path%bihar_LP1.xls par=Arealmt rng=limit!a1:i28
parameter Arealmt(c,st)   ;
$GDXIN %path%bihar_LP1.gdx
*$GDXIN  C:\Users\rajni2\Documents\gamsdir\projdir\regional.gdx
$load Arealmt
$GDXIN
PARAMETER
NR (c) netrevenue
AR (c) Existing Area
jal(c) water requirement per hectare cubic meter
mnA (c) Minimum limit of area
mxA (c) Maximum limit of area
;
*/// put * in two of the next three rows depending on the selection of the Nreturn, Ecoprice,
NRV
```

```
*NR(c)=   Arealmt(c,"Nreturn")    ;
*NR(c)=   Arealmt(c,"EcoPrice")    ;
NR(c)=   Arealmt(c,"NRV")    ;
AR (c)=  Arealmt (c,"Area")      ;
jal(c)=  Arealmt(c,"water_c")      ;
mnA (c)=  Arealmt(c,"Min_A")     ;
mxA (c)=  Arealmt(c,"Max_A")     ;
Scalars
*/// this constant is defined based on Net sown area under LP planning
tca Net sown area in Thousand Ha /4970 /
*/// gwa value is defined based on ground water available for the regional agriculture
*gwa total ground water avaialble for agriculture in Billion Cubic Meter (BCM) /34.32142/
gwa total ground water avaialble in Billion Cubic Meter (BCM) /15.50/
Aag fraction of ground water available (gwa) for crop sector /1/;
*/// next command is to verify the data as used by GAMS for LP
display  "data set as loaded in GAMS Parameter Arealmt ", Arealmt;
display "Selected Net Retun for RCP", NR;
variables
  prof  profit (in RS)
positive variables
 carea (c)  CArea (in ha)
Equations
landeq (t)  land allocaton
minArea (c) Minimum area restriction
maxArea (c) Maximum area restriction
waterc  water constraint
profit   profit from production
;
*/ area under cultivation will be limited by total cropped area in each month
landeq (t)..      sum(c, carea(c)*land(t,c)*1000) =l=  tca*1000;
*/ minimum area under each crop is constrained by the user
minArea (c)..    carea(c)*1000  =g=  mnA(c)*1000 ;
*/ maximum area under each crop is constrained by the user
maxArea (c)..    carea(c)*1000  =l=  mxA(c)*1000 ;
waterc..         sum(c, jal(c)*carea(c)*1000) =l= gwa*1000000000*Aag;
```

```
profit..   prof =e=  sum(c, NR(c)*carea(c)*1000);
Model   regional  regional crop production /all/;
*Model   regional  regional crop production /landeq,minArea,maxArea,waterc,profit/;
solve regional  using lp maximizing proof
```


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