INSTITUTION OF AGRICULTURAL TECHNOLOGISTS,

BENGALURU

EVALUATION OF RKVY PROJECTS

OF

UNIVERSITY OF AGRICULTURAL SCIENCES,

BENGALURU

"ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND"

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ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND

EXECUTIVE SUMMARY

India is an agrarian society and the agricultural sector accounts for 18% of India's gross domestic product (GDP) while providing employment to 50% of the country's workforce. India initiated its own Green Revolution programme in the field of plant breeding, irrigation development and financing of agrochemicals after 1960. The Green Revolution had several benefits, such as increase in production due to the use of high-yielding varieties of seeds, crop genetic improvements and irrigation, which led to widespread poverty reduction. However, the unabated adoption of unsustainable agricultural techniques and practices (high dependence on chemical fertilizers and pesticides) by farmers to produce more had an adverse impact on the environment. There were reports of loss of soil fertility, deteriorating state of water resources, pollution of groundwater and increase of salinity in groundwater.

Irrigation is one of the important inputs of scientific crop production. Water is a critical input into agriculture in nearly all its aspects having a determining effect on the eventual yield. Good seeds and fertilizers fail to achieve their full potential if plants are not optimally watered. The availability of adequate, timely and assured supply of water is an important determinant of agricultural productivity. Irrigation, in addition to raising productivity and cropping intensity, will also facilitate shifts in cropping patterns. Irrigated agriculture contributes to about 40 percent of the global food production from an estimated 20 percent of agricultural land, or about 300 million ha globally.

From about 16.9 percent of net irrigated area we have reached a figure of 40 percent. There are in all 119 major and 176 medium irrigation projects in the country. The efforts of the Governments have yielded rich dividends and nearly 65.6 % of the ultimate irrigation potential has been developed. From 22.6 million hectares of irrigation potential in 1950, today more than 90 million hectares of land have been brought under irrigation through major and medium (31.50 million hectares) and minor irrigation projects (57.96 million hectares). The ultimate irrigation potential of India is estimated as 139.95 million hectares including 56.00 million hectares by major and medium projects and 81.05 million hectares by minor irrigation projects comprising 17.40 million hectares by surface minor irrigation projects, 64.05 million hectares by ground water irrigation projects.

India with 17 percent of the world population has merely 4 percent of the world fresh water resources. It has a very low per capita water availability which puts it in the category of waterstressed nation. The average annual water availability in India is estimated to be 1869 billion cubic meters (BCM). However, due to hydrological, topographic and other constraints, the utilizable water is expected to be about 1123 BCM, out of which 690 BCM is from surface water and 433 BCM from replenishable groundwater.

The burgeoning world population and ever-increasing need of water is likely to cause water scarcity in the coming decades. India with a high population growth and millions of mouths to feed has immense pressure on agriculture. Even after seven decades of independence agriculture in India is primarily dependent on monsoons (INCID, 1994 and Narayanamoorthy, 1997). Farmers in India can play an active role in adopting efficient irrigation practices minimizing the wastage of water to a great extent. A large proportion of farmers in India falls in the small and marginal category (Narayanamoorthy, 1999 and 2005). All this background gives a very critical picture of the future of agriculture in India unless some radical agricultural practices are introduced to raise the production.

Water scarcity has many negative impacts on the environment, including lakes, rivers, wetlands, and other fresh water resources. Additionally, water overuse can cause water shortage, often occurs in areas of irrigation agriculture, and harms the environment in several ways including increased salinity, nutrient pollution, and the degradation and loss of flood plains and wetlands. Furthermore, water shortage makes flow management in the rehabilitation of urban streams problematic. Owing to poor water resource management system and climate change India faces a persistent water shortage. As per OECD environmental outlook 2050, India would face severe water constrains by 2050. Indian agriculture accounts for 90% water use due to fast track ground water depletion and poor irrigation systems.

As a result of climate change the country has been witnessing drought and flood at the same time, which has impacted agriculture productivity. About 40 million ha of the country is flood prone and every year about 8 million ha is affected by floods. The waterlogged area in the country is about 11.6 million ha.

Droughts have severe impacts on economy, society and environment affecting crops, irrigation, livestock, wildlife, soil, health problems, public safety ultimately leading to severe loss to human life. The period between 1950 and 1989 had 10 drought years, while there have been 5 droughts in the last 16 years (since 2000). According to meteorologists the frequency is set to increase between 2020 and 2049 (Collison, A. et al., 2000). Indian agriculture is crucially dependent on the local climate: favorable southwest summer monsoon is critical in securing water for irrigating crops. In some parts of India, the lack of monsoons results in water shortages, resulting in below-average crop yields.

Droughts mean less water availability for agriculture than usual. Increased groundwater use during droughts can help overcome such critical periods. However, the resulting groundwater overuse and quality deterioration mean there is also less groundwater available for agriculture than before, thereby causing even more pressure on agricultural production.

India is not a water rich country and is further challenged due to negative impact of climate change; enormous wastage owing partly to poor management and distorted water pricing policies. India receives an average of 4,000 billion cubic meters of precipitation every year (Vibha Dhawan, 2017). However, only 48% of it is used in India's surface and groundwater bodies. A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used. India's annual rainfall is around 1183 mm, out of which 75% is received in a short span of four months during monsoon (July to September). This result in run offs during monsoon and calls for irrigation investments for rest of the year. The population of India is likely to be 1.6 billion by 2050, resulting in increased demand for water, food and energy. This calls for infrastructure expansion and improved resource utilization.

At present, irrigation consumes about 84 %of total available water. Industrial and domestic sectors consume about 12 and 4 %of total available water, respectively. With irrigation predicted to remain the dominant user of water, "per drop more crop" is an imperative. The efficiency of water use must improve to expand area under irrigation while also conserving water. Irrigation infrastructure in India has seen substantial expansion over the years. The total irrigation potential created (IPC) has increased to 113 million ha at the end of the 11th Plan. The scope for further expansion of irrigation infrastructure on a large scale is limited. Over the years, there has been significant shift in the sources of irrigation. The share of canal in net irrigated area has declined from 39.8 % in 1950-51 to 23.6 % in 2012-13. Alongside, the share of groundwater sources has increased from 28.7 % to a whopping 62.4 % during the same period. This expansion reflects the reliability and higher irrigation efficiency of 70–80% in groundwater irrigation compared with 25-45% in canal irrigation. While proving to be a valuable source of irrigation expansion, injudicious utilization of groundwater through the explosion of tube wells has raised several sustainability issues (Vibha Dhawan, 2017).

Given the numerous challenges and the large share of water withdrawn for agriculture, irrigation and drainage, management has to address emerging climatic, technical, economic and organizational aspects through a holistic and integrated approach. In addition, increasing the surface water storage and its use has to be optimized by improving efficiency of delivery, increasing productivity and expanding irrigated area without withdrawing additional water. Measures need to be adopted in order to do this.

Some of these measures are to conserve, reuse and recycle water; to adopt improved water management and agronomical practices including water saving micro irrigation technologies such as drip irrigation, sprinkler irrigation, etc.; to reclaim degraded land; and to promote participatory irrigation management.

Different approaches have been put forward for using water efficiently, some are listed below.

1. The method of irrigation followed in the country is flood irrigation, which results in a lot of water loss. Greater efficiency in irrigation were achieved through:
    - Proper designing of irrigation system for reducing water conveyance loss.
    - Adoptions of water saving technologies such as sprinkler and drip irrigation systems have proven extremely effective in not just water conservation but also leading to higher yields.
    - New agronomic practices like raised bed planting, ridge-furrow method of sowing, sub-surface irrigation, and precision farming which offer a vast scope for economizing water use.

In this context, the Indian government has tried to inculcate new policies and schemes to improve agricultural productivity, while simultaneously increasing water use efficiency. The Indian government introduces schemes as commendable effort to increase irrigated area. One example is the launching of ~ USD 7,5 billion "Pradhan Mantri Krishi Sinchai Yojana (PMKSY)". This scheme provides a sound framework for the expansion and effective water use in irrigation. The impact of this scheme can be greatly enhanced, however, by restoring the original flexibility of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) in asset creation. Despite these efforts, still a specialized solution is required in chronically water stressed areas where measures implemented until now were ineffective.

2. Water productivity can be improved by adopting the concept of multiple water use, which is beyond the conventional sectoral barriers of the productive sectors. There is scope for increasing income through crop diversification and integration of fish, poultry and other enterprises in the farming system. The multiple water use approach can generate more income benefits, and decrease vulnerability by allowing more diversified livelihood strategies and increasing the sustainability of ecosystems.
3. Emphasis should be given on water resources conservation through watershed development in suitable areas and development of micro-water structures for rainwater harvesting. The promotion of water conservation efforts has direct implications for water resources availability, groundwater recharge, and socio-economic conditions of the population.

4. The effective water management is critically linked with the performance of local level water institutions. Therefore, institutional restructuring in favor of participatory irrigation management and water users associations (WUAs) needs to be strengthened.

Karnataka, one of India's most water scarce states, has a major challenge at hand. Its agricultural and economic growth aspirations will lead to an estimated 60 per cent increase in water demand by 2030. Karnataka will be unable to meet this demand unless it focuses on a state-driven comprehensive transformation of its water and agriculture sectors.

With agriculture accounting for 80 per cent of water use in the state, water efficiency in agriculture is a critical lever not just in meeting Karnataka's aspirations for agricultural growth, but also making water available for other sectors. Further, given that agriculture accounts for 61 per cent of employment in Karnataka, improving agricultural productivity will be essential to improve farmer income.

More ever the water management research in Karnataka remained confined to agricultural universities, institutes and research stations. The agricultural scientists of those organizations did not have much opportunity to interact with irrigation engineers and farmers in tackling on-farm water management problems. This has created a gap between the available research findings and their utilization for improving the design and operation of irrigation systems. In addition, optimum irrigation schedules for different arable or irrigated dry (ID) crops and cropping system, including intercropping, besides, seasonal water requirements, irrigation requirements and consumptive water use, progressive and peak consumptive water use rates, crop factors and soil moisture extraction patterns of different crops have been worked out for a limited number of crops. Moreover, some experiments have been conducted to evaluate different irrigation methods aiming at uniform application of required water depth to have better control of applied water to match the soil moisture deficit in the root zone before each irrigation in order to obtain higher efficiencies of water application and use.

The spatial and temporal adjustments between source/ supply and utility of water as a resource led to its scarcity in the place and time it is most needed. In recent years, its scarcity has not only jeopardized the agricultural production but also upset rural, urban and industrial development. Managing the water resources through scientific basis and organizing its developmental programmes including recycling and reuse has been a prioritized agenda at this juncture. A long term planning of water resource management for soil-water-crop in relation with weather modeling and remote sensing in Karnataka is absolutely necessary to achieve higher productivity without hampering the soil fertility. Hence, water efficient cropping systems, through crop diversification and integrated farming systems, location specific crops and cropping system models through farmer's participatory approach is the need of an hour.

To ensure that Karnataka has the water required to meet its economic growth aspirations, the state should embark on a comprehensive transformation of its water and agriculture sectors. The first step in such a transformation is to envision the end-state. Karnataka can set itself a vision of becoming the most progressive state in India in the areas of agriculture and water use. This will help unlock the potential to increase farmer income by 50 per cent by 2020 and by 100 per cent by 2030, thus improving the living standards of the large farmer community in the state.

Achieving this vision requires a state-driven transformation in water and agriculture, with private sector involvement in select areas. The transformation should leverage innovative but proven technologies in irrigation, agriculture and project execution, particularly focused on rice and sugarcane. The vision can encompass several focus areas: enabling agriculture to grow at an annual rate of 4 per cent; ensuring adequate service levels; allocating irrigation water equitably to all; and ensuring sufficient water is available for basic human needs, growth of industry.

Both surface and ground water resource management pose diverse and complicated challenges such as i) Ways and means to economize the water use, ii) Methods to conserve the water and develop water resources, iii) Strategies for economical and sustainable water use, iv) Water management research and related issues and v) Methods to fix, revise and rationalize water rates. In general, the over exploitation of underground resources, wastage of surface water, poor knowledge of water resource management; lack of policy initiatives and participatory approach indicate an obscure and insecure future, if proper strategies are not adopted to address these issues in holistic approach.

Keeping the above in view, the project, "**ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND"** was taken up by University of Agricultural Sciences, Bengaluru with Rashtriya Krishi Vikas Yojana funding. The project was implemented from 2013-14 to 2018-19. The details of the project are as under:

1.	**Title of Project**	:	**"ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND"**
2.	**Nodal officer and Principal Investigator**	:	**Dr. C. Ramachandra, Professor of Agronomy,** Zonal Agricultural Research Station, VC Farm, Mandya, UAS, GKVK, Bengaluru

3.	**Implementing Institution (S) and other collaborating Institution (s)**	**:**	**Zonal Agricultural Research Station, VC Farm, Mandya**
4.	**Date of commencement of Project**	**:**	2013-14
5.	**Approved date of completion**	**:**	2018-19
6.	**Actual date of completion**	**:**	2018-19
7.	**Project cost**	**:**	Rs. 200 lakhs

The objectives of the project are as follows:

a. To conduct, co-ordinate and promote applied water research through multi-disciplinary approach.

b. To collect, collate and disseminate information relating to available water resources and water management research and effective utilization of water.

c. To function as a nodal agency for planning, programming and policy making in the management of water at all levels.

d. To act as a nerve-centre in organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management.

The focus of Evaluation is:

i. To evaluate the usefulness of various applied water research studies taken up through multi-disciplinary approach.

ii. To evaluate the relevance of information collected relating to available water resources and water management research and effective utilization of water.

iii. To evaluate the impact of organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management.

FINDINGS AND DISCUSSION

<u>Research on water management</u>

The Centre has conducted 15 applied research studies on various crops and cropping systems. In most of the studies, the effect of various irrigation management practices and nutrition on crops was evaluated. The results were mostly confined to assessing the effect on yield of crops and in some cases on water use efficiency and water productivity. In most experiments conducted, the parameters like irrigation methods and nutrition were combined. As a result, the singular effect of irrigation management practices on crop yield could not be independently assessed. In most studies, the economics of the various treatments have not been assessed.

The studies have brought to sharp focus the advantages of System of Rice Intensification (SRI), Mechanized system of rice cultivation and Aerobic method of rice cultivation over traditional practices and a large number of farmers in the command area have started adopting these practices. The studies have also revealed that the drip fertigation and sprinkler irrigation methods area not ideally suited in rice cultivation.

While studies have been conducted on use of micro irrigation techniques in various crops, there is need to understand the water use pattern in various planting geometry such as paired row planting, wider rows etc. The focus of these studies should have been on water saving without affecting the crop yields.

The need for application of micro nutrients has been demonstrated in some studies.

The studies on characterization of water availability and management in the canal command area have not been able to bring out measured needed to solve the problems faced by tail end farmers.

No appreciable benefit appears to have accrued from the study on applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping of V C Farm, Mandya, Karnataka. Its relevance to the project needs to be elaborated.

A detailed study of the Cauvery command area pertaining to the available water resources, storage capacity of reservoirs, command area of the reservoirs, area of crops cultivated, irrigation potential created and present usage, cropping systems and their water use efficiency, soil types has been made and issues relating to water productivity have been collected. The information gathered has been comprehensive and gives a holistic view of the command area. The present scenario of the command area, reasons for poor water productivity and approaches to improve water use efficiency have been well detailed.

The centre has organized 38 training programmes/ workshops/ seminars/ brainstorming sessions/ world water day to educate the farmers on importance of water and adopting of water saving technologies for enhancing Water Use Efficiency in field crops. Around 4734 farmers have participated and benefitted from the programmes.

Large scale demonstration programmes have been conducted in farmers' fields in the command area to show case the advantages of methods of improved irrigation management practices. The large scale adoption of SRI, DSR, Mechanized rice cultivation and aerobic rice method by farmers is the culmination of the efforts of the scientists. The demonstrations have also been successful to help educate the farmers on use of water saving irrigation techniques like subsurface drip irrigation and sensor based drip irrigation. The feedback received from farmers has exemplified the efforts made by the scientists in educating the farmers.

REFLECTIONS AND CONCLUSIONS

1. The results of the research studies were mostly confined to assessing the effect on yield of crops and in some cases on water use efficiency and water productivity.
2. The singular effect of irrigation management practices on crop yield could not be independently assessed.
3. In most studies, the economics of the various treatments have not been assessed.
4. The studies have brought to sharp focus the advantages of System of Rice Intensification (SRI), Mechanized system of rice cultivation and Aerobic method of rice cultivation over traditional practices and a large number of farmers in the command area have started adopting these practices.
5. The studies have also revealed that the drip fertigation and sprinkler irrigation methods area not ideally suited in rice cultivation. Drip fertigation in aerobic / direct seeded rice is ideal under tail end areas and water scarcity situation. Hence this technology may be popularized through extensive demonstration and educating farmers on adoption of drip irrigation with an objective of considerable saving water besides improving soil health.
6. There is need to understand the water use pattern in various planting geometry such as paired row planting, wider rows etc.
7. The focus of the studies should have been on water saving without affecting the crop yields.
8. The studies on characterization of water availability and management in the canal command area have not been able to bring out measured needed to solve the problems faced by tail end farmers.
9. The relevance to the project study on applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping needs to be elaborated. A case study was conducted at Zonal Agricultural Research Stations to know the physiography and soil types for adoption of micro irrigation under various soil textures in order to improve the water use efficiency. The results are yet to be compiled.
10. The information gathered in the study of the Cauvery command area pertaining to the available water resources, storage capacity of reservoirs, command area of the

reservoirs, area of crops cultivated, irrigation potential created and present usage, cropping systems and their water use efficiency and soil types has been comprehensive and gives a holistic view of the command area. The present scenario of the command area, reasons for poor water productivity and approaches to improve water use efficiency have been well detailed.

11. The demonstrations and training programmes have comprehensively influenced the farmers to adopt new methods of irrigation management methods and techniques.
12. The project has not been able to conclusively demonstrate to the farmers the need for crop diversification. However, on station research and demonstration focused on crop diversifications viz., ragi, maize, leguminous crops like red gram, cow pea, avare and vegetable crops were conducted by involving scientists of crop improvement, protection and production team.

ACTION POINTS

a. The project has been meticulously planned and well executed. The integration of research projects with demonstration farms and training and education platforms for farmers is a novel idea which has borne exemplified results worth emulating.
b. The Water Technology Centre is only one of its kind in the entire State. There is need to establish similar water technology centres in other command areas to study the problems in irrigation management methods and techniques in those areas.
c. There is need to design research studies to evaluate the various irrigation management methods to determine their effect on water use pattern, water use efficiency, water savings and economics of the use of the method.
d. The impact of irrigation management techniques like drip, subsurface irrigation on soil characteristics and soil microflora needs to be evaluated.
e. There is need to design demonstrations to educate the farmers, especially tail end farmers, on crop diversification.
f. There is need to draw a calendar of training programmes to educate the farmers in the command area on water saving techniques.
g. Although, some government line departments were involved in the project, the convergence of line departments is necessary for better implementation of similar projects.
h. One of the objectives of the project was that the Water Technology Centre should act as a nerve-centre in organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management. This objective has only been partially achieved. There is need to

identify the Water Technology Centre as a policy making agency with regard to irrigation management practices.

ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND

INTRODUCTION

India is an agrarian society and the agricultural sector accounts for 18% of India's gross domestic product (GDP) while providing employment to 50% of the country's workforce. India is one of the largest producers of fresh fruits and vegetables, milk, major spices, several crops such as jute, staples such as millets and castor oil seed. Apart from this, India is also the second largest producer of wheat and rice. India initiated its own Green Revolution programme in the field of plant breeding, irrigation development and financing of agrochemicals after 1960. The Green Revolution had several benefits, such as increase in production due to the use of high-yielding varieties of seeds, crop genetic improvements and irrigation, which led to widespread poverty reduction. However, the unabated adoption of unsustainable agricultural techniques and practices (high dependence on chemical fertilizers and pesticides) by farmers to produce more had an adverse impact on the environment. There were reports of loss of soil fertility, deteriorating state of water resources, pollution of groundwater and increase of salinity in groundwater. In 2018, the National Institution for Transforming India (NITI Aayog) also stated that around 600 million Indians are now facing high to extreme water stress situation because of growing population and the ever-increasing demand for food (Qazi Syed Wamiq Ali and Nathaniel B Dkhar, 2019).

Irrigation is one of the important inputs of scientific crop production. Water is a critical input into agriculture in nearly all its aspects having a determining effect on the eventual yield. Good seeds and fertilizers fail to achieve their full potential if plants are not optimally watered. The availability of adequate, timely and assured supply of water is an important determinant of agricultural productivity. Irrigation, in addition to raising productivity and cropping intensity, will also facilitate shifts in cropping patterns. Irrigated agriculture contributes to about 40 percent of the global food production from an estimated 20 percent of agricultural land, or about 300 million ha globally. It also has a very long historical tradition of irrigated crops. Some of the Indian irrigation systems are more than ten centuries old. India has the largest irrigated area in the world. Irrigated farmland typically generates three times the production of an equivalent area farmed under dry-land systems.

India accounts for about 17% of the world's population but only 4% of the world fresh water resources. Distribution of these water resources across the vast expanse of the country is also uneven. The increasing demands on water resources by India's burgeoning population and diminishing quality of existing water resources because of pollution and the additional requirements of serving India's spiraling industrial and agricultural growth have led to a situation where the consumption of water is rapidly increasing while the supply of fresh water remains more or less constant. As a result, the emphasis of the Central and State Governments in all development programmes like five year plans has been on utilizing the vast irrigation water resources of the country through implementation of irrigation projects.

A look in the past few decades shows that the net sown area has increased from 118 million hectares in 1950-51 to about 140 million hectares in 2014. It has not shown any noticeable expansion since 1970. The green revolution in the late sixties has rescued us from food grain shortage and made us self-sufficient. This was possible through the use of HYV seeds, fertilizers and expansion of irrigation facilities through government's initiatives. From about 16.9 percent of net irrigated area we have reached a figure of 40 percent. There are in all 119 major and 176 medium irrigation projects in the country. The efforts of the Governments have yielded rich dividends and nearly 65.6 % of the ultimate irrigation potential has been developed. From 22.6 million hectares of irrigation potential in 1950, today more than 90 million hectares of land have been brought under irrigation through major and medium (31.50 million hectares) and minor irrigation projects (57.96 million hectares). The ultimate irrigation potential of India is estimated as 139.95 million hectares including 56.00 million hectares by major and medium projects and 81.05 million hectares by minor irrigation projects comprising 17.40 million hectares by surface minor irrigation projects, 64.05 million hectares by ground water irrigation projects.

This progress is not without its cost. There have been serious consequences of indiscriminate withdrawal of water for irrigation (GOI, 2005 and Directorate of Economics and Statistics, 2016). The water table has gone down and expansion of irrigation in arid and semiarid areas has also caused the problem of salinity and water logging. In the light of limited land and scarce water resources the challenge of increasing agricultural production is immense. It has been anticipated that India's population may rise around 1.6 billion by 2050 (present about 1.28 billion). The factors like haphazard urbanization, industrialization and pollution of water sources will put heavy stress on limited and scarce water resources. India faces a challenging task of feeding population requiring about 380 million tonnes of food grains as against the present food production of about 260 million tonnes (IAI–FICCI 2015 and ICID, 2016). Increased frequency and intensity of climatic extremes due to the impacts of climate change is likely to adversely impact the availability and quality of water resource (Khetwani and Singh, 2018). Many parts of the developing nations like India, experience seasonal water scarcity on a regular basis (ICID, 2016 , IAI–FICCI 2015 and Khetwani and Singh, 2018). In order to mitigate regional and seasonal water scarcity and ensure food and nutrition security, and increase farmer income, it is necessary to conserve and store water through creation of all kinds of storage and adoption of new innovative practices ((ICID, 2016 , IAI–FICCI 2015).

India with 17 percent of the world population has merely 4 percent of the world fresh water resources. It has a very low per capita water availability which puts it in the category of waterstressed nation. The average annual water availability in India is estimated to be 1869 billion cubic meters (BCM). However, due to hydrological, topographic and other constraints, the utilizable water is expected to be about 1123 BCM, out of which 690 BCM is from surface water and 433 BCM from replenishable groundwater.

The burgeoning world population and ever increasing need of water is likely to cause water scarcity in the coming decades. India with a high population growth and millions of mouths to feed has immense pressure on agriculture. Even after seven decades of independence agriculture in India is primarily dependent on monsoons (INCID, 1994 and Narayanamoorthy, 1997). Farmers in India can play an active role in adopting efficient irrigation practices minimizing the wastage of water to a great extent. A large proportion of farmers in India falls in the small and marginal category (Narayanamoorthy, 1999 and 2005). All this background gives a very critical picture of the future of agriculture in India unless some radical agricultural practices are introduced to raise the production.

Surveys conducted by the Tata Institute of Social Sciences (TISS) showed most of urban cities are water deficient. Nearly 40% of water demand in urban India is met by ground water. As a result, ground water tables in most cities are falling at alarming rate of 2-3 meters per year. Water scarcity has many negative impacts on the environment, including lakes, rivers, wetlands, and other fresh water resources. Additionally, water overuse can cause water shortage, often occurs in areas of irrigation agriculture, and harms the environment in several ways including increased salinity, nutrient pollution, and the degradation and loss of flood plains and wetlands. Furthermore, water shortage makes flow management in the rehabilitation of urban streams problematic. Owing to poor water resource management system and climate change India faces a persistent water shortage. As per OECD environmental outlook 2050, India would face severe water constrains by 2050. Indian agriculture accounts for 90% water use due to fast track ground water depletion and poor irrigation systems.

The average size of the around 138 million farms in India was around 1.15 ha in 2010/11 and average size of large-scale farmers' farms (1,70,000) is around 37 ha in 2016 (BMEL India country report 2016). Agricultural extension has only one extension worker per 800-1000 farmers and degree of mechanization reaches less than 50% (BMEL India country report 2016). Indicators of water stress and scarcity are generally used to reflect the overall water availability in a country or a region. As per the international norms, a country is classified as water stressed and water scarce if per capita water availability goes below 1700 m^3 and 1000 m^3, respectively. With 1544 m^3 per capita water availability, India is already a water-stressed country and is moving towards turning into water scarce.

As a result of climate change the country has been witnessing drought and flood at the same time, which has impacted agriculture productivity. About 40 million ha of the country is flood prone and every year about 8 million ha is affected by floods. The waterlogged area in the country is about 11.6 million ha.

Droughts have severe impacts on economy, society and environment affecting crops, irrigation, livestock, wildlife, soil, health problems, public safety ultimately leading to severe loss to human life. The latest findings suggest that while there have been alternate dry and wet spells over the past three decades, the frequency of occurrence of drought years has significantly increased in India. The period between 1950 and 1989 had 10 drought years, while there have been 5 droughts in the last 16 years (since 2000). According to meteorologists the frequency is set to increase between 2020 and 2049 (Collison, A. et al., 2000). Indian agriculture is crucially dependent on the local climate: favorable southwest summer monsoon is critical in securing water for irrigating crops. In some parts of India, the lack of monsoons results in water shortages, resulting in below-average crop yields. Droughts mean less water availability for agriculture than usual. Increased groundwater use during droughts can help overcome such critical periods. However, the resulting groundwater overuse and quality deterioration mean there is also less groundwater available for agriculture than there was before, thereby causing even more pressure on agricultural production.

Nearly 70% of Indian agriculture is rainfed. With evolution of technology based cropping systems and increasing frequency of droughts, if India has to emerge unscathed from the vagaries of monsoon, it would need to think innovatively of increasing irrigation potential and enlightened water use.

India is not a water rich country and is further challenged due to negative impact of climate change; enormous wastage owing partly to poor management and distorted water pricing policies. The Northern Ganga River Basin has abundant water resources, whereas the Southern River Basin has few, but with high levels of pollution in ground water and surface water. Increase in population and changing lifestyles has increased demand for water (largely for irrigation) in both urban and rural areas. India has 18% of world population, having 4% of world’s fresh water, out of which 80% is used in agriculture. India receives an average of 4,000 billion cubic meters of precipitation every year. However, only 48% of it is used in India’s surface and groundwater bodies (Vibha Dhawan, 2017). A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used. India’s annual rainfall is around 1183 mm, out of which 75% is received in a short span of four months during monsoon (July to September). This result in run offs during monsoon and calls for irrigation investments for rest of the year. The population of India is likely to be 1.6 billion by 2050, resulting in increased demand for water, food and energy. This calls for infrastructure expansion and improved resource utilization.

At present, irrigation consumes about 84 %of total available water. Industrial and domestic sectors consume about 12 and 4 %of total available water, respectively. With irrigation predicted to remain the dominant user of water, “per drop more crop” is an imperative. The efficiency of water use must improve to expand area under irrigation while also conserving water. Irrigation infrastructure in India has seen substantial expansion over the years. The total irrigation potential created (IPC) from major, medium and minor irrigation schemes has increased from 22.6 million ha during pre-plan period to 113 million ha at the end of the 11th Plan. Because this irrigation potential represents 81% of India’s ultimate irrigation potential estimated at 140 million ha, the scope for further expansion of irrigation infrastructure on a large scale is limited. Over the years, there has been significant shift in the sources of irrigation. The share of canal in net irrigated area has declined from 39.8 % in 1950-51 to 23.6 % in 2012-13. Alongside, the share of groundwater sources has increased from 28.7 % to a whopping 62.4 % during the same period. This expansion reflects the reliability and higher irrigation efficiency of 70–80% in groundwater irrigation compared with 25-45% in canal irrigation. While proving to be a valuable source of irrigation expansion, injudicious utilization of groundwater through the explosion of tube wells has raised several sustainability issues (Vibha Dhawan, 2017).

Although overall development of groundwater (groundwater draft as a proportion of the total availability) is 62.4 %, there exists wide regional variability. Over-dependence on groundwater beyond sustainable level use has resulted into significant decline in the groundwater table, especially in northwest India. The Central Groundwater Board has categorised 16.2 % of the total assessment units: Blocks, Mandals or Talukas numbering 6607 as ‘Over-exploited’. It has categorized an additional 14% as either at ‘critical’ or ‘semi-critical’ stage. Most of the over-exploited blocks are in northwest region of the country. The unsustainable groundwater use necessitates demand management and supply augmentation measures for improved water use efficiency in agriculture sector. On the other hand, Eastern region, where groundwater utilization is on a limited scale, offer greater scope for harnessing the benefits of groundwater usage to improve crop yields. Linkage of Canals (use of surface water): building storage reservoirs on rivers and connecting them to other parts of the country can impose reduction in regional imbalances and provide lot of benefits by way of additional irrigation, domestic and industrial water supply, hydropower generation, navigational facilities etc.

As per the assessment carried out by the Central Ground Water Board (CGWB) in 2011, India’s total annual replineshable groundwater resource is around 433 billion cubic meters (BCM) and net annual ground water availability is 398 BCM of which India withdraws 245 BCM (62%) annually. According to the CGWB, around 39% of the wells are showing a decline in groundwater level.

Given the numerous challenges and the large share of water withdrawn for agriculture, irrigation and drainage, management has to address emerging climatic, technical, economic and organizational aspects through a holistic and integrated approach. In addition, increasing the surface water storage and its use has to be optimized by improving efficiency of delivery, increasing productivity and expanding irrigated area without withdrawing additional water. Measures need to be adopted in order to do this. Some of these measures are to conserve, reuse and recycle water; to adopt improved water management and agronomical practices including water saving micro irrigation technologies such as drip irrigation, sprinkler irrigation, etc.; to reclaim degraded land; and to promote participatory irrigation management.

Different approaches have been put forward for using water efficiently, some are listed below.

1. The method of irrigation followed in the country is flood irrigation, which results in a lot of water loss. Greater efficiency in irrigation were achieved through:

- Proper designing of irrigation system for reducing water conveyance loss.
- Adoptions of water saving technologies such as sprinkler and drip irrigation systems have proven extremely effective in not just water conservation but also leading to higher yields.
- New agronomic practices like raised bed planting, ridge-furrow method of sowing, sub-surface irrigation, and precision farming which offer a vast scope for economizing water use.

In this context, the Indian government has tried to inculcate new policies and schemes to improve agricultural productivity, while simultaneously increasing water use efficiency. The Indian government introduces schemes as commendable effort to increase irrigated area. One example is the launching of ~ USD 7,5 billion “Pradhan Mantri Krishi Sinchai Yojana (PMKSY)”. This scheme provides a sound framework for the expansion and effective water use in irrigation. The impact of this scheme can be greatly enhanced, however, by restoring the original flexibility of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) in asset creation. Despite these efforts, still a specialized solution is required in chronically water stressed areas where measures implemented until now were ineffective.

2. Water productivity can be improved by adopting the concept of multiple water use, which is beyond the conventional sectoral barriers of the productive sectors. There is scope for increasing income through crop diversification and integration of fish, poultry and other enterprises in the farming system. The multiple water use

approach can generate more income benefits, and decrease vulnerability by allowing more diversified livelihood strategies and increasing the sustainability of ecosystems.

3. Emphasis should be given on water resources conservation through watershed development in suitable areas and development of micro-water structures for rainwater harvesting. The promotion of water conservation efforts has direct implications for water resources availability, groundwater recharge, and socio-economic conditions of the population.
4. The effective water management is critically linked with the performance of local level water institutions. Therefore, institutional restructuring in favor of participatory irrigation management and water users associations (WUAs) needs to be strengthened.

DRIP IRRIGATION

While research in the new varieties of seeds and their implications is going on across the world, new irrigation practices are also adopted to enhance water efficiency (Raman, 2010 and Palaniswamy Raman, 2012) Out of the total groundwater withdrawal about 75 to 80% goes to agricultural sector alone (Directorate of Economics and Statistics, 2016 2004 and 2015). In the field of using innovation in irrigation practice drip method of irrigation was introduced in India in the early seventies in universities and research institutions. Its adoption gave encouraging results at these places. As a result, serious efforts began to be made towards its adoption in the eighties (Keller, 1990). The practice has huge potential if our farmers adopt it in a big way. Adoption of drip method has borne fruits and countries like USA, Israel, Australia and Mexico have shown wider expansion of this practice. Israel is a country which has shown rapid progress in terms of its adoption, it also exports this technology and made it a profitable venture in commercial terms. They patented the first practical surface drip irrigation emitter (NCPAH, 2005 and Shivanappan, 1994). The goal of adoption of drip irrigation in a big way in India is not as easy as it seems, it is full of constraints and challenges. The diverse physiography, size of population, economically weak farmers and types of crops grown limit its rapid spread and to a great extent acts as a hurdle in achieving a hundred percent utilization of its potential in the country. Proper assessment and identification of the potential a country holds and the major areas of challenges if addressed successfully would revolutionize the irrigation practice by saving wastage of over 50 percent of water every year along with increasing the output. This would go a long way towards the goal of ensuring food security and saving the scarce water resource (Dhawan, 2017 and ICID, 2016).

Drip Irrigation is a form of irrigation practice that makes efficient use of water by supplying water to the roots in a manner where water drips slowly to the roots of plants through an arrangement of pipes, valves and emitter. The aim is to eliminate any wastage of water through evaporation or percolation and derive maximum benefits out of it. This technology aims to save water and therefore its adoption becomes indispensable particularly for India where we face water scarcity and also need to increase our productivity. This stressful scenario can be addressed to a large extent if we shift towards this system (IAI–FICCI 2015). The consumption of water to produce a unit of major food crop in India is 2 to 3 times more than Brazil and China. This indicates that it has very low water use efficiency in comparison with these countries. As mentioned earlier agricultural sector accounts for around 70 percent of the global freshwater withdrawals and the use of micro irrigation has potential to increase crop productivity while saving water. Therefore, its adoption in almost all the countries is one of the viable solutions that should be adopted immediately (FAO, 2017). Several regions of India are facing severe water crisis. These comprise districts and subdistricts of southern and northern regions of Karnataka; Rayalseema region; Vidarbha and Marathwada; Rajasthan and Bundelkhand region. The water storage in reservoirs has depleted due to unsustainable irrigation practices further leading to acute scarcity of drinking water during drought years. Adoptions of water saving microirrigation technologies have proven extremely effective in not only reducing the wastage of water but also leading to higher crop yields. Studies revealed that microirrigation technologies have helped in bringing positive change in several areas of the country particularly in Deccan plateau region and western Rajasthan areas where no other methods of irrigation can work better (((ICID, 2016 , IAI–FICCI 2015 and Dhawan, 2017). Consecutive droughts occurring in 2012, 2015 and 2016 has led to the emergence of microirrigation as a key policy priority in India for mitigating water scarcity. But, an indepth investigation into the criticalities across India's varied farms and river basins, linked with water resource management reveals that microirrigation program in India is coping with a risk of failure, the study also raised the need for the identification of critical factors associated with microirrigation technologies (Global Water Forum , 2017).

EMERGING CHALLENGES IN IRRIGATION

1. Given the numerous challenges and the large share of water withdrawn for agriculture, irrigation and drainage, management has to address emerging climatic, technical, economic and organizational aspects through a holistic and integrated approach. In addition, increasing the surface water storage and its use has to be optimized by improving efficiency of delivery, increasing productivity and expanding irrigated area without withdrawing additional water. Measures need to be adopted in order to do this. Some of these measures are to conserve, reuse and recycle water; to adopt improved water management and agronomical practices including water saving micro irrigation technologies such as drip irrigation, sprinkler irrigation, etc.; to reclaim degraded land; and to promote participatory irrigation management.
2. The contribution of irrigation and drainage as an essential tool deployed for ushering in Green Revolution and achieving food self-sufficiency in the country is fully recognized. The past few years saw a decline in the investment towards the

irrigation and drainage sector; also, there has hardly been any expansion of irrigated areas. Growing emphasis needs to be placed on improved management of irrigation schemes already constructed in order to improve their performance and ensuring that they provide multiple benefits such as conserving limited water supplies, reducing the impact of irrigation on water quality, and enhancing net returns for the farmers. The performance of major surface irrigation systems in our country is caught in the vicious cycle of neglect, deferred maintenance and rehabilitation. This issue needs to be addressed.

3. At the same time, it has to be recognized that the expansion of irrigated agriculture is essential as a strategy for meeting the demands of future food security of India's galloping population. Irrigated agriculture will also improve the livelihood opportunities in rainfed agriculture by providing the farmers with irrigation facilities, wherever feasible. This calls for innovative strategies for improving efficiency of water use and productivity.
4. Groundwater irrigation in India developed during the later years of Green Revolution and contributed significantly towards increasing the gross irrigated area of the country expanding it from 5 million ha to 35 million ha over a period of 50 years. However, due to unregulated groundwater withdrawals supported by faulty policies, many states are experiencing a fast decline in groundwater level leading to lower productivity of water and causing a decrease in irrigation intensity. Irrigation intensity is lower among southern states where the groundwater depletion problem is severe.
5. There is little realization among the policy makers, that the lack of capacity to absorb new technologies in the irrigation and agriculture departments is one of the major impediments in providing equitable and reliable irrigation and drainage services. Lack of utilization of the emerging technologies is posing a constraint in the sustainable growth and productivity of irrigated agriculture. There is need for a well-informed, skilled and technology savvy contingent of agriculture scientists, irrigation engineers, and extension service workers to support this effort.
6. There is an urgent need for capacity assessment of irrigation institutions to deliver the mandate that is assigned to them. Systematic efforts towards capacity development at the institutional as well as individual level cannot be given a secondary thought. An enabling environment needs to be created by encouraging networking and knowledge sharing. The irrigation staff should be exposed to the new technologies and latest techniques of management.
7. Doubling the income of farmers by 2022 will require the transformation of irrigated agriculture – to become a responsive, service oriented, component of the agricultural production enterprise.
8. There is ambiguity in understanding and evaluating irrigation performance among the irrigation specialists, policy makers and general public. Hence, a scientific understanding is called for. Irrigation efficiency, defined in terms of estimated

water requirement (m^3) relative to water applied or withdrawn (m^3) from a source, is a useful indicator of the "losses" in the distribution, conveyance, and application of irrigation water. This type of an indicator is appropriate for farm-scale irrigation investment and management decisions; design of irrigation conveyance and application systems and "real-time" monitoring and evaluation of irrigation system operational performance. However, it does not account for the capture and reuse of water within broader hydrologic systems (e.g., basins) and can lead to incorrect water allocation and investment decisions and faulty public policy at the basin scale.

9. On the other hand water productivity is defined in terms of output – quantity of crop in kg; nutrition in kcal; or net income to farmer in, $ vis-à-vis per unit of water use (water withdrawn, applied or consumed). Productivity can be used as a criterion as it is appropriate for water allocation decisions between uses (basin and farm scale) and post-season performance assessment of irrigated agriculture. It is not applicable for operational management decisions and is more complex to evaluate. But it provides an answer to the question of how well the irrigated agriculture is performing.
10. Performance of surface irrigation is often poor. Improving performance in irrigation requires capacity at farms and fields; technologies to improve operation of canals and drains; enhanced management of irrigation services; and leadership and integrated actions. Improving performance of irrigation systems requires strengthening links between the main system and farmers' fields. Poor irrigation services result in expansion of groundwater use and local storage and consequent poor cost recovery.
11. Improved farmer knowledge and simple tools and processes can improve water productivity. For example, laser grading and levelling can transform performance and reduce energy costs. Sprinkler, drip and trickle irrigation systems can reduce labour, fertilizer and water requirements. On-farm storage and/or access to groundwater help meet farmers' requirement for reliable irrigation water supply as and when it is required. This also enables farmers to get higher crop productivity. However, to achieve these goals, capacity building of farmers is essential.
12. Modernization is the process of upgrading infrastructure, operations and management of irrigation and drainage systems to sustain the water delivery service requirements of farmers as well as optimize production and water productivity. It is important, therefore, to first analyse and understand the real ground situation such as what level of water delivery service does the system currently provide; what hardware (infrastructure) and software (operational procedures, institutional setup, etc.) features affect the level of service; what improvements in the various components could make a significant difference in service delivery to users. Once rehabilitated, or otherwise, it is essential to manage irrigation assets for long-term performance. The current practice that tends

towards deferred maintenance (buildignore- rehabilitate-ignore) needs to be avoided.

KARNATAKA

Karnataka State is the eighth largest State in the country and is located in the Deccan plateau. The geographical area of Karnataka is 1,91,791 sq.km accounting for 5.83% of the total area of the country. The average annual yield of the rivers of the Karnataka has been roughly estimated as 98406 m.cum. (3475 TMC). However, the economically utilisable water potential for Irrigation is about 48,000 Mcum (1695 TMC).

The development of Irrigation in the state was slow and unsystematic during the pre independence era. However, there were some notable Irrigation works undertaken and completed during the pre-independence, such as Krishnaraja Sagar (which was the only major project completed prior to independence), Vijayanagar canals, Cauvery anicut Channels, Gokak canal, Vanivilasa Sagar, Markonahalli and Anjanapura. Though major projects like Tungabhadra, Bhadra and Ghataprabha stage-I were commenced prior to the plan period, their progress was slow and they got impetus only after their inclusion in the first five year plan. There were more than 25,000 tanks scattered over erstwhile Mysore state. But in Bombay Karnataka and Hyderabad Karnataka areas, the number of such minor irrigation works are meager. Up-to the end of March 2017 a total irrigation potential is 28,73,610 ha (Major & Medium Irrigation projects).

Karnataka, one of India's most water scarce states, has a major challenge at hand. Its agricultural and economic growth aspirations will lead to an estimated 60 per cent increase in water demand by 2030. Karnataka will be unable to meet this demand unless it focuses on a state-driven comprehensive transformation of its water and agriculture sectors.

With agriculture accounting for 80 per cent of water use in the state, water efficiency in agriculture is a critical lever not just in meeting Karnataka's aspirations for agricultural growth, but also making water available for other sectors. Further, given that agriculture accounts for 61 per cent of employment in Karnataka, improving agricultural productivity will be essential to improve farmer income.

Based on the current cropping pattern and yield improvement of 1 per cent per annum based on historical trends, Karnataka's growth aspirations will result in water demand increasing from 885 TMC in 2008, to 1,057 TMC by 2020, and to 1,397 TMC by 2030. By 2030, agricultural water demand alone is projected to increase by 33 per cent to 1,003 TMC; domestic water demand to double to 120 TMC; and industrial water demand to quadruple to 274 TMC. Karnataka's current sustainable water supply is estimated at 761 TMC, net of losses such as conveyance before the consumption point (i.e., the farm gate for agriculture). This is a combination of 497 TMC of net sustainable supply from surface water and 264 TMC of net sustainable supply from ground water. With total water demand in 2030 projected at 1,397 TMC and current sustainable supply at 761 TMC, Karnataka needs to find demand- and supply-side solutions that can address the incremental demand of 636 TMC.

Historically, the state government has responded to increased water requirement by tapping additional surface and ground water sources. The study estimates that, based on the state's water resources, an additional 290 TMC of net surface and ground water supply can be added in principle, if all sources of sustainable supply are tapped and operated at current levels of efficiency. Therefore, tapping all available supply options will address less than half of Karnataka's 636 TMC of incremental water requirement by 2030. In reality, the challenge is likely to be even greater if we account for the difficulties associated with executing surface water irrigation projects – long gestation periods (it typically takes 15 to 20 years to achieve full potential) and significant state funding requirements (approximately Rs. 50,000 crores to Rs. 70,000 crores).

Sustainable agricultural production is the main objective in developing irrigation network in India, more so in Karnataka. The research work on crop water management was initiated in India as early as 1907 by Dr. J. W Leather, then the Agricultural Chemist of the Imperial Agricultural Research Institute, Pusa and Bihar. During the last five decades most of the research on water management has been on-station under carefully controlled condition, in limited commands. The irrigated commands in Karnataka areas are too vast with diversified agro- ecological conditions which needs multi-disciplinary approach in research, the outcome of the research helps in effective teaching, training and transfer of technology in water management.

More ever the water management research in Karnataka remained confined to agricultural universities, institutes and research stations. The agricultural scientists of those organizations did not have much opportunity to interact with irrigation engineers and farmers in tackling on-farm water management problems. This has created a gap between the available research findings and their utilization for improving the design and operation of irrigation systems. In addition, optimum irrigation schedules for different arable or irrigated dry (ID) crops and cropping system, including intercropping, besides, seasonal water requirements, irrigation requirements and consumptive water use, progressive and peak consumptive water use rates, crop factors and soil moisture extraction patterns of different crops have been worked out for a limited number of crops. Moreover, some experiments have been conducted to evaluate different irrigation methods aiming at uniform application of required water depth to have better control of applied water to match the soil moisture deficit in the root zone before each irrigation in order to obtain higher efficiencies of water application and use.

The spatial and temporal adjustments between source/ supply and utility of water as a resource led to its scarcity in the place and time it is most needed. In recent years, its scarcity has not only jeopardized the agricultural production but also upset rural, urban and industrial development. Managing the water resources through scientific basis and organizing its developmental programmes including recycling and reuse has been a prioritized agenda at this juncture. A long term planning of water resource management for soil-water-crop in relation with weather modeling and remote sensing in Karnataka is absolutely necessary to achieve higher productivity without hampering the soil fertility. Hence, water efficient cropping systems, through crop diversification and integrated farming systems, location specific crops and cropping system models through farmer's participatory approach is the need of an hour.

To ensure that Karnataka has the water required to meet its economic growth aspirations, the state should embark on a comprehensive transformation of its water and agriculture sectors. The first step in such a transformation is to envision the end-state. Karnataka can set itself a vision of becoming the most progressive state in India in the areas of agriculture and water use. This will help unlock the potential to increase farmer income by 50 per cent by 2020 and by 100 per cent by 2030, thus improving the living standards of the large farmer community in the state.

Achieving this vision requires a state-driven transformation in water and agriculture, with private sector involvement in select areas. The transformation should leverage innovative but proven technologies in irrigation, agriculture and project execution, particularly focused on rice and sugarcane. The vision can encompass several focus areas: enabling agriculture to grow at an annual rate of 4 per cent; ensuring adequate service levels; allocating irrigation water equitably to all; and ensuring sufficient water is available for basic human needs, growth of industry.

In Karnataka, 85 per cent of water resources are used for irrigation for production of more than 60 per cent of agriculture output from 30 per cent of the cultivated land. Thereby, it is crucial to achieve food security of the state. But, demographic pressures with dwindling per capital holding size and un-sustained and un-scientific use of water have deepened the scarcity scenario to pose more formidable challenges in water management. Successive state Governments have spent thousands of crores of rupees in creating surface irrigation facilities to achieve quick progress through irrigated agriculture, however there is a miss match between irrigation potential created and actual irrigated area. The over exploitation of underground water resources is a challenge of greater magnitude, although government is spending on ground water use is minimal, both surface and ground water resource management pose diverse and complicated challenges such as i) Ways and means to economize the water use, ii) Methods to conserve the water and develop water resources, iii) Strategies for economical and sustainable water use, iv) Water management research and related issues and v) Methods to fix, revise and rationalize water rates.In general, the over exploitation of underground resources, wastage of surface water, poor knowledge of water resource management; lack of policy initiatives and participatory approach indicate an obscure and insecure future, if proper strategies are not adopted to address these issues in holistic approach.

The state has already taken up several initiatives to improve irrigation and service levels. In addition, the state is implementing innovative projects aimed at improving water-use efficiency across Karnataka. The solutions can be broadly classified under four objectives:

1. Augment supply through new schemes and rehabilitate the existing ones, accounting for about 20 per cent of the additional water availability. The solutions include utilising the new Krishna award, constructing lift irrigation schemes and barrages, building last-mile infrastructure and modernising canals. Excelling at project execution and maintenance of irrigation infrastructure by transforming the Water Resources Department and Nigams. Achieving excellence in water management by focusing activities of the Nigams and CADAs.
2. Improving irrigation efficiency, which would account for 33 per cent of the additional water available. These include initiatives for micro-irrigation, land levelling, reducing over-irrigation, as also the Sustainable Sugarcane Initiative, and proposals for a System of Rice Intensification and aerobic rice.
3. Improving agriculture productivity, which would account for 35 per cent of the additional water that could be made available. This includes the development and use of hybrid varieties, integrated pest management and balanced fertiliser use.
4. Moving to a more water-efficient crop mix, which would account for 12 per cent of the additional available water. This involves shifting to higher value horticulture crops without impacting food security.
5. Scaling up existing initiatives such as Bhoo-Chetana and the revitalisation of tanks to improve the productivity of rain-fed agriculture

Keeping the above in view, the project, "**ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND"** was taken up by University of Agricultural Sciences, Bengaluru with Rashtriya Krishi Vikas Yojana funding. The project was implemented from 2013-14 to 2018-19. The details of the project are as under:

1.	**Title of Project**	**:**	**“ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND”**
2.	**Nodal officer and Principal Investigator**	**:**	**Dr. C. Ramachandra, Professor of Agronomy,** Zonal Agricultural Research Station, VC Farm, Mandya, UAS, GKVK, Bengaluru
3.	**Implementing Institution (S) and other collaborating Institution (s)**	**:**	**Zonal Agricultural Research Station, VC Farm, Mandya**
4.	**Date of commencement of Project**	**:**	2013-14
5.	**Approved date of completion**	**:**	2018-19
6.	**Actual date of completion**	**:**	2018-19
7.	**Project cost**	**:**	Rs. 200 lakhs

The objectives of the project are as follows:

a. To conduct, co-ordinate and promote applied water research through multi-disciplinary approach.

b. To collect, collate and disseminate information relating to available water resources and water management research and effective utilization of water.

c. To function as a nodal agency for planning, programming and policy making in the management of water at all levels.

d. To act as a nerve-centre in organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management.

HYPOTHESIS

The context of the evaluation arises from the following facts:

1. Irrigation is one of the important inputs of scientific crop production. Water is a critical input into agriculture in nearly all its aspects having a determining effect on the eventual yield. Good seeds and fertilizers fail to achieve their full potential if plants are not optimally watered. The availability of adequate, timely and assured supply of water is an important determinant of agricultural productivity. Irrigation, in addition to raising productivity and cropping intensity, will also facilitate shifts in

cropping patterns. Irrigated agriculture contributes to about 40 percent of the global food production from an estimated 20 percent of agricultural land, or about 300 million ha globally.

2. The increasing demands on water resources by India’s burgeoning population and diminishing quality of existing water resources because of pollution and the additional requirements of serving India’s spiraling industrial and agricultural growth have led to a situation where the consumption of water is rapidly increasing while the supply of fresh water remains more or less constant.
3. In India today more than 90 million hectares of land have been brought under irrigation through major and medium (31.50 million hectares) and minor irrigation projects (57.96 million hectares). The ultimate irrigation potential of India is estimated as 139.95 million hectares including 56.00 million hectares by major and medium projects and 81.05 million hectares by minor irrigation projects comprising 17.40 million hectares by surface minor irrigation projects, 64.05 million hectares by ground water irrigation projects.
4. This progress is not without its cost. There have been serious consequences of indiscriminate withdrawal of water for irrigation (GOI, 2005 and Directorate of Economics and Statistics, 2016). The water table has gone down and expansion of irrigation in arid and semiarid areas has also caused the problem of salinity and water logging. In the light of limited land and scarce water resources the challenge of increasing agricultural production is immense. It has been anticipated that India's population may rise around 1.6 billion by 2050 (present about 1.28 billion). The factors like haphazard urbanization, industrialization and pollution of water sources will put heavy stress on limited and scarce water resources. India faces a challenging task of feeding population requiring about 380 million tonnes of food grains.
5. Increased frequency and intensity of climatic extremes due to the impacts of climate change is likely to adversely impact the availability and quality of water resource (Khetwani and Singh, 2018). Many parts of the developing nations like India, experience seasonal water scarcity on a regular basis (ICID, 2016 , IAI–FICCI 2015 and Khetwani and Singh, 2018). Indicators of water stress and scarcity are generally used to reflect the overall water availability in a country or a region. As per the international norms, a country is classified as water stressed and water scarce if per capita water availability goes below 1700 m^3 and 1000 m^3, respectively. With 1544 m^3 per capita water availability, India is already a water-stressed country and is moving towards turning into water scarce. In order to mitigate regional and seasonal water scarcity and ensure food and nutrition security, and increase farmer income, it is necessary to conserve and store water through creation of all kinds of storage and adoption of new innovative practices ((ICID, 2016 , IAI–FICCI 2015).

6. India is not a water rich country and is further challenged due to negative impact of climate change; enormous wastage owing partly to poor management and distorted water pricing policies. A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used.
7. Given the numerous challenges and the large share of water withdrawn for agriculture, irrigation and drainage, management has to address emerging climatic, technical, economic and organizational aspects through a holistic and integrated approach. In addition, increasing the surface water storage and its use has to be optimized by improving efficiency of delivery, increasing productivity and expanding irrigated area without withdrawing additional water. Measures need to be adopted in order to do this. Some of these measures are to conserve, reuse and recycle water; to adopt improved water management and agronomical practices including water saving micro irrigation technologies such as drip irrigation, sprinkler irrigation, etc.; to reclaim degraded land; and to promote participatory irrigation management.
8. Water productivity can be improved by adopting the concept of multiple water use, which is beyond the conventional sectoral barriers of the productive sectors. There is scope for increasing income through crop diversification and integration of fish, poultry and other enterprises in the farming system. The multiple water use approach can generate more income benefits, and decrease vulnerability by allowing more diversified livelihood strategies and increasing the sustainability of ecosystems.
9. The focus should be on i) improving irrigation efficiency, which would account for 33 per cent of the additional available. These include initiatives for micro-irrigation, land levelling, reducing over-irrigation, as also the Sustainable Sugarcane Initiative, and proposals for a System of Rice Intensification and aerobic rice; ii) improving agriculture productivity, which would account for 35 per cent of the additional water that could be made available. This includes the development and use of hybrid varieties, integrated pest management and balanced fertiliser use; and iii) moving to a more water-efficient crop mix, which would account for 12 per cent of the additional available water. This involves shifting to higher value horticulture crops without impacting food security.

OBJECTIVES AND ISSUES FOR EVALUATION

The scope of evaluation is to study the impact of scheme, "**ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND"** implemented by University of Agricultural Sciences, Bengaluru from 2013-14 to 2018-19.

1. Stake Holders

a) University of Agricultural Sciences, Bengaluru – Sponsorer
b) Rashtriya Krishi Vikas Yojane – as Monitoring Authority
c) Institution of Agriculture Technologists – as Consultant
d) Farmers / beneficiaries as target group of evaluation

2. Purpose of Evaluation

Evaluation Framework

The focus of Evaluation is:

iv. To evaluate the usefulness of various applied water research studies taken up through multi-disciplinary approach.

v. To evaluate the relevance of information collected relating to available water resources and water management research and effective utilization of water.

vi. To evaluate the impact of organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management.

LOG FRAME/THEORY OF CHANGE/PROGRAM THEORY

The intention of the project is i) improving irrigation efficiency, which would account for 33 per cent of the additional available. These include initiatives for micro-irrigation, land levelling, reducing over-irrigation, as also the Sustainable Sugarcane Initiative, and proposals for a System of Rice Intensification and aerobic rice; ii) improving agriculture productivity, which would account for 35 per cent of the additional water that could be made available. This includes the development and use of hybrid varieties, integrated pest management and balanced fertiliser use; and iii) moving to a more water-efficient crop mix, which would account for 12 per cent of the additional available water. This involves shifting to higher value horticulture crops without impacting food security.

EVALUATION DESIGN

Evaluation design has a rationale of requirement of field level data (primary) that is required to study evaluation objective with respect to beneficiary farmers on one part and the projects taken up for study per se on the other part. The evaluation requires analysis of administration obligations under the two heads and hence a secondary data analysis becomes important and accordingly formats were designed to procure secondary data. The third obligation under evaluation is opinion of stake holders with respect to improvement of the schemes, which require group discussions and exchange of views both in the form of a format, as well as group discussions with the stake holders. The entire evaluation process required a central administration of all activities.

A core team of experts at the Institution level considered three methods to bring a meaningful evaluation of the subject, keeping in mind the scope, evaluation questions and sub-questions duly keeping its focus on the purpose of evaluation. The three methods are:

a. Accessing and analysis of secondary data from the implementing department.
b. Interaction with Principal Investigator and his team.
c. Actual visit to the project site to study and obtain necessary information to elicit answers to the evaluation questions.

DATA COLLECTION AND ANALYSIS

The Water Technology Center which encompasses five inter-disciplinary groups viz., Agronomy, Water resources engineering, Soil science and Agricultural chemistry, Agricultural economics and Crop physiology which are involved in developing package of practices with the main focal theme on increasing Water Use Efficiency (WUE)/ Water Productivity with simultaneous increase in crop production and sustained farm income. Some of the major thrust areas are micro irrigation and fertigation, watershed management, conjunctive system, water quality and waste water recycling, agricultural drainage and water policy. Besides, the center handles state Government aided plan schemes, international collaborative schemes, Government of India schemes and other private agency funded schemes in addition training the man power for effective and efficient use of water resources.

Research on water management

The project mainly encompasses on conducting applied research on crops and cropping system, organizing large scale demonstration of water saving technologies in rice, sugarcane and irrigated dry crops and educating the farmers on judicious use of water by organizing training/ seminars/ workshop for enhancing water use efficiency in Cauvery command area of Karnataka. Research was conducted on rice, sugarcane, finger millets, maize and green manure crops from 2013 to 2018 at Zonal Agricultural Research Station/ College of Agriculture, V.C.Farm, Mandya.

Sl.No	Crop	Title of the studies
1	Rice	Enhancing water productivity and profitability of rice through different production system.
2		Bio – fortification of rice (*Oryza sativa*) with Zn & Fe in methods of rice cultivation.
		Evaluation of different irrigation management practices for their water saving potential and enhancement of the productivity and profitability in different rice establishment methods.
3		Studies on growth and yield of aerobic rice as influenced by drip fertigation.
5		Response of sprinkler irrigation on rice productivity in Cauvery command.
6	Maize	Studies on drip fertigation under different planting geometry of Maize (*Zea mays* L.)
7		Phosphorous management through foliar nutrition in drip irrigated Maize (*Zea mays* L.)
8	Finger millet	Effect of moisture regimes on growth and yield of transplanting finger millet.

9	Sugarcane	Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation
10		Standardization of water soluble fertilizers for sugarcane crop through micro irrigation
11	Green manure crop	Water requirement and water productivity estimation in green manure – rice based cropping system.
12	Ground water	Studies on characterization of water availability and management as the canals command area.
13	Fisheries	Effect of pond water salinity/ alkalinity and stocking density on the growth and survival of carps spawn reared to finger lings
14	Soil Health	Applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping of V C Farm, Mandya, Karnataka
15	Socio-economic studies	Survey on status of water management practices in Cauvery command of Karnataka.

The results from the above studies are discussed below:

Enhancing water productivity and profitability of rice through different production systems

In this experiment, conventional method of cultivation, drum seeding, direct seeding, mechanized paddy cultivation, System of Rice Intensification (SRI), mechanized SRI method and regular farmers' practice were compared. The results indicated that among different system of rice cultivation, System of Rice Intensification (SRI) recorded significantly higher grain yield (7900 kg/ ha), higher water productivity (54.87 kg/ ha cm) and used less water (130 cm). There was reduction in N-loos through leaching and volatilization. Mechanized system of rice cultivation also yielded good results (7667 kg/ ha of yield, 54.87 kg/ha cm of water productivity and 132 cm water use respectively). Aerobic method of rice cultivation is known to result in lower methane emission and increased production due to increase in soil redox potential, proper aeration of soil, beneficial microbial activity and lack of anaerobic condition which makes inactivity of methonogenic bacteria leads to mitigate methane emission (Suresh Naik et al.,2014). Lower grain yield (4982 kg/ ha) lower water productivity (17.29 kg/ ha cm) and higher water use (225 cm) was observed with farmers practices of rice cultivation.

Biofortification of rice (*Oryza sativa* L.) with Zn and Fe in methods of Rice cultivation

The experiment was conducted to evaluate the influence of Zn and Fe under different methods of cultivation, viz., conventional method of cultivation, aerobic method and System of Rice Intensification (SRI) method on yield. The results revealed that while SRI method of rice cultivation resulted in higher grain yield of 6371 kg/ ha, aerobic rice cultivation recorded higher water use efficiency (65.84 kg/ ha-cm) with less water use (84 ha/ cm). SRI method of rice cultivation (49.43 kg/ ha-cm) resulted in lower productivity than aerobic method but was better than conventional method of rice cultivation which consumed more water. Although application of $ZnSO_4$ @20kg/ ha+$FeSO_4$ @ 10kg /ha through soil application resulted in higher yields (6293 kg/ ha), seed treatment with $ZnSO_4$ @ 0.2% and $FeSO_4$ @ 0.1% resulted in comparable yield increase (6159 kg/ ha) over control (5604 kg/ ha).

Evaluation of different irrigation management practices for their water saving potential and enhancement of the productivity and profitability in different rice establishment methods

Transplanted rice (Manual and Mechanized transplanting) and direct seeded rice (direct row seeded rice using dibbling of sprouted seeds at 25 cm and direct seeded rice broadcasting (DSR)) and different irrigation management practices, viz., continuous submergence, saturation throughout crop growth stage, irrigation 3 days after disappearance of standing water (5cm depth of water) and alternate wetting and drying (irrigation at 5 days interval) were compared. Pooled data (two years) revealed that, among the methods of crop establishment, direct wet seeding in puddled soil (dibbling of sprouted seeds at 25 cm) followed by SRI principles resulted in higher grain yield (5818 kg/ ha). Among irrigation management practices, maintaining saturation up to panicle initiation and 2 cm after panicle initiation resulted in on par yield (5744 kg/ ha) with alternate wetting and drying irrigation practices (5514 kg/ ha).

Studies on growth and yield of aerobic rice as influenced by drip fertigation

Irrigation based on open pan evaporation and drip fertigation with recommended dose of fertilizers were compared. The study revealed that although providing 125 per cent recommended dose of fertilizer through drip and irrigation at 150 % CPE (cumulative pan evaporation) resulted in highest yield (4963 kg/ ha), comparable yield was obtained with irrigating at 125% CPE (4883 kg/ ha) and with 100% fertilizers and irrigating at 125% CPE (4739 kg/ ha).

Response of sprinkler irrigation on rice productivity in Cauvery command

Rice cultivation requires large quantity of water depending on the method of rice cultivation. Hence, it is necessary to develop an alternate rice production system that requires less water and increase water productivity. Micro irrigation techniques is one such tool that can reduce water use and at the same time increase yield. Using sprinkler irrigation up to different stages of growth was compared with alternate drying and wetting up to flowering and maintaining 5 cm depth of water thereafter. The results indicated that providing irrigation by alternate wetting and drying up to flowering and maintaining 5cm depth of water flowering to grain filling (6730kg/ ha) and continues submergence method of irrigation (6488 kg/ ha) were better compared to sprinkler irrigation (5749 kg/ ha) although these methods used more water compared to sprinkler irrigation. The reason for lower yield in irrigation with sprinkler throughout crop growth might be due to the application of sprinkler irrigation during flowering period cause pollen shedding resulted in lower grain yield.

Studies on drip fertigation under different planting geometry of Maize (*Zea mays* L.)

Different plant and row spacings and irrigation and fertigation with drip were compared with conventional method of flood irrigation and fertigation in maize. The results revealed that planting of maize at 30 cm between rows and 90 cm between paired row with irrigation at 80 % CPE and fertigation with conventional fertilizer N and K and water soluble P recorded higher kernel and stover yield (7732 and 7792 kg /ha, respectively) than conventional planting and surface irrigation of maize planted at 45 cm and 60 cm row spacing (5654 to 5942 and 6351 to 6582 kg/ ha, respectively). It also recorded significantly higher water use efficiency (116 kg kernel /ha-cm water) by saving 18.20% water as compared to surface irrigation with recommended practice (73 to77 kg/ha-cm).

Phosphorous management through foliar nutrition in drip irrigated Maize (*Zea mays* L.)

Different irrigation intervals and different levels of foliar application of phosphorous were compared with soil application. The results indicate that irrigation at 80 % CPE resulted higher yield (5753 kg/ ha), used less water and had high water use efficiency (124.45 kg/ ha-cm) compared to irrigation at 100 % CPE. Among phosphorus application methods, fertigation of recommended phosphorus through water soluble fertilizer resulted on par yield (5967 kg/ ha) with fertigation of water soluble fertilizer at 20 kg/ ha (5787 kg/ ha).

Effect of moisture regimes on growth and yield of transplanted finger millet

The experiment was conducted to study the optimization of soil moisture regime for enhancing higher water productivity of finger millet. The results revealed that higher grain yield was obtained with application of 100 % recommended dose of fertilizers with irrigation at 0.8 IW/ CPE (3682 kg/ ha). However, lesser amount of water was used (32.17 ha cm) in irrigation at 0.61 IW/ CPE which also recorded higher water use efficiency (101 kg/ ha-cm).

Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation

The experiment was conducted to study the effect of fertigation duration and levels on growth and yield of sugarcane, to assess the quality of sugarcane juice and jaggery and work out the nutrient use efficiency, water productivity and economics of sugarcane as influenced by subsurface drip fertigation duration and levels. The results revealed that drip fertigation upto 9.5 months with 125 per cent recommended dose of fertilizers recorded significantly higher number of millable canes (26.67 and 27.76), cane length (2.37 and 2.27 m), single cane weight (1.73 and 1.55 kg), cane yield (255 and 227 t ha-1) and water productivity (1.82 and 1.62 t ha cm-1) in plant and ratoon cane, respectively. It also recorded higher gross return and net return (Rs. 560325 and 499538 ha-1) and (Rs.448893 and 413706 ha-1) in plant and ratoon cane, respectively. On par results were observed with drip fertigation upto 9.5 months with 100 and 75 per cent recommended dose of fertilizers which also recorded higher Benefit Cost Ratio in both plant and ratoon cane (5.12 and 6.07). However, normal method of cane cultivation under surface irrigation recorded significantly lower yield and yield parameters.

Standardization of water soluble fertilizers for sugarcane crop through micro irrigation

The results of fertigation of water soluble fertilizers on growth and yield attributes of sugarcane indicated that application of 125 % NPK ha-1 recorded higher cane yield (241.7 t/ ha-1) as compared to RDF (181.7 t/ ha) resulting in 33 per cent increased yield. Application of fertilizers through fertigation increased the cane yield as compared to conventional/soil application.

Water requirement and water productivity estimation in green manure rice-based cropping system

The experiment was conducted to study the influence of different green manuring in combination with irrigation intervals on growth and yield of green manure crops and also to quantify the seasonal water use and water use efficiency in green manure – rice cropping system. The results revealed that significantly higher seed yield was recorded with dhaincha with three irrigation followed by low land rice (63.5 q/ ha). However, it was on par with dhaincha with three irrigation followed by SRI method of rice cultivation (61.6 q/ ha), sunhemp with three irrigation followed by low land rice (58.4 q/ ha), sunhemp with three irrigation followed by SRI method of rice cultivation (57.5 q/ ha) and cowpea with three irrigation followed by low land rice (55.3 q/ ha). With respect to water consumption, sunhemp with three irrigation followed by SRI rice recorded lower water consumption (558 mm) as compared to other cropping systems and was on par with dhaincha with three irrigation followed by SRI method of rice cultivation (568 mm).

Studies on characterization of water availability and management in the canal command area

Ten farmers (small: 2, medium:5, large: 3) under middle reach of Maddur branch of VC canal, Cauvery command area were identified for conduct of brief survey work with respect to agriculture, geological information and ground water status in the reach. Global positioning system device was used to identify the spatial distance from the canal to farmers' field. Most of the farmers were growing paddy and sugarcane during the release of water from canal with eight days rotation and for summer season farmers were taking up finger millet where the rotation of water is for 20 days. Most of the farmers used to adopt water sharing system from the bore well when there is stoppage of water from canal as a protective irrigation. The ground water was extracted by bore well with water availability from an average of 450 to 500 feet deep. Most of the farmers expressed dissatisfaction over availability of water from canal at crucial time and hence they used to pump water from bore wells to overcome the deficit of water.

Effect of pond water salinity/ alkalinity and stocking density on the growth and survival of carps spawn reared to finger lings

The demonstration showed that, at the end of 4 months and 12 days, the average length of Catla was 21.5 cm with average weight of 248 g. The average length of Rohu was 24.3cm with average weight 220 g and the average length of common carp was 21.7cm with average weight 230 g.

Applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping of V C Farm, Mandya, Karnataka

An intensive detailed soil survey of VC Farm was conducted during 2018-19 using high resolution satellite image with 1:12,500 scale as base map. The soils of the study area were studied in detail with respect to their external land features and morphological properties in relation to different physiographic units developed over varying landscape. A total of one hundred ninety-four surface soil samples (0-15 cm) were collected using satellite map which is super imposed on the cadastral map from each field boundary of the various blocks of V C Farm.

In general, under lower pediplain and summit lands of deep to very deep soils monocropping of paddy and sugarcane crops under irrigated condition are being done. While, in mid-land areas of shallow to medium soils are with moderate to high hydraulic conductivity and low to very low water holding capacity. In these soils pulses and fodder crops are cultivated. The major area was under acidic to normal in reaction as the soils are derived from acidic granite and granite gneiss parent material. However, the soils in blocks of A, B and D were having relatively high pH due to monocropping of Paddy and also influence water stagnation and accumulation of basic salts may be responsible for development of sodic soils. The organic carbon content values are 0.69, 0.56, 0.86, 1.03, 1.02, 0.98, 0.70, 0.83 and 0.84 in blocks of A, B, C, D, E, F, G, H and I respectively. The soils of most of the blocks fall under medium to high in organic carbon status. The crop residues of sugarcane trash, paddy straw, leaf litter and other crop residues are responsible for higher organic matter.

The available nitrogen content in most of the blocks was found to be low due to losses through leaching and volatilization in coarse texture soils and sodic soils respectively. Similar results were also reported by Sivashankaran et al., 1993. The available phosphorus was medium in most of the blocks except in block A which had high available phosphorus. The recovery of phosphorus fertilizers ranged between 10 to 20 percent due to sorption and precipitation of applied phosphorus as reported by Bopathi and Sharma (2006), this may be the prime reason for phosphorus build up in soil of various blocks.

While, the potassium content was found to be medium all the blocks, the primary minerals of feldspar and mica are responsible for medium in available potassium content.

Survey on status of water management practices in Cauvery command of Karnataka

Cauvery is an interstate river in Southern India. It is one of the major rivers of the peninsular India flowing east running into the Bay of Bengal. Cauvery basin extends over an area of 85,626.23 sq. km with a maximum length and width of 560 km and 245 km, respectively. It is bound by the Western Ghats on the west, by the Eastern Ghats on the east and south and by ridges separating it from Krishna basin and Pennar basin on the north. The basin constitutes of 3 sub-basins namely Cauvery Upper, Cauvery Middle and Cauvery Lower sub-basin. There are 132 watersheds, each of which represents a different tributary system with size ranging from 362 sq. km to 991 sq. km with maximum number of watersheds falling in Cauvery Middle Sub-basin. Cauvery River which is the main river in this basin rises at Talakaveri on the Brahmagiri range in the Western Ghats in Karnataka at an elevation of about 1341 m and flows for about 800 km before its outfall into the Bay of Bengal. The important tributaries joining the Cauvery are Harangi, Hemavathi, Kabini, Suvarnavathi and Bhavani. In the Cauvery basin, four distinct seasons occur. They are winter, summer, south-west monsoon, and north-east monsoon season. The basin is mainly influenced by South-West monsoon in the Karnataka and Kerala and North-East monsoon in Tamil Nadu. Rainfall in the delta area is of the order of 1000 mm annually (Anon, 2014, - Cauvery basin report).

The erratic monsoon in the catchment of the reservoirs has complicated the cultivation of crops. Insufficient rainfall in the catchment more often leads to inadequate storage of water in the reservoirs resulting in crops facing severe drought particularly in the summer months. This has compelled the farmers to look for alternative crops in the command area. Rice-rice and sugarcane are the most predominant cropping systems in Cauvery command area of Karnataka. Continuous cultivation of rice and sugarcane mono-cropping for longer periods has resulted in loss of soil fertility, emergence of multiple nutrient deficiency, deterioration of soil physical properties and decline in factor water productivity and crop yields in high productivity areas (Yadav, 2002).

Diversification and intensification of rice-based and sugarcane-based system to increase productivity per unit resource is very pertinent. Crop diversification has been recognized as an effective management strategy for achieving higher productivity and water use efficiency (Hedge et al., 2003). Therefore, adopting alternate cropping system to find out most productive, resource-use-efficient and remunerative cropping system for this region is needed.

Collection, collation and dissemination of information relating to available water resources and water management research and effective utilization of water.

A detailed study of the Cauvery command area was made and all relevant information pertaining to the available water resources, storage capacity of reservoirs, command area of the reservoirs, area of crops cultivated, irrigation potential created and present usage, cropping systems and their water use efficiency, soil types, issues relating to water productivity have been collected and detailed below:

Basic Information on Cauvery Command Area

Table 1: Major command areas of Karnataka state

Command areas	Reservoirs	Area (lakh.ha)
Cauvery	Kabini, Harangi, Hemavathi, KRS	2.5
Bhadra	Upper parts of Tunga, Tunga and Bhadra	1.9
Tungabhadra	Tungabhadra	3.8
Krishna	Upper parts of Krishna and Narayanapura	5.4
Ghataprabha	Krishna	1.8
Malaprabha	Krishna	1.6
Total		**18.5**

Table 2: States and their area of coverage of Cauvery command area

States	Catchment area in Sq. Kms.
Karnataka	34273
Tamilnadu	43868
Kerala	2866
Pondichery (Karaikal)	148
Total	**81155**

Table 3: Salient features of the reservoirs coming under Cauvery command area

Sl. No.	Location	Reservoirs			
		Kabini	Harangi	Hemavathi	KRS
1.	Latitude ("N)	11°0"30	12-29-30	12-45-0	12-25-0
2.	Longitude ("E)	76-21-12	75-54-20	76-03-0	76-33-0
3.	Catchment Area (Sq.kms)	2142	419.58	2810	10619
4.	Length of the Dam (ft)	8965	2775	15394	8600
5.	Height of the Dam (ft)	95	164	146	130

Table 4: Reservoirs under Cauvery command area

Reservoirs	Gross Storage (TMC)	Live storage (TMC)	Dead storage (TMC)	Full reservoir level (ft)	Cultivable Command area (ha)	Ultimate Irrigation Potential (ha)	Potential created (ha)	Reservoir evaporation loss (TMC)
Kabini	19.52	16.00	3.52	2284	8870	100120	44642	3.40
Harangi	8.50	8.07	0.43	2859	50229	54591	50229	1.45
Hemavathi	37.103	35.760	1.343	2922	-	305131	228645	3.50
KRS	49.452	41.073	8.379	124.80	26640	142073	145221	5.60

Table 5: Districts/taluks under reservoirs of Cauvery command area

Reservoirs	Districts	Taluks
Kabini	Mysore Chamarajanagar	H.D. Kote, Nanjangud and T. Narasipura. Chamarajanagar, Yalandur, Kollegal and Gundlupet.
Harangi	Kodagu Hassan Mysore	Somwarpet Arkalgud K.R. Nagar, Periyapatna,Hunsur and M.I. Tanks.
Hemavathi	Hassan Mandya Kodagu Tumkur Mysore	Hassan, Alur, Arkalgud, Holenarasipura and Channarayapatna. Mandya, K.R. Pet, Pandavapura and Nagamangala. Somwarpet Tumkur, Gubbi, Kunigal, Tiptur and Turuvekere. K.R. Nagar
KRS	Mandya Mysore	Maddur, Malavalli, Mandya, Nagamangala, Pandavapura and Srirangapatna. Mysore, H.D. Kote, Nanjangud and T. Narasipura.

Table 6: Cropping system and cropping intensity in command area

Sl. No.	Reservoirs	Cropping system			Cropping intensity (%)
		Kharif	**Rabi**	**Summer**	
1.	Kabini	Paddy/Sugarcane	Sugarcane/Paddy	Ragi/Jowar	-
2.	Harangi	Paddy/Sugarcane	Sugarcane/Paddy	Ragi/Jowar	-
3.	Hemavathi	Paddy/Sugarcane	Sugarcane/Paddy	Ragi/Jowar	-
4.	KRS	Paddy/Sugarcane	Sugarcane/Paddy	Ragi	135-150

Table 7: Major crops and cropping system and WUE in Cauvery Command Area

Cropping system	Present crop and cropping system		WUE (kg/ ha cm)
	Kharif	Summer	
Head region			
Rice-Rice	Rice (Long duration)	Rice (Medium duration)	28.00
Rice-Rice	Rice (Medium duration)	Rice (Medium duration)	26.25
Rice-Rice	Rice (Medium duration)	Rice (Short duration)	25.67
Rice-Rice	Rice (Short duration)	Rice (Short duration)	24.29
Middle region			
Rice-Rice	Rice (Medium duration)	Rice (Medium duration)	26.25
Rice-Rice	Rice (Short duration)	Rice (Short duration)	24.29
Rice-Ragi	Rice (Medium duration)	Ragi (Short duration)	31.20
Rice-Pulse	Rice (Medium duration)	Cowpea/ greengram/ blackgram/ fieldbean	25.58
Tail end region			
Rice-Ragi	Rice (Medium duration)	Ragi (Short duration)	31.20
Rice-Pulse	Rice (Medium duration)	Cowpea/ greengram/ blackgram/ fieldbean	25.58
Rice-Fodder	Rice (Medium duration)	Fodder maize/Jowar/Bajra	116.7

Table 8: Water use efficiency of rice and sugarcane in Cauvery Command Area

	Variety	WR (cm)	WUE (kg ha-cm^{-1})
Rice	Long duration variety (140-150 days)	200-220	27.3-29.5
	Medium duration variety (130-135)	185-190	24.3-26.3
	Short duration variety	165-170	24.2-26.5
Sugarcane	Planting date	200-250	500-750

Table 9: Soil physical properties of command area

Reservoirs	Soil type	Soil color	Special features
Kabini	Clay soils	Deep brown to black	These are calcarious & weekly to strongly alkaline highly cracking metamorphic clay
Hemavathi	Red sand, loamy to sandy loam in texture, intermixed to course gravel & pebbles	Red	Red sand, loamy in texture & intermixed to coarse gravel & pebbles well drained but poor in moisture retaining capacity

Harangi	Red shallow gravelly to Red sandy loam	Red	Soils are well drained & very poor WHC soil reaction in general is neutral & Acidic in nature
KRS	Red sandy loam, Red clay loam, Medium black, Lateritic	Light grey, Red & strong brown gravelly	Light grey, red & strong brown, gravelly, sandy loam to sandy loam soil

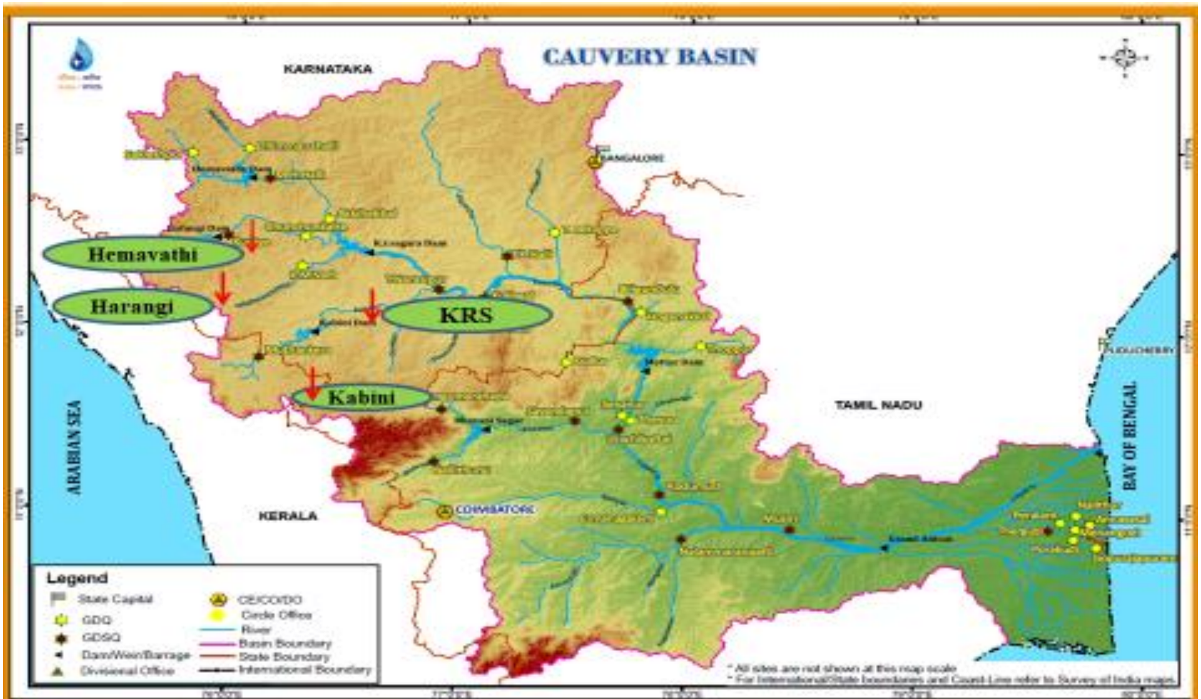

Fig. 1: Cauvery Basin

Table 10: Cauvery catchment and allocated water

Sl.No.	Name of the Basin State	Catchment area in Sq.kms	Allocated water (TMC)
1	Karnataka	34,273	270 (284.75)
2	Kerala	2,866	30
3	Tamil Nadu	43,868	419 (404.25)
4	Karaikkal region of Pondicherry	148	7
	Total	81,155	726+14*=740

*Quantity reserved for environmental protection- 10 TMC

Quantity determined for inevitable escapages into the sea- 4 TMC

Present Scenario of Command Area

- Unregulated cropping pattern
- Non-implementation of 'on and off system'
- Delay in letting the water in canals
- Underutilization of irrigation potential created
- Maintenance of canals/distributaries
- Lining of canals/distribution/field canals
- Measurement structures and measurement of flow- at distributary & field levels
- Canal flow-crop requirement issues
- Water rates on acre basis- irrespective of use of water

Reasons of Poor Water Productivity

Issues Related to Irrigation Water

- Wastage of water
- Excessive use of water
- Unregulated cropping pattern
- Loss due to poor conveyance
- Canal construction
- Reuse of irrigation water

Issues Related to Crop Productivity

- Mono-cropping
- Late release of water- reduced productivity
- Practice of plot-to-plot irrigation
- Crop selection & crop diversification
- Lack of alternate cropping plans for drought years

Approaches for higher WUE

1. Development of schedules based on cropping seasons
2. Maintenance works in canals- including repairs and weeding
3. Individual plot irrigation than presently followed plot to plot irrigation in paddy - with active involvement of water users association,
4. Strict implementation of localization and development of cropping plan based on water availability schedules and soil characters
5. Providing drainage to water logged areas, by the tile drainage reclamation of saline/alkalis soils in the area.
6. Capacity Building- by training, necessary literature about awareness
7. Lining of distributory, sub-distributory and field canals by masonry/stone structures
8. Possibilities of piped water supply in command areas
9. Use of measured quantity of irrigation for every crop as per schedule of irrigation drawn for specific season.

Organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management

Water Technology Centre (WTC) was established during 2014-15 in an area of 540 sq. m. at ZARS, V. C. Farm, Mandya coming under the jurididiction of University of Agricultural Sciences, GKVK, Bengaluru to cater the needs of farmers of Cauvery command area in relation to conduct scientific-applied research, teaching and extension in water management. The centre has a well equipped soil and water analysis laboratory, a field irrigation laboratory to cater the day-to-day research and teaching related needs and activities, a museum where in technologies and models related to water management are depicted, a conference hall of to seat 20 people with all modern audio and visual aids facilities. These facilities are used to educate the farmers in the command area to acquire knowledge and understanding of aspects of water technology and management.

The centre has organized 38 training programmes/ workshops/ seminars/ brainstorming sessions/ world water day to educate the farmers on importance of water and adopting of water saving technologies for enhancing Water Use Efficiency in field crops. Around 4734 farmers have participated and benefitted from the programmes.

Large scale demonstration on different methods of rice cultivation viz., SRI, Aerobic, MSRI and direct seeded rice (DSR) and surface and sub surface method drip irrigation of sugarcane was conducted in an area of 224 acres in Mandya and Mysore districts. Need based critical inputs were provided to the beneficiaries for effective conduct of demonstrations.

Sl. No.	Crop	Demonstration	Area (acres)	Places
1.	Rice	Mechanized System of Rice Intensification	100	Hosabudanuru, Sampahalli, Kyathungere, Mandya, Induvalu, Beeragoudanahalli,
2.	Rice	System of Rice Intensification (SRI)	85	Thorechakanahalli, Gurudevanahalli, Thippenahalli koppalu, Kallimeledoddi, Bhoppasamudra, Matadadoddi
3.	Rice	Aerobic rice	15	Mangala
4.	Sugarcane	Surface and sub surface method of irrigation	24	Mandya and Mysore
Total			**224**	

System of Rice Intensification (SRI) is considered as a system that involves holistic management to give ideal growing conditions to rice plant. SRI is emerging as a water saving technology which can help the farmer to overcome water crisis. The major changes in the system are lower seed rate (5 kg/ ha), planting young seedling of 12-14 days at wider spacing (25 x 25 cm), use of more organic nutrient sources, regular weeding with conoweeder and using less water (no flooding) to achieve higher yield.

The demonstration on SRI method of growing rice was conducted in an area of 85 acres at Thorechakanahalli, Gurudevanahalli, Thippenahalli koppalu, Kallimeledoddi, Bhoppasamudra, Matadadoddi of Maddur taluk, Mandya district. The major varieties/ hybrids used in the demonstration were KRH-4, MTU-1001 and BR-2655. The results revealed that SRI method of rice cultivation recorded 16.48 % higher yield, 18.29 % lower cost of production and higher water productivity (65.1 kg/ ha cm) compared to farmers practice. More than 1,000 farmers in the Cauvery command area, especially tail end farmers, have started adopting this technology. About 2500 acres in Nagamangala taluk have been converted to growing Direct Seeded Rice (DSR). Farmers have started adopting improved technologies in rice cultivation like use of drum seeders, rice transplanters, soil test based fertilizer application, growing of aerobic rice in low lying lands, prophylactic spray of pesticides.

The demonstration on mechanized system of rice cultivation was conducted in Maddur taluk in Hosabudanur, Sampahalli, Kyathengere and in Mandya taluk in Induvalu and Beeragoudanahalli in an area of 100 acres during 2014-15. It involves planting young seedlings at wider row spacing (23 x 23 cm) through transplanter which holds special significance in the present day production system by saving time, labour, energy and increasing profit. The results of the demonstration indicates 15.35 per cent higher yield, 11.60 per cent lower cost of production and higher water productivity (44.18 kg/ ha cm) over farmers practice.

The demonstration on Aerobic Rice cultivation was conducted in Mandya taluk in Mangala village in an area of 15 acres during 2014-15. The major varieties used were MTU-1001, BR-2655, IR-64 and Tanu. Aerobic rice is a new method of growing rice characterized by direct seeding condition without standing water. Cultivation of rice under aerobic situation leads to considerable amount of saving of water. The results revealed 11.80 % higher yield and higher water productivity of 76.86 kg/ ha cm.

The demonstration on Sub-Surface method of irrigation in Sugarcane was conducted in Mandya and Mysuru districts during 2016-17 in an area of 24 acres. Need based critical inputs were provided to the benificiaries. The results revealed that subsurface drip irrigation in sugarcane recorded higher cane yield (170.4 t/ ha), used less water (121.2 cm) over farmers practice (220.2 cm).

The results of large scale demonstrations conducted are given in Annexure.

In demonstrations on finger millet, water saved was higher in drip irrigation (50.44 %) over surface irrigation method. In maize, water saved was higher in drip irrigation (26.32 %) over surface irrigation method. In sugarcane, water saved under subsurface drip irrigation was 16.70 % over surface drip irrigation.

The demonstrations on precise water management using sensor based drip irrigation system conducted in field crops of Maize, Pigeonpea, Ragi and Tomato showed that about 50 per cent, 60 per cent, 34 per cent and 36 per cent water can be saved with sensor based drip irrigation as compared to convention methods respectively.

The demonstrations on micro irrigation in paddy showed higher grain yield (6233 kg/ ha), use of less water (81 cm) and higher WUE (76.95 kg/ ha cm) compared to conventional method of rice cultivation.

The farmers' feedback obtained is given below:

Name of farmer	Village	Taluk	Crop	Feedback
Devegowda	Beeragowdanahalli	Maddur	Rice	Purchase of rice transplanter for hiring out
Jayaramu	Jayapura	Mandya	Rice	SRI method with drum cylinder in 0.5 ac
Basavaraju	Jayapura	Mandya	Sugarcane	Soil test based fertilizer application, using organic manure
Shivakumar	Padya		Sugarcane	Surface drip irrigation
Shankaregowda	Gullenahalli		Coconut	Crop diversification
Praveen	Shivalli	Mandya	Ragi	Direct seeding, mulching
Shivaprasad	Ganadal	Mandya	Rice	SRI method in 5 acres, machine planting
Ramesh	Ganadal	Mandya	Rice	Aerobic rice on sloping land
MN Puttaswamy	Mathadadoddi	Mandya	Rice	Farmers forum, SRI method,
Satish	Mathadadoddi	Mandya	Sericulture	Drip
Srinivas	Chittamadanahalli	Mandya	Maize	Baby corn,
Manche Gowda	B. Hosur	Mandya	Rice	Machine planting
Kumar	Holalu	Mandya	Sugarcane	Sub-surface drip

DEMONSTRATIONS




SRI and Mechanized Paddy cultivation

Surface irrigation

Drip irrigation

On-station Demonstration on Drip Irrigation in Ragi


Sensor based drip irrigation in Ragi


Sensor based drip irrigation in Maize


Sensor based drip irrigation in Red gram

FINDINGS AND DISCUSSION

Research on water management

The Centre has conducted 15 applied research studies on various crops and cropping systems. In most of the studies, the effect of various irrigation management practices and nutrition on crops was evaluated. The results were mostly confined to assessing the effect on yield of crops and in some cases on water use efficiency and water productivity. In most experiments conducted, the parameters like irrigation methods and nutrition were combined. As a result, the singular effect of irrigation management practices on crop yield could not be independently assessed. In most studies, the economics of the various treatments have not been assessed.

The studies have brought to sharp focus the advantages of System of Rice Intensification (SRI), Mechanized system of rice cultivation and Aerobic method of rice cultivation over traditional practices and a large number of farmers in the command area have started adopting these practices. The studies have also revealed that the drip fertigation and sprinkler irrigation methods area not ideally suited in rice cultivation.

While studies have been conducted on use of micro irrigation techniques in various crops, there is need to understand the water use pattern in various planting geometry such as paired row planting, wider rows etc. The focus of these studies should have been on water saving without affecting the crop yields.

The need for application of micro nutrients has been demonstrated in some studies.

The studies on characterization of water availability and management in the canal command area have not been able to bring out measured needed to solve the problems faced by tail end farmers.

No appreciable benefit appears to have accrued from the study on applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping of V C Farm, Mandya, Karnataka. Its relevance to the project needs to be elaborated.

A detailed study of the Cauvery command area pertaining to the available water resources, storage capacity of reservoirs, command area of the reservoirs, area of crops cultivated, irrigation potential created and present usage, cropping systems and their water use efficiency, soil types has been made and issues relating to water productivity have been collected. The information gathered has been comprehensive and gives a holistic view of the command area. The present scenario of the command area, reasons for poor water productivity and approaches to improve water use efficiency have been well detailed.

The centre has organized 38 training programmes/ workshops/ seminars/ brainstorming sessions/ world water day to educate the farmers on importance of water and adopting of water saving technologies for enhancing Water Use Efficiency in field crops. Around 4734 farmers have participated and benefitted from the programmes.

Large scale demonstration programmes have been conducted in farmers' fields in the command area to show case the advantages of methods of improved irrigation management practices. The large scale adoption of SRI, DSR, Mechanized rice cultivation and aerobic rice method by farmers is the culmination of the efforts of the scientists. The demonstrations have also been successful to help educate the farmers on use of water saving irrigation techniques like subsurface drip irrigation and sensor based drip irrigation. The feedback received from farmers has exemplified the efforts made by the scientists in educating the farmers.

REFLECTIONS AND CONCLUSIONS

1. The results of the research studies were mostly confined to assessing the effect on yield of crops and in some cases on water use efficiency and water productivity.
2. The singular effect of irrigation management practices on crop yield could not be independently assessed.
3. In most studies, the economics of the various treatments have not been assessed.
4. The studies have brought to sharp focus the advantages of System of Rice Intensification (SRI), Mechanized system of rice cultivation and Aerobic method of rice cultivation over traditional practices and a large number of farmers in the command area have started adopting these practices.
5. The studies have also revealed that the drip fertigation and sprinkler irrigation methods area not ideally suited in rice cultivation. Drip fertigation in aerobic / direct seeded rice is ideal under tail end areas and water scarcity situation. Hence this technology may be popularized through extensive demonstration and educating farmers on adoption of drip irrigation with an objective of considerable saving water besides improving soil health.
6. There is need to understand the water use pattern in various planting geometry such as paired row planting, wider rows etc.
7. The focus of the studies should have been on water saving without affecting the crop yields.
8. The studies on characterization of water availability and management in the canal command area have not been able to bring out measured needed to solve the problems faced by tail end farmers.
9. The relevance to the project study on applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping needs to be elaborated. A case study was conducted at Zonal Agricultural Research Stations to know the physiography and soil types for adoption of micro irrigation under various soil textures in order to improve the water use efficiency. The results are yet to be compiled.
10. The information gathered in the study of the Cauvery command area pertaining to the available water resources, storage capacity of reservoirs, command area of the reservoirs, area of crops cultivated, irrigation potential created and present usage, cropping systems and their water use efficiency and soil types has been comprehensive and gives a holistic view of the command area. The present scenario of the command area, reasons for poor water productivity and approaches to improve water use efficiency have been well detailed.
11. The demonstrations and training programmes have comprehensively influenced the farmers to adopt new methods of irrigation management methods and techniques.

12. The project has not been able to conclusively demonstrate to the farmers the need for crop diversification. However, on station research and demonstration focused on crop diversifications viz., ragi, maize, leguminous crops like red gram, cow pea, avare and vegetable crops were conducted by involving scientists of crop improvement, protection and production team.

ACTION POINTS

a. The project has been meticulously planned and well executed. The integration of research projects with demonstration farms and training and education platforms for farmers is a novel idea which has borne exemplified results worth emulating.
b. The Water Technology Centre is only one of its kind in the entire State. There is need to establish similar water technology centres in other command areas to study the problems in irrigation management methods and techniques in those areas.
c. There is need to design research studies to evaluate the various irrigation management methods to determine their effect on water use pattern, water use efficiency, water savings and economics of the use of the method.
d. The impact of irrigation management techniques like drip, subsurface irrigation on soil characteristics and soil microflora needs to be evaluated.
e. There is need to design demonstrations to educate the farmers, especially tail end farmers, on crop diversification.
f. There is need to draw a calendar of training programmes to educate the farmers in the command area on water saving techniques.
g. Although, some government line departments were involved in the project, the convergence of line departments is necessary for better implementation of similar projects.
h. One of the objectives of the project was that the Water Technology Centre should act as a nerve-centre in organizing training programs, workshops, at grass root/command area based and state, national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management. This objective has only been partially achieved. There is need to identify the Water Technology Centre as a policy making agency with regard to irrigation management practices.

RESEARCHABLE ISSUES

1. Water use efficiency on the lines of Energy Usage Efficiency should be one of the focus areas of research.
2. Integration of Indigenous Techno logy Knowledges (ITKs) on management through multi-disciplinary approach should be taken up.

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TERMS OF REFERENCE FOR EVALUATION OF THE PROJECT ENTITLED "ESTABLISHMENT OF WATER TECHNOLOGY CENTER FOR CAUVERY COMMAND" IMPLEMENTED DURING THE PERIOD 2013-2019 BY UNIVERSITY OF AGRICULTURAL SCIENCES, GKVK, BENGALURU, AT ZONAL AGRICULTURAL RESEACH STATION, V C FARM, MANDYA

Title of the study:
Concurrent monitoring and evaluation of the project entitled "Establishment of Water Technology Center for Cauvery Command" (RKVY of Ministry of Agriculture Government of India, funding through Department of Agriculture GOK from 2013-14 to 2018-19)

Department / Agency implementing the Scheme:

a) Implementing Agency : University of Agricultural Sciences, Bangalore
b) Location: Zonal Agricultural Research station, VC Farm, Mandya.

Background Information;
The project was sanctioned under the Rashtriya Krishi Vikas Yojana (RKVY) which is State Plan Scheme of Additional Central Assistance Launched by the Government of India under the aegis of the National development council, which seeks to achieve four percent annual growth in agriculture by incorporating information on local requirements, geographical/climatic conditions available natural resources/technology and cropping pattern in districts so as to significantly increase the productivity of agriculture. Under this scheme several projects are being implemented with the aim of innovating new technology in agriculture for enhancing agricultural productivity. The University of Agricultural Sciences, Bengaluru is implementing many of the RKVY projects in different disciplines. The project "Establishment of Water Technology Center for Cauvery Command" is one such project.

Water is one of the most critical inputs for agriculture. However, the share of water availability to agriculture sector is declining at an alarming rate due to increasing demand for domestic, industry, energy and other purposes. The Cauvery in Karnataka is a water deficit river in the demand of water Cauvery command is for more than the water allocation made by the Cauvery Tribunal. The total irrigated area in the Cauvery Command is 18.5 lakh acres. Rice and Sugarcane are popular irrigated crops. Crops raised in command areas adopting conventional surface methods of irrigation viz, flooding, furrow border strip and ring basin involving huge conveyance and distribution losses resulting in low overall irrigation efficiencies. Efficient water management is the key role factor in production of any crop, since water is a single input which enhances the yield by 30-40 per cent. To address the above problems, Water Technology centre was established during the year 2013-14. The main focal theme on increasing Water Use Efficiency (WUE)/ Water Productivity with simultaneous maintain soil health, increase in crop production and sustained farm income.

With this background the project was planned to establish Water Technology Center at VC Farm Mandya to take up comprehensive action oriented and operational research on water management considering both surface irrigation and ground water exploitation to achieve the water productivity with the following objectives.

Objectives:

i. To conduct, coordinate and promote applied water research through multi-disciplinary approach.

ii. To collect, collate and disseminate information relating to available water resources and water management research and effective utilization of water.

iii. To function as a nodal agency for planning, programming and policy making in the management of water at all levels.

iv. To act as a nerve-centre in organizing training programs, workshops, at grass root/command area based and state national level seminars and to conduct short courses to acquire broad understanding of all aspects of water technology and management.

Review of Literature:

Anchal Dass and Subhash Chandra (2012) reported that SRI method of rice cultivation resulted in higher grain yield (6.10 t /ha) than the conventional method of transplanting (5.22 t/ha) which produced higher grain yield than conventional method. Water saving in SRI was to the tune of 30-40 per cent over conventional rice cultivation in India (Kumar et al., 2006). Zhu Defeng and Zhang Yuping (2007) reported that SRI method gave almost double yield than conventional method. Higher yield under SRI method was mainly due to more number of tillers per plant and wider spacing in turn leads to higher yield and nutrient uptake.

Thiyagarajan et al. (2007) observed that SRI method saved irrigation water up to 56 per cent as compared to conventional method in Tamilnadu. The result revealed that a combination of mechanization and SRI method can bring positive change in rice cultivation. It will increase production and further enhance income by reducing production cost. Mechanization will be a good option to the problem of labour scarcity, besides these farmers who can save valuable time by mechanization can take on other additional work for bettering their livelihoods (Rajendra Uperty, 2009).

Bouman and Twong (2001) revealed that shift from anaerobic to aerobic system of cultivation will have major positive consequences with respect to weed, disease and insect pest management, nutrient and soil organic matter dynamics and green house gas emission, carbon sequestration at experimental station at Beijing Changping. The potential water savings were larger in rice was grown under upland condition with high seepage rate.

Dixit et al. (2007) studied the difference between two methods by classifying the transplanter on the basis of nursery used i.e. machine using root wash seedling and machine used mat type seedlings (Mat type of seedling raised on a polythene sheet with the help of frames and observed that 20-30 seedlings were found to be suitable for transplanting). Lu et al (2000) concluded that local practices of mid season drainage reduced CH4 emission by 44 per cent as compared with continuous flooding. CH4 emission could further be reduced by intermittent irrigation yielding a 30 per cent reduction as compared to mid season drainage.

Agriculture sector is one of the largest consumers of water. The overall efficiency of the flood irrigation system ranges between 25 and 40 per cent in sugarcane crop. Adoption of subsurface drip irrigation may help in saving significant amount of water and increase the quality and quantity of the produce. All this emphasizes the need for water conservation and improvement in water-use efficiency to achieve, more crop per drop.

Application of water with integral drip lines at predetermined depth in the soil depending upon the soil type and crop water requirements. The development of improved plastic materials (thin walled drip tapes) has made subsurface drip irrigation system less costly and adoptable for many crops like cotton, maize and sugarcane (Smith et al., 1991).
Subsurface drip irrigation has evolved into an irrigation method with high potential for efficient and economical productivity and its use has progressed from being a novelty employed by researchers to an accepted method of irrigation for both perennial and annual crops (Ayars et al., 1999).

Parikh et al. (1996) reported that higher cane (185 t ha-1) and sugar yield (17.2 t ha-1) was observed under subsurface drip irrigation. Dineshkumar and Hunsigi (1997) opined that yield attributes like cane length (3.2 m), cane diameter (3.4 cm) and single cane weight (1.88 kg) were increased through subsurface drip irrigation. Compared to surface irrigation yield attributes like cane length (2.8 m), cane diameter (3.1 cm) and single cane weight (1.61 kg).

Chaudhari et al. (2000) opined that sub surface drip irrigation system resulted into higher cane yield (153.35 t ha-1) which was 9 per cent higher over to that of conventional method (141.76 t ha-1). Application of water through subsurface drip gave significantly higher sugarcane yield (183 t ha-1) and recorded higher growth and yield parameters over surface flood irrigation method (121 t ha-1) (Vaishnava et al., 2002). Raskar and Bhoi (2001) observed that maximum cane yield improvement with 125 per cent fertilizer level (157.19 and 17.35 t ha-1 cane and CCS yield, respectively). However, the yield obtained due to application of 75 and 100 per cent recommended dose of water soluble fertilizer through sub surface drip was on par, indicating 25 per cent savings in fertilizer. Among the various sources, yield of water soluble fertilizer (145.73 t ha-1) was at par with the yield obtained by fertigation of urea, diammonium phosphate and muriate of potash

Bhoi et al. (2001) reported that under paired rows (75 cm), four rows (90 cm) and subsurface drip irrigation through N fertigation in 4, 10 and 20 splits recorded mean cane yield of 171.4 t ha-1 and was found highest with four row planting with 20 splits. However, paired row planting with 20 splits of N produced similar yield of 169.9 t ha-1. Deshmukhe et al. (2001) reported that millable cane length (2.3 m), girth (2.8 cm) and number of internodes (25.0) were higher under drip irrigation at weekly interval than furrow method of irrigation (1.9 m, 2.55 cm, 22.0, respectively).

Sugarcane cultivation through subsurface drip recorded 1530 kg cane ha cm-1 of water, whereas it was only 690 kg ha-cm-1 under surface irrigation (Selvaraj et al., 1997). Application of fertilizer through drip resulted in significant increase in cane yield (28 %) over surface irrigation method (21 %) (Bangar and Chaudhari, 2001). Hapase et al. (2002) reported that 50-55 per cent water saving in daily drip irrigation with 12-37 per cent increase in yield and 2.7 times higher water use efficiency compared to conventional furrow irrigation.

Mode of Implementation:

The project was implemented from 2013-2019 at Zonal Agricultural Research Station, V C Farm, Mandya to cater the needs of the farmers of Cauvery command area in relation to conduct scientific-applied research, teaching and extension in water management. The issue on enhancing water productivity was highlighted and awareness created to the farmers, extension functionaries and scientific staff through organizing large scale demonstration, field days, trainings/seminars and workshop.

Research studies were conducted in multidisciplinary approach on rice, sugarcane, maize, finger millet, soil and water conservation, fisheries and other semi irrigated crops of Cauvery command indicates that increased in water productivity with higher yield on different crops and cropping systems. The large scale demonstration on water saving technologies in Rice and Sugarcane were conducted in an area of 224 acres in Mandya and Mysore district and created awareness among the farmers on judicious use of water and enhancing water productivity.

Research activities: Research activities are formulated based on the thrust areas identified and were conducted in multidisciplinary approach. Research on rice, sugarcane, finger millets, maize and green manure crops were conducted from 2013-2018 at Zonal Agricultural Research Station / College of Agriculture, V.C.Farm, Mandya. The details of the experiments are as follows.

Sl.No Crop Title of the studies
1 Rice Enhancing water productivity and profitability of rice through different production system.
2 Bio – fortification of rice (Oryza sativa) with Zn & Fe in methods of rice cultivation.
Evaluation of different irrigation management practices for their water saving potential and enhancement of the productivity and profitability in different rice establishment methods.
3 Studies on growth and yield of aerobic rice as influenced by drip fertigation.
5 sponse of sprinkler irrigation on rice productivity in Cauvery command.
6 Maize Studies on drip fertigation under different planting geometry of Maize (Zea mays L.)
7 Phosphorous management through foliar nutrition in drip irrigated Maize (Zea mays L.)
8 Finger millet Effect of moisture regimes on growth and yield of transplanting finger millet.
9 Sugarcane Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation
10 Standardization of water soluble fertilizers for sugarcane crop through micro irrigation
11 Green manure crop Water requirement and water productivity estimation in green manure – rice based cropping system.
12 Ground water Studies on characterization of water availability and management as the canals command area.
13 Fisheries Effect of pond water salinity/ alkalinity and stocking density on the growth and survival of carps spawn reared to finger lings
14 Soil Health Applications of Remote Sensing and Geographical Information System for Soil Fertility Mapping of V C Farm, Mandya, Karnataka
15 Socio-economic studies Survey on status of water management practices in Cauvery command of Karnataka.

Large scale Demonstration: The large scale demonstration on water saving technologies in rice and sugarcane was conducted in an area of 224 acres in Mandya and Mysore district. The beneficiaries were selected based on PAR techniques for implementation of demonstration in Mysore and Mandya districts of Cauvery Command.

Sl. No.	Crop	Demonstration	Area (acres)	Places
1.	Rice	Mechanized System of Rice Intensification	100	Hosabudanuru, Sampahalli, Kyathungere, Mandya, Induvalu, Beeragoudanahalli,
2.	Rice	System of Rice Intensification (SRI)	85	Thorechakanahalli, Gurudevanahalli, Thippenahalli koppalu, Kallimeledoddi, Bhoppasamudra, Matadadoddi
3.	Rice	Aerobic rice	15	Mangala
4.	Sugarcane	Surface and sub surface method of irrigation	24	Mandya and Mysore
Total			224	

Capacity building and awareness: Organized 38 training programmes/ workshop/ seminars/ brainstorm/world water day to educate the farmers on importance of water and adoptin of water saving technologies for enhancing Water Use Efficiency in field crops. Around 4734 farmers were participated and benifitted from the programme.

Evaluation questions and minimum expectations:

1. Is there any similar center established in the State? – No

Water Technology Centre (WTC) was established under GoK (RKVY) project during 2014-15 in an area of 540 sq. m. at ZARS, V. C. Farm, Mandya coming under the jurisdiction of University of Agricultural Sciences, GKVK, Bengaluru to cater the needs of farmers of Cauvery command area in relation to conduct scientific-applied research, teaching and extension in water management. It plays a vital role in making an assessment of the available resources of water and economic utilization for maximizing agricultural production with suitable on-farm water management practices developed for different situations. The related institute working on both land and water by Water and Land Management Institute (WALMI), established by Government of Karnataka under World Bank assistance at Dharwad.

2. Whether the Water Technology Centre is being useful to the farmers of the Cauvery Command Area? Yes

Water Technology Center is being useful to the farmers of the Cauvery command by developing scientific research on water management in crops and cropping system, popularization of technologies through conducting large-scale demonstrations and creating awareness on judicious use of water among the farmers. Farmers of command area adopting water saving technologies in rice like., DSR, SRI, mechanized SRI, drum seeding and surface and subsurface drip irrigation in sugarcane for enhancing water productivity and profitability through,

- Through awareness programme on judicious use of water in association with line department and conducted large scale demonstrations of water saving technologies in rice and sugarcane crops.
- Exhibited on farm demonstrations of water saving technologies infield crops for the benefit of farming community.

 Utilized facilities available at soil and water testing laboratory in order to know the soil and water quality parameters.

3. Have the farmers and extension functionaries will be benefitted from Water Technology Centre? Yes

i. The farmers and extension functionaries are being benefitted through technologies developed from the center. The center is organized 38-40 training/ seminars/brainstorming programmes by involving 4500- 5000 progressive farmers and extension functionaries.

ii. Organized 200-500 acres large scale demonstration on water saving technologies in rice, sugarcane, maize, ragi, redgram and vegetable crops.

4. Whether the established soil and water testing laboratory have been benefitted by the farming and scientific community? Yes

The facilities available are being utilized by the farmers and scientific community for the soil and water analysis. Approximately 1500-2000 soil samples were analyzed and suitable recommendation was provided.

5. Is there any water saving technologies has been developed in Rice and Sugarcane crops for enhancing water productivity?

Based on the outcome of the studies, the following technologies were developed and included in package of practices.

a) Standardization of agro-techniques for System of Rice Intensification (SRI) and mechanized SRI.

b) Standardization of tray nursery techniques for mechanized SRI

c) Standardization of drip fertigation in aerobic rice

d) Standardization of subsurface drip fertigation in sugarcane

6. Have the established water saving technology demonstration plots have useful to the farming and scientific community? Yes

Water technology museum and water saving technologies demonstration blocks are being useful to the farming communities, students and line departments of different districts and state during their visit to the center.

7. Have the selected farmers acquired knowledge on water saving technologies in Rice and
Sugarcane crops? Yes

The selected farmers of the Cauvery command have acquired knowledge on water saving technologies in rice and sugarcane developed from the center. The line department's viz. KSDA, CADA, Cauvery Niravari Nigma etc. encouraging in adoption of drip fertigation in sugarcane and water saving technologies in field crops by conducting training, seminars, field days and through organizing field demonstrations.

8. Have the farmers acquainted themselves with the water saving technologies in Rice and Sugarcane crops? Yes

The knowledge acquired from the center, now the farmers themselves practicing water saving technologies in crops and cropping system. Farmers are practicing DSR in rice, drum seeding and SRI, surface and subsurface drip fertigation in sugarcane and sprinkler irrigation in ragi and vegetable crops.

9. Whether the methodologies of water saving technologies have been acquainted for increasing water use efficiency? Yes

Through large scale demonstrations and hands on training programmes (skill oriented) helped for knowing the methodologies of water saving technology in enhancing water use efficiency.

10. Whether the public have been made aware of the water saving technologies over conventional method? Yes

The center has created awareness on adopting water saving technologies over conventional method by organizing training / workshop / seminars, field days and interactions. The merits and demerits of improved method of irrigation over conventional method being convinced to the public.

11. Whether the standard methods have been followed for adoption of water saving techniques? Yes

The water measuring devices like water meter and knowing the discharge rater of the laterals in flood and drip irrigation respectively.

12. Have the farmers benefitted as results of converting the flood method of irrigation to water saving technologies in Rice (SRI, Mechanized SRI, DSR, Drum seeder etc.,)?Yes

The improved water saving technologies in rice resulted 20-40 per cent of water saving as compared to conventional method of irrigation besides improvement in soil health.

13. Have the farmers benefitted as results of converting the furrow method of irrigation to surface and subsurface drip irrigation in Sugarcane? Yes,

The surface and subsurface method of irrigation in sugarcane resulted in 45-50 per cent water saving over farmer's practice of irrigation besides improvement in soil health.

14. Have the farmers gained knowledge on enhancing water productivity in rice and sugarcane? Yes

The farmers gained knowledge on various water saving technologies through training, seminars, visiting to research and demonstration plots, museum and mass medias like news paper clippings, radio talks, doordarsan programmes, krushi darshan and leaflets and folders.

15. Have the farmers realized the importance of judicious use of water/water saving technologies? Yes

The following are the advantages by using judicious use of water are,

An area of 4000ha in rice and 1000ha in sugarcane is increased under water saving technologies after intervention of the project.

Enhancing water productivity / Water Use Efficiency

Increase in yield (20-25 per cent in rice and 45- 50 per cent in sugarcane)

Reduction in usage of fertilizers (20-30%)

Reclamation and prevention of saline and alkali soils (Soil health)

Saving labour

Reduction in cost of cultivation

Increase in income

16. Has water saving methods of rice cultivation (SRI, DSR and Drum seeder method) acquired popularity among the farmers? Yes

The developed technologies were spread through audio-visual aids and water users association apart from scientists and line departments.

17. Has surface drip and subsurface method of drip irrigation in sugarcane acquired popularity among the farmers? Yes

The surface and subsurface drip fertigation irrigation in sugarcane acquired the popularity among the farmers through audio visual aids and necessary subsidies from the line departments.

Evaluation Methodology and Sampling:

1. Interaction with Co-ordinator and Principal Investigators to seek information.
2. The Water Technology Centre, Water technology museum, Soil and Water analysis laboratory, and field demonstration units are to be inspected and evaluated for their utility.
3. Response of the beneficiary farmers/ stake holders is to be documented.
4. The extent of knowledge dissemination on water saving technologies in rice, sugarcane and other semi irrigated crops to be ascertained.

Deliverables:

A detailed report of the project on Establishment of Water Technology Center for Cauvery Command” needs to be submitted.

Duration and time schedule for the study:

The task should be completed in three months’ time

- Visit to water technology center and inspection of Water technology museum, Soil and Water analysis laboratory, and field demonstration units
- Discussion with Principal Investigator
- Discussion with Farmers and stake holders
- Preparation of draft report
- Presentation of draft report
- Final report to be submitted

Quality Expected from the Evaluation Report:

1. The importance of water saving technologies as projected through the project implementation
2. The utility of water saving technologies as enhancing water use efficiency
3. The impact of water saving technologies in enhancing water productivity
4. The impact of transferring technology to stake holders

Recommendations:

Specific recommendations leading to policy changes in water management in rice and sugarcane shall be useful.

Cost and Schedule of Budget:

a. The first installment of the consultation fee of 30 % of the total fee shall be paid as advance to the consultant after the approval of the inception report, but only on execution of a bank guarantee of a schedule nationalized bank valid for a period of at least one month from the date of receipt of advance.

b. Second installment of consultation fee of 50 per cent of the total fee shall be payable to consultant after the approval of the draft report.

c. Third and final installment of consultation fee amounting to 20 per cent of the total fee shall be payable to the consultant after the receipt of hard and soft copies of the final report in the format and number as prescribed in the agreement along with all original documents.

d. Tax will be deducted from each payment as per the rates in force; in addition the evaluator is expected to pay statutory taxes at their end.

Minimum qualification of the consultant:

Consultants should have and provided details of evaluation team members having technical qualification/capacity as below.

1. Post graduate agriculture and allied sectors having knowledge of Agronomy and Soil Science
2. Research Assistants with good data processing skills
3. And in such numbers that the evaluation is completed within three months of the schedule time prescribed by in the TOR. Consultants not having these number and kind of personnel will not be considered as competent for evaluation.

Providing oversight:

Karnataka Evaluation Authority will provide the funds and oversight for the study. All technical aspects of the study are subjects to their approval.

Contact Persons:

Dr.C.Ramachandra, Professor, Department of Agronomy, Zonal Agricultural Research Station, V C Farm, Mandya-571405, +91-9449137362, Email: ramaakhil09@gmail.com will be the contact person for giving information and details for this project.

EVALUATION TEAM MEMBERS

Sl. No.	Name	Designation
1	Dr. B. C. Suryanarayana	Principal Investigator
2	Dr. M. A. Shankar	Associate Investigator
3	Sri. Siddaraju	Associate Investigator
4	Dr. M. Ananthachar	Subject Matter Specialist

Dr.Suryanarayana, B.C. is a doctorate in Agriculture with specialization in Agronomy and is a Certified Associate of Indian Institute of Banking (CAIIB), Fellow of Indian Institute of Valuers. He worked in State Bank of India from the year 1981 to 2014 as a Technical Officer and retired as Asst. General Manager (Rural Development). He is a practicing consultant in the field of Agriculture, Horticulture, poultry, dairy, fisheries and plant tissue culture and covered cultivation. He has about 35 years of experience in the field and has prepared several project reports for financial institution, written books in vanilla cultivation, anthurium, medicinal and aromatic crops, minor irrigation, poultry and dairy farming. He has appraised more than 6,000 proposals in agriculture and related fields for funding by the Bank and has also been involved in many studies relating to development of Agriculture and allied activities. He has served as a General Manager in a bio-fertilizer, bio-pesticides and organic manures manufacturing company and is also a Technical Director in a company involved in manufacture of agricultural implements and equipment.

Dr. M. A. Shankar is a doctorate in Agriculture with specialization in Agronomy. He is former Director of Research, University of Agricultural Sciences, Bengaluru and presently the Executive Member of Institution of Agricultural Technologists, Bengaluru and Co-Chairman of Agribusiness Consultancy Subcommittee. He has implemented 51 research projects for the University funded by International organizations, Central and State governments, Private firms. He has guided 6 Ph. D. students and 15 M. Sc., (Agri) students. As Dean of College of Agriculture, Hassan, he has, with his administrative skills, streamlined accounting, financial, academic and administrative issues. He has been involved in review and evaluation of Technical Reports of 32 All India Co-ordinated Research Projects (AICRP) spread all over India. He has also evaluated 11 operational research projects for the technical feasibility and implementation. He has published 173 peer reviewed research papers. He has also penned 54 booklets and books for the University. He has vast experience in evaluation studies of projects.

Sri. Siddaraju is a Graduate in Agriculture with more than 35 experience in the field of Agriculture. He has served in the Karnataka State Department of Agriculture (KSDA) as Asst. Agricultural Officer in Farmers' Training and Education Centre, Soil Testing laboratory and as Subject Matter Specialist. He was Deputy Director of Agriculture (Commercial Crops) for 6 years, District Watershed Development Officer for 2 years. He has also been Joint Director of Agriculture (Inputs) for 5 years. He was involved in preparation of Annual Programme Planning booklets pertaining to Agricultural Inputs in Department of Agriculture. After retirement, he is serving as Chairman, Agriculture Consultancy Subcommittee, Institution of Agricultural Technologists, Bengaluru and has been actively involved in evaluation studies of projects.

Dr. M. Anantachar has a mechanical engineering degree from Karnataka University, Dharwad, a post graduate degree in Farm Power and Machinery from Tamilnadu Agricultural University and a Ph. D. in Mechanical Engineering Sciences from Vishveshwaraya Technological University, Belgaum. He is a Fellow of Institution of Engineers (India) and a life member of Indian Society of Agricultural Engineers. He has over 35 years' experience in teaching and research in Farm Machinery and Power. He has authored four books and published 23 research papers on Farm Power and Machinery is International and National research journals. He has also published 12 international papers, 42 national papers, 52 papers in other research journals and conducted/ participated in 72 national level seminars. He also has 98 popular articles and 37 teaching manuals/ extension bulletins and e-resources to his credit. He has been a Technical Committee member in Mechanization Scheme of Department of Agriculture, Govt of Karnataka from 2006 to 2017, Krishi Yantra Dhare Scheme in Raichur district, SMAM Meeting from 2013 to 2017, for establishment of RFMSC (Rural Farm Machinery Service Centres) in Karnataka during 2016-17 and a member for preparation of technical specification for Farm Machinery Tender document from 2008 to 2017. He was also Principal Investigator of Farm Implements and Machinery (Mechanization scheme of ICAR) project from 1996 to 2017.