AN ECONOMIC EVALUATION OF WATER PRODUCTIVITY IN UPPER KRISHNA PROJECT (UKP) AND MALAPRABHA GHATAPRABHA PROJECT (MGP) COMMAND AREAS IN KARNATAKA

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CERTIFICATE

This is to certify that the thesis entitled "AN ECONOMIC EVALUATION OF WATER PRODUCTIVITY IN UPPER KRISHNA PROJECT (UKP) AND MALAPRABHA GHATAPRABHA PROJECT (MGP) COMMAND AREAS IN KARNATAKA" submitted by Mr. VEERESH S. WALI for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ECONOMICS, to the University of Agricultural Sciences, Dharwad, is a record of research work carried out by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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JUNE, 2016 **(Veeresh S. Wali)**

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LIST OF ABBREVIATIONS

Sl. No	Abbreviation	Expansion
01	ALBC	Almatti Left Bank Canal
02	IBC	Indi Branch Canal
03	MLBC	Malaprabha Left Bank Canal
04	GRBC	Ghataprabha Right Bank Canal
05	UKP	Upper Krishna Project
06	MGP	Malaprabha Ghataprabha Project
07	HR	Head Region
08	TR	Tail Region
09	GEWP	Gross Economic Water Productivity
10	NEWP	Net Economic Water Productivity
11	GCA	Gross Cropped Area
12	NCA	Net Cropped Area
13	CI	Cropping Intensity
14	Max.	Maximum
15	Min.	Minimum

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1. INTRODUCTION

"Water is probably the only natural resource to touch all aspects of human civilization from agricultural and industrial development to cultural and religious values embedded in society."

–Koichiro Matsurra,

As water resources around the world are threatened by scarcity, degradation and overuse, and food demands are projected to increase, it is important to improve our ability to produce food with less water. There are only a few basic methods of using the earth's water resources to meet the growing food demands: continuing to expand rainfed and irrigated lands; increasing production per unit of water; trade in food commodities; and changes in consumption practices. Land expansion is no longer a viable solution. Therefore, improving agricultural productivity on existing lands using the same amount of water will be essential. Increasing water productivity means using less water to complete a particular task, or using the same amount of water, but producing more. Increased water productivity has been associated with improved food security and livelihood.

Additionally, it leads to savings in fresh water, making it available for other uses, such as healthy ecosystem functioning. Increased water productivity is therefore an important element in improved management of water and ecosystems for sustainable agriculture and food security. Water productivity is the amount of beneficial output per unit of water depleted. In its broadest sense, it reflects the objectives of producing more food, and the associated income, livelihood and ecological benefits, at a lower social and environmental cost per unit of water used. Usually, water productivity is defined as a mass (kg), monetary ($) or energy (calorific) value of produce per unit of water evapotranspired, and, as such, it is a measure of the ability of agricultural systems to convert water into food (Palanisami *et. al.,* 2009*)*.Water use efficiency and water productivity are often used in the same context of increasing agricultural outputs while using or degrading fewer resources. Although definitions vary, water use efficiency usually takes into account the water input, whereas water productivity uses the water consumption in its calculation. In this study, both terms are used interchangeably, reflecting the most common use in field.

Improving agricultural water productivity is not about increasing the production of rainfed or irrigated crops, but also about maximizing the products and services from livestock, trees and fish per unit of water use. Crop water productivity has been the subject of many years of research, and its assessment and means for improvement are well documented. However, for other agricultural outputs and systems, such as livestock, agroforestry, fisheries and aquaculture, research on improving water productivity is still in its infancy. In recent years though, a growing body of evidence is creating a clearer picture on the potential solutions and ways forward. Besides going beyond crops, there is a need to emphasize the need for careful targeting of technologies and enabling policies and institutions for successful adoption in farmer communities.

Even as an agriculture dominated economic environment has been prevailing in India, industrialization coupled with urbanization is emerging as the new arena of economic growth. Urbanization has been becoming quite inevitable in order to harvest the fruits of globalization towards improvising upon the standards of living of an exponentially exploding population. Be it agriculture or industry or any other equivalent national growth determinant, water plays the pivotal role to churn in the expected level of performance efficiency or the order of physical as well as economic productivity. Increasing or at least sustaining the productivity is of paramount importance when water, the elixir of life, has been becoming a scarce resource on account of over exploitation to meet the multifarious demands in the order of preference. Present circumstances warrant redefining the conceptual framework of water productivity on various scales of reference incorporating all possible vital factors such as the crop genetic material, water management practices, agronomic processes and the economic and policy incentives. If we can devise appropriate situations wherein more food production can be triggered by using less water (or in a sense, the correct quantum of water application with minimum or zero losses), the water saved becomes water earned for additional area of cultivation besides increasing the physical as well as the economic productivity in terms of yield or its equivalent income over unit depth of water consumed per unit area of application.

Globally, population growth, rising incomes and urbanization are increasing the demand for water from the household and industrial sectors (Strzepek and Boehlert,2010).Today's world population of 6,000 million is expected to reach about 8,100 million by 2030, an increase of 35per cent. The growing population will result in considerable additional demand of food, water and other necessities. Developing countries are expected to experience an increase in non-agricultural demand for water of 100 per cent between 1995 and 2025 (Turner et al., 2004) and, for the first time, absolute growth in non agricultural water consumption is greater than absolute growth in agricultural water consumption (Rosegrant, Cai, and Cline, 2002). Simultaneously, and for the same reasons, there is an increasing demand for food that is resulting in greater demand for water for agriculture. Heightened demand from the household, industrial and agricultural sectors is increasing the competition for water and this increased competition, coupled with concerns about national food security, has lead to growing interest in irrigation as a way to increase national production, especially given the increased uncertainty regarding the possible impacts of climate change on water availability (Bank, 2006). A recent FAO analysis of 93 developing countries expected agricultural production to increase over the period 1998–2030 by 49 per cent in rain fed systems and by 81per cent in irrigated systems. Therefore, much of the additional food production is expected to come from irrigated land, three quarters of which is located in developing countries. Simultaneously, the water demand from non-agricultural sectors will keep growing in both developed and developing countries. One of the critical challenges of the early 21st century is the resolution of the water crisis. Increased competition for water brings with it an increased need to quantify its value in different uses.

The concept of *water productivity* (WP) used by plant physiologists, molecular biologists, and plant breeders refers to the crop output (either grain or biomass) per unit of transpiration by the plant. (This is typically referred to as *water use efficiency* (WUE)). There has been steady improvement in grain yield per hectare through plant breeding in rainfed and most particularly in irrigated areas. The development of short season varieties, reducing the growing time from five months to three and a half to four months has also been a major source of water savings (more crop per drop per day). The development of water storage facilities and expansion of irrigated area in the dry season has allowed this savings to be translated into increases in water productivity. Pure physical productivity is defined as the quantity of the product divided by the quantity of the input e.g., Crop yield per hectare or per cubic meter of water either diverted or consumed by the plant. The existing literature provides several measures of water productivity, that is, ratio between output and water use. The water productivity in India is very low and is approximately 0.48 kg/m^3. Given these complexities, it is small wonder that there is little agreement among scientists, practitioners, and policy makers as to the most appropriate course of action to improve the management of water resources for the benefit of society. This fact notwithstanding, the growing scarcity of water increases the need and for sound economic analyses. The purpose of this study is to analyze water productivity in the command areas to generate inputs for informed policy. Even as an agriculture dominated economic environment has been prevailing in India, industrialization coupled with urbanization is emerging as the new arena of economic growth. Urbanization has been becoming quite inevitable in order to harvest the fruits of globalization towards improvising upon the standards of living of an exponentially exploding population. Be it agriculture or industry or any other equivalent national growth determinant, water plays the pivotal role to churn in the expected level of performance efficiency or the order of physical as well as economic productivity. Increasing or at least sustaining the productivity is of paramount importance when water, the elixir of life, has been becoming a scarce resource on account of over exploitation to meet the multifarious demands in the order of preference. Present circumstances warrant redefining the conceptual framework of water productivity on various scales of reference incorporating all possible vital factors such as the crop genetic material, water management practices, agronomic processes and the economic and policy incentives. If we can devise appropriate situations wherein more food production can be triggered by using less water (or in a sense, the correct quantum of water application with minimum or zero losses), the water saved becomes water earned for additional area of cultivation besides increasing the physical as well as the economic productivity in terms of yield or its equivalent income over unit depth of water consumed per unit area of application.

Water Productivity: Definition and conceptual framework

By and large, the term ‘water productivity’ refers to the magnitude of output or benefit resulting from the input quantum of water as applied on a unit base. In the domain of agriculture, it is expressed as the net consumptive use efficiency in terms of yield per unit depth of water consumed per unit area of cultivation. If the field water conveyance, application, storage and distribution efficiencies are accounted to depict the seepage, run-off and deep percolation losses (not consumed by plant; evapo-transpiration loss is included as an implicit component of field water balance) it would be termed as the gross irrigation water use efficiency. However, the term water use efficiency is a manifestation of integrated physical or economic land and water productivity as the numerator is the yield or equivalent income and the denominator is the depth of water consumed per unit land area used (tones per hectare per cm of water, for instance). When isolated as 'water productivity' it becomes a partial productivity of one factor viz., water, irrespective of the land unit but in reference to the scale of production in the range of a single plant's effective root zone to a basin or system of irrigation command. As more and more water losses are incurred when the scale of reference expands, the apparent or relative water productivity is bound to decrease. However, for an increasing scale, the chances of recovering the so called 'losses' of water are bound to increase and at one stage, may be a project or basin scale, the loss at one point will be a gain at another point (as deep percolation leading to groundwater recharge or runoff leading to surface detention and storage) for recycling. In other words, the basic net input of water required in the effective root zone of a plant scale is subsequently reckoned as a gross input of water incorporating the irrigation efficiencies (□) at farm/field level and fixing the flow duty (D), field duty (Δ) and storage duty (S) at a system/project/basin/command level. The overall conceptual framework should account for all these transformation parameters from scale to scale.

Opportunities for improving crop water productivity mainly lie in choosing adapted, water-efficient crops, reducing unproductive water losses and ensuring ideal agronomic conditions for crop production (Bouman, 2001). In general, agronomic measures directed at healthy, vigorously growing crops favour transpirational and productive water losses over unproductive losses. An important principle for crop water productivity is that taking away water stress will only improve water productivity if other stresses (nutrient deficiencies, weeds and diseases) are also alleviated or removed (Bouman, 2001), i.e. water management should go hand in hand with nutrient management, soil management and pest management (Bennet 2003).

India is still an agrarian country, although the structure of the economy is gradually changing. Industrialization and urbanization set off in the 1990s have resulted in a greater contribution from the manufacturing and service sectors to the national economic output. Today, agriculture sector contributes to only 13per cent of the gross domestic product (GDP), yet nearly 70 per cent of the country's population live in rural areas and a major part of this depends on agriculture-related economic activities for their livelihoods. Projections show that it would take another five decades before the population starts stabilizing (Visaria and Visaria 1997). Hence, sustaining agriculture production, particularly the production of food grains in tune with population growth and changing consumption patterns, is an important task. This task is not only essential for feeding the growing population for a large country like India, but also important for supporting livelihoods and reducing the poverty of India's large rural population1 (Chaturvedi 2000). Moreover, water demand in non agricultural sectors, including that for the environment is increasing and many regions in the country are facing severe water stress (Amarasinghe *et al.* 2008). Thus, efforts to manage water efficiently in the agriculture sector and produce more crop and value per drop are gaining momentum now more than ever before. Agriculture continues to account for a major share of the water demand in India (Amarasinghe et al. 2007). South-west monsoon provides a major part of India's annual rainfall, and the quantum varies widely across space (GOI 1999). In most places, growing crops requirean artificial provision of water during non-monsoon season and in some places even during the monsoon. In fact, only one-third of the agricultural production in the country comes from rain-fed areas, which account for two-thirds of the crop lands. As per official projections, a major share of the future growth in India's agriculture production would have to come from increasing cropping intensity, and bringing rainfed areas under irrigated production, rather than expanding the net cultivated area (GOI 2002), all of which would require irrigation water.

The existing literature provides several measures of water productivity, that is, ratio between output and water use. The water productivity in India is very low and is approximately 0.48 kg/m3. Given these complexities, it is small wonder that there is little agreement among scientists, practitioners, and policy makers as to the most appropriate course of action to improve the management of water resources for the benefit of society. The growing scarcity of water has increased the need for sound economic analyses. The purpose of this study is to analyze water productivity in the command areas to generate inputs for informed policy.

1.1 Specific Objectives of the study

1. To analyze the cropping pattern in the Upper Krishna Project (UKP) and Malaprabha Ghataprabha Project (MGP) command areas
2. To assess the productivities of selected crops in the command areas
3. To estimate economics of water productivity of selected crops in the command areas
4. To document perceptions of stakeholders in enhancing water productivity in command area.

1.2 Hypotheses

1. Recommended cropping pattern in the command area is in variance with practice
2. Productivities of selected crops are low in the study area
3. Economic water productivity of selected crops is low
4. Stakeholders have difficulties in improving water productivity.

1.3 Limitations of the study

1. Secondary data was not available from UKP command area for analysis of cropping pattern.
2. Measurement of water in quantitative terms was not very accurate as it was done based on the level of depth only and other losses (distribution and irrigation losses) were not accounted.

Some villages had not received the canal water and therefore volumetric assessment was done in those villages.

1.4 Presentation of the study

The study is presented under the following chapters

Introduction: Covers the nature and importance of research problem, specific objectives and hypotheses of the study.

Review of Literature: Review of the relevant past studies related to the present study are presented under different heads keeping in view the objectives of the study.

Methodology: This chapter highlights overview of the study area, the nature and sources from where relevant data have been collected, the analytical tools employed for evaluating the objectives of the study and definitions of various concepts used.

Results: The results of the study and their analysis have been presented in this chapter.

Discussion: It emphasizes on interpretations of the results and attempts to establish relationships between certain variables and their outcomes.

Summary and Policy Implications: Brief summary of the main findings of the study along with policy implications drawn from the findings have been presented.

References: The list of the referred research articles, theses, books and journals are presented in this section.

2. REVIEW OF LITERATURE

2.1 Cropping pattern in the command areas

Mayya and Prasad (1989) conducted a study on the effect of optimal use of irrigation potential in southern Indian minor irrigation tank systems. The method involved developing a linear programming model to optimize the net profit from the system and to determined the optimal cropping pattern under the influence of various parameters, e.g. animal power, labour, fodder production, farmers' resources, system's nutritional energy requirement as well as water availability. The solution demonstrates the effectiveness of prevailing agricultural practices that are consistent with the availability of water resources in the initial crop season

Ghosh (1990) conducted a study to identify the possible factors that promote multiple cropping in the prevailing conditions in Andhra Pradesh. The analysis was conducted separately for the state as a whole and for each agro climatic region of the state. The dominant source of irrigation were canals, followed by tanks, other wells, tube wells and other sources. The state was broadly classified into five regions on the basis of rainfall and cropping patterns; the first two regions belonged to the more fertile coastal Andhra Pradesh; the third region comprises the Rayalaseema area; and Telangana area was divided to produce the last two regions. Irrigation intensity was highest in region 1 followed by region 2. Canal irrigation emerges as the most important factor promoting Cropping Intensity. Tank irrigation was dominant in region 3. Tubewell irrigation was insignificant in the state. Fertilizer was a significant positive factor in determining Cropping Intensity in regions 1, 2, and 3. In regions 4 and 5 fertilizer did not play any favourable role.

Balasubramaniam *et al.* (1996) studied the cropping pattern in Aralikottai tank command by Linear Programming (LP) modeling of the existing situation and the best allocation policy was carried out for the Aralikottai tank system, Tamil Nadu, India. The actual conditions were simulated at each sluice command level whereas the best operation policy was attempted for the entire system as a whole. The analysis was conducted separately for a drought year (1988) and a surplus year (1990) with the available five year data from 1988 to 1992. The conclusions showed that the late transplantations of the rice crop and the excess water application during the periods of water availability (leading to water stress during the last stages of crop maturity) are the causes of meager benefits in a drought year. In a surplus year, the excess water application over the entire cropping season resulted in under-utilization of land resources and moderate benefits. The existing status of irrigation can be improved to obtain the maximum benefits from the tank command area based on the quantification done.

Karunakaran and Palanisami (1998) analysed the impact of irrigation particularly different sources of irrigation on cropping intensity with a view to evaluate investment pattern in major and minor irrigation projects and maximizing benefits of available resources using secondary data from 1969/70-1993/94 in Tamil Nadu, India. Linear regression models were used in the study and the estimated results revealed evidence of close relationship between irrigation development and intensity of cropping at the state level. These results are also confirmed by cross section regression analysis with different sources of irrigation. Besides canal and tank irrigation, dug well irrigation also showed significant positive impact on the cropping intensity up to 1979-80. The tubewell and dugwell irrigation had more impact on cropping intensity. Inspite of a declining trend in tank irrigated area, its significant positive impact on cropping intensity called for immediate attention to revive the tank irrigation system.

Chand and Chauhan (2002) reported that due to favourable irrigation facility, Haryana continued to shift the cropping pattern towards rice and thus attain the top position in diversification.

Utpal (2003) studied changing cropping pattern in theory and practice with special reference to Agrarian West Bengal. Based on earlier studies the study made some assumptions that cropping pattern was introduced to raise the expected farm income and changes in technology might influence cropping pattern. Also improvement of infrastructure, expected normal price, expansion of irrigation, market forces and rainfall played a dominant role in the determination of area allocation among the food crops. Relative price, irrigation facility, soil condition, price policies of the government, yield of crops, technology, infrastructure etc. were responsible for crop diversification in different places.

Sekar and Ramasamy (2003) conducted a study on application of the advanced break even methodology on rice, groundnut and green gram within and between crop enterprises in the tank fed environment of Chengalpattu district of Tamil Nadu state, India. Primary data were randomly collected from a sample of 120 farms from the tank ayacut for theobjectives and options of the location; conveyance and application methods; crops and their irrigation requirements; productivity; the demands of the population in terms of the amount of food grains, pulses, oilseeds and nutrients; and the availability of different inputs to achieve an optimal design of all components of the system.

Goswami *et al.* (2003) made a studied on land use dynamics in Mizoram using the secondary data on land use pattern area, production and productivity of principal crops. Using exponential distribution compound growth rates of various categories of land use, compound growth rates of area, yield and production of major crops were computed for (period of study was 1992-93 to 2000-01). For measuring variability of different land use coefficient of variation was used and to measure crop diversification Herfindahl index was used. The overall cropping pattern indicated that less and less number of crops were grown in the recent years as compared to the number of crops grown in the initial years of study. Reduction in the area of available wasteland may be due to the diversion of the land for cultivation and also for non-agricultural uses. The other crops included vegetables, sugarcane and ragi grown to a limited extent. The study shows that rice, groundnut and green gram had an ability to withstand some degree of fluctuation while maintaining non-negative returns above total costs. In the tank fed situation, rice was able to withstand a significant fall in product yield and price and rise in costs and input requirements. Breakeven elasticity analysis also implies that rice cultivation was more favorable under increasing price market and soaring cost situations. The study suggested that other factors such as crop rotation, soil fertility and government policy restrictions, etc., also need to be considered while making production decisions.

Singh and Sidhu (2004) analyzed factors in declining crop diversification, which is a case study of Punjab. Agricultural production in Punjab has been characterized by a sharp decline in diversity in the cropping pattern and the emergence of wheat-rice specialization over the past few decades. Due to improved yields and increased area wheat and rice experienced the highest growth in output. Diversification index was calculated to know crop diversity. Growth in the aggregate value of output was decomposed into growth in area and average yield. Over use of natural resources, ecological problems and growing income risk were the serious repercussions of that declining diversity.

Goswami and Challa (2004) made an analysis on Indian land use scenario. The main assumption of the study was the changes in cropping showed a gradual shift. Shift in area from food crops to non-food crops indicated more diversification in recent times. Authors assumed income, demand, price and preference, rural-urban interferences, infrastructure development, government policy and global market as some of the socio-economic factors affecting land use planning. The study was based on secondary data, which were collected from various issues of Agriculture in Brief published by the Ministry of Agriculture. Five measures of crop diversification such as Herfindahl Index, Ogive Index, Entropy Index, Modified Entropy Index and Composite Entropy Index were used to measure crop diversification. From the analysis of changes in the cropping pattern for the periods 1950-51 to 1997-98 it could be seen that the proportion of area under total cereals to total cropped area decreased from 61.1 per cent in 1950-51 to 53.8 per cent in 1997-98. The change from subsistence cropping to commercial cropping was noticed in the area shift between just after independence and 1997-98. Food crops area, which was 76 per cent of total cropped area, came down to 65.8 per cent and non-food crops increased to 34.2 per cent.

Singh *et al.* (2006) studied impact of land irrigability classes on cropping pattern under Mahi right bank (MRB), Ukai-Kakrapar Right Bank (UKRB) and Kakrapar Left Bank (KLB) canal command areas of the Gujarat state. The multi-stage random sampling method was used to select the farmers. The major crops grown in the UKRB were sugarcane, rice, cotton and pigeon pea, while sugarcane and rice were the major crops in the KLB. Similarly, in the MRB, rice, pearl millet, groundnut, wheat and tobacco crops occupied 95 per cent of the total irrigated area. The study revealed that farmers violated the recommended cropping pattern and were growing high water-requiring crops, irrespective of their suitability to land.

Birthal *et al.* (2007) reported that agriculture diversification towards high value crops can potentially increase especially in a country like India where demand for high value food products has been increasing more quickly than that for staple crops. Indian agriculture is overwhelmingly dominated by small holder, and researcher have long debated the ability of a small holder dominated subsistence farm economy to diversified into riskier high value crops. This forces the farmers to go for high value crops and creates way for diversification of Indian agriculture.

Shergill (2008) examined India's food security and observed that it depends upon vitally on wheat and rice production in Punjab, which contributes more than 50 per cent of the central pool of cereal stocks. The sustainability of wheat and rice production at the present scale in Punjab has been questioned by some experts, both on economic and ecological grounds. The evaluation of empirical evidence on economic and ecological aspects of wheat-ricecultivation in Punjab, however, showed that it was quite sustainable, the economics of rotation was sound, a growing domestic market was assured for the next few decades and the minimum support prices programme would continue in the foreseeable future.

Sahoo (2008) observed that growth of area under different individual crops, the acreage under rice, wheat and sugarcane increased at the cost of coarse cereals. In the 1990s the area under oilseeds, cotton and sugarcane indicated increasing trend. Thus, decelerations in area under food grain crops and rise in area under non food grain crops have been witnessed and prospective farmers showed a preference in favor of rich cash crops like fruits vegetables, potatoes and cashew.

Satish (2010) studied the cropping pattern under Cauvery, Malaprabha and Ghataprabha, Bhadra, Tungabhadra and Upper Krishna irrigation projects in Karnataka.Tabular analysis was employed to study the cropping pattern. The results revealed that cropping pattern followed was more in favour of light irrigated crops in the command are as against the general tendency of farmer’s inclination towards water intensive crops in the command areas like paddy and sugarcane

Zaveri and Parmar (2013) concluded that Narmada main canal water is blessing for farmers of Barmer district of Rajasthan. More than 65 % of lands were barren and could grow only thorny trees. Before Narmada main canal water availability, bajra was the major crops for Barmer region. In Barmer, before Narmada main canal water availability, most of the areas were irrigated by wells and total irrigated area was 106249 ha. After availability of Narmada main canal water total irrigated area is increased 18 %. After Narmada main canal water area the production of wheat, jowar and onion increased while the area of onion decreased. Wheat and jowar witnessed an increase in area. Area, production & yield of most of crops are increased after Narmada main canal water supply.

Vijayalaxmi (2015) studied the cropping pattern in command and non command areas of Karnataka Community Based Tank Management in Vijayapur district. It was found that area under crops in each season was more in command area than in non-command area. Further, the area under commercial and horticultural crops like sugarcane and grape was also more in command area than in non-command area. The cropping intensity was found to be more by about 23 per cent in command area over non-command area. It was inferred that this was possible because of availability of water for irrigation from the tanks.

Laxmi (2015) studied the cropping pattern in Vijayapur district under the Ganga Kalyana Yojane (GKY). The results revealed that on an average, the farm of SC farmer supported under Dr.B.R. Ambedkar Corporation, in kharif, the total dry land area under cultivation decreased from 1.31 ha. before Ganga Kalyana Scheme to 0.88 ha. after the scheme. While no area was under irrigation before the scheme. Area under irrigation increased to 1.1 ha. in the post project period showing increase of about 51 per cent change. This enhancement could be attributed to the availability of irrigation water from the Ganga Kalyan Scheme bore wells.

2.2 Productivity of selected crops in the irrigated command areas

Chavas (2001) analyzed international agricultural productivity using nonparametric methods to estimate productivity indices. The analysis used FAO annual data on agricultural inputs and outputs for twelve developing countries between 1960 and 1994. Technical efficiency indices for time series analysis results suggested that in general the technology of the early 1990s was similar to the one in the early 1960s. This showed that the improvement in agricultural production was not because of technology but because of other inputs such as fertilizer and pesticides. The general empirical results indicated only weak evidence of agricultural technical change and productivity growth both over time 16 and across countries. There was much evidence of strong productivity growth in agriculture over the last few decades corresponding to changes in inputs

Chang *et al.* (2001) determined how to promote agricultural productivity growth to achieve sustainable food security most efficiently in Asia and the Pacific. The study looked at the role of investment, both in physical and human capital, in maintaining and increasing agricultural productivity. In order to achieve the objectives the study used TFP and partial factor productivity functions. Results indicate that agricultural output growth has remained positive from 1961 to 1994 with only one exception, Japan, compared to a slowdown during1975-1987 in output and labour productivity growth in Australia and the United States.

Grant (2002) estimated agricultural productivity from regional accounts for twenty one regions in 1880/4, 1893/7 and 1905/9 in Germany. The estimates were derived from regional accounts for agricultural production and costs. Results indicated that productivity in East- Elbian agriculture was growing rapidly in the period, and tending to converge on the German average. Productivity in Southern region was not growing so fast, which showed that yield improvements were not limited to large farms and estates, but that smaller holdings also had access to new technology and improved husbandry methods. The main conclusion to emerge from this analysis was that there was a strong process of convergence which brought productivity up in the rural east to level equal to or above the national average. This convergence mechanism was associated with the spread of more advance agricultural techniques

Gajja *et al.*(2006) studied the impact of land irrigability classes on crop productivity has been reported based on the survey of Mahi right bank (MRB), Ukai-Kakrapar right bank (UKRB) and Kakrapar left bank (KLB) canal command areas of the Gujarat state. The multi-stagerandom sampling method was used to select the farmers. The MRB and UKRB areas have five different soils environment in terms of land irrigability classes, while the KLB area has only three soils environment. The major crops grown in the UKRB are sugarcane, rice, cotton and pigeon pea, while sugarcane and rice are the major crops in the KLB. Similarly, in the MRB, rice, pearl millet, groundnut, wheat and tobacco crops occupy 95 per cent of the total irrigated area. The study has revealed that farmers have violated the recommended cropping pattern and are growing high water-requiring crops, irrespective of their suitability to land. In the land irrigability classes III, IV and V, cultivation of sugarcane and rice has led to waterlogging and secondary salinization problems, and reduction in crop yields. Hence, the cultivation of lower irrigability classes with minimum use of major inputs is not an advisable proposition. It would be better if crops are selected according to land irrigability classes which might result in a higher production with lower unit cost of production in the command areas under the study

Montazar (2009) conducted a study to assess the global water productivity (GWP) within the major irrigation command areas of Islamic Republic (I.R.) Iran. For this purpose, fourteen irrigation command areas located in different areas of Iran were selected. In order to calculate the global water productivity of irrigation command areas, data on the delivered water to cropping pattern, cultivated area, crops water requirement, and yield production rate during 2002-2006 were gathered. The results indicated that the lowest GWP belonged to Mahyar and Borkhar irrigation areas, 0.24 kg m-3, and the highest was that of the Dez irrigation area, 0.81 kg m-3. The findings demonstrated that water management in the two irrigation areas is just efficient. The difference in the GWP of irrigation areas was due to variations in the cropping pattern, amount of crop productions, in addition to the effective factors in the water use efficiency in the irrigation areas.

Lashari and Mahesar (2012) from a study on improving water and agricultural productivity in Pakistan concluded that improving agriculture productivity was lying in promoting efficient and environmentally sound water management practices. Increasing water productivity, gaining more crop yield and value per unit of water was an effective means of intensifying agricultural production and reducing environmental degradation. The actions needed are: bringing the production levels of low-yield farmers up to 80% of what high-yield farmers get from comparable land by better water management. The greatest potential increases in yields were in rain-fed areas, where many of Pakistan's poor rural people live and where better water management was the key to such increases.

Sivasankar *et al.* (2014) studied economic efficiency of irrigation water resources in Krishna Western Delta (KWD) of Andhra Pradesh. The net area irrigated also showed declining growth at a rate of –3.98 per cent. Chilly is the most profitable crop cultivated in KWD. Regarding paddy, it was highest for System of Rice Intensification (SRI) technology

Raut *et al.* (2014) studied efficacy of irrigation management of *rabi*rice and small vegetable crops grown in the Balipatna Canal Command area of Orissa (subhumid region) using land use map derived through supervised Maximum Likelihood Classification, Survey Of India (SOI) toposheets and field verification and from irrigation scheduling efficiencies obtained through FAO model CROPWAT 8.0. Irrigation scheduling efficiencies for vegetables were computed from crop coefficients, amount of water supplied at different growth stages, soil water depletion and crop water requirement. For computing water requirement of rice, factors related to land preparation, puddling and soil as suggested by FAO were taken into account. Agro-meteorological data in combination with land use map approximated the deficiency of applied irrigation amount as compared to requirement. Irrigation application at 25-85 Days After Transplanting (DAT), for two times of applications, 30-60-100 DAT for three, 20-40-70-100 DAT in case of four irrigations resulted in better scheduling efficiencies for vegetables.

Gade and Chavan (2014) analyzed the agriculture productivity pattern in Karad tahsil command area in Krishna canal, Maharastra This study was based on secondary data collected from secondary records. The data regarding area under different crops was computed with the help of Singh's ranking co-efficient technique of agricultural productivity. Administratively the command area of Krishna canal was divided into 14 villages. The study gave an idea of agricultural productivity in command area of Krishna canal in Karad Tahsil and revealed that there was positive impact on productivity of crop through the agricultural inputs. Agriculture production was influenced by physical, climatologically, socio economic, technological, organizational factors, farmer's attitude etc.

2.3 To estimate economics of water productivity of selected crops in the command area

Dang *et al.* (2001) defined the water productivity in three different ways. The water productivity per unit of evapotranspiration (WPET) is the mass of crop production divided by the total mass of water transpired by the crop and lost from the soil. The water productivity per unit of irrigation (WPI) is the crop production divided by irrigation flow. The water productivity per unit of gross inflow (WPG) is the crop production divided by the rain plus irrigation flow. Water productivity with reference to evapotranspiration WPET takes into accounts only water evaporated or transpired and is therefore focused on plant behaviour whereas WPI and WPG include not only ET but also water used in other ways for crop products and water that is wasted.

Ximing Cai (2003) predicted the increment of global average water productivity of rice and other cereals from 0.39 kg m-3 to 0.52 kg m-3 and 0.67 kg m-3 to 1.01 kg m-3respectively from 1995 to 2025. He also reported that water productivity of irrigated crops is higher than that of rainfed crops in developing countries, is lower in developed countries.

Barker *et. al.*(2003) addressed the confusion in definitions of irrigation and water use efficiency and productivity. *Irrigation efficiency* created potential, instead of creating additional potential. Experts opined that prioritization of irrigation works in Karnataka should be in the descending order of tanks, minor irrigation schemes, barrages, bore well and major and medium irrigation About 44 per cent of the respondents felt that there existed a regional imbalance between north and south Karnataka with respect to irrigation development.

Bennett (2003) He makes clear that increasing crop water productivity is a challenge at various levels. The first challenge is to continue to enhance the marketable yield of crops without increasing transpiration. The second challenge is at field, farm and system levels to reduce as much as possible all outflows that do not contribute to crop production. These three levels are interlinked and the available water for crop production must be used to its greatest advantage within the basin.

Hugar (2004) conducted a study to know the economics of canal irrigation water and its distribution revealed that the estimated productivity of water at the head region (Rs. 2446.38 million ha cm) of Tungabhadra Left Bank Canal system in Karnataka was found to be lower than that of middle (Rs. 2,778.71 lakh per million ha cm) and tail (Rs. 2853.03 lakh/ million ha cm) regions. Even though the cost of water distribution has increased considerably over years (Rs. 13.263 lakh per million ha cm in 1984-85 to Rs. 45.758 lakh per million ha cm in 1993-94), it was profitable to invest in canal irrigation since the net returns (Rs. 952.98 lakh per million ha cm) accrued were at higher level. Similarly, as the cost of water distribution (Rs.320.10/ha) was more than the existing maximum water rate (Rs. 250/ha in paddy), there is scope for upward revision of water rate if the farmers are assured of regular and adequate supply of water.

Van dam *et al.* (2006) evaluated the water productivity, net groundwater recharge and salt build up in Sirsa district of Haryana. Factors responsible for low values of water productivity in the district included a high share of soil evaporation into evapotranspiration (17–54%, highest in the case of rice), percolation from fields and seepage losses from the conveyance system (in total 34–43% of the total canal inflow). The study revealed a large variation of net groundwater recharge and salt build-up over different canal commands.

Montazar *et al.* (2007) conducted a study with an objective develop a nonlinear model for determining optimal cropping pattern under different water regimes. The objective function of the model was the water productivity index defined as the net profit to the volume of water used. Using the data collected from Ghazvin irrigation network located in a semi- arid region in Iran, the model was executed and the results obtained were evaluated. The results showed that among the crop types, sunflower had the highest water productivity value while tomato had the lowest. These values under drought conditions for optimal cropping pattern of the two crops were estimated at 1778.96 Rials,m-3 and 353.22 Rials.m-3. The overall water productivity of the irrigation network with relevant cropping pattern management can rise to as high as 504.38 Rials.m-3 under drought conditions. This is while in normal and wet years, depending on the water availability and the optimal cropping pattern, the values for this index were estimated to be 535.352 and 667.13 Rials.m-3,respectively. Investigations showed that under drought conditions, the water productivity of the irrigation network could be raised to as high as the value in normal year.

Dinesh (2007) The studies included analyses of the productivity of irrigation water for several crops from both physical and economic point of view. All the analyses are based on well-irrigated crops and the volume of applied water was used in the denominator of water productivity. There are major variations in water productivity across farmers within the same location. This is not only restricted to water productivity in economic terms, but also to the physical productivity of water use. For instance, in the case of Batinda in Punjab, the data on water productivity in wheat were analyzed for 80 farmers and the variations are remarkable. The physical productivity of water varies from 1.29 kg/m3 to 4.27 kg/m3. The water productivity in economic terms ranges from a lowest of Rs.1.25/m3 to a highest of Rs.13.35/m3. While the ratio of the highest and the lowest values of physical

Qureshi *et al.* (2008) analyzed water productivity of irrigated wheat and maize in the Karkheh River Basin KRB. The results revealed that the average amount of water applied to wheat and maize is 3514 and 8284 m3/ha, respectively. The large gap between maximum and minimum values shows that farmers do not plan their irrigations according to crop water requirements. These findings were in agreement with the observations of Keshaverz et al. (2003). They have reported irrigation water applications of over 6000 m3/ha for wheat and 10,000-13,000 m3/ha for maize. These water application rates were also higher than the net irrigation requirements recommended by the Ministry of Agriculture. They have recommended 2600 m3/ha for wheat and 5900 m3/ha for maize, respectively (National Database, 1998). This is a clear demonstration of the fact that farmers tend to maximize their crop yields through excessive irrigation. However, in most cases, irrigation water is applied at less water sensitive stages of the growth cycle causing significant losses through evaporation thereby reducing the efficiency of water use. The study suggests that increase in charges for surface water use removal of subsidies on electricity will discourage excessive use of water for agriculture. Furthermore, farmers should be trained to optimize irrigation water and fertilizer application in order to save scarce water resources and reduce production costs and increase farm returns. These steps are of great importance for ensuring sustainability of irrigated agriculture and to alleviate poverty in rural areas of KRB.

Sharma *et al*. (2009) studied the Assessing and Improving Water Productivity in Conservation Agriculture Systems in the Indus-Gangetic Basin. Study suggest that Increasing WP in IGB requires not only more food production but also less water consumption and especially for rice production. Rice water productivity in IGB (Table 2) is generally low compared with other parts of the world. The mean WP for rice over actual evapotranspiration is 0.618 kg/m3, which is at the lower end given by Zwart and Bastiaanssen (2004) from a review of 84 studies. Low WP values are primarily due to low rice yield. The average yield in 2005 is only 1.94 ton/ha while the ET over rice growth season remains 335 mm. The four major countries India, Pakistan, Bangladesh and Nepal showed similar levels of rice WP. At the country level, Nepal takes the lead with average of 0.701 kg/m3 while India has the lowest of 0.603 kg/m3

Montazar (2009) conducted a study to assess the global water productivity (GWP) within the major irrigation command areas of Islamic Republic (I.R.) Iran. For this purpose, fourteen irrigation command areas located in different areas of Iran were selected. In order to calculate the global water productivity of irrigation command areas, data on the delivered water to cropping pattern, cultivated area, crops water requirement, and yield production rate during 2002-2006 were gathered. The results indicated that the lowest GWP belonged to Mahyar and Borkhar irrigation areas, 0.24 kg m-3, and the highest was that of the Dez irrigation area, 0.81 kg m-3. The findings demonstrated that water management in the two irrigation areas is just efficient. The difference in the GWP of irrigation areas was due to variations in the cropping pattern, amount of crop productions, in addition to the effective factors in the water use efficiency in the irrigation areas.

Karthikeyan *et al.* (2009) determined the economic value of tank irrigation water through Contingency Valuation Method by analyzing farmers' willingness to pay for irrigation water under improved water supply conditions during wet and dry seasons of paddy cultivation. Quadratic production function was used to determine the value of irrigation water. Comparison of economic value of water estimated using different methods strongly suggested that the existing water use pattern would not lead to sustainable use of the resource in the tank command areas.

Mahesh (2011) conducted a study to analyze trend and pattern of public investment in irrigation development in Karnataka and reported that about 97 per cent of the respondents opined that there were gaps between potential created and utilization. This indicated the need on the part of the Government to address constraints that prevented efficient utilization of

Lashari and Mahesar (2012) from a study on improving water and agricultural productivity in Pakistan concluded that improving agriculture productivity was lying in promoting efficient and environmentally sound water management practices. Increasing water productivity, gaining more crop yield and value per unit of water was an effective means of intensifying agricultural production and reducing environmental degradation. The actions needed are: bringing the production levels of low-yield farmers up to 80% of whathigh-yield farmers get from comparable land by better water management. The greatest potential increases in yields were in rain-fed areas, where many of Pakistan's poor rural people live and where better water management was the key to such increases.

Mohammad *et al.* (2013) suggested a methodology to evaluate the economic value of water. The methodology involved the use of agricultural sector models incorporating water as a scarce input. The economic values of water for different crops were estimated from the shadow prices of water and irrigated land constraints. The economic value of irrigation water for wheat, rice, sugarcane and cotton was Rs. 1.13, 0.63, 0.30 and 1.52, respectively. For the minor crops like potato, onion, and sunflower, the economic value of irrigation water was Rs. 6.60, 13.10, and 0.53, respectively.

Sivasankar *et al*. (2014) studied economic efficiency of irrigation water resources in Krishna Western Delta (KWD) of Andhra Pradesh. Regarding paddy, it was highest for System of Rice Intensification (SRI) technology (1.16) than semi-dry and transplanted technologies. The reduction in irrigation cost in SRI and semi-dry paddy production technologies was significant, as indicated by the decline to a tune of 45 percent and 55 percent respectively over transplanted technology. This clearly indicated that, by less water usage, paddy returns can be boosted by adopting SRI and semi-dry production technologies.

Dinesh (2007) analyzed the productivity of irrigation water for several crops from both physical and economic point of view. All the analyses were based on well-irrigated crops and the volume of applied water was used in the denominator of water productivity. There were major variations in water productivity across farmers within the same location. This is not only restricted to water productivity in economic terms, but also to the physical productivity of water use. For instance, in the case of Batinda in Punjab, the data on water productivity in wheat were analyzed for 80 farmers and the variations are remarkable. The physical productivity of water varies from 1.29 kg/m^3 to 4.27 kg/m^3. The water productivity in economic terms ranges from a lowest of Rs.1.25/m^3 to a highest of Rs.13.35/m^3. While the ratio of the highest and the lowest values of physical productivity was 3.0 in eastern UP in Ganges, the corresponding ratio for combined physical and economic productivity is 4.8 for the same location. While the ratio of the highest and the lowest values of physical productivity of irrigation water in wheat is 3.25 in south-western Punjab in the Indus, the corresponding value for water productivity in economic terms for the same location is 12.6. The ratio of average physical productivity of irrigation water in wheat across basins is 1.45 (3.69/2.54) and when south western Punjab and eastern UP were compared, the corresponding ratio for combined physical and economic productivity was 2.15 (10.57/4.90).

Raut *et al.* (2014) studied efficacy of irrigation management of *rabi* rice and small vegetable crops grown in the Balipatna Canal Command area of Orissa (sub humid region) using land use map derived through supervised Maximum Likelihood Classification, Survey Of India (SOI) toposheets and field verification and from irrigation scheduling efficiencies obtained through FAO model CROPWAT 8.0. Irrigation scheduling efficiencies for vegetables were computed from crop coefficients, amount of water supplied at different growth stages, soil water depletion and crop water requirement. For computing water requirement of rice, factors related to land preparation, puddling and soil as suggested by FAO were taken into account. Agro- meteorological data in combination with land use map approximated the deficiency of applied irrigation amount as compared to requirement. Irrigation application at 25-85 Days After Transplanting (DAT), for two times of applications,30-60-100 DAT for three, 20-40-70-100 DAT in case of four irrigations resulted in better scheduling efficiencies for vegetables.

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Frija *et al*. (2014) studied Marginal Water Productivity of Irrigated Durum Wheat inSemi-Arid Tunisia. Results show that 31.7% of the farmers were applying water volumes above the economic optimal volume (more than 2700 m3/ha). Moreover, 50% of the farmers were found to be applying less irrigation water than this optimal volume. Applying water above the optimal volume means that the benefit farmers obtain from each supplementary unit of irrigation water is lower than the market price of irrigation water currently applied in the region (0.110 TND/m3). Then, water is wasted. However, using less water than the optimal volume means that farmers can make further supplementary irrigations and obtain more benefit from it (extra-yield). The study also shows that most of the farmers in the study area do not apply good practices with respect to irrigation scheduling and irrigation doses. Improving irrigation performance will largely preserve water resources and enhance food security in Tunisia.

2.4 To document perceptions of farmers in enhancing water productivity in command area

Mahoo *et al*. (2007) opined that comprehensive Assessment is organized through the CGIAR's Systemwide Initiative on Water Management (SWIM), which is convened by the International Water Management Institute. The Assessment is carried out with inputs from over 100 national and international development and research organizations—including CGIAR Centers and FAO. Farmers in the Mkoji sub-catchment have an understanding of productivity of water. They define productivity of water with reference to the yield from their fields, which to them is dictated by the amount of rainfall. In a 'wet year' (a year when rainfall is above average: 760 millimeters (mm)), farmers consider productivity of water to be

Palanisami *et al*.(2009) studied that the water productivity can be improved by Minimizing the water use or water conservation measure Proper land leveling and grading is a prerequisite for efficient water application, Lining of farm channels will reduce the water losses through seepage, Reducing unproductive water outflows through the following ways will also be helpful viz., minimizing idle periods during land preparation, soil management to increase resistance to water flow (shallow tillage before land preparation to close cracks, puddling and soil compaction etc.) and water management to reduce hydrostatic pressure, Pipes may be laid for water conveyance in farms wherever feasible to cut the water conveyance losses

Zaman (2012) conducted a research in selected deep tube well commands of West Bengal and developed a package of intervention or component technology for different field crops. The results revealed that here were positive impacts of irrigation water on crop productivity, cropping intensity, input use efficiency, farmers' income and employment generation on adoption of water management technologies with active participation of farmers.

Kebede *et al.* (2013) assessed farmers' opinion on the effect of soil and water conservation (SWC) structures, particularly level soil bunds and stone bunds, in improving agricultural crop production. A household survey was carried out by stratified random sampling. Twenty-seven percent of the farmers who adopted SWC structure (29 households from the upper watershed and 62 households from the lower watershed) were randomly selected and interviewed. Three group discussions were also conducted. Based on their own indicators, a high proportion of those interviewed (79.3% in the upper and 87.1% in the lower watershed) had a positive opinion about Level Soil Bunds (LSB) and Stone Bunds (SB) on their cropland, in relation to its role in improving soil fertility and crop production. Ninety- three percent of farmers in both the upper watershed and the lower watershed perceived a change in crop yield within two years after implementation of structures. The study suggested creation of awareness and for monitoring the correct management of existing soil and water conservation structures, to ensure that they functioned as intended, and to improve their efficiency, high. But when seasonal rainfall is below average, farmers consider productivity of water to be low. Results of the understanding of farmers about productivity of water in the Mkoji sub-catchment are shown in Figure 2. These results show that approximately 53 percent of the farmers interviewed understood productivity of water as efficient utilization of water, while approximately 10 percent of the farmers interviewed understood productivity of water as having a good yield. To the farmers, a good yield means a harvest of approximately 2.5-3.5tonnes per hectare (t/ha) of cereal crop. Approximately 20 percent of the farmers interviewed understood productivity of water in the light of the importance of water in agricultural production, while 17 percent perceived productivity of water as the coping strategies during scarcity of water. All of these understandings carry the context of benefits of water used.

2.5. To assess the resource use efficiency of selected crops in the command area

Sampath (1979) studied the total economic efficiency of recourses like human labour, fertilizers and manure and other farm inputs. They explain the role of farm size and farmer's economic background for enhancing the resource use efficiency. They concludes that the small farmers and economically well off farmers achieved greater efficiency in various farm inputs in the surveyed regions.

Dinesh (1992) analyzed the resource-use efficiency in different irrigated systems. Human labour, bullock labour, seeds, fertilizer and manure and tractor power 100 farmers were surveyed by multi-stage random sampling in Ghaziabad district of UP. The study observed that human labour, bullock labour and tractor power were used in excess on all the irrigation system

Velavan and Balakrishnan (2000) examined the resource-use efficiency in groundnut. Various input for groundnut cultivation 120 farmers selected from irrigated andun-irrigated regions in Salem district of Tamil Nadu. The study indentified that there is large scope for adding more farm inputs in both irrigated and un-irrigated groundnut cultivation.

Ramarao *et. al*. (2003) examined the technical efficiency of crop production. Technical efficiency of various farm inputs From the Anhdra Pradesh farm management survey three representative districts were chosen for study. The study found that the technical efficiency of production is determined by farmer's education. Therefore, it suggests that motivation of formal and informal education for farmers

Reddy and Sen (2004) in their study in the Sone Canal command area of the state of Bihar. A sample of 270 farmers comprising 207 marginal (< 1 hectare), 31 small (1-2hectares), 22 semi-medium (2-4 hectares) and 10 medium (4-10 hectares) farms were selected through stratified random sampling method. Technical inefficiency of the individual farms was estimated through stochastic frontier production function analysis. This study reveals that the technical inefficiency in rice production decreased with increase in farm size. The average technical inefficiency was highest in marginal farms (27.28%) followed by small farms (22.05%). Minimum average and technical inefficiency was observed in medium group. Technical inefficiency in the production of rice is negatively related with farm size.

Sarker and Sudpita (2004) attempted to examine the extent of efficiency under different types of nature and different farm sizes in two types of villages – Technologically Advanced villages and Technologically Backward villages. This study considering all farm sizes in both the type of villages together, it can be said that except the lowest farm size where all farms are efficient, the proportion of efficient farm increase with the increase of farm size. This analysis shows that the use of high technological inputs in Agriculture is not so important in improving the efficiency level of the farms. This might suggest that only high use of technical inputs like irrigation, HYV seeds, chemical fertilizer per unit of land does not necessarily bring about maximum possible output for a given set of inputs, nor does it only make 'best practice' relationship between inputs and outputs.

Senthil and Alagumani (2005) explored the resource use efficiency in paddy cultivation. Various input factors for paddy cultivation 90 farmers surveyed from head, mid and tail reach of the Lower Bhavani Basin Project (LBP) Command Area of Tamil Nadu. The study suggests that there is scope for further use of various input factors for enhancing the productivity.

Koshta and Chndrakar (2005) analyzed the economic efficiency of paddy production. Various input factors for paddy cultivation 202 farm households selected from irrigated and rainfed regions of Chattisgarh. The cost of cultivation is much higher in irrigated area as compared to rainfed region.

Suresh and Reddy (2006) in their in the Peechi Command Area of Thrissur district in the Kerala state, examined the resource productivity and allocative as well as the technical efficiency of paddy production. The study has used the primary data collected from 71 rice farmers of the command area using the stratified random sampling. The cost of cultivation of paddy in the command area has been found as Rs 21603/ha, resulting in a BC ratio of 1.34. The elasticity coefficients for chemical fertilizers, farmyard manure and human labour have been observed significant and positive. The allocative efficiency has indicated that marginal return per one rupee increase under these heads would be Rs 2.83, Rs 1.57 and Rs 1.17, respectively. The average technical efficiency of the paddy farmers in the command area has been found as 66.8 per cent.

Shanmugam and Venkatraman (2006) analyzed the technical efficiency in agriculture production in India. Technical efficiency of various farm inputs was found out. Secondary data was taken from Indian Agricultural Statistical Research Institute during the period of 1990-91. They concluded that technical efficiency greatly depends on agro-climatic zones, technological factors and crop mix.

Bhende and Kalirajan (2007) analyzed the technical efficiency of major food and cash crops in Karnataka. Secondary data used from University of Agricultural Sciences during the period of 1993-94. The results of the study revealed educational achievements of the farm household determine technical efficiency in both food and cash crops in Karnataka. In addition to that the farm size and technical efficiency were having inverse relationship.

Fernandez and Peter (2009) identified the sources of input use inefficiency in sugar cane production. A total of 140 respondents were interviewed in Negros Island by using random sampling method. The study revealed that overall technical efficiency of sugar cane farmers in Central Negros was positively related to farmers' age and experience, access to credit, nitrogen fertilizer application, soil type and farm size.

Rangappa (2014) Opined that the resource use efficiency analysis assumes greater importance in ascertaining whether production at the farm level could be increased profitably to an optimum level by making reallocation of existing resource use pattern. Tank irrigated paddy farmers are using relatively lesser quantity inputs and still many of these farmers are using local variety seeds due to their inability to manage the irrigation efficiently. The estimated Cobb-Douglas production functions were significant and good fit for both canal and tank irrigated paddy. Relatively higher MVP was reported in canal irrigated paddy compared to tank irrigated paddy for all inputs except fertilizer and PPC. The estimates of production function for canal and tank irrigated paddy are presented. A perusal of the table reveals the significance of both the production functions as proved by the significance of F value at 1 per cent probability level. The coefficient of determination (R^2) for canal irrigated (53.4 per cent) and tank irrigated paddy (66.2 per cent) production function indicated a fairly high degree of 'goodness of fit'. The regression coefficients of FYM, fertilizer and PPC were positive and significant in both production functions. The coefficient for human labour in tank irrigated paddy and bullock labour in canal irrigated paddy were also found to be positive and statistically significant. In the Cobb-Douglas production function, regression coefficients are equivalent to production elasticities. The production elasticities of all the inputs were less than unity showing the diminishing marginal productivity with respect to each of the inputs.

Vijayalaxmi (2015) studied the resource use efficiency for crops in command and the non command areas of Karnataka Community Based Tank Management project . The results revealed that summation of regression coefficient of sunflower and maize crops was high in command area than non-command area i.e increasing returns to scale which indicated increasing returns to scale *i.e.,* one per cent increase in expenditure on all inputs would results in more than one per cent increase in these crop returns.

3. MATERIAL AND METHODS

This chapter deals with the description of the study area, sampling procedure adopted, method of survey, nature and sources of data, techniques employed for analyzing the data in evaluating the results. At the end of the chapter, the terms and concepts used in the study are also defined to facilitate a clear understanding of the important issues with which the present study is concerned. The chapter is presented under following heads.

3.1 Description of the study area

3.2 Sampling procedure

3.3 Nature and sources of data

3.4 Analytical techniques

3.5 Concepts used in the study

3.1 Description of the study area

3.1.1 Karnataka

The state of Karnataka lies between 11.50° and 19.00° N latitudes and between 74° and 78.30° E longitudes. It is the eighth largest state in India in area and ninth in population with an area of 1, 91,791 km^2 and the population of about 6, 10,95,000 according to 2011 census. The state is bounded by Maharashtra, Goa, Andhra Pradesh, Tamil Nadu and Kerala in the north, east, southeast and southwest, respectively. The state has 30 districts with 176 taluks Karnataka is situated in tropical zone and enjoys warm climate throughout the year. The mean temperature ranges from 21.5℃ to 31.7℃, the maximum and minimum temperature being 420℃ and 140℃ respectively. The normal rainfall of the state ranges from as low as 569 mm to as high as 4,029 mm. Average annual rainfall of the state is 1,139 mm. The major part of the rainfall of the state is received from the southwest monsoon, which commences in the first week of June and continues till the end of September. Major part of the state has red soils. Laterite soils are found in the hilly and coastal regions of the western parts. The northern part of the state has black soils with high moisture holding capacity.

3.1.1.1 Upper Krishna Project

The Upper Krishna Project (UKP) is one of the major projects in Karnataka and is the most prestigious multipurpose (irrigation and power) project. It is the economic lifeline of chronically drought hit districts of North Karnataka, as it would irrigate a command area of 1 m. ha on full development. The irrigation water was first let out in September 1982. The intensity of irrigation originally envisaged in Stage-I was 107.5 per cent.

The UKP comprises of the following work:

i. A storage dam of Almatti

ii. A diversion dam of Narayanpur

iii. Two gravity flow canal systems namely Narayanpur Left Bank Canal (NLBC) and Narayanpur Right Bank Canal (NRBC) from Narayanpur dam.

iv. Lift schemes from the foreshores of the above two reservoir, viz., Almatti Left Bank Canal (ALBC), Almatti Right Bank Canal (ARBC), Mudbal Lift Canal from Almatti reservoir, Rampur Lift Canal from Narayanpur reservoir and Indi Lift Canal from NLBC.

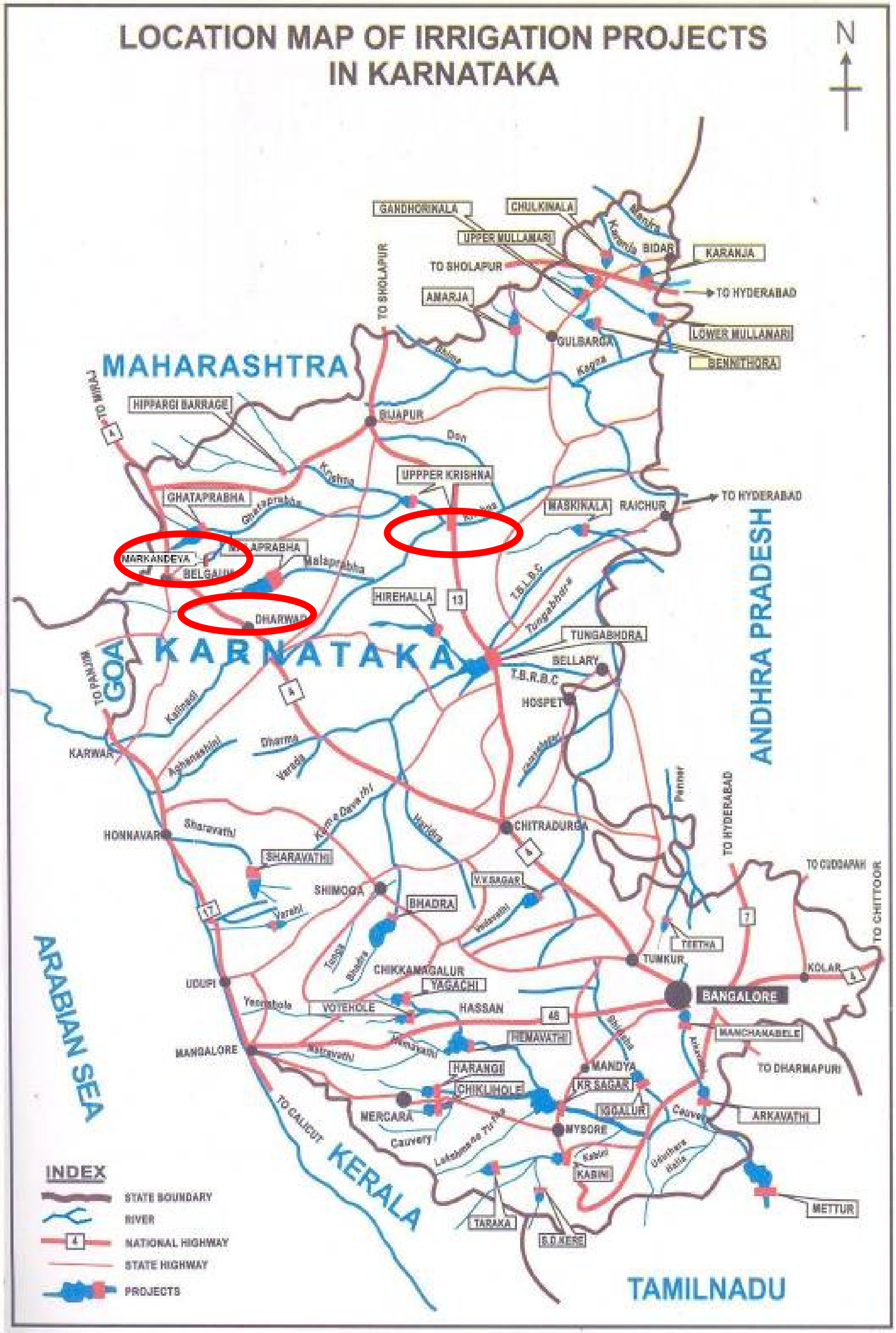

Fig. 3.1a: Map showing the irrigation projects (red encircled)

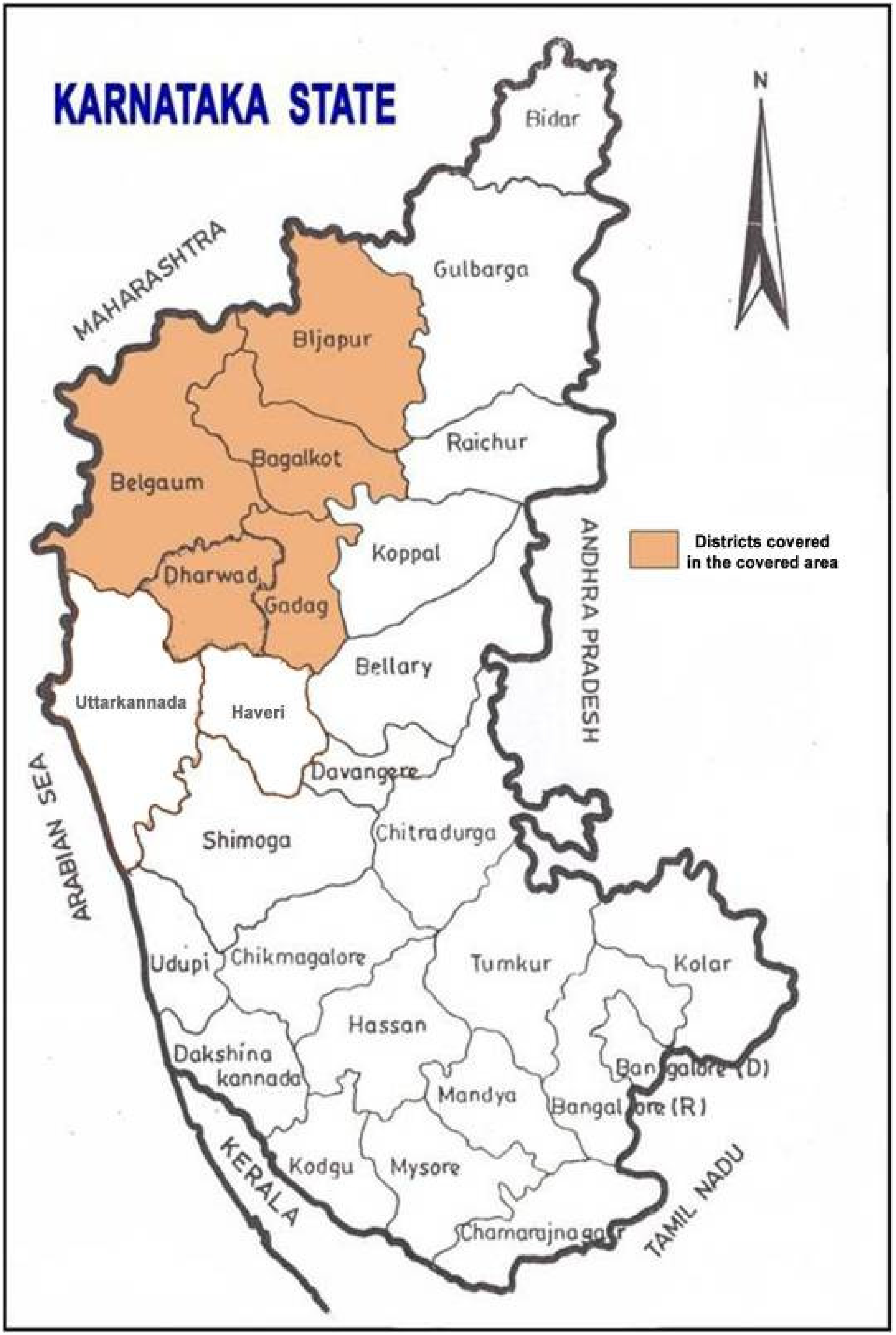

Fig. 3.1b: Map showing the districts covered under study area

3.1.1.2 Salient features of the canals of the study

Almatti Left Bank Canal (ALBC): It is a lift irrigation canal proposed on the left flank foreshore of the Almatti reservoir. It provides irrigation to an area of 20,235 ha of Bijapur district.

Indi Branch Canal (IBC): It is a bifurcation of Narayanpur Left Bank Canal (NLBC) at 78 km, i.e. Indi. It covers Indi and Sindagi taluks. It has highest length of 175 km with an irrigable command area of 76,416 ha.

3.1.2 Malaprabha Ghataprabha Project

The Malaprabha Irrigation Project is located in the northern part of Karnataka State, India. It comes under the northern dry region-II, zone 3 and located at 15^{0}-48^{I}-0^{II}N latitude and 75^{0}-6^{I}-0^{II} E longitude with an altitude of about 600 meters above the mean sea level. Malaprabha Irrigation Project covers eight taluks namely, Bailhongal, Ramdurga and Saudatti of Belgaum district, Hubli and Navalgund taluks of Dharwad district, Nargund and Ron taluks of Gadag district and Badami taluk of Bagalkot district. The total command area under the project is 2,20,028 hectares

3.1.3.1 Canal system of the project

The Malaprabha Irrigation Project at present has two main canals *viz.,* Malaprabha Right Bank Canal and Malaprabha Left Bank Canal.

a. Left bank canal

The length of the canal is 150 kms. The works are generally completed upto the 150 kms and water has been let out for irrigation upto km 132 upto the end of March 2011. The irrigable command area under this canal is 53,134 hectares. It has a discharge capacity, at head, of 38.91 cumecs.

In addition to these canals, there are ten lift irrigation schemes with a view mainly to benefit the rehabilitated people. The irrigable command area under these ten lift irrigation schemes is 26,971 hectares.

3.1.4 Ghataprabha project

Ghataprabha project is taken up on the Ghataprabha river basin near Hidkal in Hukkeri village of Belagavi district, Karnataka. It has a total catchment area of 1412 Km^2 with a yield of 69.60 Tmc capacity. It comprises of two canals viz., Ghataprabha Right Bank (GRBC) and Ghataprabha Left Bank Canal (GLBC)

a. Ghataprabha Right Bank Canal (GRBC): The length of the canal is about 202 km and it has a total irrigated area of 169129 ha with a capacity of 66.56 cumecs. It covers Belagavi and Bagalkote districts.

The project is implemented in three stages, the details of the stages are as follows,

Stage I

The first stage consists of a 71 km long left bank canal from the Dupdal weir constructed across Ghataprabha river in 1897 near Dupdhal in Gokak canal for providing irrigation to an extent of 0.425 lakh ha.

Stage II

The second stage comprises of extension of left bank canal from the Dupdal weir from Km 72 to its full length of 109 Km and a reservoir across Ghataprabha river near Hidkal, upto a partial height of RL 650.14 mtr.(RL 2133.00 feet) creating a storage of 659 Mcum for providing irrigation to a total extent of 1.396 lakh Ha inclusive of the area under stage I.

Stage III

The third stage comprises of raising the FRL of Hidkal dam to its final level of RL 662.94 Mtr (RL 2175.00 feet) creating gross storage of 1448 Mcum and providing a 202 Km long Right Bank Canal and 86 Km long Chickkodi Branch Canal to irrigate 191386 Ha bringing the total area under the project to 3.31 lakh ha.

3.2 Sampling Procedure

Since the main objective was to estimate the economics of water productivity in the command areas of UKP and MGP, four canals viz., ALBC,IBC,MLBC and GRBC were selected to estimate the quantity of water used for different crops.

The villages were selected from the head and tail regions of the canals. The farmers from these villages were selected as the respondents and the primary data was collected from them.

The perceptions of stakeholders was documented by collecting the perceptions from both farmers and officers/staff of the Command Area Development Authority (CADA) and Irrigation Departments (ID).

3.3 Nature and sources of data

The required data for evaluating the objectives of the study were collected from both primary and secondary sources.

3.3.1 Primary data

Primary data was collected from 120 respondents from head and tail regions of Almatti Left Bank Canal (ALBC), Indi Branch Canal (IBC), Malaprabha Left Bank Canal (MLBC) and Ghataprabha Right Bank Canal of both Upper Krishna Project (UKP) and Malaprabha Ghataprabha Project (MGP) command areas.

The data on the cropping pattern, depth of the irrigations, frequency and time of the individual irrigations etc were collected. The perceptions of stakeholders in enhancing water productivity was documented using the personal interview schedule.

3.3.2 Secondary data

The data on cropping pattern, water discharge rates, area, production and productivity were collected from offices of Irrigation departments (Dharwad, Belagavi and Vijayapur) and Command Area Developments Authority, Bheemarayanagudi.

3.4 Definition and concepts of terms used

3.4.1 Water Productivity: The term 'water productivity' refers to the magnitude of output or benefit resulting from the input quantum of water as applied on a unit base. It depicts the ratio between crop yield and the total water applied to the crops. It is expressed as

$$WP = \frac{\text{Crop Yield (kg per ha)}}{\text{Water applied } (m^3)}$$

Unit: kg/m^3

3.4.2 Water Productivity in economic terms:It is the value of production per unit of water

$$WP = \frac{\text{Total economic returns (Rs per ha)}}{\text{Quantity of water applied } (m^3)}$$

Unit Rs./ m^3

3.5 Analytical tools

To fulfill the specific objectives of the study, data collected was subjected to the analyses using Tabular Analysis, Descriptive Analysis and other tools.

3.5.1 Cropping pattern

Area of various crops from 1999-00 to 2014-15 were collected from department of agriculture in Malaprabha and Ghataprabha Project zones and were analyzed using Markov Chain Analysis and the primary data from farmer respondents was collected and was analyzed using tabular analysis.

3.5.2 Water Productivity

Physical water productivity WP = Y /d /A

Where,

'Y' is overall yield of the farm

'd' is combine depth of irrigation or water pumped from the well source (cm)

'A' is total area of the farm under cultivation (ha)

Unit will be Kg m^{-3} for a reference crop. Accordingly the economic productivity can be obtained.

Economic water productivity WP = Py /Q

Where,

'Py'is overall value of yield from the farm.

'Q' is quantity of water (m^3) obtained by depth with unit area.

Unit will be Rs m^{-3} for a reference crop. Accordingly the economic productivity can be obtained.

3.5.3 Resource Productivity

The production function approach was used to find out the productivity of resources used in sugarcane and cotton cultivation. For this purpose, the Cobb-Douglas production function was employed. The single most advantage of this production function has been that the input coefficients constituted the respective elasticities. The function was modified to include dummy variables.

The modified form of Cobb-Douglas production function is by Eq. (1):

$$Y= a X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8} + e \ldots (1)$$

Where,

Y = Total returns from crop cultivation (Rs)

X_1 = Value of seed/seedlings (Rs)

X_2 = Cost on application of Farm Yard Manure

X_3 = Cost on chemical fertilizers (Rs)

X_4 = Cost on labour used in cultivation (Rs)

X_5 = Cost of machinery used in cultivation (Rs)

X_6 = Cost on plant protection chemicals (PPC) (Rs)

X_7 = Amount of water applied (ha cm)

This Cobb-Douglas function was estimated using ordinary least square (OLS) approach after converting it into log linear form. The estimable form of the equation is given below:

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + \mu$ …(2)

The coefficients were tested for statistical significance by using 't' test. Where profit maximization was the objective of the rational farmer, it was imperative that he allocated his resources consistent with their respective marginal contributions in monetary terms. The degree to which it was accomplished was measured by allocative efficiency. If the marginal contribution of one unit of input was greater than the price of the input in question, then the farmer was said to be allocating the resources efficiently and there was further scope for allocating more unit of that particular input. If the marginal contribution was negative, then the farmers were said to be using the input excessively so that the fixed resources were no longer responsive to the variable input- applied.

Allocative efficiency (AE) was determined by calculating the ratio of the marginal value product (MVP) to the marginal factor cost (MFC), i.e.

AE = MVP/ MFC …(3)

MVP = MPPi × Py

where,

MVP = Marginal value product

MPPi = Marginal physical product of the ith input

Py = Price of output

MPPi = bi Y/ Xi …(4)

Where,

bi = Elasticity coefficient of the ith independent variable

Y = Geometric mean of the output, and

Xi = Geometric mean of the ith input

Technical Efficiency

The technical efficiency evaluated the farm's ability to obtain the maximum possible output from a given level of resources. The Cobb-Douglas production function did not distinguish between technical and allocative efficiencies (Sampath, 1979). It ignored the problem of technical efficiency by assuming that all the techniques of production were identical across farms and each farmer was technically efficient, which many a times was not true. The concept of frontier production function introduced by Farrel (1957) distinguished technical and allocative efficiencies. Timmer (1971) operationalized the concept by imposing Cobb-Douglas type on the frontier and evolved an output-based measure of efficiency. The approach adopted here was to specify a fixed parameter frontier amenable to statistical analysis. This takes a general form as:

$Y = f(X)\, e(\mu)$ …(5)

Where,

Y = Output (dependent variable)

X = Vector of inputs (independent variables)

μ = Error-term

3.5.4 Perception of farmers in improving Water Productivity:

The perceptions of the farmers and staff of different offices of Irrigation department and CADA are documented. They are analyzed using Garrette ranking method.

This technique was used to evaluate the problems encountered in sugarcane cultivation and marketing. In this method, the farmers were asked to rank the given problem according to the magnitude of the problem. The orders of merit given by respondents were converted into ranks by using the following formula.

$$\text{Percentage Position} = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij}= Rank given for i^{th} item by j^{th} individual

N_j= Number of items ranked by j^{th} individual

The percentage position of each rank thus obtained was converted into scores by referring to the table given by Garrett. Then for each factor the scores of individual respondents were added together and divided by total number of respondents for whom the scores were added. These mean scores of all the factors were arranged in the order of their ranks and inferences were drawn.

3.5.5 Markov Chain Model

The direction of change in cropping pattern was analyzed using the First Order Markov Chain Approach. The Lingo Software was adopted to study the Transition Probability Matrix. Central to Markov Chain Analysis is the estimation of the transitional probability matrix 'P' whose elements, P_{ij} indicate the probability of a shifting its area from one crop 'i' to another crop 'j' over time. The diagonal element P_{ij} where i=j, measures the probability of a crop retaining its share.

Data on cropping pattern was collected for the period 1999-2014 and were used to analyze the shift in area of one crop to another crop. The average area shifted to a particular crop was considered to be a random variable which depends only on the past crop, which can be denoted algebraically as :

$$E_{jt} = \sum_{i=1}^{n} [Ei_{t-1}] P_{ij} + e_{jt}$$

Where,

E_{jt} = Area of the crop shifted towards the particular j^{th} crop in the year t

Ei_{t-1} = Area lost of i^{th} crop during the year t-1

P_{ij} = The probability the area lost will shift from i^{th} crop to j^{th} crop

e_{jt} = The error term which is statistically independent of Ei_{t-1}

n = The number of crops.

The transitional probabilities P_{ij}, which can be arranged in a (c x n) matrix, have the following properties.

$$\sum_{i=1}^{n} P_{Ij} = 1 \text{ and } 0 \leq P_{Ij} \leq 1$$

Thus, the expected area share of each crop during period 't' is obtained by multiplying the area to these other areas in the previous period (t-1) with the transitional probability matrix. The probability matrix was estimated for the period 1999 to 2014.

Thus, Transitional Probability Matrix (T) is estimated using Linear Programming (LP) framework by a method referred to as minimization of Mean Absolute Deviation (MAD).

Min. OP* + I e

Subject to

X P* + V = Y

GP* = 1

P* ≥ 0

Where

P* is a vector of the probabilities P_{Ij}

O is the vector of zeros

I is an appropriately dimensioned vector of area.

e is the vector of absolute errors

Y is the proportion of area of the crops.

X is a block diagonal matrix of lagged values of Y

V is the vector of errors

G is a grouping matrix to add the row elements of P arranged in P* to unity.

4. EXPERIMENTAL RESULTS

The major findings of the study are presented in this chapter under the following heads.

4.1 General characteristics of the sample farmers in the study area

4.2 Canal wise extent and sources of irrigation in the command areas.

4.3 Cropping pattern in the command areas.

4.4 Productivities of selected crops in command areas.

4.5 Economics of water productivities in command areas.

4.6 Resource use efficiency of cotton and sugarcane in command areas.

4.7 Perceptions of stake holders in enhancing water productivity in command areas.

4.1 General characteristics of the sample farmers in the study area

A review of the results presented in Table 4.1 indicates that, in ALBC command area the average age of the sample respondents was 45.63 years, whereas the average age of the farmers in IBC command area was 44.40 years. The farmers in MLBC and GRBC command area are of 50.0 and 52.70 years respectively. The overall average age of the farmers in the command area was 48.15 years.

The average family members in ALBC and IBC command areas were 4.46 and 4.63 persons respectively with an average of 85.87 per cent of them working on farm and 14.13 per cent of them working off farm in ALBC command area. In case of IBC command area it was 84.23 per cent and 15.77 per cent of the farmers working on and off farm, respectively.

The average family members in MLBC and GRBC command areas were 4.46 and 4.63 persons respectively with an average of 85.10 per cent of them working on farm and 14.90 per cent of them working off farm in MLBC command area. In case of GRBC command area it was 84.85 per cent and 15.15 per cent of the farmers working on and off farm, respectively.

4.2 Canal wise extent of irrigation in the command area

Table 4.2 a presents the canal wise area under dry farming and irrigation. On an average the cultivated area of farmer respondents was 3.73 ha across the canals in the different command areas. The percentage of irrigated area was about 92 per cent while the dry land was about 8 per cent.

Among the different canals, the percentage of area under irrigation was more under ALBC (97.3 per cent) followed by MLBC (94.25 per cent),GRBC (92.5 per cent) and IBC(82.82 per cent)

4.2.1 Canal wise source of irrigation in the study area

Table 4.2 b depicts the different sources of irrigation under different canals. Of the total irrigated area, on an average 61 per cent of land across all canals was under canal irrigation while 28 per cent of land was under open wells and only 11 per cent was irrigated from bore wells.

Across the canals , the area irrigated by canals was more under MLBC (75.4 per cent) followed by ALBC (71.38 per cent), GRBC (59.22 per cent) and IBC (34.96 per cent). About 51 per cent area of IBC irrigated area was covered by open wells . The percentage of area covered by the bore wells was highest under ALBC (19.60 per cent0 followed by IBC (14.21per cent).

Table 4.1 General characteristics of the sample respondents

(n=120)

Canal	Age	Family members	On farm	%	Off farm	%
ALBC	45.63	4.46	3.83	85.87	0.63	14.13
IBC	44.4	4.63	3.9	84.23	0.73	15.77
MLBC	50	4.7	4.0	85.10	0.7	14.90
GRBC	52.7	4.16	3.53	84.85	0.63	15.15
Total	48.15	4.49	3.82	85.07	0.67	14.13

Table 4.2 a Canal wise extent of irrigation in the command area

(n=120)

Command area	Total	Dry land	%	Irrigated land	%
ALBC	3.65	0.1	2.70	3.592	97.30
IBC	3.79	0.66	17.18	3.18	82.82
MLBC	3.65	0.212	5.75	3.48	94.25
GRBC	3.85	0.292	7.50	3.6	92.50
Average	3.73	0.316	8.36	3.46	91.64

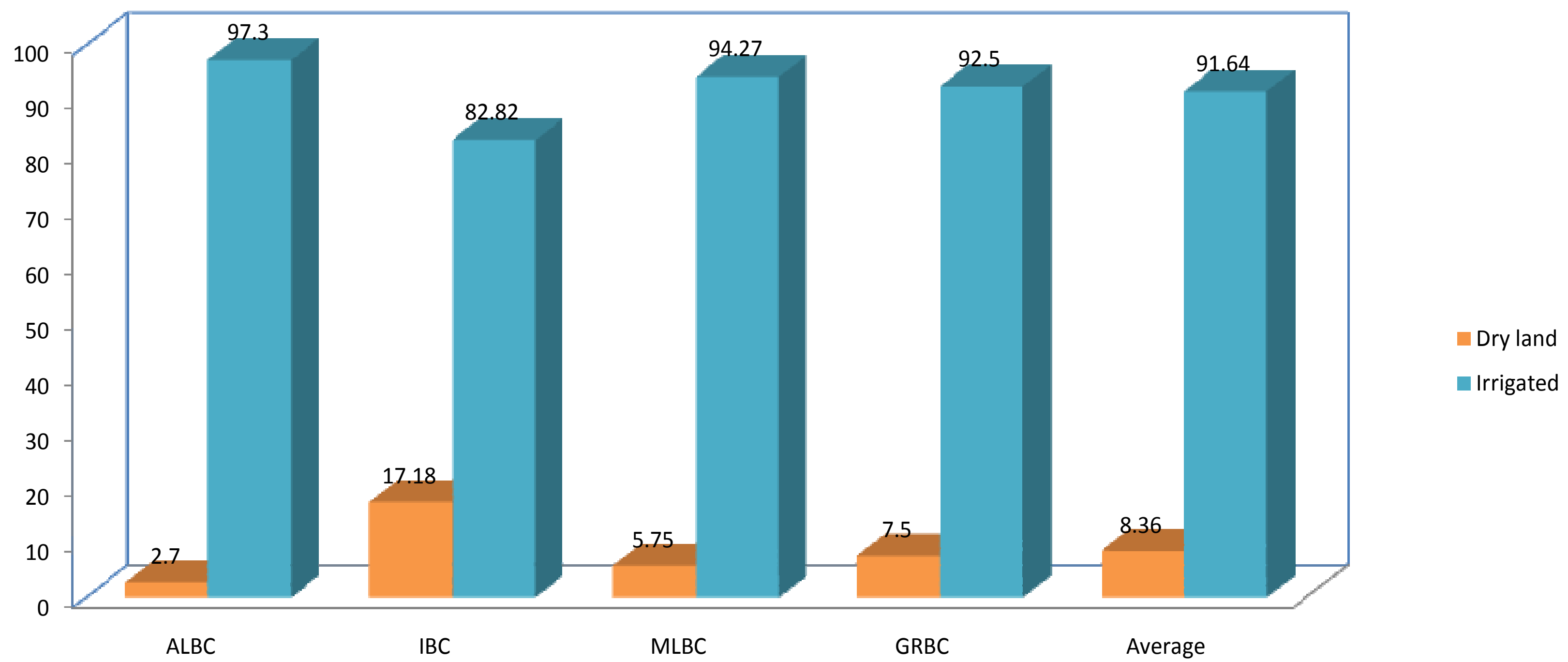

Fig. 4.1 Command area wise extent of irrigation

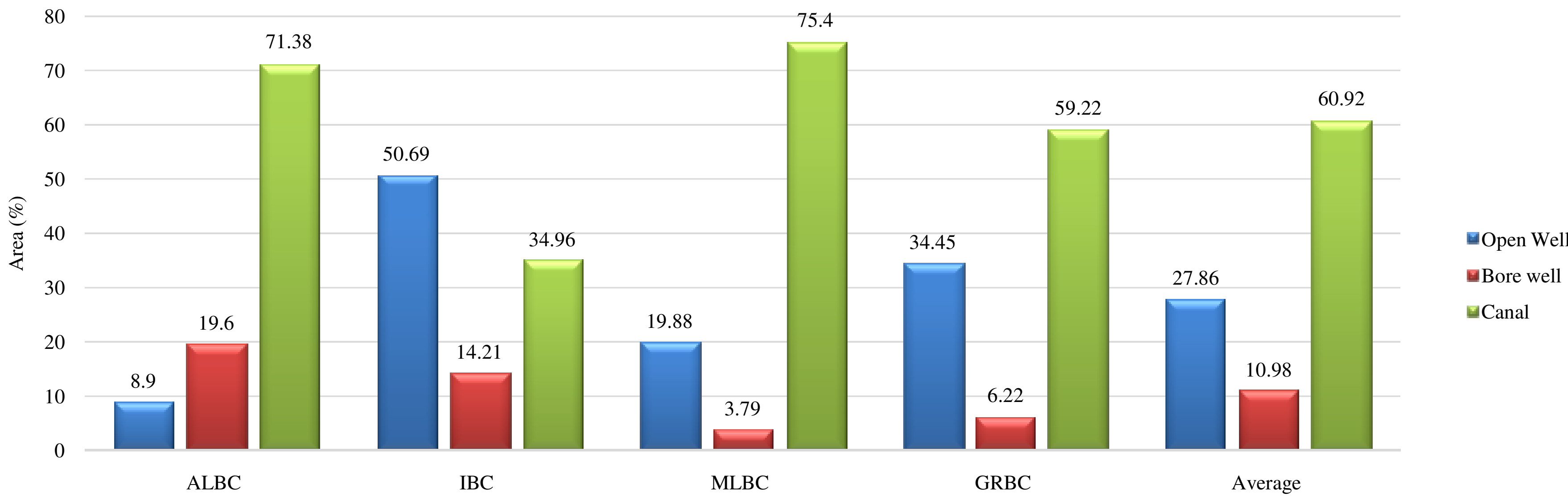

Fig. 4.2 Percentage sources of irrigation in different canal command areas

4.3 Cropping pattern in the command areas

4.3.1 Analysis of Structural Changes in Area under Different Crops in MGP command areas

The dynamics in the direction of changing pattern in the command area under different crops in Karnataka over a period of 1999-00 to 2014-15 are analyzed by employing the Markov Chain model. The trend in sustaining the existing area and the gains and losses to different competing crops were obtained from the transition probability matrices. The transitional probability matrix gives a broad indication of the changes in the direction of area under different crops in Malaprabha and Ghataprabha Project command area. The diagonal elements in the transitional probabilities matrix indicate the probability of the retention in the acreage under the crop. The other elements in the rows provide the information on loss in share of the particular crop on account of diversion of acreage to other competing crops. Similarly, the column elements depict the probability of retention of acreage and the gains in the acreage from other competing crops.

It is evident from the transition probability matrix depicted in Table 4.3 a, that the crops such as hybrid maize, hybrid jowar and soybean were having stable acreage during the period. The probability that the crops such as hybrid maize and soybean retained their share from one year to another year was 83 per cent and 85 per cent respectively during the period from

1999-00 to 2014-15. Accordingly, the probability that the crop hybrid jowar retained its share from one year to another year was 16 per cent during the same period. Hence it can be inferred that, the area under hybrid maize, hybrid Jowar and Soybean remained stable without much variation during the period.

4.3.2 Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for Rabi season.

It is evident from the transition probability matrix depicted in Table 4.3 b, that the crops such as rabi jowar , hybrid maize, sunflower, wheat and pulses were having relatively stable acreage during the period. The probability that the pulses retained their share from one year to another year was 54 per during the period from 1999-00 to 2014-15. Accordingly, the probability that the crops rabi jowar , hybrid maize, sunflower and wheat retained their share from one year to another year was 27 per cent, 23 per cent ,23 per cent and 25 per cent respectively during the same period. Hence it can be inferred that, the area under pulses remained stable with significant variation during the period.

4.3.3 Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for biseasonal crops

It is evident from the transition probability matrix depicted in Table 4.3 c, that the sugarcane was having highly stable acreage during the period. The probability that the sugarcane retained its share from one year to another year was 97 per cent during the period from 1999-00 to 2014-15. Accordingly, the probability that the cotton retained its share from one year to another year was 45 per cent. Hence it can be inferred that, the area under sugarcane remained highly stable without much variation during the period.

4.3.4 Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Malaprabha project command areas for Kharif season.

It is evident from the transition probability matrix depicted in Table 4.3 d , that the Hybrid maize evidenced higher stability in acreage over hybrid jowar and sunflower. The probability that Hybrid maize retained its share from one year to another year was 82 per during the period from 1999-00 to 2014-15. Accordingly, the probability that the crops Hybrid jowar and sunflower retained their share

Table 4.2 b Command area wise source of irrigation in the study area

(n=120)

Canal	Open Well	Per cent	Bore Well	Per cent	Canal	Per cent
ALBC	0.32	8.90	0.704	19.60	2.564	71.38
IBC	1.612	50.69	0.452	14.21	1.112	34.96
MLBC	0.692	19.88	0.132	3.79	2.624	75.40
GRBC	1.24	34.45	0.224	6.22	2.132	59.22
Average	0.964	27.86	0.38	10.98	2.108	60.92

Table 4.3 a. Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for Kharif season

Kharif	Hybrid maize	Hybrid sorghum	Sunflower	Soybean	Ground nut	Others
Hybrid Maize	0.83	0.02	0.03	0.00	0.01	0.11
Hybrid Sorghum	0.00	0.16	0.42	0.42	0.00	0.00
Sunflower	0.97	0.03	0.00	0.00	0.00	0.00
Soybean	0.00	0.00	0.07	0.85	0.08	0.00
Ground nut	0.73	0.00	0.09	0.18	0.00	0.00
Others	0.00	0.00	0.15	0.75	0.10	0.00

Table 4.3 b. Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for Rabi season

	R. sorghum	Hybrid Maize	Sunflower	Wheat	Pulses	Others
Rabi sorghum	0.27	0.00	0.00	0.36	0.00	0.37
Hybrid maize	0.12	0.23	0.06	0.22	0.00	0.37
Sunflower	0.00	0.77	0.23	0.00	0.00	0.00
Wheat	0.00	0.00	0.00	0.25	0.19	0.56
Pulses	0.00	0.14	0.00	0.32	0.54	0.00
Others	0.19	0.60	0.16	0.00	0.00	0.04

Table 4.3 c. Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for biseasonal crops

	Sugarcane	Cotton
Sugarcane	0.97	0.03
Cotton	0.55	0.45

Table 4.3 d Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Malaprabha project command areas for Kharif season

Kharif	Hybrid sorghum	Hybrid maize	Pulses	Sunflower	Ground nut	Others
Hybrid sorghum	0.15	0.00	0.60	0.25	0.00	0.00
Hybrid maize	0.00	0.82	0.05	0.01	0.04	0.08
Pulses	0.00	0.97	0.00	0.00	0.00	0.03
Sunflower	0.38	0.07	0.00	0.37	0.13	0.05
Ground nut	0.32	0.47	0.00	0.21	0.00	0.00
Others	0.00	0.89	0.11	0.00	0.00	0.00

from one year to another year was 15 per cent and 37 per cent respectively during the same period. Hence it can be inferred that, the area under Hybrid maize remained stable without much variation during the period.

4.3.5 Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Malaprabha project command areas for Rabi season.

It is evident from the transition probability matrix depicted in Table 4.3 e, that the crops such as sunflower, rabi jowar and pulses were having relatively stable acreage during the period. The probability that the sunflower retained its share from one year to another year was 72 per during the period from 1999-00 to 2014-15. Accordingly, the probability that the crops such as pulses and hybrid jowar retained their share from one year to another year was 45 and 33 per cent respectively during the same period. Hence it can be inferred that, the area under sunflower remained stable with significant variation during the period.

4.3.6 Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for biseasonal crops

It is evident from the transition probability matrix depicted in Table 4.3 f , that the Hybrid Cotton was having very high stable acreage during the period. The probability that the hybrid cotton retained its share from one year to another year was 100 per during the period from 1999-00 to 2014-15.

4.3.7 Cropping pattern in UKP command area (n=60)

Cropping pattern in UKP command area is presented in Table 4.3 g. Sorghum, wheat and bajra were the major cereal crops, pigeon pea, green gram and bengal gram were the major pulse crops grown. Vegetables were grown in summer and sugarcane was the major annual/bi seasonal crop grown by the sample farmers in the command area.

In ALBC command area pigeon pea was grown on an area of 0.65 ha and 0.72 ha in Head and Tail regions, respectively in Kharif season. Bajra was grown on an area of 0.50 ha and 0.56 ha in Head and Tail regions, respectively. Green gram was grown on an area of 0.58 ha and 0.52 ha in Head and Tail regions, respectively. While in rabi wheat was grown on an area of 0.49 ha and 0.50 ha in Head and Tail regions respectively. Bengal gram was grown on an area of 0.54 ha and 0.52 ha in Head and Tail regions respectively. Sorghum was grown on an area of 0.65 ha and 0.70 ha in Head and Tail regions respectively. Vegetables were grown in summer with an area of 0.45 ha and 0.30 ha in Head and Tail regions respectively. Annual crop, sugarcane was grown on an area of 1.92 ha and 1.84 ha in Head and Tail regions respectively by the sample farmers.

The gross cropped area in the Head region was 5.78 ha with a net cropped area of 3.65 ha having the cropping intensity of 158.35 per cent. The gross cropped area in the Tail region was 5.66 ha with a net cropped area of 3.64 ha having the cropping intensity of 155.49 per cent.

In case of IBC command area pigeon pea was grown on an area of 0.51 ha and 0.32 ha in Head and Tail region, respectively in Kharif . Bajra was grown on an area of 0.70 ha and 0.76 ha in Head and Tail regions, respectively. Green gram was grown on an area of 0.64 ha and 0.72 ha in Head and Tail regions, respectively in kharif season. While in rabi wheat was grown on an area of 0.71 ha and 0.73 ha in Head and Tail regions, respectively. Bengal gram was grown on an area of 0.36 ha and 0.30 ha in Head and Tail regions, respectively. Sorghum was grown on an area of 0.75 ha and 0.82 ha in Head and Tail regions, respectively. Vegetables were grown in summer with an area of 0.40 ha and 0.25 ha in Head and Tail regions, respectively. Annual crop, sugarcane was grown on an area of 1.92 ha and 1.90 ha in Head and Tail regions, respectively by the sample farmers.

The gross cropped area in the Head region was 5.99 ha with a net cropped area of 3.77 ha having the cropping intensity of 158.88 per cent. The gross cropped area in the Tail region was 5.8 ha with a net cropped area of 3.7 ha having the cropping intensity of 156.75 per cent.

Table 4.3 e Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Malaprabha project command areas for Rabi season

Rabi	Rabi sorghum	Hybrid maize	Wheat	Pulses	Sunflower	Others
Rabi sorghum	0.33	0.00	0.51	0.16	0.00	0.00
Hybrid maize	0.00	0.00	0.00	1.00	0.00	0.00
Wheat	0.49	0.29	0.00	0.00	0.12	0.10
Pulses	0.00	0.04	0.51	0.45	0.00	0.00
Sunflower	0.00	0.00	0.00	0.13	0.72	0.15
Others	0.00	0.00	0.00	0.03	0.00	0.97

Table 4.3 f. Area Share Pattern of Different Crops during 1999-00 to 2014-15 in Ghataprabha project command areas for biseasonal crops

Biseasonal	Hybrid Cotton	Imp. Cotton
Hybrid Cotton	1.0	0.0
Imp. Cotton	1.0	0.0

Table 4.3 g Cropping pattern in UKP command area (n=60)

Season	ALBC				IBC			
	HR		TR		HR		TR	
Kharif	Area	Percent	Area	Percent	Area	Percent	Area	Percent
Pigeon pea	0.65	11.25	0.72	12.73	0.51	8.51	0.32	5.52
Bajra	0.50	8.65	0.56	9.90	0.70	11.68	0.76	13.1
Green gram	0.58	10.03	0.52	9.18	0.64	10.68	0.72	12.41
Sub total	1.73		1.80		1.85		1.80	
Rabi								
Wheat	0.49	8.47	0.50	8.84	0.71	11.85	0.73	12.58
Bengal gram	0.54	9.35	0.52	9.18	0.36	6.02	0.30	5.17
Sorghum	0.65	11.24	0.70	12.37	0.75	12.53	0.82	14.14
Subtotal	1.68		1.72		1.82		1.85	
Summer								
Vegetables	0.45	7.80	0.30	5.30	0.40	6.68	0.25	4.33
Sub-total	0.45		0.30		0.40		0.25	
Bi seasonal								
Sugarcane	1.92	33.21	1.84	32.50	1.92	32.05	1.90	32.75
Sub-total	1.92		1.84	32.50	1.92		1.90	
GCA	5.78	100.00	5.66	100.00	5.99	100.00	5.8	100.00
NCA	3.65		3.64		3.77		3.7	
CI	158.35		155.49		158.88		156.75	

4.3.8 Cropping pattern in MGP command area

Table 4.3 h presents cropping pattern under Head and Tail regions of MLBC and GRBC in different seasons. As shown in the table, maize was the major cereal crop, pigeon pea, green gram and bengal gram were the major pulse crops.. Ground nut and sunflower were the major oil seed crops. Vegetables were grown in summer and sugarcane, cotton and chilli were the major annual/bi seasonal crop grown by the sample farmers in the study area.

In MLBC command area maize was grown on an area of 0.60 ha and 0.50 ha in Head and Tail region respectively. Ground nut was grown on an area of 0.42 ha and 0.66 ha in Head and Tail region respectively. Sunflower was grown on an area of 0.30 ha and 0.24 ha in Head and Tail regions respectively and green gram was grown on an area of 0.22 ha and 0.10 ha in Head and Tail respectively in kharif season. While in rabi maize was grown on an area of 0.62 ha and 0.50 ha in Head and Tail regions, respectively. Ground nut was grown on an area of 0.42 ha and 0.66 ha in Head and Tail regions, respectively. Bengal gram was grown on an area of 0.47 ha and 0.35 ha in Head and Tail regions, respectively. Vegetables were grown in summer with an area of 0.64 ha and 0.54 ha in Head and Tail regions, respectively. Annual crops like sugarcane was grown on an area of 0.36 ha and 0.18 ha in Head and Tail regions, respectively. Chilli was grown on an area of 0.65 ha and 0.48 ha in Head and Tail regions, respectively. Cotton was another major crop grown in the study area with an area of 1.09 ha and 1.46 ha in Head and Tail regions, respectively by the sample farmers.

The gross cropped area in the Head region was 5.79 ha with a net cropped area of 3.64 ha having the cropping intensity of 159.06 per cent. The gross cropped area in the Tail region was 5.64 ha with a net cropped area of 3.62 ha having the cropping intensity of 155.80 per cent.

In GRBC command area maize was grown on an area of 0.80 ha and 0.64 ha in Head and Tail region, respectively. Ground nut was grown on an area of 0.64 ha and 0.48 ha in Head and Tail regions, respectively. Sunflower was grown on an area of 0.25 ha and 0.22 ha in Head and Tail regions, respectively and green gram was grown on an area of 0.16 ha and 0.16 ha in Head and Tail respectively in kharif season. While in rabi maize was grown on an area of 0.86 ha and 0.70 ha in Head and Tail regions, respectively. Ground nut was grown on an area of 0.80 ha and 0.62 ha in Head and Tail regions, respectively. Bengal gram was grown on an area of 0.22 ha and 0.26 ha in Head and Tail regions respectively. Vegetables were grown in summer with an area of 0.75 ha and 0.62 ha in Head and Tail regions respectively. Sugarcane was major commercial crop grown on an area of 1.97 ha and 1.84 ha in Head and Tail regions respectively. Chilli was grown on an area of 0.42 ha in Tail region only and was not grown in Head region by the sample farmers.

The gross cropped area in the Head region was 6.45 ha with a net cropped area of 3.85 ha having the cropping intensity of 167.53 per cent. The gross cropped area in the Tail region was 5.96 ha with a net cropped area of 3.84 ha having the cropping intensity 155.20 of per cent.

4.3.9 Recommended and the actual cropping pattern in the study area (n=120)

Table 4.3 i represents the recommended and the actual cropping pattern practiced in the command area. In case of UKP command area sugarcane was cultivated with a highest deviation of 32.62 per cent. While pigeon pea , vegetables and green gram were cultivated with a deviation of 7.00 per cent , 6.02 per cent and 5.57 per cent, respectively. Rabi sorghum bengal gram and wheat were cultivated with a small deviation of 2.57 per cent, 2.43 per cent and 0.43 per cent.

In case of MGP command area sugarcane, cotton, maize and vegetables were cultivated with a deviation of 17.70 per cent, 12.35 per cent, 12.86 per cent and 10.66 per cent, respectively. While other crops like sunflower, ground nut and green gram were cultivated with a deviation of 5.75 per cent, 3.42 per cent and 2.5 per cent, respectively. Bengal gram and chilly were cultivated with a small deviation of 0.52 per cent and 1.08 per cent, respectively.

Table 4.3 h Cropping pattern in MGP command area

(n=60)

Seasons	MLBC				GRBC			
	HR		TR		HR		TR	
Kharif	Area	Percent	Area	Percent	Area	Percent	Area	Percent
Maize	0.60	10.36	0.50	8.87	0.80	12.40	0.64	10.73
Ground nut	0.42	7.25	0.66	11.70	0.64	9.92	0.48	8.05
Sunflower	0.30	5.18	0.24	4.25	0.25	3.87	0.22	3.69
Green gram	0.22	3.79	0.10	1.77	0.16	2.48	0.16	2.68
Sub total	1.54		1.50		1.85		1.50	
Rabi								
Maize	0.62	10.70	0.75	13.30	0.86	13.34	0.70	11.74
Ground nut	0.42	7.25	0.38	6.73	0.80	12.40	0.62	10.40
Bengal gram	0.47	8.11	0.35	6.20	0.22	3.41	0.26	4.36
Sub total	1.55		1.48		1.88		1.58	
Summer								
Vegetables	0.64	11.05	0.54	9.58	0.75	11.62	0.62	10.40
Sub total	0.64		0.54		0.75		0.62	
Bi seasonal								
Chilli	0.65	11.22	0.48	8.51	0.00	00.00	0.42	7.04
Cotton	1.09	18.82	1.46	25.89	0.00	00.00	0.00	00.00
Sugarcane	0.36	6.21	0.18	3.20	1.97	30.54	1.84	30.87
Sub total	2.10		2.12		1.97		2.26	
GCA	5.79	100.00	5.64	100.00	6.45	100.00	5.96	100.00
NCA	3.64		3.62		3.85		3.84	
CI	159.06		155.80		167.53		155.20	

Table 4.3 i Recommended and the actual cropping pattern in the study area

(n=120)

Sl. No.	Crop	Recommended area (%)	UKP		MGP	
			Actual Area (%)	Violation (%)	Actual Area (%)	Violation (%)
01	Maize	10	00.00	10	22.86	12.86
02	Ground nut	15	00.00	15	18.42	3.42
03	Bajra	10	10.83	0.83	00.00	10
04	Sun flower	10	00.00	10	4.25	5.75
05	Green gram/ Pulses	05	10.57	5.57	2.68	2.32
06	Red gram	2.5	9.5	7.0	00.00	2.5
07	Chick pea	5	7.43	2.43	5.52	0.52
08	R. Sorghum	10	12.57	2.57	00.00	10
09	Wheat	10	10.43	0.43	00.00	10
10	Vegetables	00	6.02	6.02	10.66	10.66
11	Sugarcane	00	32.62	32.62	17.70	17.70
12	Chilly	10	00.00	10	8.92	1.08
13	Cotton	10	00.00	10	22.35	12.35
14	Horticulture crops	2.5	00.00	2.5	00.00	2.5

4.3.10 Economics of cropping pattern in ALBC command area

Table 4.3 j indicates the different crops grown in ALBC command area. In Kharif season Pigeon pea, bajra , green gram and maize were grown both Head and Tail regions. An economic analysis involving cost and returns revealed that on an average the net returns per ha across the crops was higher in the Head region (Rs.52,942.97) compared to those in Tail region (Rs. 38,926.31) .

In the Head region pigeon pea was found to be earning highest net returns per ha (Rs. 61,546) followed by other crops whereas in Tail region bajra was more profitable (Rs. 43,171.25) compared to other crops.

Sorghum , chick pea , sunflower and ground nut were the crops grown in rabi in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs. 33,965) as compared to those in Tail region (Rs. 28,381.25).

In the Head region sunflower was found to be earning higher net returns per ha (Rs. 43,710) followed by other crops whereas in Tail region ground nut was more profitable (Rs.36,150) compared to other crops.

Vegetables like tomato, brinjal and bhendi were grown in summer in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs.41,479) as compared to those in Tail region (Rs. 33,750).

Sugarcane was the bi-seasonal crop grown in both Head and Tail regions. The average net returns per ha for sugarcane was higher in Head region (Rs.97,500) as compared to those in Tail region (Rs. 76,500).

In general across the seasons and crops the average net returns in the Head region was higher (Rs. 47,464.07) than those in Tail regions (Rs. 37,248.67).

4.3.11 Economics of cropping pattern in IBC command area

Table 4.3 k indicates the different crops grown in IBC command area. In Kharif season Pigeon pea, bajra and green gram were grown both Head and Tail regions. An economic analysis involving cost and returns revealed that on an average the net returns per ha across the crops was higher in the Head region (Rs. 44,597) compared to those in Tail region (Rs.40,713.34).

Pigeon pea was found to be earning highest net returns per ha in Head and Tail regions followed by other crops. The average net returns per ha in Head region was Rs.47,796.25 while that of in Tail region was Rs. 44,195.

Wheat, Bengal gram and sorghum were the crops grown in rabi in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs.25,741) as compared to those in Tail region (Rs.24,216.67).

Wheat was found to be earning highest net returns per ha in Head and Tail regions followed by other crops. The average net returns per ha in Head region was Rs.32,100 while that of in Tail region was Rs. 31,250.

A few vegetables were grown in summer in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs.37,500) as compared to a loss in Tail region (Rs. 21,750).

Table 4.3 j Economics of cropping pattern in the ALBC command area

(n=30)

Seasons	Head region				Tail region			
	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)
Kharif								
Pigeon pea	15.66	24625.00	86171.25	61546.00	12.15	24750.00	66783.75	42033.75
Bajra	29.66	8625.00	57851.63	49225.00	24.66	8625.00	51796.5	43171.25
Green gram	11.25	7250.00	56250.00	49000.00	7.50	7000.00	37500.00	30500.00
Maize	71.25	33500.00	85500.00	52000.00	62.5	35000.00	75000.00	40000.00
Subtotal A.	-	-	-	211771.88	-	-	-	155705.25
Average	-	-	-	52,942.97	-	-	-	38,926.31
Rabi								
Sorghum	23.75	22500.00	52250.00	29750.00	19.75	22500.00	41475.00	18975.00
Chick pea	18.00	15000.00	41400.00	26400.00	16.25	15000.00	37375.00	22375.00
Sunflower	31.66	19625.00	63335.00	43710.00	2.825	19625.00	55650.00	36025.00
Ground nut	26.25	37500.00	73500.00	36000.00	24.55	37500.00	73650.00	36150.00
Sub total B.	-	-	-	135860.00	-	-	-	113525.00
Average	-	-	-	33,965.00	-	-	-	28,381.25
Summer								
Tomato	25.00	62500.00	120000.00	57500.00	25.00	62500.00	120000.00	57500
Brinjal	45.00	50000.00	94500.00	44500.00	37.5	50000.00	78750.00	28750
Bhendi	8.75	37500.00	59937.00	22437.00	7.5	37500.00	52500.00	15000
Sub total C.	-	-	-	124437.00	-	-	-	101250
Average	-	-	-	41,479.00	-	-	-	33,750
Bi seasonal								
Sugarcane	100.00	112500.00	210000.00	97500.00	95.00	112500.00	190000.00	76500.00
Sub total D.	-	-	-	97500.00	-	-	-	76500.00
Total (A+B+C+D)	-	-	-	569568.88	-	-	-	446980.25
Average				47,464.07				37,248.67

Table 4.3 k Economics of cropping pattern in the IBC command area.

(n=30)

Seasons	Head region				Tail region			
	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)
Kharif								
Pigeon pea	13.17	24625.00	72421.25	47796.25	12.50	24625.00	68750.00	44195.00
Bajra	24.67	8625.00	51801.75	43176.75	20.92	8625.00	43890.00	35265.00
Green gram	10.00	7250.00	50000.00	42730.00	10.00	7250.00	50000.00	42750.00
Subtotal A	-	-	-	133793.00	-	40500.00	162640.00	122140.00
Average	-	-	-	44,597.00	-	-	-	40,713.34
Rabi								
Wheat	25.75	40000.00	72100.00	32100.00	23.75	40000.00	71250.00	31250.00
Chick pea	17.50	20000.00	40250.00	20250.00	18.00	20000.00	41400.00	21400.00
Sorghum	23.75	25000.00	49875.00	24875.00	22.50	25000.00	45000.00	20000.00
Sub total B.	-	85000.00	162225.00	77225.00	-	85000.00	157650.00	72650.00
	-	-	-	25,741.00	-	-	-	24216.67
Summer								
Vegetables	25.00	62500.00	100000.00	37500.00	12.5	50000.00	31250.00	-21250.00
Sub total C.	-	62500.00	100000.00	37500.00	-	50000.00	31250.00	-21750.00
	-	-	-	37500.00	-	-	-	-21750.00
Bi seasonal								
Sugarcane	95.00	125000.00	200000.00	75000.00	90.00	125000.00	189000.00	64000.00
Sub total D.	-	125000.00	200000.00	75000.00	90.00	125000.00	189000.00	64000.00
Total (A+B+C+D)	-	313000.00	636448.00	323518.00	-	300500.00	544040.00	237040.00
	-	-	-	40,439.75	-	-	-	29,630.00

Table 4.3 I Economics of cropping pattern in the MLBC command area

(n=30)

	Head region				Tail region			
Seasons	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)
Kharif								
Maize	75.00	37500.00	90000.00	52500.00	71.25.00	37500.00	85500.00	48000.00
Ground nut	30.00	50000.00	96000.00	46000.00	26.25.00	50000.00	81375.00	31375.00
Sunflower	35.00	20000.00	70000.00	50000.00	30.00	20000.00	60000.00	40000.00
Green gram	12.50	8750.00	62500.00	53750.00	11.25	8750.00	56250.00	47500.00
Sub total A		116250.00	318500.00	202250.00		116250.00	283125.00	166875.00
				50,562.5.00				
Rabi								
Maize	75.00	37500.00	90000.00	52500.00	66.25	37500.00	79500.00	42000.00
Ground nut	31.25	45000.00	93750.00	48750.00	25.00	50000.00	75000.00	25000.00
Chick pea	20.00	20000.00	46000.00	26000.00	18.00	20000.00	41400.00	21400.00
Sub total B		102500.00	229750.00	127250.00		107500.00	195900.00	88400.00
				42,416.67.00				
Summer								
Vegetables	30.00	62500.00	150000.00	87500.00	25.00	62500.00	125000.00	62500.00
Sub total C		62500.00	150000.00	87500.00		62500.00	125000.00	62500.00
Bi seasonal								
Chilli	15.00	50000.00	87000.00	37000.00	15.00	50000.00	90000.00	40000.00
Cotton	25.00	50000.00	100000.00	50000.00	21.25	50000.00	85000.00	35000.00
Sugarcane	95.00	125000.00	199500.00	74500.00	90.00	125000.00	199500.00	74500.00
Sub total D		125000.00	199500.00	161500.00		125000.00	199500.00	149500.00
				248500.00				49.833.34
Total (A+B+C+D)				470500.00				342275.00
				42772.73.00				31,115.90

Sugarcane was the bi-seasonal crop grown in both Head and Tail regions. The average net returns per ha for sugarcane was higher in Head region (Rs. 75,000) as compared to those in Tail region (Rs. 64,000).

In general across the seasons and crops the average net returns in the Head region was higher (Rs. 40,439.75) than those in Tail regions (Rs. 29,630.50).

4.3.12 Economics of cropping pattern in MLBC command area

Table 4.3 l indicates the different crops grown in MLBC command area. In Kharif season maize, ground nut, sunflower and green gram were grown both Head and Tail regions. An economic analysis involving cost and returns revealed that on an average the net returns per ha across the crops was higher in the Head region (Rs.50,562.5) compared to those in Tail region (Rs. 41,718.75).

In the Head region green gram was found to be earning highest net returns per ha (Rs. 53,750) followed by other crops whereas in Tail region maize was more profitable (Rs.48,000) compared to other crops.

Maize ,ground nut and chick pea were the crops grown in rabi in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs. 42,416.67) as compared to those in Tail region (Rs. 29,466.67).

Maize was found to be earning highest net returns per ha in Head and Tail regions followed by other crops. The average net returns per ha in Head region was Rs.52,500 while that of in Tail region was Rs. 42,000.

Vegetables were grown in summer in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs.87,500) as compared to those in Tail region (Rs. 62,500).

Sugarcane, cotton and chilli were the bi-seasonal crops grown in both Head and Tail regions. The average net returns per ha across the crops were higher in Head region (Rs. 53,833.34) as compared to those in Tail region (Rs. 49,833.34).

Sugarcane was found to be earning highest net returns per ha in Head and Tail regions followed by other crops. The average net returns per ha in Head region was Rs.74,500 while that of in Tail region was Rs. 64,000.

In general across the seasons and crops the average net returns in the Head region was higher (Rs. 52,590.90) than those in Tail regions (Rs. 42,479.55).

4.3.13 Economics of cropping pattern in GRBC command area

Table 4.3 m indicates the different crops grown in GRBC command area. In Kharif season. Maize, ground nut and sunflower were grown both Head and Tail regions. An economic analysis involving cost and returns revealed that on an average the net returns per ha across the crops was higher in the Head region (Rs. 49,500) compared to those in Tail region (Rs. 39,791.67).

Maize was found to be earning highest net returns per ha in Head and Tail regions followed by other crops. The average net returns per ha in Head region was Rs.52,500 while that of in Tail region was Rs. 48000.

Table 4.3 m Economics of cropping pattern in the GRBC Command area

(n=30)

Seasons	Head region				Tail region			
	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)	Yield (per ha)	Total cost (Rs per ha)	Total returns (Rs per ha)	Net returns (Rs per ha)
Kharif								
Maize	75.00	37500.00	90000.00	52500.00	71.25	37500.00	85500.00	48000.00
Ground nut	30.00	50000.00	96000.00	46000.00	26.25	50000.00	81375.00	31375.00
Sunflower	35.00	20000.00	70000.00	50000.00	30.00	20000.00	60000.00	40000.00
Subtotal A.				148500.00		107500.00	226875.00	119375.00
Average				49,500.00				39,958.34
Rabi								
Maize	75.00	37500.00	90000.00	52500.00	66.25	37500.00	79500.00	42000.00
Ground nut	31.25	45000.00	93750.00	48750.00	25.00	50000.00	75000.00	25000.00
Chick pea	20.00	20000.00	46000.00	26000.00	17.50	20000.00	40250.00	20250.00
Sunflower	30.00	20000.00	60000.00	40000.00	30.00	20000.00	60000.00	40000.00
Subtotal B.				167250.00		127500.00	254750.00	127250.00
Average				41,812.50				31812.50
Summer								
Vegetables	30.00	62500.00	150000.00	87500.00	25.00	62500.00	125000.00	62500.00
Subtotal C				87500.00		62500.00	125000.00	62500.00
Average				87500.00				62,500.00
Bi seasonal								
Sugarcane	95.00	125000.00	199500.00	74500.00	90.00	125000.00	189000.00	64000.00
Subtotal D.				74500.00		125000.00	189000.00	64000.00
Average				74500.00				64000.00
Total (A+B+C+D)				473250.00				373125.00
				52583.34.00				41458.34

Maize, ground nut, Bengal gram and sunflower were the crops grown in rabi in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs. 41,812.5) as compared to those in Tail region (Rs.31,812.50).

Maize was found to be earning highest net returns per ha in Head and Tail regions followed by other crops. The average net returns per ha in Head region was Rs.52,500 while that of in Tail region was Rs. 42,000.

A few vegetables were grown in summer in both Head and Tail regions. The average net returns per ha across the crops was higher in Head region (Rs.87,500) as compared to those in Tail region (Rs. 62,500).

Sugarcane was the bi-seasonal crop grown in both Head and Tail regions. The average net returns per ha for sugarcane was higher in Head region (Rs. 74,500) as compared to those in Tail region (Rs. 64,000).

In general across the seasons and crops the average net returns in the Head region was higher (Rs. 53,083.34) than those in Tail regions (Rs. 41,458.34).

4.4 Productivity of selected crops in the study area. (n=120)

Table 4.4 reveals the productivity of selected crops in the UKP and MGP command areas. Sugarcane grown across different canals was grown on an area of 178.95 ha with a production of 16,536.77 tonnes. Cotton was grown on an area of 76.5 ha with a production of 2,220.79 quintals. Maize was grown on an area of 72.25 ha with a production of 5,394.90 quintals. Ground nut was grown on an area of 66.3 ha with a production of 676.26 quintals.

Productivity was worked out as a ratio of production to the area. The productivity of sugarcane across all the canals was 92410 kg per ha. The productivity of cotton was 2903 kg per ha in the command area. Maize and ground nut were having a productivity of 7265 kg per and 2250 kg per ha, respectively.

4.5 Economics of water productivity of selected crops in UKP and MGP command areas

4.5.1 Water productivity of sugarcane in ALBC command area (n=30)

Table 4.5 a indicates the average water applied to the sugarcane crop in the Head region was 36,560 m^3 while that in the Tail region was 17,930 m^3. While the maximum quantity of water applied in the Head region was 39,480 m^3 per ha ,the minimum was 29,280 m^3 per ha . The maximum quantity of water applied in Tail region was 20,520 m^3 per ha and the minimum was 14,620 m^3per ha.

Average yield of sugarcane in Head and Tail regions was 96.18 tonnes per ha and 88.83 tonnes per ha, respectively. In the Head region the yield ranged between a maximum of 105 tonnes per ha to a minimum of 87.5 tonnes per ha. Similarly in the Tail region the yield ranged between a maximum of 100 tonnes per ha to a minimum of 75 tonnes per ha.

Water productivity defined in terms of yield obtained and water applied per ha was 6.59 kg per m^3 in the Head region. Water productivity in the Head region ranged from 4.89 kg per m^3 to 8.43 kg per m^3. Similarly in the Tail region it was 12.49 kg per m^3 ranging from 9.29 kg per m^3 to 16.62 kg per m^3.

Table 4.4 Productivity of selected crops in the study area (n=120)

Crop	Area (ha)	Production (Quintals)	Productivity (Kg. per ha)
Sugarcane (tonnes)	178.95	16536.77	92410.00
Cotton	76.50	2220.79	2903.00
Maize	72.25	5394.90	7265.00
Ground nut	66.30	1712.529	2250.00

Table 4.5 a Water productivity of sugarcane in ALBC command area (n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	39480	29280	36560	20520	14620	17930
Average yield (tonnes per ha)	105	87.5	96.175	100	75	88.825
Water Productivity.(kg per m^3)	8.43	4.89	6.59	16.62	9.29	12.49

4.5.2 Water productivity of sugarcane in IBC command area (n=30)

Table 4.5 b indicates the average water applied to the sugarcane crop in the Head region was 35,936 m^3 while that in the Tail region was 17,590.67 m^3. While the maximum quantity of water applied in the Head region was 39,240 m^3 per ha ,the minimum was 20,520 m^3 per ha . The maximum quantity of water applied in Tail region was 19,480 m^3 per ha and the minimum was 15,040 m^3per ha.

Average yield of sugarcane in Head and Tail regions was 96.83 tonnes per ha and 87.65 tonnes per ha, respectively. In the Head region the yield ranged between a maximum of 100 tonnes per ha to a minimum of 90 tonnes per ha. Similarly in the Tail region the yield ranged between a maximum of 85 tonnes per ha to a minimum of 75 tonnes per ha.

Water productivity defined in terms of yield obtained and water applied per ha was 7.55 kg per m^3 in the Head region. Water productivity in the Head region ranged from 6.35 kg per m^3 to 8.95 kg per m^3. Similarly in the Tail region it was 14.38 kg per m^3 ranging from 12.07 kg per m^3 to 17.45 kg per m^3.

4.5.3 Water productivity of cotton in MLBC command area (n=30)

Table 4.5 c indicates the average water applied to the cotton crop in the Head region was 9,677.34 m^3 while that in the Tail region was 7,940.8 m^3. While the maximum quantity of water applied in the Head region was 12,480 m^3 per ha ,the minimum was 6,920 m^3 per ha .The maximum quantity of water applied in Tail region was 12,212 m^3 per ha and the minimum was 6,300 m^3per ha.

Average yield of cotton in Head and Tail regions was 31.06 quintals per ha and 27 quintals per ha, respectively. In the Head region the yield ranged between a maximum of per 37.5 quintals per ha to a minimum of 25 quintals per ha. Similarly in the Tail region the yield ranged between a maximum of 31.25 quintals per ha to a minimum of 22.50 tonnes per ha.

Water productivity defined in terms of yield obtained and water applied per ha was 0.82 kg per m^3 in the Head region. Water productivity in the Head region ranged from 0.60 kg per m^3 to 1.13 kg per m^3. Similarly in the Tail region it was 0.86 kg per m^3 ranging from 0.63 kg per m^3 to 1.12 kg per m^3.

4.5.4 Water productivity of sugarcane in GRBC command area (n=30)

Table 4.5 d indicates the average water applied to the sugarcane crop in the Head region was 38,520 m^3 while that in the Tail region was 16,480 m^3. While the maximum quantity of water applied in the Head region was 39,480 m^3 per ha ,the minimum was 29,280 m^3 per ha . The maximum quantity of water applied in Tail region was 20,520 m^3 per ha and the minimum was 14,620 m^3per ha.

Average yield of sugarcane in Head and Tail regions was 94.16 tonnes per ha and 88.82 tonnes per ha, respectively. In the Head region the yield ranged between a maximum of 101.6 tonnes per ha to a minimum of 86.83 tonnes per ha. Similarly in the Tail region the yield ranged between a maximum of 95.00 tonnes per ha to a minimum of 72 tonnes per ha.

Water productivity defined in terms of yield obtained and water applied per ha was 7.80 kg per m^3 in the Head region. Water productivity in the Head region ranged from 9.05 kg per m^3 to 9.88 kg per m^3. Similarly in the Tail region it was 12.5 kg per m^3 ranging from 12.90 kg per m^3 to 14.15 kg per m^3.

Table 4.5 b Water productivity of sugarcane in IBC command area (n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	39240	20520	35936	19480	15040	17590.67
Average yield (tonnes per ha)	100	90	96.825	85	75	87.65
Water Prod. (kg per m^3)	6.35	8.95	7.55	17.45	12.075	14.375

Table 4.5 c Water productivity of cotton in MLBC command area (n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	12480	6920	9677.333	12211	6300	7940.8
Avg. yield (quintals per ha)	37.50	25.00	31.06	31.25	22.50	27.00
Water Prod. (kg per m^3)	1.13	0.60	0.82	1.12	0.63	0.86

4.5.5 Water productivity of maize in command areas (n=30)

Table 4.5 e indicates the average water applied to the maize crop in the Head region was 3,960 m^3 while that in the Tail region was 3,352 m^3. While the maximum quantity of water applied in the Head region was 5,160 m^3 per ha ,the minimum was 2160 m^3 per ha . The maximum quantity of water applied in Tail region was 4,080 m^3 per ha and the minimum was 2,040 m^3per ha.

Average yield of maize in Head and Tail regions was 76.67 quintals per ha and 72.65 quintals per ha, respectively. In the Head region the yield ranged between a maximum of 80 quintals per ha to a minimum of 70 quintals per ha. Similarly in the Tail region the yield ranged between a maximum of 75 tonnes per ha to a minimum of 70 tonnes per ha.

Water productivity defined in terms of yield obtained and water applied per ha was 5.60 kg per m^3 in the Head region. Water productivity in the Head region ranged from 5.1 kg per m^3 to 8.68 kg per m^3. Similarly in the Tail region it was5.87 kg per m^3 ranging from 4.29 kg per m^3 to 8.57 kg per m^3.

4.5.6 Water productivity of ground nut in command areas (n=30)

Table 4.5 f indicates the average water applied to the ground nut crop in the Head region was 2,088 m^3 while that in the Tail region was 1,376 m^3. While the maximum quantity of water applied in the Head region was 3,240 m^3 per ha , the minimum was 1,440 m^3 per ha . The maximum quantity of water applied in Tail region was 2,040 m^3 per ha and the minimum was 1,376 m^3per ha.

Average yield of ground nut in Head and Tail regions was 27.65 quintals per ha and 24 quintals per ha, respectively. In the Head region the yield ranged between a maximum of 30 quintals per ha to a minimum of 25 quintals per ha. Similarly in the Tail region the yield ranged between a maximum of 30 quintals per ha to a minimum of 20 quintals per ha.

Water productivity defined in terms of yield obtained and water applied per ha was 2.85 kg per m^3 in the Head region. Water productivity in the Head region ranged from 1.92 kg per m^3 to 5.2 kg per m^3. Similarly in the Tail region it was 4.42 kg per m^3 ranging from 3.05 kg per m^3 to 5.2 kg per m^3.

4.5.7 Economic water productivity of sugarcane in the ALBC command area (n=30)

Table 4.5 g reveals economic water productivity of sugarcane crop in ALBC command area. In the Head region of the canal area, on an average 36,560 m^3 per ha water was applied with a range between 29,280 m^3 per ha to 39,480 m^3 per ha. Similarly the average water applied per ha in Tail region was 17,930 m^3 with a range from 7,120 m^3 per ha to 20,520 m^3 per ha.

The average sugarcane yield obtained in this command area was 96.17 tonnes per ha in the Head region and 88.83 tonnes per ha in the Tail region.

Average gross returns per ha in sugarcane cultivation were Rs. 2,01,500 per ha which ranged from a minimum of Rs. 1,75,000 to a maximum of Rs. 2,20,500 per ha in the Head region. In the Tail region, the average gross returns per ha was 1,78,833 with a range of Rs. 1,50,000 to 2,00,000 per ha.

Gross Economic Water Productivity (GEWP) was worked out as a ratio of gross returns to the total water applied per unit area. In this case GEWP in the Head region was Rs. 13.59 per m^3 while the average ranged from a minimum of Rs. 12.45 per m^3 to Rs. 15.23 per m^3. In the Tail region, average GEWP was Rs. 15.66 per m^3 while it ranged from Rs. 11.78 per m^3 to Rs. 27.85 per m^3.These figures reflect upon higher GEWP in the Tail region compared to Head region.

The average net returns (Rs. per ha) were worked out by deducting cost of cultivation per ha from the per ha gross returns.

Table 4.5 d Water productivity of sugarcane in GRBC command area (n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	39480	29280	38520	20520	14620	16480
Avg. Yield (tonnes per ha)	101.16	86.83	94.16	95	72	88.825
Water Prod. (kg per m^3)	9.875	9.05	7.8	14.15	12.9	12.5

Table 4.5 e Water productivity of maize in command areas (n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	5160	2160	3960	4080	2040	3352
Avg. yield (quintals per ha)	80	70	76.67	75	70	72.65
Water Prod. (kg per m^3)	8.675	5.10	5.60	8.575	4.28	5.87

Table 4.5 f Water productivity of ground nut in command areas

(n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	3240	1440	2088	2040	1200	1376
Avg. yield (quintals per ha)	30	25	27.65	30	20	24
Water Prod. (kg per m^3)	5.2	1.925	2.85	5.2	3.05	4.42

Table 4.5 g Economic water productivity of sugarcane in the ALBC command area

(n=30)

Particulars	Head region			Tail region		
	Max.	Min.	Average	Max.	Min.	Average.
Total water applied (m^3)	39480	29280	36560	20520	7120	17930
Avg. yield (tonnes per ha)	105	87.5	96.1675	100	75	88.825
Gross returns (Rs per ha)	2,20,500	1,75,000	2,01,500	2,00,000	1,50,000	1,78,833.3
GEWP (Rs. per m^3)	15.2275	12.45	13.595	27.85	11.775	15.655
Net returns (Rs per ha)	1,07,500	40,000	70,852.48	97,500	35,000	73,466.64
NEWP (Rs. per m^3)	7.35	2.74	6.00	12.0325	3.82	6.83

The average net returns in the Head region of ALBC was Rs. 70,852 per ha. These net returns ranged from a minimum of Rs. 40,000 to a maximum of Rs. 1,07,000 per ha. In the Tail region, the average net returns were about Rs. 73,466.64 per ha with a range of Rs. 35,000 to Rs. 97,500 per ha.

Finally Net Economic Water Productivity (NEWP) was calculated as monetary returns per m^3 of water applied in case of sugarcane. The table shows that the NEWP was higher in case of Tail region (Rs. 6.83 per m^3) compared to Head region (Rs. 6.00 per m^3)

Thus the Net Economic Water Productivities were not uniform across Head and Tail regions. It was more in Tail region compared to Head region, thereby highlighting higher economic water productivity of sugarcane in Tail region of ALBC command area.

4.5.8 Economic water productivity of sugarcane in the IBC command area (n=30)

Table 4.5 h reveals economic water productivity of sugarcane crop in IBC command area. In the Head region of the canal area, on an average 35,936 m^3 per ha water was applied with a range between 20,520 m^3 per ha to 39,240 m^3 per ha. Similarly the average water applied per ha in Tail region was 17,590.67 m^3 with a range from 15,040 m^3 per ha to 19,480 m^3 per ha.

The average sugarcane yield obtained in this command area was 96.82 tonnes per ha in the Head region and 87.66 tonnes per ha in the Tail region.

Average gross returns per ha in sugarcane cultivation were Rs. 2,10,500 per ha which ranged from a minimum of Rs. 1,75,000 to a maximum of Rs. 2,10,000 per ha in the Head region. In the Tail region, the average gross returns per ha was 1,78,750 with a range of Rs. 1,50,000 to 2,00,000 per ha.

Gross Economic Water Productivity (GEWP) was worked out as a ratio of gross returns to the total water applied per unit area. In this case GEWP in the Head region was Rs. 13.5 per m^3 while the average ranged from a minimum of Rs. 12.02 per m^3 to a maximum of Rs. 15.60 per m^3. In the Tail region, average GEWP was Rs. 16.92 per m^3 while it ranged from Rs. 12.45 per m^3 to Rs. 26.55 per m^3.These figures reflect upon higher GEWP in the Tail region compared to Head region.

The average net returns (Rs. per ha) were worked out by deducting cost of cultivation (per ha) from the gross returns (per ha).

The average net returns in the Head region of IBC was Rs. 70,666.67 per ha. These net returns ranged from a minimum of Rs. 40,000 to Rs. 1,07,500 per ha. In the Tail region, the average net returns were about Rs.72,166.59 per ha with a range of Rs. 35,000 to Rs. 97,500 per ha.

Finally Net Economic Water Productivity (NEWP) was calculated as monetary returns per m^3 of water applied in case of sugarcane. The table shows that the NEWP was higher in case of Tail region (Rs. 7.50 per m^3) compared to Head region (Rs. 5.72 per m^3)

Thus the Net Economic Water Productivities were not uniform across Head and Tail regions. It was more in Tail region compared to Head region, thereby highlighting higher economic water productivity of sugarcane in Tail region of IBC command area.

4.5.9 Economic water productivity of cotton in the MLBC command area (n=30)

Table 4.5 i indicates economic water productivity of cotton crop in MLBC command area. In the Head region of the canal area, on an average 9,677.33 m^3 per ha water was applied with a range between 6,920 m^3 per ha to 12,480 m^3 per ha. Similarly the average water applied per ha in Tail region was 7,940 m^3 with a range from 6,300 m^3 per ha to 12,210 m^3 per ha.

The average cotton yield obtained in this command area was 31.06 quintals per ha in the Head region and 27.00 quintals per ha in the Tail region.

Table 4.5 h Economic water productivity of sugarcane in the IBC command area

(n=30)

Particulars	Head region			Tail region		
	Max.	Min.	Average	Max.	Min.	Average.
Total water applied (m^3)	39240	20520	35936	19480	15040	17590.67
Avg. yield (tonnes per ha)	100	90	96.825	95	75	87.6675
Gross returns (Rs per ha)	2,10,000	1,75,000	2,01,500	2,00,000	1,50.000	1,78,750
GEWP (Rs per m^3)	15.6	12.025	13.5	26.55	12.45	16.925
Net returns (Rs per ha)	1,07,500	40,000	70,666.68	97,500	35,000	72,166.59
NEWP (Rs per m^3)	7.00	3.425	5.725	13	5.7	7.5025

Table 4.5 i Economic water productivity of cotton in the MLBC command area

(n=30)

Particulars	Head region			Tail region		
	Max.	Min.	Average	Max.	Min.	Average.
Total water applied (m^3)	12480	6920	9677.325	12210	6300	7940.668
Avg. Yield (tonnes per ha)	62.5	25	53835	62.5	45	49.85
Gross returns (Rs per ha)	250000	100000	215333.3	250000	180000	199333.3
GEWP (Rs per m^3)	65.925	12.45	23	89	12.45	28.82
Net returns (Rs per ha)	200000	62500	162833.3	187500	117500	149166.7
NEWP (Rs per m^3)	52.725	5.7	14.475	67.325	5.675	18.6

Average gross returns per ha in cotton cultivation were Rs. 1,24,267 per ha which ranged from a minimum of Rs. 1,00,000 to a maximum of Rs.1,50,000 per ha in the Head region. In the Tail region, the average gross returns per ha was Rs.1,10,667 with a range of Rs. 90,000 to Rs. 1,35,000 per ha.

Gross Economic Water Productivity (GEWP) was worked out as a ratio of gross returns to the total water applied per unit area. In this case GEWP in the Head region was Rs. 32.85 per m^3 while the average ranged from a minimum of Rs. 24.03 per m^3 to a maximum of Rs.45.28 per m^3. In the Tail region, average GEWP was Rs.35.49 per m^3 while it ranged from Rs.27.63 per m^3 to Rs. 48.50 per m^3.These figures reflect upon higher GEWP in the Tail region compared to Head region.

The average net returns (Rs. per ha) were worked out by deducting cost of cultivation (per ha) from the gross returns (per ha).

The average net returns in the Head region of MLBC was Rs. 71,766.7 per ha. These net returns ranged from a minimum of Rs. 57,500 to a maximum of Rs.87,500 per ha. In the Tail region, the average net returns were about Rs.60,500 per ha with a range of Rs. 37,500 to Rs. 87,500 per ha.

Finally Net Economic Water Productivity (NEWP) was calculated as monetary returns per m^3 of water applied in case of sugarcane. The table shows that the NEWP was higher in case of Tail region (Rs. 19.21 per m^3) compared to Head region (Rs. 19.04 per m^3)

Thus the Net Economic Water Productivities were not uniform across Head and Tail regions. It was more in Tail region compared to Head region, thereby highlighting higher economic water productivity of cotton in Tail region of MLBC command area.

4.5.10 Economic water productivity of sugarcane in the GRBC command area (n=30)

Table 4.5 j reveals economic water productivity of sugarcane crop in GRBC command area. In the Head region of the canal area, on an average 36,576 m^3 per ha water was applied with a range between 29,280 m^3 per ha to 39,480 m^3 per ha. Similarly the average water applied per ha in Tail region was 17,930 m^3 with a range from 14,620 m^3 per ha to 17,930 m^3 per ha.

The average sugarcane yield obtained in this command area was 94.16 tonnes per ha in the Head region and 88.82 tonnes per ha in the Tail region.

Average gross returns per ha in sugarcane cultivation were Rs. 2,01,500 per ha which ranged from a minimum of Rs. 1,75,000 to a maximum of Rs. 2,31,000 per ha in the Head region. In the Tail region, the average gross returns per ha was 1,78,833 with a range of Rs. 1,50,000 to 2,00,000 per ha.

Gross Economic Water Productivity (GEWP) was worked out as a ratio of gross returns to the total water applied per unit area. In this case GEWP in the Head region was Rs. 13.60 per m^3 while the average ranged from a minimum of Rs. 12.45 per m^3 to Rs. 15.22 per m^3. In the Tail region, average GEWP was Rs. 15.65 per m^3 while it ranged from Rs. 11.78 per m^3 to Rs. 27.85 per m^3.These figures reflect upon higher GEWP in the Tail region compared to Head region.

The average net returns (Rs. per ha) were worked out by deducting cost of cultivation per ha from the per ha gross returns.

The average net returns in the Head region of GRBC was Rs. 70,534.68 per ha. These net returns ranged from a minimum of Rs. 40,000 to a maximum of Rs. 1,07,500 per ha. In the Tail region, the average net returns were about Rs. 71,083.30 per ha with a range of Rs. 35,000 to Rs. 97,500 per ha.

Table 4.5 j Economic water productivity of sugarcane in the GRBC command area

(n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	12480	6920	9677.32	12210	6300	7940.69
Avg. yield (tonnes per ha)	37.50	25.00	31.06	31.25	22.50	27.00
Gross returns (Rs per ha)	2,50,000	1,00,000	2,15,333.3	2,50,000	1,80,000	1,99,333.3
GEWP (Rs per m^3)	65.925	12.45	23	89	12.45	28.82
Net returns (Rs per ha)	2,00,000	62,500	1,62,833.3	1,87,500	1,17,500	1,49,166.7
NEWP (Rs per m^3)	52.725	5.70	14.475	67.325	5.675	18.6

Finally Net Economic Water Productivity (NEWP) was calculated as monetary returns per m^3 of water applied in case of sugarcane. The table shows that the NEWP was higher in case of Tail region (Rs. 6.83 per m^3) compared to Head region (Rs. 6.10 per m^3).

Thus the Net Economic Water Productivities were not uniform across Head and Tail regions. It was more in Tail region compared to Head region, thereby highlighting higher economic water productivity of sugarcane in Tail region of GRBC command area.

4.5.11 Economic water productivity of maize in command areas (n=30)

Table 4.5 k indicates economic water productivity of maize crop in command area. In the Head region of the canal area, on an average 3,960 m^3 per ha water was applied with a range between 2,160 m^3 per ha to 5,160 m^3 per ha. Similarly the average water applied per ha in Tail region was 3,351 m^3 with a range from 2,040 m^3 per ha to 4,080 m^3 per ha.

The average maize yield obtained in this command area was 76.67 quintals per ha in the Head region and 72.65 quintals per ha in the Tail region.

Average gross returns per ha in maize cultivation were Rs. 92,400 per ha which ranged from a minimum of Rs.84,000 to a maximum of Rs 96,000 per ha in the Head region.

In the Tail region, the average gross returns per ha was Rs.87,200 with a range of Rs. 84,000 to Rs. 90,000 per ha.

Gross Economic Water Productivity (GEWP) was worked out as a ratio of gross returns to the total water applied per unit area. In this case GEWP in the Head region was Rs. 64.67 per m^3 while the average ranged from a minimum of Rs. 40.70 per m^3 to a maximum of Rs. 104.16 per m^3. In the Tail region, average GEWP was Rs. 67.3 per m^3 while it ranged from Rs.51.47 per m^3 to Rs. 102.93 per m^3.These figures reflect upon higher GEWP in the Tail region compared to Head region.

The average net returns (Rs. per ha) were worked out by deducting cost of cultivation (per ha) from the gross returns (per ha).

The average net returns in the Head region of command area was Rs. 48,733.34 per ha. These net returns ranged from a minimum of Rs. 21,500 to a maximum of Rs.60,000 per ha. In the Tail region, the average net returns were about Rs. 47,200 per ha with a range of Rs. 34,000 to Rs. 60,000 per ha.

Finally Net Economic Water Productivity (NEWP) was calculated as monetary returns per m^3 of water applied in case of sugarcane. The table shows that the NEWP was higher in case of Tail region (Rs. 36.3 per m^3) compared to Head region (Rs. 32.64 per m^3)

Thus the Net Economic Water Productivities were not uniform across Head and Tail regions. It was more in Tail region compared to Head region, thereby highlighting higher economic water productivity of maize in Tail region of command area.

4.5.12 Economic water productivity of Ground nut in command areas (n=30)

Table 4.5 l indicates economic water productivity of ground nut crop in command area. In the Head region of the canal area, on an average 2,088 m^3 per ha water was applied with a range between 1,340 m^3 per ha to 3,240 m^3 per ha. Similarly the average water applied per ha in Tail region was 1,376 m^3 with a range from 1,200 m^3 per ha to 2,040 m^3 per ha.

The average ground nut yield obtained in command area was 27.65 quintals per ha in the Head region and 24 quintals per ha in the Tail region.

Table 4.5 k Economic water productivity of maize in command areas (n=30)

Particulars	Head region			Tail region		
	Max .	Min.	Average	Max.	Min .	Average.
Total water applied (m^3)	5160	2160	3960	4080	2040	3351
Avg. yield (quintals per ha)	80	70	76.675	80	70	72.65
Gross returns (Rs per ha)	96000	84000	92400	96000	84000	87200
GEWP (Rs per m^3)	104.1667	40.69768	64.67	102.925	51.475	67.3
Net returns (Rs per ha)	60000	21500	48733.33	60000	34000	47200
NWP (Rs per m^3)	69.44445	12.79762	32.64703	57	22.125	36.3

Table 4.5 I Economic water productivity of Ground nut in command areas (n=30)

Particulars	Head region			Tail region		
	Max.	Min.	Average	Max.	Min.	Average.
Total water applied (m^3)	3240	1340	2088	2040	1200	1376
Avg. yield (quintals per ha)	30	25	27.65	30	20	24
Gross returns (Rs per ha)	90000	75000	82200	84000	56000	69066.75
GEWP (Rs per m^3)	156.25	57.85	104.77	145.82	91.90	127.07
Net returns (Rs per ha)	52500	25000	39700	54000	25000	37066.68
NWP (Rs per m^3)	78.12	23.12	52.82	93.75	43.4	68.15

Average gross returns per ha in ground nut cultivation were Rs. 82,200 per ha which ranged from a minimum of Rs. 75,000 to a maximum of Rs 90,000 per ha in the Head region. In the Tail region, the average gross returns per ha was Rs. 69,066.75 with a range of Rs. 56,000 to Rs.84,000 per ha.

Gross Economic Water Productivity (GEWP) was worked out as a ratio of gross returns to the total water applied per unit area. In this case GEWP in the Head region was Rs. 104.76 per m^3 while the average ranged from a minimum of Rs. 57.85 per m^3 to a maximum of Rs. 156.25 per m^3. In the Tail region, average GEWP was Rs. 127.07 per m^3 while it ranged from Rs.91.9 per m^3 to Rs. 145.82 per m^3.These figures reflect upon higher GEWP in the Tail region compared to Head region.

The average net returns (Rs. per ha) were worked out by deducting cost of cultivation (per ha) from the gross returns (per ha).

The average net returns in the Head region of command area was Rs. 39,700 per ha. These net returns ranged from a minimum of Rs. 25,000 to a maximum of Rs.52,500 per ha. In the Tail region, the average net returns were about Rs. 37,066.69 per ha with a range of Rs. 25,000 to Rs. 54,000 per ha.

Finally Net Economic Water Productivity (NEWP) was calculated as monetary returns per m^3 of water applied in case of sugarcane. The table shows that the NEWP was higher in case of Tail region (Rs. 68.15 per m^3) compared to Head region (Rs. 52.83 per m^3)

Thus the Net Economic Water Productivities were not uniform across Head and Tail regions. It was more in Tail region compared to Head region, thereby highlighting higher economic water productivity of ground nut in Tail region of command area.

4.6 The estimated production functions of cotton and sugarcane grown in command areas

The results in Table 4.6 revealed that, inputs included in model explained about 82 per cent of the variation in cotton output as revealed by the coefficient of multiple determinations (R^2). The summation of regression coefficients indicated increasing returns to scale (3.83) *i.e.,* for each incremental use of inputs simultaneously farmers would get more than one (3.83 units) unit of output. The regression coefficients for seed (1.27), FYM (0.65) and machinery (0.14) were observed to be non-significant positive elasticities. The regression co-efficient for a chemical fertilizer (1.75) was positive and found to be significant at one per cent level and f water (0.33) found to be significant at 5 per cent. The regression co-efficients for labour (-0.008) and PPC (-0.31) were negative and found to be insignificant.

Inputs included in model explained about 86 per cent of the variation in sugarcane output as revealed by the coefficient of multiple determinations (R^2). The summation of regression coefficients indicated increasing returns to scale (1.85) *i.e.,* for each incremental use of inputs simultaneously farmers would get more than one (1.85 units) unit of output. The regression coefficients for Farm Yard Manure (0.09) , chemical fertilizers (1.23) , labour (0.03) and machinery (00.009) were observed to be non-significant positive elasticities. The regression co-efficient for PPC (0.22) was positive and found to be significant at one per cent level and for seed (0.42) found significant at 5 per cent. The regression co-efficient for water (-0.1) was negative and found to be significant at one per cent level.

4.7 Ratio of marginal value product to the marginal factor cost of cotton and sugarcane grown in Command area

4.7.1 Ratio of marginal value product to marginal factor cost

The Cobb-Douglas function estimates and geometric levels of inputs were used to estimate the marginal value product. The knowledge of the marginal value products of resources facilitates

Table 4.6 Production function estimates of cotton and sugarcane grown in Command area

Sl. No.	Particulars	Parameters	Crop	
			Cotton	Sugarcane
1	Intercept	a	23.59	5.34
2	Seed (X1)	b_1	1.273 (0.557)	0.429* (0.220)
3	FYM (X2)	b_2	0.658 (0.417)	0.095 (0.175)
4	Chemical Fertilizers (X3)	b_3	1.750** (0.499)	1.239 (0.432)
5	Labour (X4)	b_4	-0.008* (1.188)	0.030 (0.112)
6	Machinery (X5)	b_5	0.145 (0.360)	0.009 (0.085)
7	PPC (X6)	b_6	-0.318* (0.593)	0.227** (0.054)
8	Water (X7)	b_7	0.333* (0.132)	-0.171** (0.039)
9	Coefficient of multiple determination	R^2	0.82	0.86
10	Returns to scale ($\sum b_i$)		3.83	1.85

Note: Figures in the parenthesis indicate standard error of respective co-efficients.
**indicates significant at 1 percent
*indicates significant at 5 percent

Table 4.7 Ratio of marginal value product to the marginal factor cost of cotton and sugarcane grown in Command area

Sl. No	Resources	Crop	
		Cotton	Sugarcane
		MVP/MFC	MVP/MFC
1	Seeds	1.17	0.51
2	FYM	0.59	0.11
3	Chemical fertilizers	1.44	0.48
4	Labor	-0.006	0.03
5	Machinery	0.13	0.01
6	PPC	-0.28	0.36
7	Water	0.29	-0.19

comparison of marginal value product with marginal factor cost of the resources to arrive at optimal use of resources.

4.7.2 Ratios of Marginal Value Product (MVP) to Marginal Factor Cost (MFC) of resources of cotton and grown in command area.

The MVP to MFC ratios of resources in cotton cultivation in command area are presented in Table 4.7. The ratio of MVP to MFC in the case of seeds and Chemical fertilizers was 1.17 and 1.44 respectively indicating returns of Rs.1.17 and 1.44 for every additional unit of input used in that order. The positive MVP to MFC ratio for FYM, machinery and water were 0.59, 0.13 and 0.29 respectively indicating returns of Rs 0.59 ,0.13 and 0.29 this indicating that factors were used in more quantities than required and can be reduced till it reaches 1.00.

The negative ratio of MVP to MFC for labour (-0.006) and PPC(-0.28) indicated that the factors were used at higher level than necessary, resulting in a loss due to excess use.

The MVP to MFC ratios of resources in sugarcane cultivation in command area are presented in Table 4.7. The positive MVP to MFC ratio for seeds, FYM, labor, machinery and PPC were 0.51, 0.11, 0.03, 0.01 and 0.36 respectively indicating returns of Rs 0.51, 0.11, 0.03, 0.01 and 0.36 thus indicating that factors were used in more quantities than required and it can be reduced till it reaches 1.00.

The negative ratio of MVP to MFC for water (-0.19) indicated that the factor was used at higher level than necessary, resulting in a loss due to excess use.

4.8 Perceptions of stake holders in enhancing water productivity in command areas

Results of the survey conducted to know the perceptions of various stakeholders are presented below.

4.8.1 Opinions of the farmers in UKP and MGP command areas

Table 4.8 a reveals that in case of farmers in the Head Region of the command area, it was observed that formation of Water Users' Association (WUA) for water management ranked I which recorded a mean score of 70 followed by proper functioning of WUCs to ensure efficient irrigation management ranked II with a mean score of 58. Good cooperation from the staff / officials ranked III with a mean score of 54. Changing the localization pattern and adoption of cultivation of light irrigated crops and installation of water meters at the field gates were ranked IV with a mean score of 49. Timely release of water from the canal ranked V with a mean score of 46. Adequate release of water and proper repair of canals and cement lining of FICs to avoid water losses were ranked VI with a mean score of 42. Collection of water charges on a quantitative basis ranked VII with a mean score of 41.

The farmers in the Tail region perceived the change in the localization pattern and adoption of cultivation of light irrigated crops and ranked it I with a mean score of 63. Similarly formation of Water User Associations (WUAs) for water management and good cooperation from the farmers were ranked II and III, respectively with mean scores of 56 and 52. Adequate release of water from the canal ,proper functioning of WUAs to ensure efficient irrigation management, timely release of water from the canal, cement lining of FICs to avoid water losses and installation of water meters at the field gates were ranked IV, V, VI, VII and VIII, respectively with mean scores of 49.46,45,41 and 39.

Table 4.8 a. Perceptions of farmers in enhancing water productivity in ALBC

Sl. No.	Perception	Head Region			Tail Region		
		Percent	G. Score	Rank	Percent	G. Score	Rank
A	Formation of Water User Associations (WUA) for water management.	14.44	70	I	38.14	56	II
B	Proper functioning of WUCs to ensure efficient irrigation management.	33.70	58	II	58.14	46	V
C	Change the localization pattern and adopt cultivation of light irrigated crops.	50.74	49	IV	24.07	63	I
D	Adequate release of water and proper repair of canals.	64.07	42	VI	52.22	49	IV
E	Cement lining of FICs to avoid water losses.	65.55	42	VI	67.03	41	VII
F	Collection of water charges on a quantitative basis	66.29	41	VII	38.14	56	II
G	Timely release of water from the canal	58.88	46	V	59.62	45	VI
H	Installation of water meters at the field gates.	52.22	49	IV	71.48	39	VIII
I	Good cooperation from the staff/ officials	41.85	54	III	45.55	52	III

4.8.2 Opinions of officials/ staff of Irrigation Department and CADA

Table 4.8 b represents the results of perceptions of officials of staff of Irrigation department and CADA. Adequate release of funds for canal repairs and training and capacity building to farmers were ranked I with a mean score of 57. Scientific quantification of water at the field level was ranked II with a mean score of 51. Timely inspection and supervision of the canal sites was ranked III with a mean score of 46. Good cooperation from the officials / staff was ranked IV with a mean score of 45. Installation of water meters at the field gates was ranked V with a mean score of 41 and proper lining of FICs to ensure the natural flow was ranked VI with a mean score of 19.

Table 4.8 b Perceptions of officials of Irrigation Department (ID) and Command Area Development Authority (CADA) in enhancing water productivity in UKP & MGP command areas

	Perception	HR		
		Percent	G. Score	Rank
A	Adequate release of funds for canal repairs	36.63	57	I
B	Training and capacity building to farmers	36.67	57	I
C	Scientific quantification of water at field level	47.78	51	II
D	Proper lining of FICs to ensure natural flow	94.81	19	VI
E	Installation of water meters at farm gates	67.03	41	V
F	Timely inspection and supervision of canal sites	58.18	46	III
G	Good cooperation from farmers.	60.33	45	IV

5. DISCUSSION

The results presented in previous chapter are discussed in this chapter and are presented under the following Heads.

5.1 General characteristics of sample farmers in the study area

5.2 Canal wise extent and sources of irrigation in command area.

5.3 Cropping pattern in UKP and MGP command area

5.4 Economics of different cropping patterns in the command areas.

5.5 Productivity of selected crops in command areas.

5.6 Economics of water productivities of different crops

5.7 Resources use efficiency of sugarcane and cotton

5.8 Opinions of stakeholders in enhancing water productivity

5.1 General characteristics of sample farmers in the study area

Table 4.1 reveals general characteristics of sample respondents in the command areas. It was found that the average age of the respondents was 48.15 years in the study area. The possible reason for this might me that younger population in the command area are out of farming profession therefore the middle and old aged people were engaged in agriculture.

Average family size of the respondents was 4.49 members per family amongst which 3.82 members were working on farm and the remaining of 00.67 members in the family were working off farm. This might be due to the fact that all the command areas being well irrigated and involved many agricultural operations throughout the year, most of the family members (85.30 %) worked on farm and lesser (14.70 per cent) worked off farm.

5.2 Canal wise extent and sources of irrigation in command area

Canal wise extent of irrigation in the command areas was worked out (Table 4.2 a). It was found that nearly 92 per cent of the area was irrigated and the remaining area remained as dry land.

ALBC was found to have highest area under irrigation which is mainly due to the presence of dam (Almatti dam) near the villages under the canal. In case of IBC the area under irrigation was comparatively less due to the reason that the canal has not been completely constructed and the distribution network in the area was not working in full condition.

On an average, MLBC and GRBC have a greater area under irrigation. This might be due to the fact that these two canals are quiet old and matured canals in the Malaprabha and Ghataprabha project command areas.

Command area wise sources of irrigation are presented in Table 4.2 b. It was found that ALBC had nearly 72 per cent of area under canal irrigation and about 20 per cent area under bore well.

This is due to the presence of dam near to the villages and presence of adequate quantity of ground water resources in the region. IBC had about 51 per cent of area under open wells while about 35 per cent of area was under canals. The major source of irrigation was open well in the command area. This might be due to fact that IBC command area has good number of traditional water harvesting and storage structures. Another important reason is that the canal has not been completely working and therefore adequate water has not been released from the canal to the villages in the command area.

MLBC (75.40 %) and GRBC (59.27%) have a significant share of canals irrigation in the command area. This is due to the fact that these canals are quiet old and matured and therefore working efficiently. The agro climatic conditions in these command areas are favorable to good rainfall and hence the water is available in adequate quantities in these command areas.

5.3 Cropping pattern in command area

5.3 a Cropping pattern in UKP and MGP command area.

Cropping pattern of UKP presented in Table 4.3 g reveals that sugarcane was the dominant crop in the command area. Other crops like pigeon pea, sorghum, bajra, bengal gram were grown to a considerable extent. The choice of sugarcane crop in the command area was mainly due to the presence of canals and other sources of irrigation in the command area and also large number of sugar factories working in the region.

Nearly 1/3rd of the area under cultivation across all the canals was for sugarcane. Rabi sorghum, bengalgram and redgram were dominant seasonal crops in the command area.The reason for this is the agro climatic factors suitable for crops. Further labour shortage in the area is forcing people to go for crops like sugarcane which involves lesser labour with low drudgery on the farmers.

Cropping pattern of MGP command area is presented in Table 4.3 h. It was found that maize and groundnut were grown in both the seasons to a greater extent. Cotton, sugarcane and chilly were the important commercial crops grown in the command area.

MLBC and GRBC command areas are popularly known for chilly, cotton and sugarcane. This is mainly due existence of favorable agro climatic conditions required for chilly and cotton area in Malaprabha command area while sugarcane is dominating in Ghataprabha command area due to existence of many sugar factories in Belgavi and Bagalkot districts. The presence of sugar factories and good irrigation facilities area attracting farmers to go for sugarcane in this command area.

Maize, chilly and cotton are equally profitable and popular crops of Malaprabha command area because of existance of international chilly and cotton markets and processing industries in the nearby districts. The Findings of the study are in agreement with the results obtained by Srivastava (1996) and Satish (2010) thereby rejecting the hypothesis.

5.3 b Structural changes of area under different crops in MGP command areas.

Markov Chain analysis was employed to know the structural changes in the cropping pattern in Malaprabha and Ghataprabha project command areas over a period of 15 years (1999-00 to 2014-15) for kharif, rabi and bi seasonal crops. The results of analysis revealed that in case of GP, for kharif season Hy. maize, soybean and hy. jowar were the stable crops to the extent of 83 per cent, 85 per cent and 16 per cent, respectively.

The reason for this is that Hy. maize lost its area to Hy. jowar (2 %), sunflower (3%), ground nut (1%) and other crops (11 %). Hy.jowar lost its share of area to sunflower and soy bean (42 per cent each). Soybean lost its share of area to ground nut (8 per cent) and sunflower (7 %). There was a gain in the area of Hy. Maize from sunflower (97 %) and from ground nut (73 %) While there was a gain of area from other crops (75 %), Hy. jowar (45 %) and ground nut (18 %) to soy bean.

In case of Ghataprabha Project, for rabi season rabi jowar, hybrid maize, sunflower , wheat and pulses were the crops which were stable to the extent of 27 per cent, 23 per cent , 23 per cent,25 per cent and 54 per cent, respectively.

The reason for this is that rabi jowar lost its area to wheat (36 %), sunflower (6 %) and other crops (37 %). Sunflower lost its share of area to hybrid maize (77 %). Wheat has lost its share of area to pulses (19 %) and other crops (56 %). Pulses lost their share of area to wheat (32 %) and hybrid maize (14 %).

In case of bi seasonal crops, sugarcane and cotton retained their share of area to the tune of 97 per cent and 45 per cent stability. The reason for retention of area by sugarcane relatively ease of cultivation and stability of produce prices.

In case of Malaprabha Project, for kharif season hybrid jowar, hybrid maize and sunflower retained their share of area with 15 per cent, 82 per cent and 37 per cent of stability.

The reason for this is that hybrid jowar lost its share of area to pulses (60 %) and sunflower (25 %). Hy .maize lost its share of area to pulses (5 %) , sunflower (1%), and ground nut (4 %). Sunflower lost its share of area to ground nut (13 %) and other crops (5 %). There was a gain of about 38 per cent area from sunflower and 32 per cent area from ground nut to hybrid jowar. While there was a gain of area from other crops (89 %), ground nut (47 %) and pulses (97 %) to hybrid maize. Sunflower gained about 21 per cent area from ground nut.

In case of Malaprabha Project, for rabi season rabi jowar , pulses and sunflower were found to retain their share of area with 33 per cent , 45 per cent and 72 per cent of stability, respectively.

The reason for this is that hybrid jowar lost its share of area to wheat (51 per cent) and pulses (16 %). Pulses lost their share of area to wheat (51 %) . Sunflower lost its share of area to other crops (15 %).There was a gain of about 49 per cent area from wheat to hybrid jowar. While there was a gain of area from sunflower (13 %) to pulses.

In case of bi seasonal crops in Malaprabha command area hybrid cotton retained its 100 per cent share over the years which was gained 100 per cent area from local cotton.

5.4 Economics of different cropping patterns in command areas

Economics of cropping pattern in the four canal command areas was worked out and the results are presented in Tables 4.3 j, k, l and m.

In case of ALBC command area were results revealed that there was a difference in net returns of Rs. 10,215 per ha existing between Head and Tail region across all the seasons and all the crops. In case of IBC the average net returns per ha across all the seasons and crops was higher in Head region than the Tail region with a difference of about Rs. 10,810. In case of MLBC the average net returns per ha across all the seasons and crops was higher in the Head region than the Tail region with a difference of about Rs. 11,657. In case of GRBC command area it was found that the average net returns earned per ha across all the seasons and crops was higher in Head region than in Tail region with a difference of Rs. 11,125. Thus, overall the per hectare net returns in different crops were higher in Head region as compared to Tail region in all commands.

This is mainly due to the fact that the farmers in the Tail region were realizing lower yields compared to their counter parts in the Head region. The cost of cultivation remaining nearly same in both Head and Tail regions created disparity among the farmers in the form of lesser net returns earned per ha crops all the seasons and all the crops.

The findings obtained in the study of economics of major crops were similar to those obtained by Sivashankar *et. al.,*(2014) in Krishna Western Delta (KWD) of Andhra Pradesh for crops like paddy, Bengal gram, ground nut, cotton, chilly, maize, and sugarcane. Shinde *et.al.*(2015) has reported similar findings.

5.5 Productivity of selected crops in the command areas

Productivity of selected crops like sugarcane, cotton, maize and ground nut were calculated as a ratio of production to the area. The average productivity value for sugarcane was 92.41 tonnes per ha while that of cotton was 29.03 quintals per ha. The productivity of maize and ground nut was 72.65 quintals per ha and 22.5 quintals per ha, respectively.

The reasons for lower crop productivities is that farmers were carrying out unscientific crop and water management which included excess use of inputs like fertilizers, plant protection chemicals and water. extensive fertilizers , plant protection chemicals and excess water for irrigation.

The productivity of sugarcane and groundnut are on par with the productivity levels obtained by Gade and Chavan (2014) in Karad Tahsil command area of Maharashtra and Gajja *et. al.* (2006) in canal command area of Gujarat. Thus the hypothesis was proved.

5.6 Economics of water productivities of selected crops in the command area

5.6 a Water productivities of selected crops in the command area

A glance at Tables 4.5 a, b, c, d, e and f reveals that the water productivities were higher in the Tail regions of canal than compared to Head regions in any command area. The evaluation was done for sugarcane, cotton, maize and ground nut. The lower values were noticed in the Tail regions across all the canals and the crops. This was mainly due to the reason that the farmers in the Head region have plenty of water when compared to their counterpart in the Tail region. The amount of water applied being more in the Head region was the main reason for getting lower productivity value. The Tail enders experienced a reverse situation wherein they had less amount of water available for irrigation, therefore they applied lesser amount and as a result the productivity values were higher in the Tail regions. There are other reasons also which lead to impaired distribution of water in the command areas. Some of them being (a) improper leveling of fields coupled with improper application methods, even in agriculturally advanced areas and (b) unscientific designing of field irrigation channels (FICs) and quantification of water in the command areas. Lack of crop zoning, lack of an efficient water management and distribution system in the canal commands is leading to such disparities in the command areas. Non-adoption of appropriate cropping systems recommended for the area was another major drawback in the command areas.

Farmers in the command areas are attracted to grow high value crops in spite of their high water demand which makes the use of excess of irrigation water and this in turn creates the problem of salinity and alkalinity. The high water demanding crops such as sugarcane should be restricted to specific zones of high water availability and high rainfall areas. The area under sugarcane should be rationalized. Short duration, low water demanding and high value crops should be introduced in the water scarce areas as prescribed by the CADAs. However, there was a tendency to violate these prescribed crop plans which should be discouraged.

5.6 b Economic water productivities of selected crops in the command area

A look at Tables 4.5 g, h, I, j, k and l reveals that GEWP and NEWP of crops in the command areas were higher at the Tail ends due to lower yields obtained in the command areas. The lower water productivity levels in the Head regions was due to high water consumption in the Head regions. This is due the unscientific irrigation management in the command area. Basin irrigation with broadcasting was more predominant method of irrigation which uses excess water and despite enormous losses

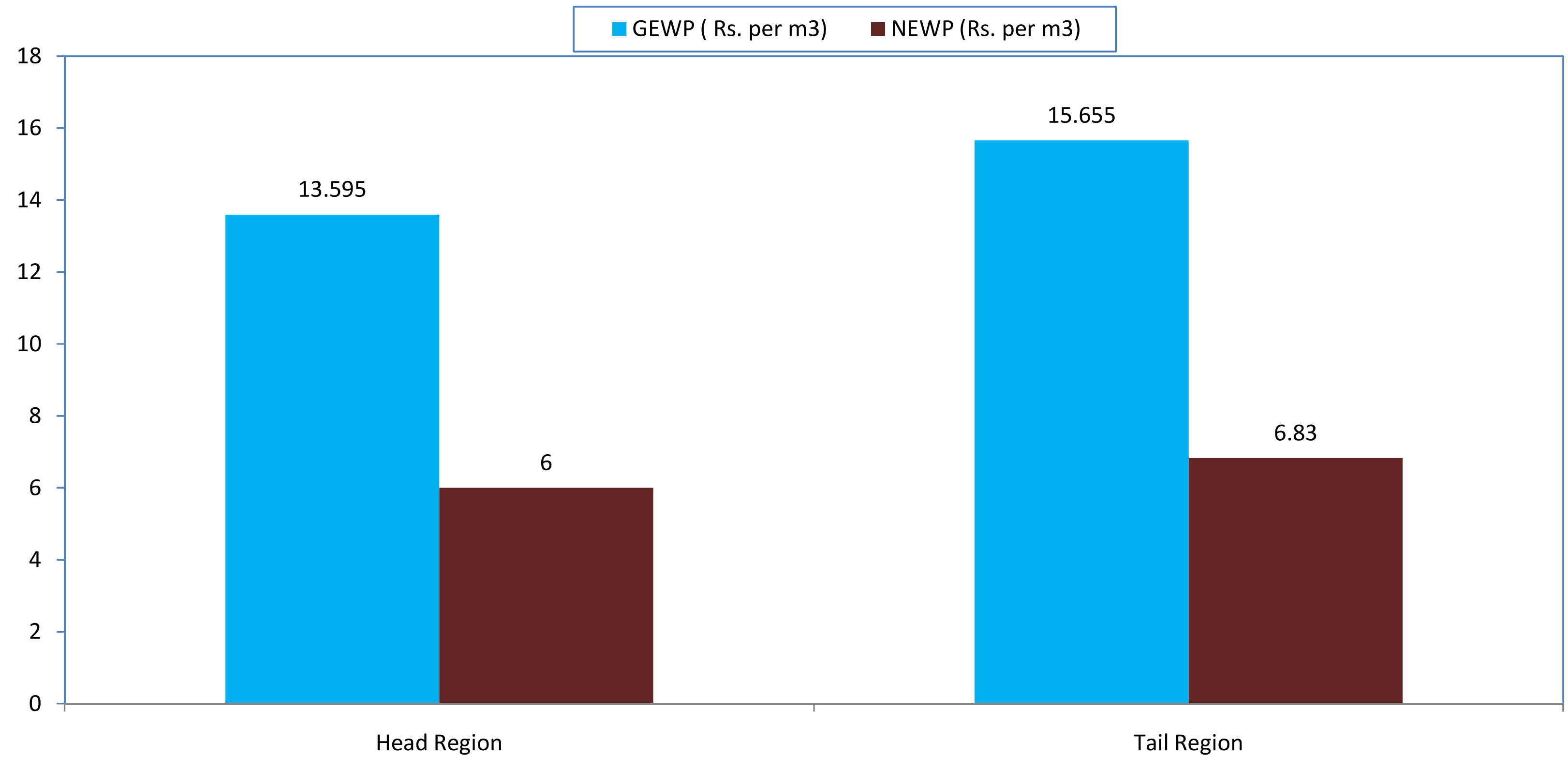

Fig. 4.3. Economic water productivity of sugarcane in ALBC command area

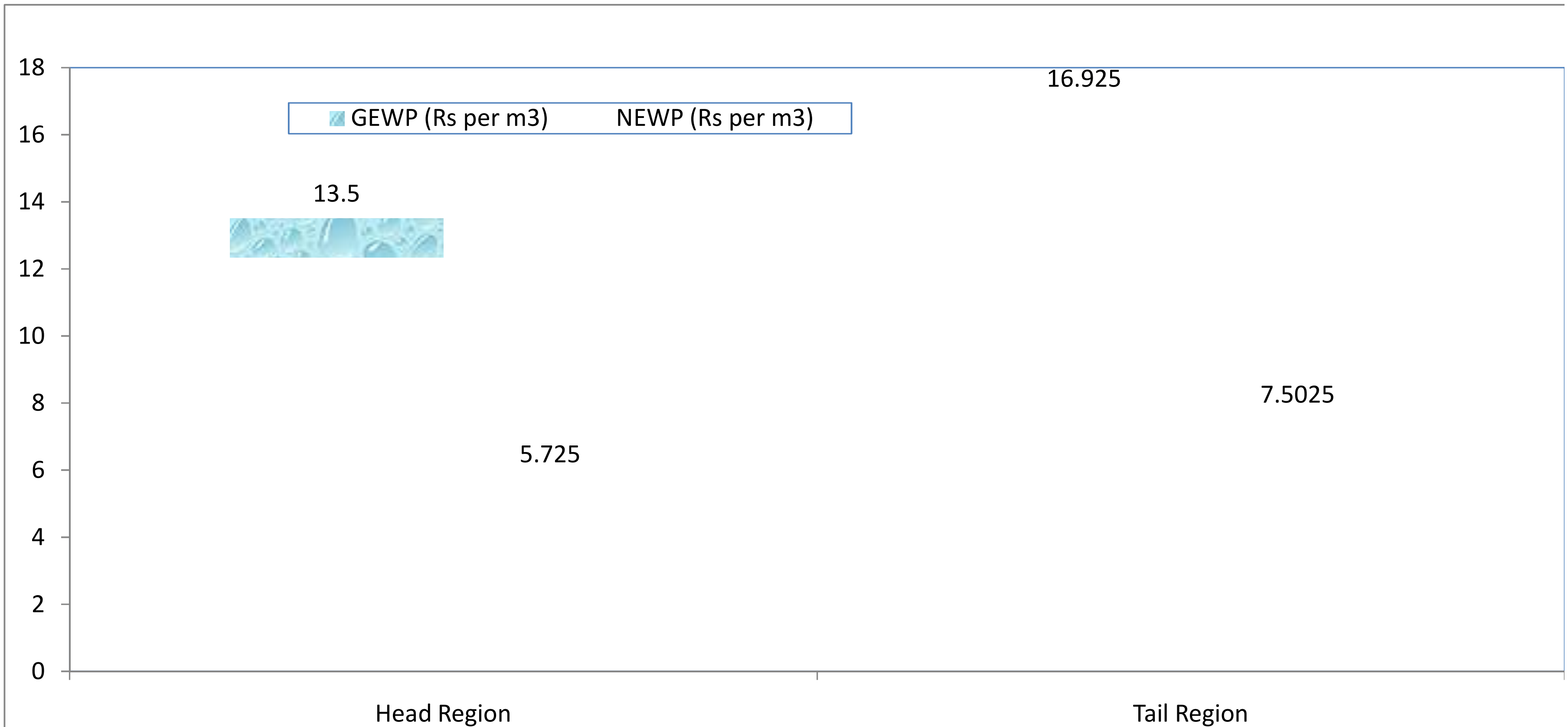

Fig. 4.4. Economic water productivity of sugarcane in IBC command area

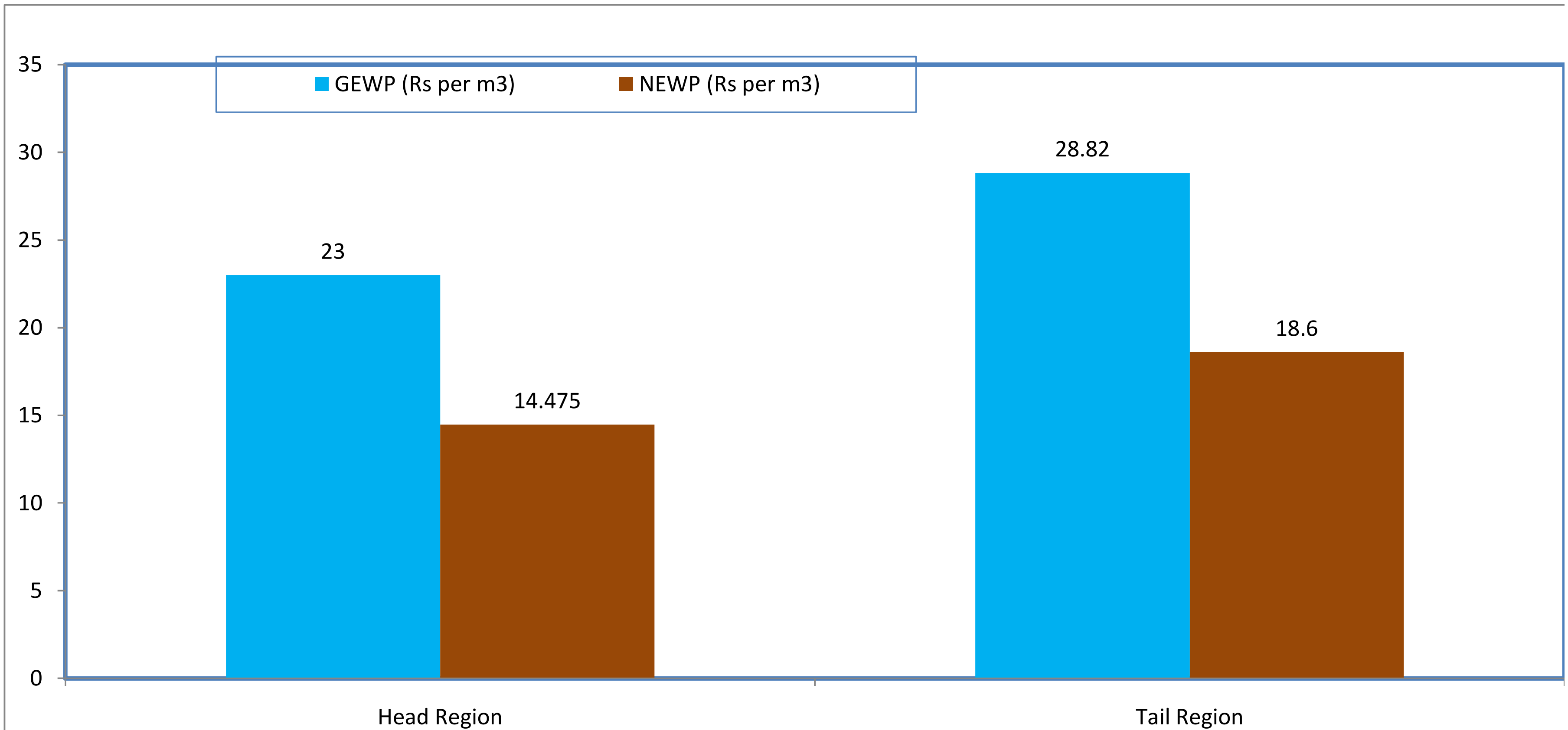

Fig. 4.5. Economic water productivity of cotton in MLBC command area

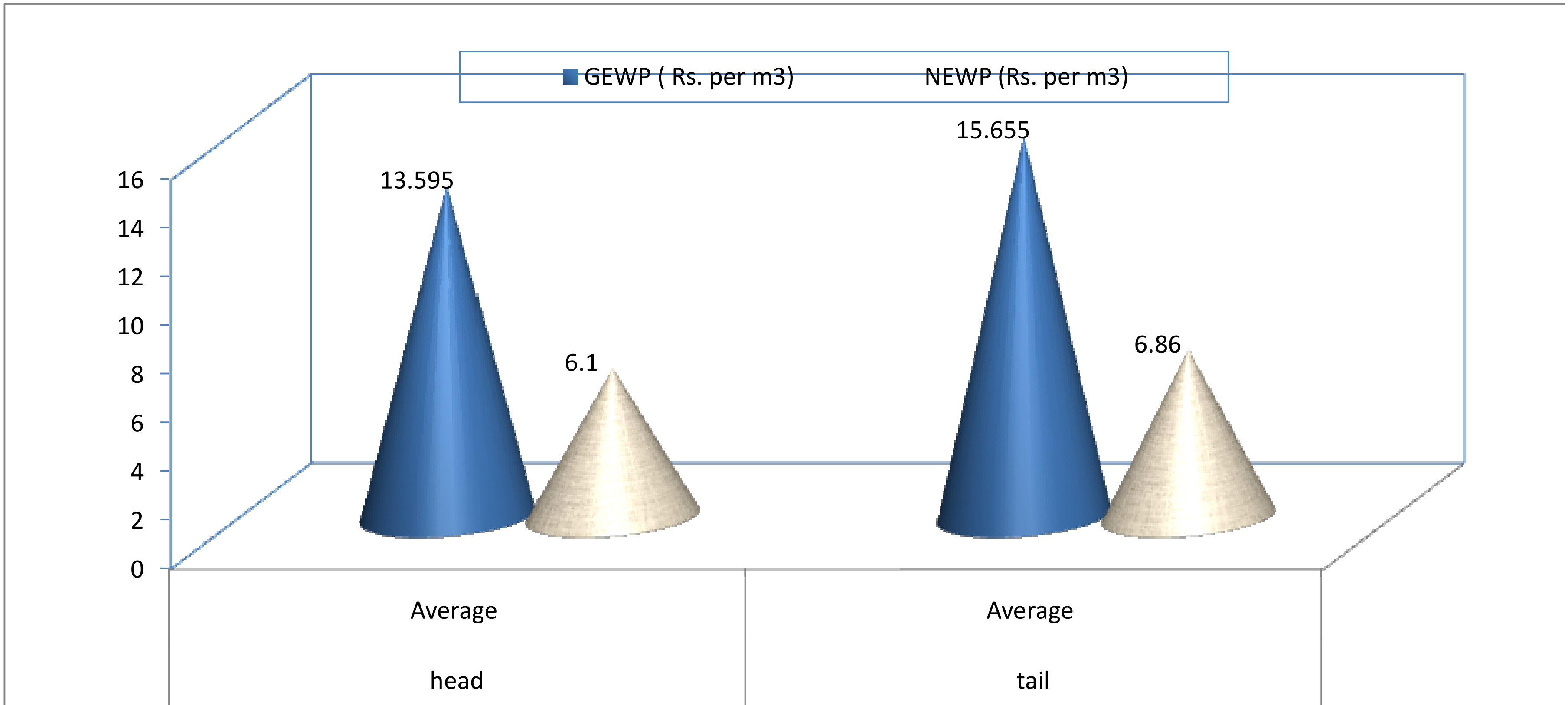

Fig. 4.6. Economic water productivity of sugarcane in GRBC command area

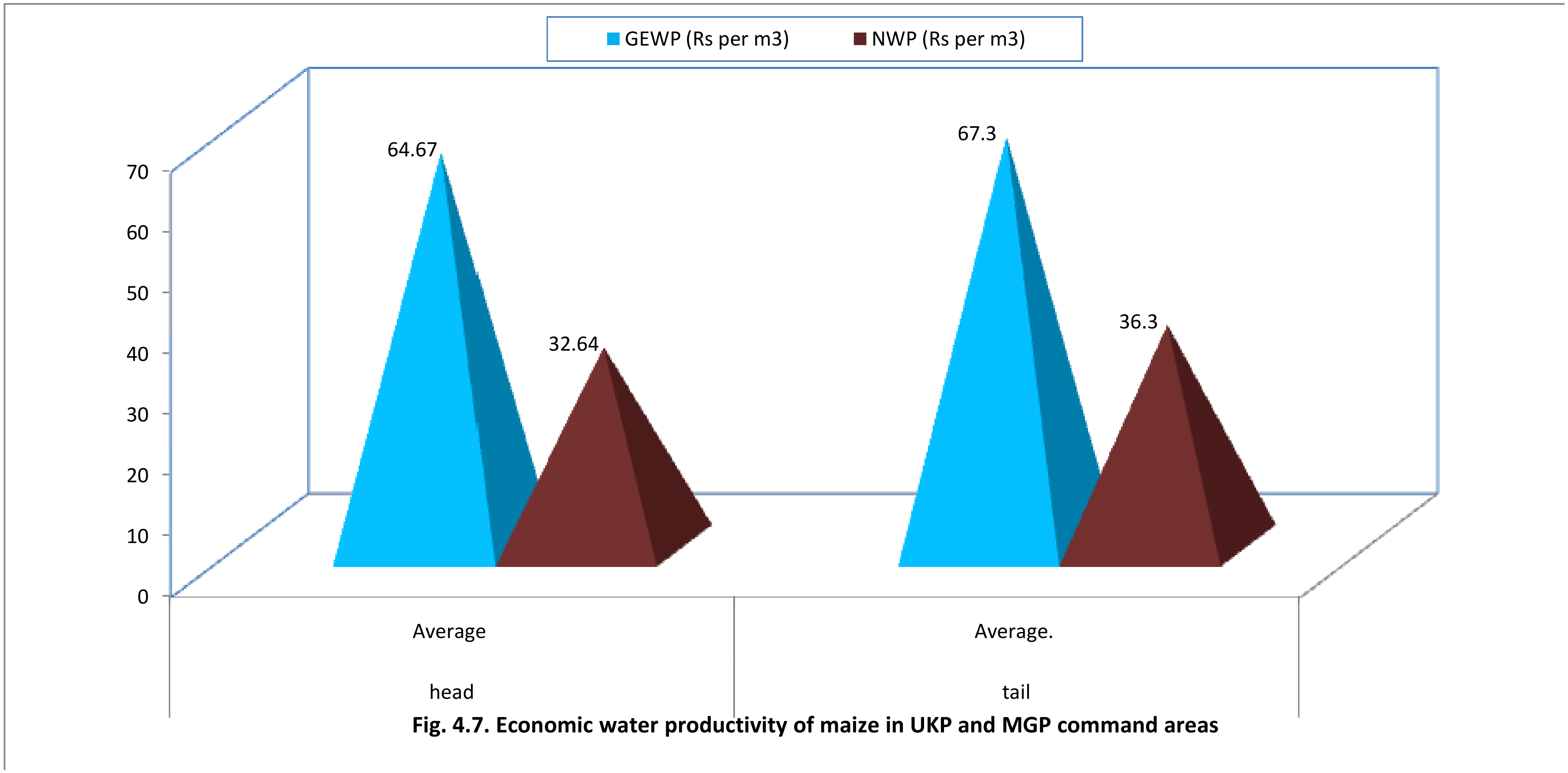

Fig. 4.7. Economic water productivity of maize in UKP and MGP command areas

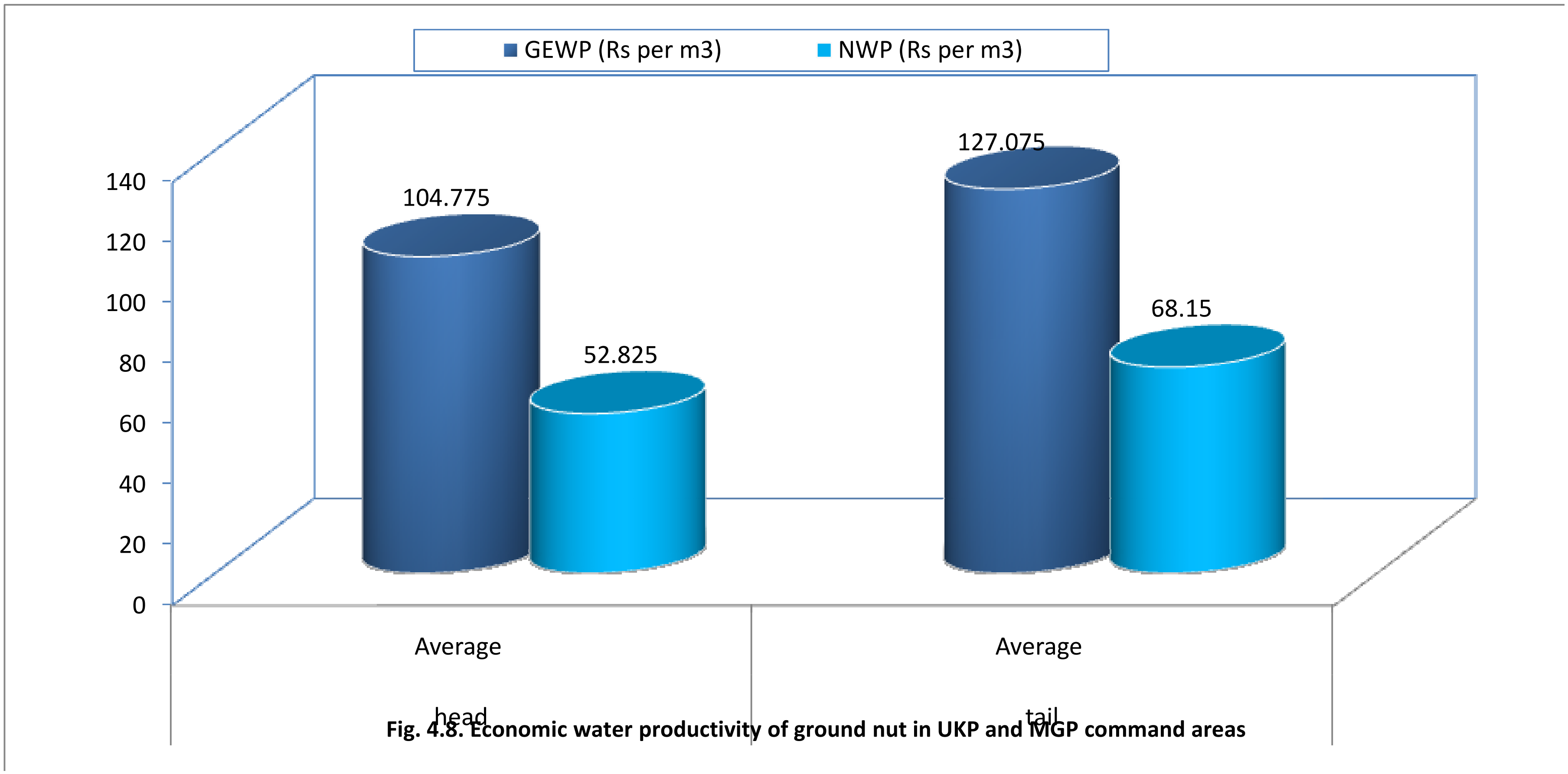

Fig. 4.8. Economic water productivity of ground nut in UKP and MGP command areas

the farmers were still using highly inefficient and obsolete methods of irrigation. This was mainly due to lack of knowledge about irrigation scheduling and the perception that yield increases with increase in application of water.

Over irrigation contributes to water logging and water pollution. Proper scheduling of irrigation helps in irrigating the optimum quantity of water for crops. It also reduces the nutrient leaches due to excess water thereby reducing the crop yields and net income. Water productivity of an agricultural ecosystem can be improved either by reducing the water losses that occur in various ways during water conveyance and irrigation practices or increasing the economic produce of the crop through efficient water management techniques. Similar findings were obtained by Ashraf *et. al*., (2001 and 2010) and Palanisami *et. al.,*(2006) thereby rejecting the hypothesis.

5.7 Resource productivity of inputs used in cultivation of cotton and sugarcane in UKP and MGP command areas

Table 4.6 depicted that the resource use efficiency in case of sugarcane and cotton was studied with the help of Cobb-Douglas production function. It was estimated for sugarcane and cotton. The production function analysis for cotton revealed that plant protection chemicals (PPC) and labor were negatively significant. This implied that, one rupee increase in PPC and labor cost would decrease gross income by 0.34 per cent and 0.008 per cent. However, the coefficient of multiple determinations (R^2) worked out to be 0.82, indicated that the variables included in the function explained about 82 per cent of variations in cotton returns. The summation of regression coefficients worked out to be 3.83, which indicated increasing returns to scale *i.e.,* one per cent simultaneous increase in expenditure on all inputs would result in 3.83 per cent increase in cotton returns. The negative coefficient w.r.t labour and PPC was due to the fact that these were used in excess quantities than required. Rationalization of those inputs is needed

Sugarcane showed positive and significant coefficients for seeds and PPC which implied an increase in one rupee on seeds and PPC would increase the returns by Rs 0.42 and Rs 0.225, respectively. This was because these inputs were not used in full quantities and there was scope to increase them. Water showed highly negative significance because it was used in highly excess quantities which increased the chances to cause a decline in the yields. The results suggested that urgent measures were needed to improve water management.

The study conducted by Suresh and Reddy (2006) and Rangappa (2014) showed similar results.

Allocative efficiency in cotton and sugarcane cultivation in UKP and MGP command areas

In cotton cultivation, the allocative efficiency analysis (MVP: MFC ratio) was more than unity for seeds and chemical fertilizers in command areas. It indicated that an additional rupee spent on seeds and chemical fertilizers would enhance the total returns. The MVP: MFC ratio for labor and PPC have been found negative in the command area, indicating over use of labor and PPC. Whereas in case of sugarcane the negative value of MVP: MFC ratio for water in the command area indicated that above mentioned resource were over utilized by the farmers. Therefore use of these inputs in crop production should be regulated in the command areas.

These findings of the study are in conformity par with the results of by Fernandez and Peter (2009) and Vijayalaxmi (2015). These suggested modification in resource use pattern, on the basis of ratios of MVP and MC of the input factors.

5.8 Opinions of stakeholders in enhancing water productivity.

A perusal of Table 4.8 a shows that farmers in the command areas were of the opinion that formation of WUAs for irrigation management will enhance the water productivity. This was mainly due to the disparity between Head and the Tail region farmers regarding share of canal water. The formation of WUAs will lead to uniform, efficient and timely distribution of water to the fields. Collection of water on quantitative basis and good cooperation from the officials and staff of the departments and CADA was expected by the farmers. Installation of water meters at the field gates was suggested by the farmers which will result in scientific quantification of the water in the command areas.

Results of Table 4.8 b indicate the opinions of officials and other staff of irrigation departments (ID) and Command Area Development Authority (CADA). Adequate release of funds and effective training and capacity building for farmers to enhance water productivity was expressed by them.This is mainly due to inadequate release of funds for canal development works and lack of training and capacity building to farmers and officers..

The findings of the study were similar to those obtained by Madhava Chandran (2001) in Kerala and Singh *et. al.,*(2004) in Mahanadi Delta Irrigation Project (MIDP)in Orissa and the hypothesis of the study was accepted

6. SUMMARY AND CONCLUSIONS

Water resources around the world are threatened by scarcity, degradation and overuse, and food demands are projected to increase, It is important to improve our ability to produce more food with less water. There are only a few basic methods of using the earth's water resources to meet the growing food demands: continuing to expand rainfed and irrigated lands; increasing production per unit of water; trade in food commodities; and changes in consumption practices. Land expansion is no longer a viable solution. Therefore, improving agricultural productivity on existing lands using the same amount of water will be essential. Increasing water productivity means using less water to complete a particular task, or using the same amount of water, but producing more. Increased water productivity has been associated with improved food security and livelihood. Therefore an analysis especially of economics of water productivity assumes importance.

Water Productivity: Definition and conceptual framework

By and large, the term 'water productivity' refers to the magnitude of output or benefit resulting from water as applied on a unit base. In the domain of agriculture, it is expressed as the net consumptive use efficiency in terms of yield per unit depth of water consumed per unit area of cultivation. If the field water conveyance, application, storage and distribution efficiencies are accounted to depict the seepage, run-off and deep percolation losses (not consumed by plant; evapo-transpiration loss is included as an implicit component of field water balance) it would be termed as the gross irrigation water use efficiency. However, the term water use efficiency is a manifestation of integrated physical or economic land and water productivity as the numerator is the yield or equivalent income and the denominator is the depth of water consumed per unit land area used (tonnes per hectare per cm of water, for instance). When isolated as 'water productivity' it becomes a partial productivity of one factor viz., water, irrespective of the land unit but in reference to the scale of production in the range of a single plant's effective root zone to a basin or system of irrigation command. As more and more water losses are incurred when the scale of reference expands, the apparent or relative water productivity is bound to decrease. However, for an increasing scale, the chances of recovering the so called 'losses' of water are bound to increase and at one stage, may be a project or basin scale, the loss at one point will be a gain at another point (as deep percolation leading to groundwater recharge or runoff leading to surface detention and storage) for recycling. In other words, the basic net input of water required in the effective root zone of a plant scale is subsequently reckoned as a gross input of water incorporating the irrigation efficiencies (□) at farm/field level and fixing the flow duty (D), field duty (Δ) and storage duty (S) at a system/project/basin/command level. The overall conceptual framework should account for all these transformation parameters from scale to scale.

The purpose of this study is to analyze water productivity in the command areas to generate inputs for informed policy.

6.1 Specific Objectives of the study

1. To analyze the cropping pattern in the Upper Krishna Project (UKP) and Malaprabha Ghataprabha Project (MGP) command areas
2. To assess the productivities of selected crops in the command area
3. To estimate economics of water productivity of selected in the command area
4. To document perceptions of stakeholders in enhancing water productivity in command area.

6.2 Selection of the study area

It was a fact that excess water is used to produce crops thereby reflecting on poor economic benefits to the farmers. Two Command areas situated in the jurisdiction of UAS Dharwad were purposively selected in view of the complaints of declining water productivity and economics of cropping pattern in the command areas. These command areas are Upper Krishna Project (UKP) and Malaprabha Ghataprabha Project Command area.

- ✓ Upper Krishna Project is an irrigation project designed across the Krishna River to provide irrigation to the drought-prone areas of Vijayapur, Bagalkot, Kalburgi, Koppal and Raichur districts in Karnataka. The project has been implemented by the Government of Karnataka, it has irrigated 6.22 lakh ha.

- ✓ Malaprabha Ghataprabha Project is designed across the tributaries of river Krishna i.e., Malaprabha and Ghataprabha. The project aims at providing irrigation to Belagavi, Bagalkot, Dharwad and Gadag districts. The project has irrigated 1.821 lakh ha.

Four canals from these two project commands were selected namely. Almatti Left Bank Canal (ALBC) and Indi Branch Canal (iBC) from UKP while Malaprabha Left Bank Canal (MLBC) and Ghataprabha Right Bank Canal (GRBC) were selected from MGP. Further different farmers from Head and Tail regions of these command areas were selected for the study.

6.3 Analytical tools used

The cropping pattern in MGP command areas was analyzed using Markov Chain Analysis. Further, the cropping pattern in both UKP and MGP command areas was analyzed using the tabular analysis from the primary data obtained from the respondents. Economics of cropping pattern in four canal commands were worked analyzed using simple tabular analysis. Productivity, as a ratio of production to the area was worked out for sugarcane, cotton , maize and ground nut. It was analyzed using simple tabular analysis.

Water productivity of sugarcane, cotton, maize and ground nut were worked out as a ratio of yield obtained to the water applied to those crops. Further the returns obtained per unit of water was estimated and analyzed using simple tabular analysis. The perceptions of stakeholders in enhancing water productivity were documented and were analyzed using Garret ranking method.

6.4 Major findings of the study

6.4.1 Cropping pattern in UKP command areas

Sorghum, wheat and bajra were the major cereal crops, pigeon pea, green gram and bengal gram were the major pulse crops grown. Vegetables were grown in summer and sugarcane was the major annual/bi seasonal crop grown by the sample farmers in the command area.

In case of ALBC , the gross cropped area in the Head region was 5.78 ha with a net cropped area of 3.65 ha having the cropping intensity of 158.35 per cent. The gross cropped area in the Tail region was 5.66 ha with a net cropped area of 3.64 ha having the cropping intensity of 155.49 per cent

In case of IBC, the gross cropped area in the Head region was 5.99 ha with a net cropped area of 3.77 ha having the cropping intensity of 158.88 per cent. The gross cropped area in the Tail region was 5.8 ha with a net cropped area of 3.7 ha having the cropping intensity of 156.75 per cent.

6.4.2 Cropping pattern in MGP command area

Maize was the major cereal crop, pigeon pea, green gram and bengal gram were the major pulse crops.. Ground nut and sunflower were the major oil seed crops. Vegetables were grown in summer and sugarcane, cotton and chilly were the major annual/bi seasonal crop grown by the sample farmers in the command area.

In case of MLBC, the gross cropped area in the Head region was 5.79 ha with a net cropped area of 3.64 ha having the cropping intensity of 159.06 per cent. The gross cropped area in the Tail region was 5.64 ha with a net cropped area of 3.62 ha having the cropping intensity of 155.80 per cent.

In case of GRBC, the gross cropped area in the Head region was 6.45 ha with a net cropped area of 3.85 ha having the cropping intensity of 167.53 per cent. The gross cropped area in the Tail region was 5.96 ha with a net cropped area of 3.84 ha having the cropping intensity 155.20 of per cent.

6.4.3 Productivities of selected crops in the command area

Productivity was worked out as a ratio of production to the area. The productivity of sugarcane across all the canals was 92.41 tonnes per ha. The productivity of cotton was 29.03 quintals per ha in the command area. Maize and ground nut were having a productivity of 72.65 quintals per and 22.5 quintals per ha, respectively.

6.4.4 Economics of water productivity in UKP and MGP command areas.

Water productivities for sugarcane, cotton, maize and ground nut were computed as a ratio of yield obtained to the total water applied.

In case of ALBC sugarcane had a productivity of 14.9 kg per m^3 in Head region while it was 8.23 kg per m^3 in Tail region. In case of IBC, productivity of sugarcane was 14.38 kg per m^3 in Head region while it was 7.55 kg per m^3 in Tail region. In GRBC, sugarcane had a productivity of 12.5 kg per m^3 in head region and 7.8 kg per m^3 in tail region.

In case of MLBC cotton had a productivity of 0.85 kg per m^3 in Head region while it was 0.8 kg per m^3. Maize had a productivity of 5.87 kg per m^3 in Head region while it was 5.6 kg per m^3 in Tail region while groundnut had a productivity of 4.42 kg per m^3 and 2.82 kg per m^3, respectively in MGP command areas.

Gross economic water productivities (GEWP) for sugarcane, cotton, maize and ground nut were computed as a ratio of total returns earned to the total water applied.

In case of ALBC sugarcane had a productivity of Rs 13.59 per m^3 in Head region while it was Rs 15.65 per m^3 in Tail region. In case of IBC, productivity of sugarcane was Rs 13.5 per m^3 in Head region while it was Rs.16.92 per m^3 in Tail region. In GRBC, sugarcane had a productivity of Rs.13.15 per m^3 in head region and Rs.16.72 per m^3 in tail region.

In case of MLBC cotton had a productivity of Rs.23 per m^3 in Head region while it was Rs.28.82 per m^3. Maize had a productivity of Rs.64.67 per m^3 in Head region while it was Rs.67.3 per m^3 in Tail region while groundnut had a productivity of Rs.104.78 per m^3 and Rs.127.08 per m^3, respectively in MGP command areas.

Net economic water productivities (NEWP) for sugarcane, cotton, maize and ground nut were computed as a ratio of net returns earned (Rs. per ha) to the total water applied (m^3).

In case of ALBC sugarcane had a productivity of Rs 6.00 per m^3 in Head region while it was Rs 6.83 per m^3 in Tail region. In case of IBC, productivity of sugarcane was Rs 5.72 per m^3 in Head region while it was Rs. 7.50 per m^3 in Tail region. In GRBC, sugarcane had a productivity of Rs.per m^3 in head region and Rs.16.72 per m^3 in tail region.

In case of MLBC cotton had a productivity of Rs.14.47 per m^3 in Head region while it was Rs.18.6 per m^3. Maize had a productivity of Rs. 32.64 per m^3 in Head region while it was Rs. 36.3 per m^3 in Tail region while groundnut had a productivity of Rs.52.85 per m^3 and Rs.68.15 per m^3, respectively in MGP command areas.

6.4.5 Perceptions of stakeholders in enhancing water productivity

The perceptions of the farmers in the command areas of UKP and MGP were analyzed. It was observed that formation of Water Users' Association (WUA) for water management ranked I which recorded a mean score of 70 followed by proper functioning of WUCs to ensure efficient irrigation management ranked II with a mean score of 58. Good cooperation from the staff / officials ranked III with a mean score of 54. Changing the localization pattern and adoption of cultivation of light irrigated crops and installation of water meters at the field gates were ranked IV with a mean score of 49. Timely release of water from the canal ranked V with a mean score of 46. Adequate release of water and proper repair of canals and cement lining of FICs to avoid water losses were ranked VI with a mean score of 42. Collection of water charges on a quantitative basis ranked VII with a mean score of 41.

Perceptions of officials of CADA and Irrigation Departments (IDs) were documented and analyzed. It was observed that adequate release of funds for canal repairs and training and capacity building to farmers were ranked I with a mean score of 57. Scientific quantification of water at the field level was ranked II with a mean score of 51. Timely inspection and supervision of the canal sites was ranked III with a mean score of 46. Good cooperation from the officials / staff was ranked IV with a mean score of 45. Installation of water meters at the field gates was ranked V with a mean score of 41 and proper lining of FICs to ensure the natural flow was ranked VI with a mean score of 19.

6.4.6 Policy implications

- It was observed that the farmers in command areas were using conventional methods of irrigation which lead to use of excess water therefore adoption of micro irrigation should be made mandatory to all the farmers growing sugarcane.
- The quantity of water used by farmers in Head region was more compared to Tail region therefore there should be a scientific quantification of water in command areas ensuring equal distribution of water to both Head and Tail regions.
- It could be observed that farmers in the command areas were growing water intensive crops, therefore alternative crop plans (Cotton, ground nut and maize) need to be suggested thereby replacing the water intensive crops in the command areas.
- It was observed that the farmers are of the opinion for formation of Water Users' Association (WUAs) in the command areas should be encouraged and attention needs to be given to strengthen Participatory Irrigation Management (PIM) to ensure efficient water management in command areas.

7.REFERENCES

Aheeyar, M. M., 1999, Impact of irrigation management policy on environment: lessons from Sri Lanka, *Asia. Pacific. J. Rurl. Dev*, 9(1): 71-78.

Amarasinghe, U.A.Bhaduri, A. Singh, O.P.; Ojha, A. Anand, B.K. 2008. Cost and benefits of intermediate water storage structures: Case study of diggies in Rajasthan. Proceedings of the CGIAR *Challenge Program on Water and Food and 2nd International Forum on Water and Food.*Addis Ababa, Ethiopia, November 10-14 2008. Volume III (pp. 79-82).

Amarasinghe, U.A.Shah, T. McCornick, P. 2008. Seeking calm waters: Exploring policy options for India's water future. *Natural Resource Forum,* 32 (4): 305-315.

Anonymous, 2006, Reengaging in agricultural water management: Challenges and Options. *The World bank report*, Washington, DC. pp 98.

Balasubramamiam, C., Somasundaram, M. V. and Pundarikanthan, N. V., 1996, LP analysis in a tank irrigation system for near real representation and optimal allocation of area. *Irrigat. Drain. Sys.*, 10 (2): 143-158.

Barker, R. and Levine, G., 2012, Water productivity in context; The experiences of Taiwan and the Philippines over the past half-century. *J. Econ. History,* 38(4):839-864

Barker, R., David, D. and Arlene, I., 2003, Water productivity in agriculture; limits and opportunities for improvement, CABI Publishing, New Delhi, India. pp19-35.

Bennett, J. 2003. Opportunities for Increasing Water Productivity of CGIAR Crops through Plant Breeding and Molecular Biology. In: Water Productivity in Agriculture: Limits and Opportunities for Improvement. (Eds) Kijne.J.W., R.Barker and D.Molden. CABI Publishing. UK. Pp-103-126

Bhende, M. J. and Kalirajan. K. P. 2007, Technical efficiency of major food and cash crops in karnataka*. indian J. Agric. Econ.*, 62(2): 176-189.

Birthal, P. S., Joshi, P. K., Devesh, R. and Amith, T., 2007, Diversification in Indian agriculture towards high crops. *IFPRI Discussion Paper 007*27, November. Pp-29

Bouman, B.A and Tuong, T.P. 2001. Field water management to save water and increase its productivity in irrigated rice. *Agricultural Water Management*. 49(1): 11-30.

Chamber, R., 1990, Managing canal irrigation: Practical analysis from south Asia. *Geographical J.*, 156(2): 225.

Chambouleyron, J., 1996, Performance parameters for a decentralized and participatory water administration. *Sustainability of Irrigated Agriculture Proceedings of the NATO Advanced Research Workshop*, Vimeiro, Portugal, 21-26 March, 1994.

Chaturvedi, M. C. 2000. Water for food and rural development, developing countries. Water International 25 (1): 40-53.

Dang, B., Loeve, R., Li, Y. H., Chen, C. D., Deng, L. and Molden, D. 2001. Water productivity in the Zhanghe irrigation system issues of scale. pp 97-115.

Dehnarayan Sarker and Sudpita, De., 2004, High technical efficiency of farms in two different agricultural lands: A study under determine production frontier approach. *Indian J. Agric. Econ.*, 59(2):197

Dinesh Kumar, M., 2007, Groundwater management in India: Physical, institutional and policy alternatives, SAGE publications, India Pvt Ltd , India.

Dinesh, C., 1992, Resource use efficiency in different irrigation system in Khaziabhad district of AndhraPradesh. *Indian J. Agric. Econ*., 47(3): 494-514

Farrell, M. J., 1957, The measurement of production efficiency. *J. Royal Statistical Society*, 120 (2): 253-281.

Fernandez, M. D. P. and Peter, L. N., 2009, Technical efficiency in the production of sugarcane in central Negros area, Philippines: An application of data envelopment analysis. *J. International Society for Southeast Asian Agric. Sci*., 15(1): 77-90.

Frija, A., Frija, I., Chebil, A., M'Hamed, H. C., Speelman, S. and Makhlouf, M., 2014, Marginal Water Productivity of Irrigated Durum Wheat in Semi-Arid Tunisia. *J Agric. Sci. Canada*, 6(1): 10.

Gade, A. D. and Chavan, S. M., 2014, Soil degradation in krishna canal command area (Maharashtra): A micro level analysis. *J. Shivaji Univ. Sci. and Tech.,* 41(1):4-9

Ghosh, N., 1990, Role of fertilizer and irrigation in determining cropping intensity: A region wise study of Andhra Pradesh. *Indian J. Agril. Econ*., 45 (4): 510-517.

GoI (Government of India). 1999. Integrated water resource development: A plan for action. Report of the National Commission on Integrated Water Resources Development-Volume I,New Delhi: Government of India.

GoI. (Government of India) 2002. India's planning experience. New Delhi: Planning Commission.

Goswami and Challa, 2004, Indian land use scenario. *Agric. Situation in India*, 60(12): 786

Goswami, S. N., Dubey, P. N., Sen, T. K. and Challa, Q., 2003, Land use dynamics in Mizoram. *Agric. Situation in India*, 9(8): 531.

Gulati, Ashok, Dick, R. M. and Raju, K. V. . 2005, Institutional Reforms in Indian Irrigation, Sage Publications, New Delhi. P-322.

Gupta, R, K., 2004, Water governance in Gujarat State, India. *Int. J. Wat. Res. Dev.* 20(2): 131-147.

Hugar, L. B., 2005, Economic of Canal Irrigation Water and Its Distribution in Tungabhadra Project, Karnataka. *Karnataka J. Agric. Sci.,*18 (3):702-705

Karthikeyan, C., Palanisami, K., Paramasivam, P. and Rajagopal, A., 2009, Sustainable management of tanks in South India. pp150-160.

Karunakaran, K. R. and Palanisami, K., 1998, An analysis of impact of irrigation on cropping intensity in Tamil Nadu. *Indian Econ. Rev*., 33 (2): 207-220.

Kebede, W., Moges, A. and Yimer, F., 2013, Farmers perception of the effects of soil and water conservation structures on crop production: The case of Bokole watershed, Southern Ethiopia. *African J. Env. Sci. and Tech.,* 7(11): 990-1000.

Kebede, W., Moges, A. and Yimer, F., 2013, Farmers perception of the effects of soil and water conservation structures on crop production: The case of Bokole watershed, Southern Ethiopia. *African J. of Environ. Sci. and Tech.,*Vol. 7(11) :990-1000.

Keller, A., Keller J. and Seckler, D. 1996, Integrated Water Resources Systems: Theory and Policy Implications. Research Report 3, International Water Management Institute, Colombo.

Kijne, J. W., Barker, R. and Molden, D., 2003, Water productivity in agriculture; Limits and opportunities for improvement. CABI Publishing, New Delhi, India.

Koshta, A. K. and Chndrakar, M. R., 2005, A Comparative study of Economic Efficiency in production of Rainfed and Irrigated Rice of Chattisgarht. *Indian J Agric. Econ*., 60(1-4): 524 – 535.

Kumar Utpal, D., 2003, Changing cropping pattern system in theory and practice: An economic insight into the agrarian West Bengal. *Indian J. Agric. Econ*., 58(1): 64-83.

Lashari, B. and Mahesar, M. A., 2012, Potentials for improving water and agriculture productivity in Sindh, Pakistan. Sixteenth International Water Technology Conference, IWTC 16, Istanbul, Turkey.

Lashari, B. and Mahesar, M. A., 2012, Potentials for improving water and agriculture productivity in Sindh, Pakistan. Sixteenth International Water Technology Conference, Istanbul, Turkey.

Laxmi., 2015, socio-economic performance of Ganga Kalyana Yojana (GKY) in Karnataka with special reference to Vijayapura district *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad.

Lokanadha Reddy, E. and Radhakrishna Reddy, D., 2014, A Study on resource use efficiency of agricultural input factors with reference to farm size in three revenue Mandals of Nellore district: Andhra Pradesh. *Global J. Mgt. Business Res.: E. Mark.,* 14(5):14-22

Mahesh, 2011, Investment pattern in irrigation development in Karnataka: An economic prospective. *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad.

Mahoo, H. F., Mkoga, Z. J., Kasele, S. S., Igbadun, H. E., Hatibu, N., Rao, K. P. and Lankford, B., 2007, Productivity of water in agriculture: Farmers' perceptions and practices. *Discussion Paper 5, International Water Management Institute*, Colombo, Sri Lanka.

Malhotra, S. P., Raheja, S. K. and Seckler, D., 1984, A methodology for monitoring the performance of large scale irrigation systems. A case study of the warabandhi system of north - west India. *Agric. Admin,* 17(4): 231-259.

Marothia, D. K., 2005, Institutional reforms in canal irrigation system - lessons from Chhattisgarh. *Econ. Pol. Wee.* 40(28): 3074-3084.

Martuccelli, A. M., 1997, Participatory irrigation management: the Italian consortiums. *Med. Sem. Mediterraneens,* 8(2): 41-44.

Mayya, S. G. and Rama Prasad., 1989, Systems analysis of tank irrigation; Crop staggering. *J. Irrigation and Drainage Engg.*, 115(3): 384-405.

Mohammad, S., Bahman, R. and Allahyari, 2013, Farmers opinions regarding effective factors on optimum agricultural water management. *J. Saudi Society of Agric. Sci.,* 13(1): 15–21.

Montazar, A., 2009, Assessing the global water productivity of some irrigation command areas in Iran, *International Sci. Index,* 3(9): 408-412

Montazar, A., Nazari Far, M. H., Mardi, E., 2007, Optimal water productivity of irrigation systems in a semi- arid region, pp 87- 98.

Palanisami, K., Senthilvel, S. and Ramesh, T., 2009, Water productivity at different scales under canal, tank and well irrigation systems, International water management institute, Colombo, Sri Lanka.

Poddar, R. S., Hiremath, G. K. and Basavaraja, H., 2001, Participatory approach for small-scale irrigation development- a case study of Chikkapadasalagi Barrage, India. *Indian J. Soc. Dev.,* 1 (1): 93-104.

Punithavathi, J. and Baskaran, R., 2010, Changes in the cropping pattern, crop concentration, agricultural efficiency in Papanasam taluka, Thanjavur district, Tamil Nadu. *India Recent Res. in Sci. and Tech.*, 2(5): 1-7.

Qureshi, A. S., Oweis, T., Karimi, P. and Porehemmat, J., 2010, Water productivity of irrigated wheat and maize in the karkheh river basin of Iran. *Irrigation and drainage*, 59(3): 264-276.

Rama Rao, C. A., Chowdry, K. R., Reddy, Y. V. R. and Krishna Rao, G. V., 2000, Measuring and explaining technical efficiency in crop production in Andhra Pradesh. *Indian J. Agric. Econ.*, 58(2): 768–778.

Ramachandrappa, B. K., Patil, V. C. and Havanagi, G. V., 1990, Performance of dryland crops on broad beds in conjunction with paddy under tank irrigation. *Madras Agril. J.,* 77 (7-8): 333-336.

Ramesh, C. and Chauhan, S., 2002, Socio-Economic factors in agricultural diversification in India. *Agric. Situation in India*, 58 (11):523-529.

Rangappa, K. B., 2014, Resource Use Efficiency In Paddy Production Under Different Sources of Irrigation in Shimoga District, Karnataka: An Analysis of Farm Level Data. *Indian J. Applied Res.,* 4 (5): 155-157.

Raut, S., Panda, D, K. and Kannan, K., 2014, Managing irrigation in a canal command area located in a subhumid region based on agrometeorology and remotely sensed Land Use Map. *J. Agric. Phys.*, 10(2): 21-27.

Reddy, A. R. and Sen, C., 2004, Technical inefficiency in rice production and its relationship with farm-specific socio-economic characteristics. *Indian j. Agric. Econ.*, 59(2): 259-267.

Rosegrant, M. X., Cai. and Cline, S., 2002, World water and food to 2025; Dealing with scarcity. International food policy research institute publication, Battarmulla, Sri Lanka.

Sahoo, B. B., 2008, Indian agriculture retrospect and prospects. *Kurukshetra*, 56(7) :13-18.

Sampath, R. K., 1979, Nature and measurement of economic efficiency in Indian agriculture. *Indian J. Agric. Econ.*, 34(2): 17-34.

Satish, H. N., 2010, Impact of land degradation in Malaprabha command area in Karnataka:An economic analysis. *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad.

Sekar, I. and Ramasamy, C., 2003, Decision making in risk ridden tank fed farms in Tamil Nadu – An application of advanced breakeven analysis. *Indian J. Agril. Econ.*, 58 (1): 146-154.

Senthil kumar, C. and Alagumani, T., 2005, Resource use efficiency in lower Bhavani basin Command area in Tamil Nadu. *Indian J Agric. Econ.*, 60(2): 551 – 568.

Shahi, H. N., 2002, Sugarcane crushing prices cause concern. The Hindu year book, Chennai. pp119.

Shanmugam, K. R., and Venkatraman, A., 2006, Technical efficiency in agricultural production and its determinants: An exploratory case study at district level. *Indian J. Agric. Econ*., 61(2): 169 - 181.

Sharma B R., Amarasinghe U. and Cai X., 2009, Assessing and Improving Water Productivity in Conservation Agriculture Systems in the Indus-Gangetic Basin, *Invited Lead paper for the " 4th World Congress on Conservation Agriculture- Innovations for Improving efficiency, Equity and Environment", Pusa, New Delhi, India.*

Sharma, J. L. 1990, Interstate disparities in growth of agriculture in India. *Agric. Situation in India*, 45(7) : 453 – 456.

Sharma, V. K., 1985, Water resource planning and management. *Himalaya Publishing House, Bombay*. *pp* 80-101.

Shergill, H. S., 2008, Sustainability of wheat- rice production in Punjab: A re-examination. *Economic and Political Weekly,* 42(52): 29

Singh, I. J., Rai, K. N. and Karwara, J. C., 1997, Regional variation in agricultural performance in India. *Indian J. Agric. Econ*., 52(3): 374 – 386.

Singh, J. and Sidhu, R. S., 2004, Factors in declining crop diversification- A case study of Punjab. *Econ. and Polit. Weekly*, 39(52):25-31.

Singh, M., Prasad, K., Singh, P. J. and Mohan, G. B., 2000, Changing scenario in cropping system of Meerut region. *Indian Farming,* 50(4): 15-16.

Singh, Y. V., Gajja, B. L. and Chand, K ., 2006, Impact of land irrigability classes on crop productivity in canal command area of Gujarat: An economic analysis. *Agric. Econ. Res. Review,* 19(1):83-94.

Sinha, B. and Kumar, R., 2000, PIM - a reality in Asia?. Challenges facing irrigation and drainage in the new millennium. *Proc. US Committee on Irrigation and Drainage*, Fort Collins, Colorado, USA, June, 2000; 415-427.

Siva Sankar, A., Reddy, B. And Ravi Kumar, K., 2014, Low economic efficiency of irrigation water resource in Krishna Western delta of Andhra Pradesh demanding water management interventions. *J. Int. Academic Res. for Multidisciplinary,* 2(1): 527-545.

Srivastava, R. C., 1996, Methodology for optimizing design of integrated tank irrigation system. *J. Water Resour. Planning Mgt*., 122 (6): 394-402.

Strzepek, K. and Boehlert, B., 2010, Competition for water for the food system. *Philosophical Transactions of the Royal Society,* 365(1554): 2927-2940.

Sun, P. P. C., 2000, *Policy Issues in Managing Irrigation and Drainage,* Extension Bulletin Food and Fertilizer Technology Center, 490 : 7.

Suresh, A. And Reddy, K., 2006, Resource-use efficiency of paddy cultivation in peechi command area of Thrissur district of Kerala: An economic analysis. *Agric. Econ. Res. Rev.,*19(1): 159-171.

Suresh, K., 2011, Innovative Technologies for Water Saving in Irrigated Agriculture. *International J Water Res. and Arid Env.,* 1(3): 226-231.

Svendsen. M., Trava. J. and Johnson. S. H., 2000, A synthesis of benefits and second generation problems. Case studies in participatory irrigation management. WBI Learning Resources Series, Washington, DC, USA: World Bank.

Taiwo, R. A., Omolehin, and Ibrahim, U., 2011, Efficiency of resource use in hybrid and open-pollinated maize production in Giwa LGA of Kaduna state, Nigeria. *American J. Experimental Agric.*, 1(3): 86-95.

Timmer, C. P., 1971, Using probabilistic production function to measure technical efficiency. *J. Political Econ.*, 79(4): 776-794.

Van Dam, J. C., Singh, R. and Feddes, R. A., 2006, Water productivity of irrigated crops in Sirsa district, India. *Agric. water mgt.*, 82(3):253-278

Velavan, C., Balakrishnan, V., 2000, Resource use efficiency in canal Groundnut cultivation of Salem district; Tamil Nadu. *Agric. Situation in India*; 58(3): 755-757.

Vijayalaxmi., 2015, "Socio-economic evaluation of impact of Karnataka community based tank management project in Vijayapura district". *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad.

Vivekananda, M. and Sathyapriya, V. S., 1994, Karnataka changing cropping pattern. *Agric. Situation in India,* 49(6): 441 – 444.

Ximing Cai and Rodegrant, M. W., 2003, World water productivity: Current situation and future options. pp163-178.

Zaman, A., 2012, Participatory approach on adoption of water management technologies to ensure agricultural productivity. *International Coference on Agriculture and Horticultural Science*, International Convention Centre, Hyderabad, India.

Zaveri, P. and Parmar, A., 2013, Change in cropping pattern utilizing narmada main canal water: A case study of barmer district. *Inter. J. Res. in Eng. and Tech.*, 2(10): 1-10.

APPENDIX – I

WORKSHEET - WATER PRODUCTIVITY OF DIFFERENT CROPS

I. Sugarcane

Name of the farmer	:	Chandrakant Sheelavant
Area	:	One acre
Farm yield	:	95000 kg / acre
Price of produce	:	Rs. 2000 per tonne
Gross returns	:	Rs. 1,90,000
Cost of cultivation	:	Rs. 95,000
Net profit	:	Rs. 95000
Irrigation source	:	Canal water
Irrigation method	:	Surface irrigation

Total quantity of irrigation water:

i. Between O-15 Days irrigation was given by the farmers @ 10 cm depth at 7 days interval.

Totally 2 irrigations were given from canal at 5 cm depth

= (10/100) X 2X 10000 = 2000 m^3 (1 ha = 10,000 m^2)

ii. Between 16-25 Days irrigation was given by the farmers @ 12 cm depth at 3 days interval. Totally 3 irrigations were given from canal at 5 cm depth

= (12/100) X 3X 10000 = 3600 m^3.

iii. Between 25-45 Days irrigation was given by the farmers @ 10.2 cm depth at 4 days interval. Totally 5 irrigations were given from canal at 5 cm depth

= (10.2/100) X 5 X 10000 = 5100 m^3.

iv. Between 45 till maturity irrigation was given by the farmers @ 11 cm depth at 5 days interval. Totally 18 irrigations were given from canal at 5 cm depth

= (11/100) X 18 X 10000 = 19,800 m^3.

Total water used for sugarcane cultivation = 2,000 + 3,600 +5,100 +19,800 = 30,500 m^3

Water productivity = 95,000 kg per 30,500 m^3= 3.11 kg of sugarcane per m^3 of water.

Gross economic water productivity = Rs. 1,90,000 per 30,500 m^3= Rs. 6.22 per m^3 of water

Net economic water productivity = Rs. 95,000 per 30,500 m= Rs. 3.11 per m^3 of water.

II. Cotton

Name of the crop	:	Cotton
Area	:	One acre
Average farm yield	:	3,225 kg / acre
Price of produce	:	Rs. 100.5 / kg
Cost of cultivation	:	Rs. 61500/-
Gross returns	:	Rs. 1,29,645/-
Net profit	:	Rs.68,145 /-
Irrigation source	:	Canal water
Irrigation method	:	Surface irrigation

Total quantity of irrigation water:

Irrigation was given by the farmers @ 7 cm depth at 15 days interval. Totally 10 irrigations were given from canal at 11 cm depth.

= (7/100) X 10X 10000 = 7000 m^3 (1 acre = 4000 m^2)

Physical water productivity = 3225 kg per 7000 m^3= 0.46 kg of rice per m^3 of water.

Gross economic water productivity = Rs. 1,29,645 per 7000 m^3= Rs. 18.52 per m^3 of water

Net economic water productivity = Rs. 68,145 per 7000 m^3= Rs. 9.73 per m^3 of water.

APPENDIX – II

UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD

Personal Interview Schedule

Research Topic : An Economic Evaluation of Water Productivity in Upper Krishna Project (UKP) and Malaprabha Ghataprabha Project (MGP) Command Areas in Karnataka.

Name of the Student: VEERESH S. WALI

Schedule no:_____________
Date: _______________

I. GENERAL INFORMATION

1. Name of the farmer : __________________
2. Village : _________________
3. Education : _______________
4. Taluk and district : _______________
5. Command Area : __________________
6. Canal Name : _______________
7. Region :
8. Distributory: ________
9. Survey No.:__________

5. Family Composition

Men	Women	Children	Total	Off farm	On farm

6. Organizational Participation

Sl. No.	Name of the Institution	Nature of participation

7. Size of holding (acres)

Sl. No.	Type	Irrigated				Dry land /Rain fed
		Open-well	Tube-well	Tank	Canal	
1.	Own land					
2.	Leased in					
3.	Leased out					
4.	Land revenue					
5.	Land value					

9. Irrigation Structure details (all)

a) Bore well / Open well

Sl.No.	Year of digging	Cost of Digging	Subsidy component
01			
02			
03			

b) Pump sets

Sl. No.	Horse power	Year of purchase	Cost	AMC	Elec. Charges

c) Tank: Annual charges (Inclusive of all the crops):

d) Canal : Annual charges(Inclusive of all the crops):

10. Finance availed

Sl. No.	Name of the Institution	Type of loan	Amount availed	Interest	Purpose	Amount paid
01						
02						
03						
04						

11. Farm inventory

a) Major farm implements

Sl. No.	Items	No's	Year of purchase	Average life (years)	Annual repairs (Rs)	Purchase value

12. Source of income and expenditure

a) Farm income and expenditure

Sl.No.	Name of the crop	Yield	Price	Returns	Total cost	Net Income

b) Non farm income

Sl. No.	Nature of occupation	Income

Cropping pattern

Season / crop	Area (acre)		Source of irrigation Code*	Total Production (quintals)		Quantity Sold (quintals)		Average Price (Rs/quintal)	
	Irrigated	RRain fed		Main	By product	Main	By product	Main	By product
Kharif									
Rabi									
Summer									
Annuals /Pere-nnials									

Source Code (major source)*: Open well =1; Tube well =2; Canal =3; Tank =4; Others =5.

Water productivity of selected crops in the command areas

Quantity of water (Input)

Irrigation details

Sl. No.	Crop	No. of Irrigations at each growth stage	Time of each irrigations (Hrs)/Depth of each irrigation	Quantity of water per hour	Quantity of water per irrigation	Total water given
01	Sugarcane a. Stage 1 b. Stage 2 c. Stage 3 d. Stage 4 e. Stage 5 f. Stage 6 g. Stage 7					
02	Cotton a. Stage 1 b. Stage 2 c. Stage 3 d. Stage 4 e. Stage 5 f. Stage 6 g. Stage 7					

03	Maize a. Stage 1 b. Stage 2 c. Stage 3					
04	Ground nut a. Stage 1 b. Stage 2 c. Stage 3 d. Stage 4 e. Stage 5					

Yield & Value of the crops (Output)

Total value of the crops

Sl. No.	Crop	Area	Production	Yield	Rate / Unit	Total value
01						
02						
03						
04						

PART III: PERCEPTIONS OF STAKEHOLDERS

PART IV-A

PERCEPTION OF FARMERS

Sl. No	Particulars	Response
01	Formation of Water User Associations (WUA) for water management.	
02	Proper functioning of WUCs to ensure efficient irrigation management.	
03	Change the localization pattern and adopt cultivation of light irrigated crops.	
04	Adequate release of water and proper repair of canals.	
05	Cement lining of FICs to avoid water losses.	
06	Collection of water charges on a quantitative basis	
07	Timely release of water from the canal	
08	Installation of water meters at the field gates.	
09	Good cooperation from the staff/ officials	

PART IV-B

PERCEPTION OF OFFICERS (CADA, IRRIGATION DEPT.)

Sl. No	Particulars	Response
01	Adequate release of funds for canal repairs	
02	Training and capacity building to farmers	
03	Scientific quantification of water at field level	
04	Proper lining of FICs to ensure natural flow	
05	Installation of water meters at farm gates	
06	Timely inspection and supervision of canal sites	
07	Good cooperation from farmers.	

APPENDIX – III

AGRICULTURE SECTOR ACTIVITIES IN THE COMMAND AREA

INTRODUCTION

Agricultural development programmes are being implemented in Upper Krishna Project since irrigation was introduced during the year 1982. The Agricultural Wing is engaged in popularizing improved varieties of seeds, improved irrigation management practices and crop production practices. Crop demonstrations are taken up to enable the farmers to take up improved new agriculture technologies. The Agriculture Wing is engaged in Agriculture extension activities in command area of Upper Krishna Project and also giving trainings on soil & water management, Agriculture production Technology & other allied subjects (Argil activities) are organized through the Land Development Training Centre situated at Bheemarayangudi.

The Deputy Director of Agriculture (Agri-Divn),CADA UKP Bheemarayangudi & Principal, Land Development Training Centre, CADA UKP, Bheemarayangudi are in over all charge of the extension & training aspects respectively in the Command Area & they are under administrative control of Land Development Officer (Agri) CADA UKP Bheemarayangudi. There are three Agriculture sub-Divisions, comprising of 15 Taluks. one situated at of Surapur Taluk. second at Bheemarayanagudi of Shahapur Taluk.& Third at Salotagi of Indi Taluk.

OBJECTIVES

The Agriculture Wing performs various Agricultural extension activities with the following objectives.

1. Formulation and implementation the Agril schemes for the Development of irrigated Agriculture in the Command Area.
2. To co- ordinate water management at outlet points to encourage farmers to adopt improved irrigation management practices for the improvement of irrigation efficiency.
3. Planning on Cropping pattern and adoption of New Agril production Technology to boost Agril production in the Command Area.
4. To Organize training programmed, such as Field days , Demonstrations and other extension activities to enrich knowledge, skill, attitudes and create wide spread awareness in farmers
5. Through Department of Agriculture & University of Agriculture Sciences training to farmers and CADA extension staff to envisage more knowledge for successful implementation for CADA Agril schemes.

Training

Farmers of Command Area are trained in Land Development Training Centre for two ways(on-campus & Off campus) soil and water management, Crop production practices, organic farming, Animal Husbandry, Vermicompost etc..distributions of printed Leaflets, Booklets and also conducting study tours for men , women farmers and Agricutral Assistants to adopt new technology practices

Area targeted for kharif season 2014-15 is 623108 hectares out of which 488691hectares area covered. Totally 78%of sowing was achieved. similarly for Rabi-2014-15 area targeted 624191 hectares ,out of which 548539 hectares area covered, totally 87%of sowing achieved Targeted crops are Maize, wheat & mixed crops and for improvement of soil fertility, INM components like greenmannure crops and vermi compost demonstrations are implemented, to avoid paddy/sugarcane.

The cropping intensity with the present cropping pattern as on 2003 is 53% in Khariff,82% in Rabi & 20% in Bi-seasonal. However the designed irrigation intensity for the UKP is 115% with 57.5% area under kharif, 35% Rabi & 22.5% Bi-seasonal. Therefore the following alternative cropping pattern is suggested to achieve the envisaged irrigated area with full use of available water in the reservoirs.

New Recommended Cropping Pattern

Sl. No.	Season	Crops	Percentage Area
1	Kharif	1) Maize	10
		2) Ground nut	15
		3) Bajra	10
		4) Sun flower	10
		5) Greengram/Pulses	05
		6) Horticulture crops	7.5
		Total	57.5
2	Bi-Seasonal	1) Red gram	2.5
		2) Chilly	10
		3) Cotton	10
		Total	22.5
3	Rabi	1) Rabi jowar	05
		2) Wheat	10
		3) BengalGram	05
		4) Sunflower	10
		5) Horticulture crops	05
		Total	35
		Grand Total	115

AN ECONOMIC EVALUATION OF WATER PRODUCTIVITY IN UPPER KRISHNA PROJECT (UKP) AND MALAPRABHA GHATAPRABHA PROJECT (MGP) COMMAND AREAS IN KARNATAKA

VEERESH S WALI **2016** **Dr. R. S. PODDAR**

CHAIRMAN

ABSTRACT

Water resources around the world are threatened by scarcity, degradation and overuse, and food demands are projected to increase, it is important to improve our ability to produce more food with less water. The present study was taken up to evaluate the economic water productivity of selected crops in UKP and MGP command areas, Karnataka. The study made use of both primary and secondary data. Tabular analysis, Markov chain analysis and Garrett ranking were used to analyze the data. Net economic water productivities (NEWP) for sugarcane, cotton, maize and groundnut were computed as a ratio of net returns earned to the total water applied. In case of ALBC sugarcane had a productivity of Rs 6.00 per m^3 in Head region while it was Rs 6.83 per m^3 in Tail region. In case of IBC, productivity of sugarcane was Rs 5.72 per m^3 in Head region while it was Rs. 7.50 per m^3 in Tail region. In GRBC, sugarcane had a productivity of Rs.13.17 per m^3 in head region and Rs.16.72 per m^3 in tail region. Similarly in MLBC, cotton had a productivity of Rs.14.47 per m^3 in Head region while it was Rs.18.6 per m^3. Maize had a productivity of Rs. 32.64 per m^3 in Head region while it was Rs. 36.3 per m^3 in Tail region of MGP command areas. Groundnut had a productivity of Rs.52.85 per m^3 and Rs.68.15 per m^3, respectively in MGP command areas. It was observed that there was a huge disparity in the productivity levels at Head and Tail regions in canal command areas which was mainly due to unequal distribution of water and unscientific irrigation management practices.