DEVELOPING SUSTAINABILITY RELATED KNOWLEDGE AND CAPABILITY FOR FARMERS:

A CASE STUDY OF NONAVINAKERE IRRIGATION TANK IN TUMKUR

A REPORT BY INDIAN INSTITUTE OF MANAGEMENT BANGALORE
WITH SUPPORT FROM HANNS-SEIDEL-STIFTUNG INDIA

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INTRODUCTION

1. Introduction

Water is the essential resource for sustainable development worldwide. Apart from sustaining human life, it is crucial for the agriculture, industry, and economic growth of a country. Moreover, it is the vital component of the environment and has significant impact on health and nature conservation. An alarming challenge to feed rising population along with the industrial development and climate change, are stressing the quantity and quality aspects of this natural resource. The need to increase the food production by 50 percent till 2030 and double the production by 2050 is considered as an enormous challenge in India as well as in other parts of the world (Leflaive, 2012). Water available for agriculture is seen as a major constraint in achieving these targets due to the pressures from growing urbanization, industrialization and climate change. A mere expansion of the area under cultivation, possible only in few countries, it is no longer sufficient to meet the ever-growing food demand of a growing population.

Most agriculture related government interventions in India revolve around the provision of seed/fertilizer/pesticide-subsidies, free power/water for irrigation, and support prices, for farmers. While such policies may provide relief in the short term, they engage resources in an unsustainable way. For example, minimum support prices for certain grains could lead to farmers overproducing them leading to crop-monoculture and over-exploitation of soil and water. Similarly, the availability of free power/irrigation could make farmers over-use water, and fertilizer/pesticide subsidies could lead to the over and inappropriate usage of these inputs. While subsidies and support systems such as above are considered by policy makers crucial to guarantee a certain basic level of market participation for farmers to ensure their economic livelihoods, the overall Indian agriculture policy landscape has mainly focused only on these, and ignored other policy spheres such as farm specific knowledge provision through appropriate mechanism, market infrastructure provision, etc. Moreover, these support policies have not worked well in developing stable agricultural practices that are also economically viable in reducing costs and increasing productivity and ensuring environmental sustainability.

Global irrigated area has increased more than six-fold over the last century, from approximately 40 million hectares in 1900 to more than 260 million hectares (Postel, 1999; FAO, 1999).

Today 40 percent of the world's food comes from the 18 percent of the cropland that is irrigated. Irrigated areas increase almost 1 percent per year (Jensen, 1993) and the irrigation water demand will increase by 13.6 percent by 2025 (Rosegrant and Cai, 2002). On the other hand, 8-15 percent of fresh water supplies will be diverted from agriculture to meet the increased demand of domestic use and industry. Furthermore, the efficiency of irrigation is very low, since only 55 percent of the water is used by the crop. However, average water use efficiency of irrigation projects is estimated to be only 30-35 percent in India (Bhalage et al., 2015).

We argue that rather than overtly relying on subsidies and price- and input-support systems to help make farming economically viable, government policies should heavily focus on proper management of natural resources such as water and providing information on best practices on farming. This is because, typically, proper resource management, scientific cultivation practices and effective market participation requires complex decisions and currently farmers do not have the right kind of information to sustainably use inputs such as pesticides, fertilizers, or water, at the right time, in right amount, and in the right way.

The policymakers realize the increasing scarcity problems of natural resources and started searching for alternative methodology as "use and discard" methodology no longer cannot be followed either with water resources or any other natural resource. As a result, the need for a consistent policy of rational management of water resources has become evident. To overcome water shortage for agriculture it is essential to increase the water use efficiency and to use marginal waters (reclaimed, saline, drainage) for irrigation.

Under scarcity conditions and climate change considerable effort has been devoted over time to introduce policies aiming to increase water efficiency based on the assertion that more can be achieved with less water through better management. Better management usually refers to improvement of water allocation and/or irrigation water efficiency. The former is closely related to adequate pricing, while the latter depends on the type of irrigation technology, environmental conditions and the scheduling of water application.

An efficient agricultural water management (AWM) in conventional smallholder farming systems provides a win-win solution in the provision of opportunities for crop production, thus enabling other much-needed investments in, for example, nutrients, weeding and timely operations. However, the emerging effects and efficiencies on landscape water resources induced by many farmers/community changing their field-scale water management strategies are unpredictable and context specific. It is increasingly being realized that to ensure successful and sustainable adoption of new AWM approaches, a range of different issues must be addressed. Moreover, AWM needs to be biophysically and technically appropriate, along with economically viable. Moreover, there is also an increasing awareness of the need to focus on the formal and informal institutional setting, which ultimately define the governance of water and land at the local scale. The complementary support to institutions and community mobilization at the mesoscale of small catchments is equally important to gain successful adoption of new AWMs. The emerging externalities, both on water and land resources not subject to AWM interventions needs, as well as social and equity issues, must be addressed: who benefits and who loses?

2. About this study

The tank irrigation programs are considered as an effective tool for addressing water related problems and recognized as potential engine for agricultural growth and development in fragile and marginal rain fed areas. Such programs are initiated to improve and sustain the productivity and production of the dry and rain fed regions through adoption of appropriate production and conservation techniques. The stakeholders are the tank management authorities or officials and villagers. The efficiency of tank management authorities prominently depends on the efficient management, supply augmentation, efficient distributional process, proper institutional structure, and good infrastructure. Likewise, their performance as tank maintaining and distributing body. Proper knowledge and well awareness of the managing authority on all the aspects of the water tank and use of water also enhance the equal and efficient use of water. Moreover, climatic factors are playing a very important role in efficient and equal distribution of water and proper management of the water tank.

The beneficiaries are the competing water users like villagers and farmers. The tank management bodies are not solely responsible for efficient use of water and efficiency of a water tank irrigation program. The beneficiaries are playing a crucial role to ensure efficient and sustainable tank irrigation program. Beneficiaries' socio-economic, institutional factors, management and use of water in different activities will influence the water use efficiency. Therefore, an efficient and sustainable water tank irrigation system depends on the efficiency of the stakeholders and beneficiaries. Further, the relationship between the tank management authorities and beneficiaries is one of the determining factors of efficient tank irrigation program. The climatic factors like rainfall, soil quality, ground water level, and vegetation have both direct and indirect impact on efficient and sustainable water tank irrigation system. The present study is focusing on management of water resources at local level and water use along with the other input usage and how advisory services can help moving towards best practices to strengthen the efficiency of water use.

3. Background of the study area

Nonavinakere waterbody is situated under Tiptur Taluk, Tumkur district. Hence it is important to note the district and physiographical setup while analysing the waterbody, as part of the study. Census data (2011) and the district handbook does give a good amount of information about the district, which is referred to here to under broad details about the district. It is located on the eastern belt in the southern region of the State. Tumkur district comprises of an area of 10,597 sq.km. It is the third largest district in terms of area in the State. The district's north to south extension runs to 174 km. and east to west extension is measured as 125 km. Tumkur is a part of the southern Karnataka plateau and located in the eastern belt in the southern half of the State. Tumkur is a land locked district. It has no natural features like rivers or mountains dividing it from the other districts of the State. The landscape consists mainly of undulating plains interspersed with a sprinkling of hills. To the east of Tumkur and north by Devarayanadurga, there is a short stretch of hilly country intersected by cultivated villages.

Photograph 1: Nonavinakere water tank

3.1 Physiography

There are several hill ranges and isolated hills as well. While the western parts are occupied by long ranges of hills running in a south by south-easterly direction, the eastern parts are occupied by a narrow range of granitic hills running north and south. There are two parallel ranges running north to south and the first one of these in the eastern portion passes through Pavagada, Madhugiri, Koratagere and northern part of Tumkur taluk. The second range, mainly composed of schistose rocks, passes through the western parts of the district in the taluks of Chiknayakanahalli, Sira and Gubbi. There is another cluster of hills covering the middle and the southern parts of Kunigal taluk. In this zone the tree growth is comparatively dense and trees tend to grow taller and stouter.

3.2 Climate

The year may be divided into four seasons. The district experiences continuous rise in temperature during the months of March to May and April is usually considered as hottest month. Maximum temperature may reach about 40-41 Degree C during the hot season. Southwest monsoon sets in during the period of June to September. In this season, the temperature drops appreciably, and the weather is pleasant throughout the season.

October and November may be termed as post- monsoon season and during the period temperature decreases steadily and remains cool till February. Winter sets in December and prolongs up to February. December is generally the coolest month of the year and the daily minimum temperature in this season sometime reaches 9 - 10 Degree C.

3.3 Forest

The total forest area constitutes 4.3 percent of the total geographical area. These forest areas lie in the dry belt zone. The vegetation in this dry belt is inferior to those found in evergreen forests. Forest region in the district is found to a larger extent on the lower slopes of hill ranges.

3.4 Geology & soils

Geologically, Tumkur district is situated right on the archaeon complex. The rock formations are represented by the crystalline schists, the granitic gneisses and the newer granites. The crystalline schists of this district, which form the southern extension of the well-defined Chitradurga.

3.5 Soil

The soil in the district is generally hard and less fertile. More commonly seen in the district are red soil, black soil and sandy soil. The red soil also known as ragi soil is seen in southern and western taluks, while the black soils in northern taluks and sandy soils in eastern tract are spotted in the district. As per the definition of National Soil survey Organization & Land Use Planning, the soils in the district can be classified as Ustalfs and Ustalfs-Tropepts. Red, gravelly, sandy, clay loam, blade soil, sandy clay, clay and alkaline soils confined to Koratagere taluk alone are the other types of soils found in the district. The red soil is found in the taluks of Tumkur, Madhugiri, Pavagada, Tiptur, Turuvekere, Kunigal and Gubbi. Especially in Tumkur, Kunigal and Sira, the soils are red loams and are 2 to 5 feet fairly deep. They are under laid with murram and are well drained but poor in lime and bases. The red and red loamy soils are suitable for graining a wide variety of crops with manuring and proper irrigation. These soils occur in regions of medium rainfall ranging from 25 inches to 60 inches. Except plantation crops like coffee and cardamom, almost all crops are grown in the district. The black soil is more suitable for cultivation of cotton crops is found in large extent in Madhugiri taluk. This type of soil is also found in Sira, Chiknayakanahalli, Gubbi, Tiptur, Turuvekere and Pavagada taluks. These soils are rich in bases and have a high-water holding capacity. The rainfall in these tracts is generally lower than in other parts and farming is of the dry type. Black soils are particularly suited for rain-fed crops like short staple cotton, groundnut, jowar and toor.

3.6 Cropping

The economy of Tumkur is mainly dependent on agricultural land. The district in spite of being not blessed with major rivers and irrigation projects, the agricultural activity and its contribution to the district economy is worth mentioning. Another feature of the agricultural economy of the district is that a considerable portion of its land lies in the coconut belt. According to 2011 Census, cultivators form 37.35 percent and agricultural labourer form 26.01 percent, which highlights that agricultural activity is still predominant in the district. The size of the agricultural land holdings is one of the important factors that determine the productivity of the land. The landholdings for the year 2005-06 of different size are given in the table 2. From the table, it is observed that the number of marginal holdings below one hectare and small holdings of size one to two hectares constitute 74.50 percent of the total holdings. Only 1.05 percent of holders own land more than ten hectares.

Table 1: Area, production, and average yield of paddy for 2009-10 under all seasons

Crop	Area in hectare	Production in tonnes	Yield in kgs per hectare	Area in hectare	Production in tonnes	Yield in kgs per hectare	Area in hectare	Production in tonnes	Yield in kgs per hectare
Paddy	35871	138415	4062	464	950	2155	36335	13965	4037

Table 2: Land holdings in hectares 2005-06

LAND HOLDINGS IN HECTARES 2005-06

Sl. No.	Name of Taluk	Marginal (Below 1)		Small (1-2)		Semi-Medium (2-4)		Medium (4-10)		Large (10 and above)		Total Holdings	
		Holder	Area	Holder	Area	Holder	Area	Holder	Area	Holder	Area	Holder	Area
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Chiknayakan halli	18934	9209	10728	15350	7323	20176	3214	18175	243	3178	40442	66088
2	Sira	15133	7994	13341	19370	10470	28811	5827	33953	988	14713	45759	104841
3	Pavagada	14096	7481	9409	13356	7850	21404	5470	32813	1599	25152	38424	100206
4	Madhugiri	21342	10402	11578	16609	7338	19932	2912	16838	382	5395	43552	69176
5	Koratagere	14173	6871	7659	10922	4602	12658	1905	10696	152	2322	28491	43469
6	Tumkur	30520	13963	12542	17813	7204	19654	2723	16590	236	3355	53275	71375
7	Gubbi	28514	13302	13270	18830	8214	22394	2825	15987	219	2970	53042	73483
8	Tiptur	24113	10946	10504	14867	5825	15994	2156	12174	179	2570	42777	56551
9	Turuvekere	18005	8850	8772	12609	5563	15249	2234	12415	215	2957	34789	52080
10	Kunigal	22109	9997	10121	14317	6946	19103	2663	15029	213	2925	42052	61371
	Total	**206939**	**99015**	**107924**	**154043**	**71335**	**195375**	**31929**	**184670**	**4426**	**65537**	**422603**	**698640**

Source: Tumkur District at a glance 2009-10, District Statistical Office, Tumkur.

Ragi is most extensively cultivated food crop of the district. It is grown both under irrigated and rainfed conditions. The total area put under cultivation of ragi roughly constitutes one-third of the total cropped area. Paddy, maize and jowar are the other important crops that is being raised in the district. The major oil seeds grown in the district are sunflower, castor, groundnut, niger seeds besides rape and mustard, sesamum and soyabean. Cotton, sugarcane and tobacco are the commercial crops raised in the district (Table 3).

Table 3: Area, production, and average yield of principal crops for 2009-10 under all seasons

AREA, PRODUCTION AND AVERAGE YIELD OF PRINCIPAL CROPS FOR 2009-10 UNDER ALL SEASONS

Principal Crops	Irrigated			Un-irrigated			Total		
	Area in hectare	Production in tonnes	Yield in Kgs per hectare	Area in hectare	Production in tonnes	Yield in Kgs per hectare	Area in hectare	Production in tonnes	Yield in Kgs per hectare
1	2	3	4	5	6	7	8	9	10
Jowar	277	450	1710	7090	5490	815	7367	5940	849
Bajra	0	0	0	136	42	327	136	42	327
Maize	8587	17126	2099	11719	22222	1996	20306	39348	2040
Ragi	8186	16269	2092	171981	236219	1446	180167	252488	1475
Wheat	0	0	0	0	0	0	0	0	0
Total small Millets	-	-	-	-	-	-	2880	2026	740
Total cereals and Millets	-	-	-	-	-	-	**247191**	**392803**	**1673**
Total Pulses	-	-	-	-	-	-	**65040**	**36136**	**585**

Coconut, mango, grapes, brinjal, potato, banana, tomato, papaya and cabbage are some of the plantation and horticultural crops cultivated in the district. Among condiments and spices, the district is known for dry chillies, dry ginger, coriander, black pepper and garlic.

3.7 Village details

Nonavinakere is a Village in Tiptur Taluka, Tumkur district and Karnataka State. Nonavinakere Village Total population is 4631 and number of houses are 1,153 (Table 4).

In Nonavinakere village population of children with age 0-6 is 450 which makes up 9.72 percent of total population of village (Table 4). Average Sex Ratio of Nonavinakere village is 969 which is lower than Karnataka state average of 973. Child Sex Ratio for the Nonavinakere as per census is 923, lower than Karnataka average of 948.

Nonavinakere village has higher literacy rate compared to Karnataka. In 2011, literacy rate of Nonavinakere village was 85.96 percent compared to 75.36 percent of Karnataka. In Nonavinakere Male literacy stands at 89.94 percent while female literacy rate was 81.87 percent (Table 5).

Table 4: Demography of Nonavinakere village

Particulars	Total	Male	Female
Total no. of houses	**1,153**	-	-
Population	**4,631**	2,352	2,279
Child (0-6)	**450**	234	216
Schedule Caste	**365**	157	208

Table 5: Details of literacy and workforce of Nonavinakere village

Particulars	Total	Male	Female
Literacy	**85.96%**	89.94%	81.87%
Total Workers	**2,033**	1,478	555
Main Worker	**1,759**	-	-
Marginal Worker	**274**	181	93

Table 6: Details of population, sex-ratio, literacy, and cast of Nonavinakere village

Particulars	Numbers (percentage)
Number of Households	141
Population	628
Male Population	325 (51.75%)
Female Population	303 (48.25%)
Children Population	94
Sex-ratio	0.932
Literacy	63.54%
Male Literacy	68.31%
Female Literacy	58.42%
Scheduled Tribes (ST)%	9.39%
Scheduled Caste (SC)%	26.11%

3.8 Location and administration

Nonavinakere Village Gram Panchayath name is Nonavinakere. Nonavinakere is 14 km distance from Sub District Head Quarter Tiptur and it is 86 km distance from District Head Quarter Tumkur. Nearest Statutory Town is Tiptur in 14 km Distance. Nonavinakere total agricultural area is 424.62 hectares, non-agricultural area is 354.73 hectares and total irrigated area is 243.65 hectares

3.9 Education

Private Pre-Primary, Govt Primary, Govt Middle and Govt Secondary Schools are available in this Village. Nearest Government Degree, Private Engineering College and Govt Polytechnic College are in Tiptur. Nearest Govt Disabled School and Private Medical College are in Tumkur.

3.10 Health

There is a Primary Health care centre, a Primary Health Sub-Centre, a Maternity and Child Welfare centre, a TB Clinic, a Veterinary Hospital, a Family Welfare centre in the village.

There is one MBBS Doctor, one RMP doctor and five medical shops are available in this village.

3.11 Agriculture

Coconuts, paddy and ragi are major crops taken in this village. Total irrigated area in this village is 243.65 hectares from Boreholes/Tube wells.

3.12 Drinking-water and sanitation

Treated Tap Water Supply all-round the year is available. Open well, Hand Pump and Tube Wells/Boreholes are other drinking water sources. The village has open drainage system. There is no proper system to collect garbage from the streets. Drain water is discharged directly into water bodies.

3.13 Nonavinakere tank

Nonavinakere is one of the huge water bodies in Tiptur taluk with the adjoining, yet another massive water body Mallaghattakere. Both these water bodies exist in a series and support very

Photograph 2: Left bank canal gate

large areas of agricultural and irrigation activities. Nonavinakere water body was constructed in 1890 with a catchment area of 69.98 sq. km. It supported a water spread area of 499.30 Ha with a total capacity of 354.91 million cubic feet and live capacity of 296.00 million cubic feet and the length of the bund is reported to be 2 km.

The discharge capacity was planned to be 11656 cu. secs, proposed utilisation was estimated at 191.75 mill cubic feet and registered atchkat was 540.92 Ha. The tank is supported with 2 canals, left bank with 6.5 km and right bank with 4.5 km with 3 waste weirs.

METHODOLOGY

4. Methodology

4.1 Research questions and objectives of the study

4.1.1 Key research questions

The present study tries to address the following research questions related to an irrigation tank to generate scientific knowledge on integrated water resources management for efficient and sustainable use of water by farmers for agricultural practices.

1. How are irrigation tanks managed to enhance equity and improve water use efficiency?
2. How efficiently farmers are using water for irrigation purposes?
3. What are the initiatives taken individually and by the community to improve the management of water resources?
4. What improvements in the management of tanks and creating awareness among farmers will enhance equity and improved the use of water?

4.1.2 Research objectives

Based on research gaps and research questions, the following four research objectives are framed.

1. To identify the influence of the management factors on equal and efficient use of water
2. To analyse the irrigation process and to identify the factors which influence the farmers' efficient water use level
3. To identify the initiatives taken individually and by the community to improve the management of water resources
4. To find the improvements in the management of tank and the programs to create awareness among farmers to enhance equal and efficient use of water.

The study is an attempt of contextualized understanding of tank irrigation management. The methodology chosen to address the research objective is the intensive study of a tank irrigation command. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundary between phenomenon and context are blurred and multiple evidence are used (Yin, 1992). The case study method differs from a sample-based study as it seeks to generalize to a theory than a population. The focus thus is not on statistical generalization but analytic generalization (Yin, 1992). Several studies have examined how irrigation systems should be managed and made extensive listing of many problems that occur in tank/canal irrigation command. But very few detailed and comprehensive studies are available on how actually the systems are managed, operated, what are the dynamics among various stakeholders and how these phenomena should be explained. Also, it is important to understand to how crop irrigation is based on scientific observations can help improve water use efficiency.

The study intends to use both qualitative and quantitative methods of inquiry to address the objectives. It attempts to build grounded theory approach in understanding the problem rather than testing theoretically derived hypotheses. The field research methods to develop the case study include semi-structured and structured interviews, focus group discussions with main actors in the village and the local authorities. The study explores the water budgeting exercise with the help of sensor data. The study will further explore the steps taken by tank management authorities to improve the water distribution system in the command area. The team interacted with the different agriculture and water resource departments officials to understand the level of advisory regarding irrigation and other agricultural activities provided to the farmers. The data is collected on the following main variables.

Water use variables: quantity of water used, crop yield, water fees/cost of water; income, sources of water – canals, tank, borewell, open well, method of irrigation (flooding, ridges and furrow, sprinkler, drip); if water budgeting exercise by the tank management committee is done; cropping pattern.

Water governance: water user association (formal/informal), water governance committee, compliance with governance rules.

Climatic variables: rainfall, moisture level, wind, level of water in the tank, amount of water released for irrigation purpose.

Considering the objectives of this study, a multi-disciplinary approach is adopted, as the focus of this study is to address the societal problem of water management at both community and individual farmer (or water user level). This requires a better understanding of local context, uncertainty of supply and demand, and relationships between water users, water technologies and the institutions mediating water control, making linkages across disciplinary boundaries (Mollinga, 2008). The study is an attempt of contextualized understanding of tank irrigation management. The tank location is given in figure 1.

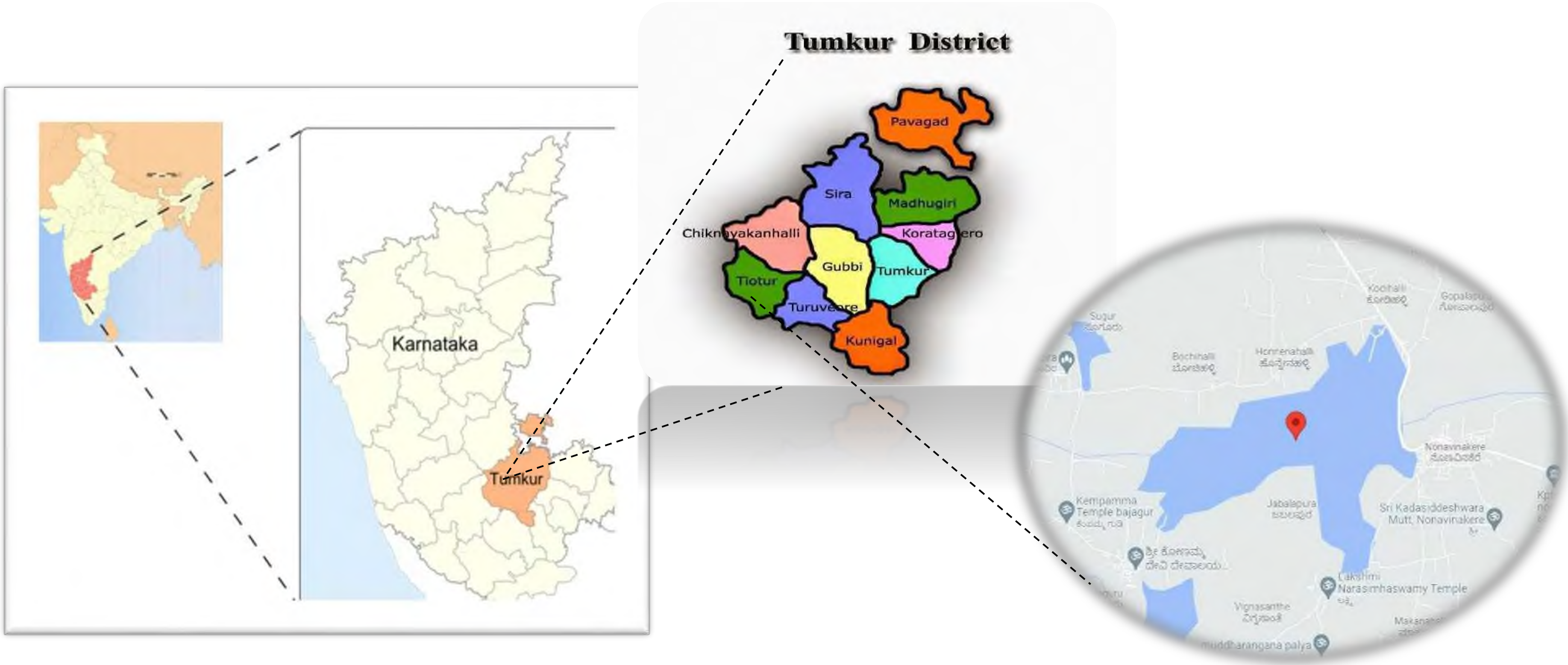


Figure 1: The tank location Nonavinakere

4.1.3 Sampling design and data collection

The tank water is managed by the sub-division of Cauvery Neeravari Nigam Limited (CNNL) - a corporation established in 2003, as a special purpose vehicle for the speedy implementation of irrigation projects. We interacted with the officials of CNNL and collected information on the salient features of the tank and canals, the overall management and distributional structure and challenges faced by the management authority. A multistage sampling method where both purposive and random sampling is followed to collect the primary data from 200 respondents using semi-structured schedule and collected information regarding household income, age, gender, education, number of people dependent on the water tank; area of land owned/cultivated, area of land leased, income generated through the farm, different crops grown, sources of water – canals, tank, borewell, open well, method of irrigation (flooding, ridges and furrow, sprinkler, drip), member of any water user association (formal/informal), etc. Apart from this, we conducted some focus group discussions with the farmers to understand the operations of the irrigation system on the ground and the challenges faced by the farmers at the time of cultivation.

The study used a combination of remote sensing data and field survey data to facilitate overall understanding of tank operations and management of water tank. Acquiring and generating agricultural maps and resources data is one of the significant factors in the improvement of the command area. Moreover, the study is trying to measure the water holding capacity of the water tank, water re-charge due to rain, water loss due to evaporation, and agriculture use. To carry out these analyses, IIMB reached out to one expert organization Cultyvate.

4.2 Objectives-wise methodology

Objective 1: To identify the influence of the management factors on equal and efficient use of water

The efficiency of water use primarily depends on efficient management, supply augmentation, efficient distributional process, proper institutional structure, and good infrastructure. Proper knowledge and well awareness of the managing authority on all the aspects of the water tank and use of water also enhance the equal and efficient use of water. In an efficient water management system, it is crucial to have a good relationship and mutual trust between farmers and people who control water provisions. Technical systems, such as gates and various details of the conveyance structure, are important to physically control water and reduce seepage.

The set of indicators chosen to analyse the determinants of efficient management of water tank, efficient distributional process, the proper infrastructure of the water tank and canals and as a management and distributional body are presented in Table 7.

Table 7: The indicators chosen to analyse the determinants of efficient management of water tank

Sl. No.	Indicators	Parameters
1.	Physiology of the tank	a) Flow of water to the tank b) Surface water level c) Ground water level d) Level of erosion
2.	Infrastructural factors	a) Conditions of the canals b) Maintenance of the canals c) Maintenance of the gates d) Leakages in canals and repairment e) Maintain the turns
3.	Institutional factors	a) Management and administration regime b) Rules and regulations at the management level c) Dispute settlement d) Fund requirements and proposal for improving the canal system and tank
4.	Distributional factors	a) Water releasing schedule b) Command area c) Out of command area d) Number of villages and beneficiaries e) Control structure f) On-demand and water supply system g) Partitions like head, middle and tail reach h) Tail ender water rights i) Crop requirement wise water supply system j) Seasonal variations in the supply system

		k) Wastewater management
5.	Performance factor	a) Timely evaluation of the water distribution system b) Gaining updates c) Bookkeeping and availability of data on tank and irrigation system d) Field visit and village level monitoring system e) Interaction with beneficiaries f) Availability of water man g) Proper follow up of schedule and rules h) Water requirement measurement system i) Crop wise or season wise distribution regime

The study also used remote sensing data to acquire factual information about the changes in the structure and distributional process of the tank over time to ensure efficient management and use of the water. Acquiring and generating agricultural maps and resources data is one of the significant factors in the improvement of the command area. Statistics on crops, rangeland, and other related agricultural resources are necessary for the implementation of effective management decisions. The wide variety of Time series satellite data would help us to explore the changes in the surface water level of the tank, changes in the structure and distributional process of the tank over the period of time, and land cover change assessment. Moreover, we try to explore the drainage network, Watershed boundaries, and other layers and use Digital Elevation Model (DEM).

Objective 2: To analyse the irrigation process and identify the factors which influence the farmers' efficient water use level

In addition to water tank management bodies, the beneficiaries are playing a crucial role to ensure efficient and sustainable water tank irrigation program. Beneficiaries' socio-economic, institutional factors, management and use of water in different activities will influence the water use efficiency. Therefore, an efficient and sustainable water tank irrigation system depends on the efficiency of the stakeholders and beneficiaries.

As a part of our study, 30 farmers around the lake within a radius of 2 km are identified in whose farms the Cultyvate team will install the soil moisture sensors. Of these 30 farmers, 10 farmers would be considered as control farmers where we would install the sensors to understand the water use without our advice. The remaining 20 farmers would also have the soil moisture sensor, but we will also send advisory messages and ensure that the advisory is followed by using the IVR as detailed. The crop advisory and improved irrigation advisory services will be provided to these 20 farmers by organizing a workshop with experts from different agriculture and horticulture institutions.

Efficiency in agricultural production is an important subject matter in the field of agricultural development. It is essential for growth in output with respect to the utilization of the existing resources in an efficient manner for the given technological constraints. Hence, it is essential to evaluate the use and allocation of existing inputs for given resource constraints and examine the existing potentialities for revamping the efficiency of agricultural production.

The efficient production method of producing a given level of output is the method which employs the minimum level of resources. In general, the efficiency analysis of the farm is the ability to produce a definite maximum level of output with a package of given resources or a definite level of production at a minimum cost. The improvement in the farms' production and productivity are the direct significances of higher efficient use of input with the existing technology (Ogundari and Ojo, 2007; Isoto, Sam, and Kraybill, 2017). Michael Farrell (1957) first introduced the concept of productive efficiency or economic efficiency (EE) which consists of two efficiency components namely Technical Efficiency (TE) and Allocative Efficiency (AE). TE refers to the ability of a farm to attain the level of frontier output, whereas AE indicates the ability of a farm to produce a given level of output with the help of cost-minimizing inputs combination. TE reveals the deviation of actual isoquant from the optimal or frontier isoquant, and AE indicates the deviations of actual cost input ratios from the minimum cost input ratios. (Farrell, 1957; Kopp and Diewert, 1982).

The frontier production function of a farm can be explained with the production of output Y using n number of inputs (X_1, X_2, …, X_n). The alteration of inputs efficiently into output is represented by the optimal production function $f(X_i)$, it is the attainable optimum output level achieved by using different input vectors. The function in Equation 1 represents the stochastic frontier production function and it assumes that the existence of TI in the production.

$$Y_i = f(X_i; \alpha) + \varepsilon_i \text{ for } i = 1, 2, \dots, n \qquad (1)$$

Where, Y_i refers to the output of the farmer i and the vector X_i represents input variables, α_i are the production coefficients, and the error term ε consists of two elements, i.e.,

$$\varepsilon = v_i - u_i \quad (2)$$

Where the stochastic error v_i is independently, identically, and normally distributed with zero mean and constant variance (σv^2). Both one-sided error term (u_i) and stochastic error term (v_i) are independent of each other. The one-sided error term (u_i) has zero mean and constant variance (σu^2) and follows a normal distribution.

Objective 3: To identify the initiatives taken individually and by the community to improve the management of water resources

The active participation of the farmers in decision making process and initiatives taken by farmers at individual and community level in system design and management of water resources helps to ensure the sustainability of the system, improve efficiency, equity, and standards of service.

In order to assess the farmers participation at individual and community level in irrigation management initiative, a number of indicators are chosen for the present analysis. The cross-tabulation method is used to address the objective. The set of indicators chosen for the present study are presented in Table 8. Moreover, a few focus group discussions (FGDs) are also conducted to get insights about participation of the farmers in decision making process and initiatives taken by farmers at individual and community level in system design and management of water resources.

Table 8: Indicators considered to assess the farmers participation in water resource management

Sl. No.	Indicators	Parameters
1.	Knowledge and awareness about water management	a) Farmers' knowledge about water tank management authority b) Information and awareness about water releasing schedule c) Information about the availability of water in the tank d) Information about the water distribution procedure e) Information about the condition of the canals system f) Knowledge about water scarcity g) Knowledge about innovative irrigation or water saving irrigation systems
2.	Participation rate	a) Formation of water user association b) Member of farmer association c) Interaction with the officials of water tank management authority d) Participation in decision making process related water tank management e) Participating in extension classes to resolve water problems f) Participate in group activities to construct canals g) Participating in maintenance of canals h) Farmers' participation in irrigation management i) Share the farmers' opinion in decision making about water problems
3.	Obstacles for farmers participation	a) Dissatisfaction with water tank authority operators b) Delay in water release schedule c) Unequal distribution of water among farms d) Suspension of cultivation due to delay in water release

Objective 4: To find the improvements in the management of tank and the programs to create awareness among farmers to enhance equal and efficient use of water.

The field research methods to develop the case study include semi-structured and structured interviews, focus group discussions with main actors in the village and the local authorities. The study explores the water budgeting exercise with the help of sensor data. The study explores the steps taken by tank management authorities to improve the water distribution system in the command area. We interact with the different agriculture and water resource departments to understand the level of advisory regarding irrigation and other agricultural activities provided to the farmers.

Organisation of preliminary consultation program to understand requirements and challenges of the farmers. The study conducts soil test of some selected farmers to understand the quality and soil content of farm land and share the results with the Krishi Vigyan Kendra (KVK) scientists. The study prepares an advisory regarding irrigation and other agricultural activities with the help of KVK scientists and share with the farmers to create awareness.

The crop advisory and improved irrigation advisory services are provided to the selected 30 farmers by organizing a training program with scientists from KVK, officials of Raita Samparka Kendra, and officials of agriculture department. A workshop is organized and share findings of our study with Experts from various academic institutions, scientists from KVK, officials of water management authority, officials of agriculture and irrigation departments, and farmers.

ANALYSIS AND DISCUSSION

5. Analysis and discussion

5.1 Nonavinakere waterbody & land use/ cover analysis

Nonavinakere water body and surrounding area is considered for the study. This is done by obtaining satellite data from various sources and systematically stacked for analysis. Following data and other important input data are organised for analysis

1. Multi-time satellite data
2. Basemap layers
3. Drainage map
4. Watershed and Catchment area boundary
5. Village Boundaries
6. Digital Surface Model
7. Other available thematic maps

Some of the examples of the satellite images that are created and georeferenced to facilitate a geospatial analysis of multiple layers of data are shown as below.

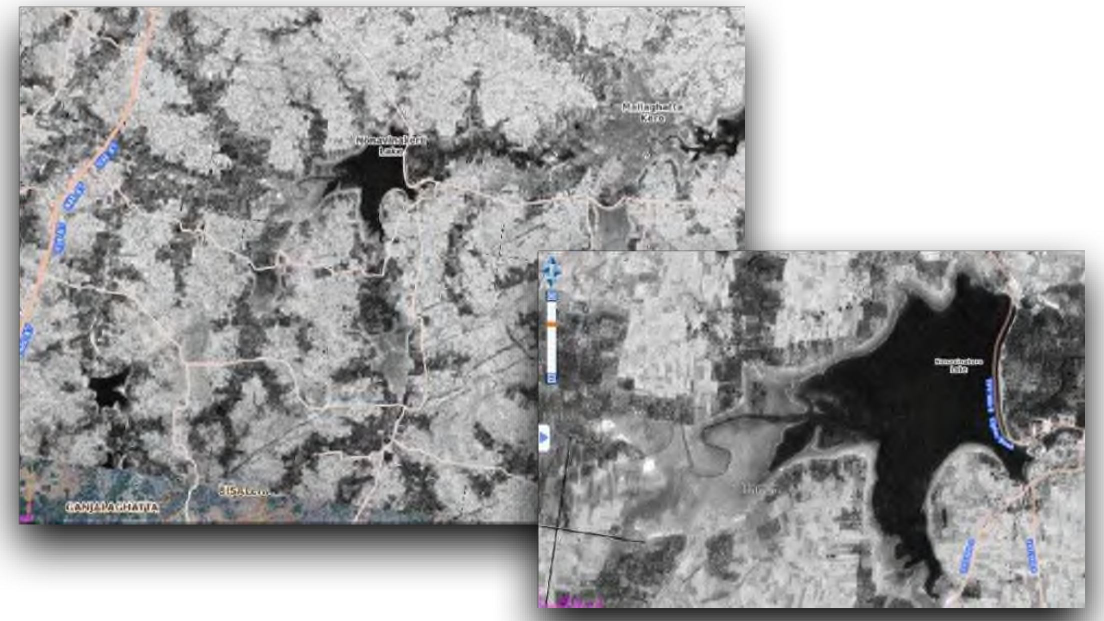


Image 1: Satellite Image of 1979

Status of Nonavinakere can be assessed by interpretation and analysis of the satellite images of different time periods. Image 1 is one of the oldest satellite image available that clearly shows the status of the land and water features, that can be analysed with respect to the resources. The satellite images show broad drainage structures and also the surface waterbody of Nonavinakere waterbody at that point of time. Various water channels and also agriculture and plantations can be assessed from the above image.

A series of satellite images, taken for about 10 to 15 years could give a reasonably good information on the waterbody in focus and also the agricultural activities at different point of time. In the present study, we carry out such an analysis of time series data.

Image 2: Premonsoon image of 2013

Image 3: Postmonsoon image of 2013

It is clear from the above images that the post monsoon image clearly shows increase in surface water spread area for nonavinakere and others (Images 2 & 3).

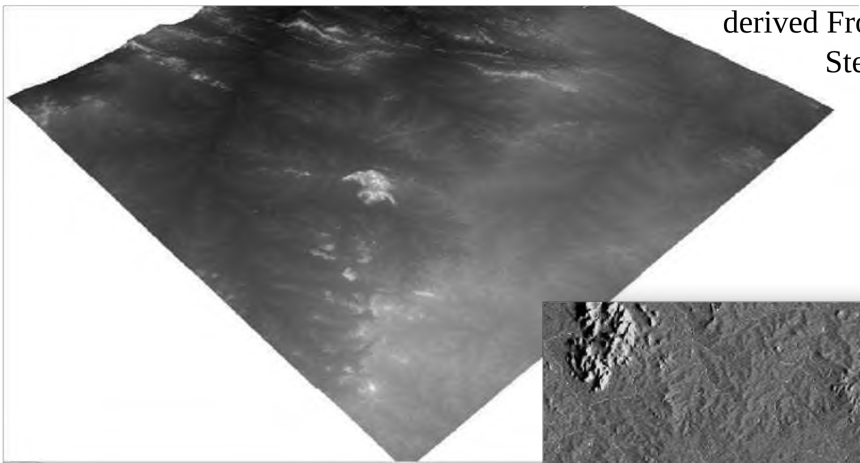
5.1.1 Village and watershed boundaries

Village boundaries with village names as attributes and watershed boundaries are super imposed on one of the recent satellite data, which shows very little water in nonavinakere and almost no water in the Mallaghattakere (Image 4). The watershed boundaries are very important to analyse the dynamics of soil and water conservation. Basemap information on road infrastructure are also superimposed on the data for necessary geo-referencing and analysis. The illustration below, with overlay of base layer, watersheds and village boundaries demonstrates the above-mentioned facts. The dynamics of water status in waterbodies can be effectively analysed using seasonal satellite remote sensing data that gives clear information on the surface waterbodies in the area of interest. It also brings out the fact that these waterbodies depend on the rainwater from the catchment areas and hence the relevance of watersheds and catchments for analysis.

Image 4: Nonavinakere area with Village Boundary Overlay (shown in Blue color)

5.1.2 Digital surface model & derived product

Image 5: Digital Surface Model derived From CAR TOSAT-1 Stereo images



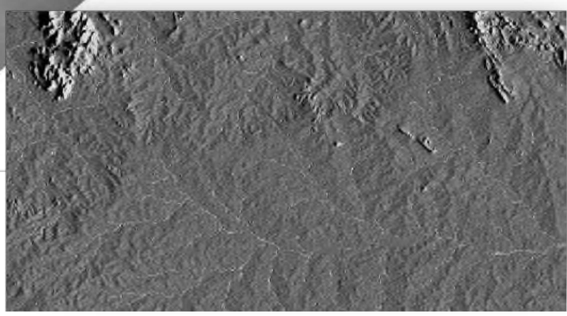


Image 6: Relief Shaded Image & drainage of study area

For a study of waterbody and its dynamics, it is essential to generate Digital Surface model (DSM) and use the same with respect to the analysis related to slopes and gradients in the area of interest. A derived product, shaded relief image, is prepared from the DSM that allows better visualisation of the terrain. The drainage network, derived from DSM, is also superimposed to visualise the drainage network on this undulating terrain (Images 5 & 6).

5.1.3 Land use / land cover classification

Satellite images of the study area are further used for image classification with a focus on the agricultural activities. This helps in understanding the areas that are predominantly into agriculture plantations (in yellow) including coconut and the seasonal cropping in the given area (Image 7).

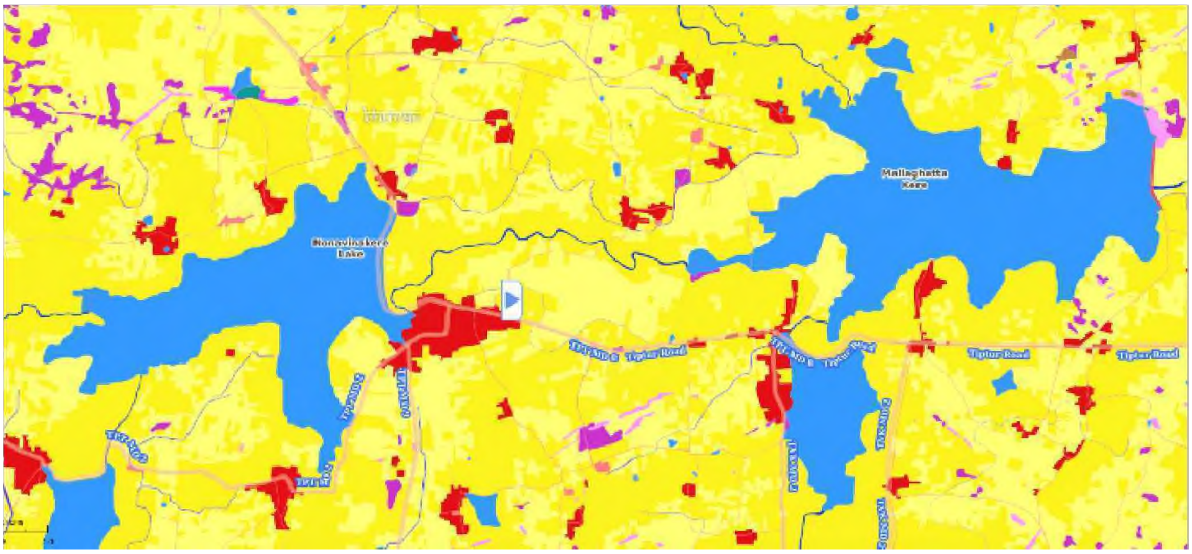


Image 7: Status of agriculture plantations (in yellow) including coconut and the seasonal cropping

To better understand the dynamics of the nonavinakere water tank and surroundings, it is essential to analyse multi-time satellite data for both surface water body and agriculture or cropping situation. While analysing the crop map, it is also essential to have the drainage network to understand the gradient and crop-water dynamics.

The crop map depicted above, with the overlay of drainage network, clearly shows that all the waterbodies are very well connected through the different orders of streams and rivers that allows rainwater flow and also has enabled creation of water ponds of different sizes, depending on slopes and natural conditions for water holding capacity. The image 8 shows that,

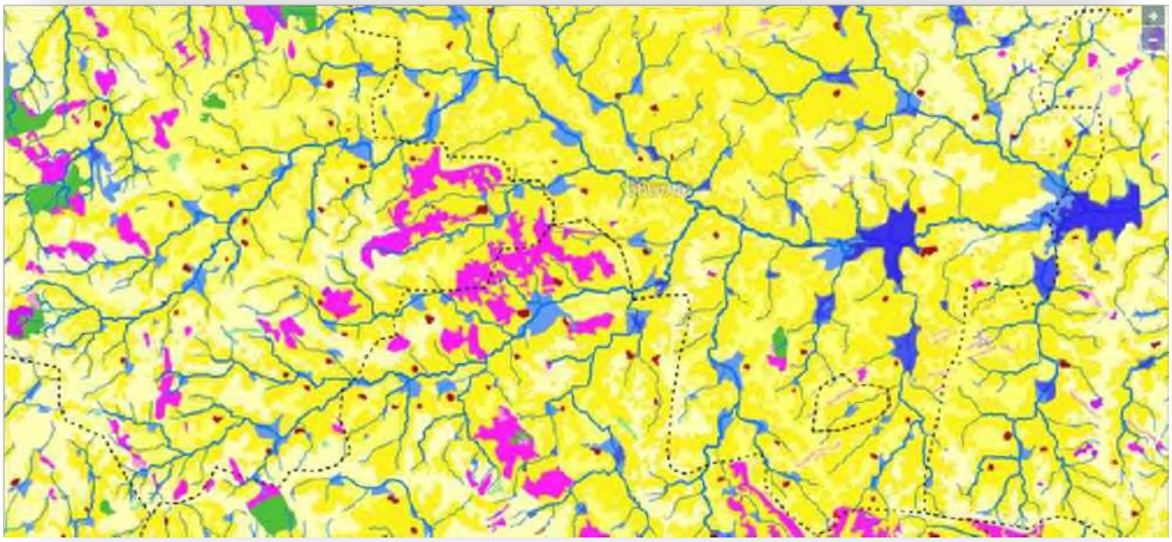


Image 8: Crop map of the study area

Nonavinakere and Mallaghattakere are the biggest waterbodies in the given area of interest with large capacity to support agriculture and horticulture activities.

The crop map depicted above, with the overlay of drainage network, clearly shows that all the waterbodies are very well connected through the different orders of streams and rivers that allows rainwater flow and also has enabled creation of water ponds of different sizes, depending on slopes and natural conditions for water holding capacity. The image shows that, Nonavinakere and Mallaghattakere are the biggest waterbodies in the given area of interest with large capacity to support agriculture and horticulture activities.

5.1.4 Time series analysis

Considering the large sized waterbodies like Nonavinakere, it is appropriate to carry out analysis with regard to water spread in the pond and related to agricultural activities by looking into a well organised time series data. Hence, best available satellite data for more than 20 years is considered for the analysis. A quick assessment of water spread area from 1995 to 2020 shows that there is reduction in the water spread. Water spread was about 350 hectares in 1995 - 96 and it is about 300 Hectares in 2019 - 20. There has been a gradual decrease in this number ever since 1995, except that in 2011 the value was about 311 Ha. More detailed analysis needs to be done to get clear reasoning and related details of such a reduction, which could also be due to silt accumulation and hence reduction in the storage capacity of the water body.

5.1.5 Watershed-wise analysis

As it has been addressed above, carrying out analysis with well-defined natural boundaries helps in making better assessment of the agricultural activities and the related waterbodies, acting as major water storage and also providing support for agriculture and horticultural activities, like a command area. Hence, a group of watersheds around Nonavinakere waterbody have been considered and they have been dissolved using GIS tools to make a uniform catchment/command boundary. Satellite data analysis has been done using the catchment boundary as a mask to arrive at a definitive finding with regard to water storage in nonovinakere and the agricultural activities in the area. Following set of images show the land use data with regard to nonavinakere catchment area (Images 9 & 10).

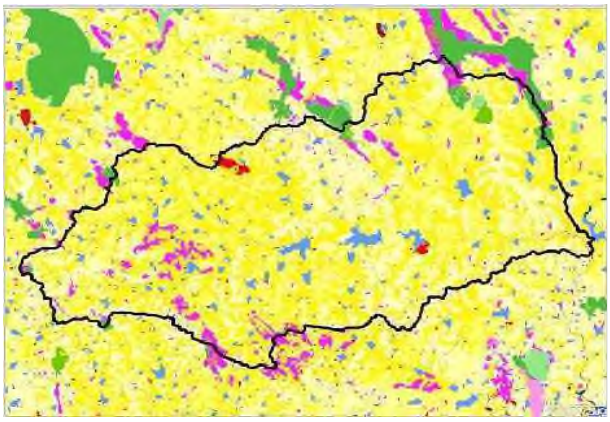


Image 9: Agricultural Land use/ Land Cover **(2005-06)**

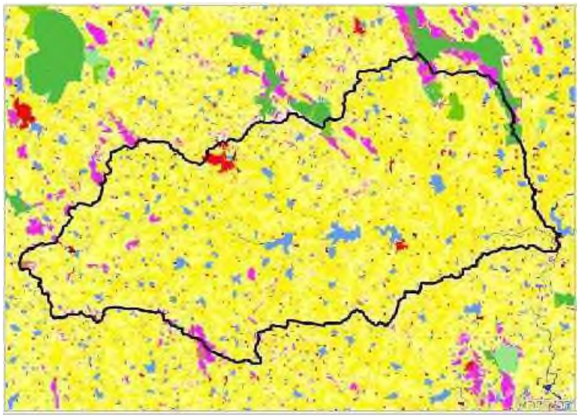


Image 10: Agricultural Land use/ Land Cover **(2011-12)**

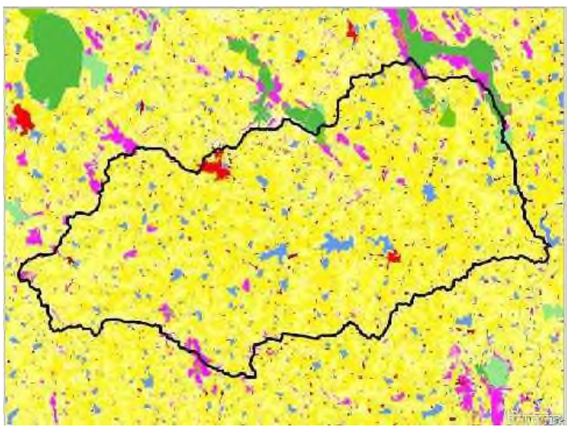


Image 11: Agricultural Land use/ Land Cover **(2015-16)**

Major crops in irrigated fields are jowar, maize and ragi, while crops in unirrigated areas cover jowar, bajra, maize and ragi including cereals, millets and pulses. As it can be seen from image 11, majority of the land use/ cover in the area happens to be Agriculture crop land / Agriculture plantation / Agriculture fallow classes in the vicinity of nonavinakere. The above three classification images, done from 2005-06 to 2015-16, also shows the dissolved watershed boundaries that has been considered as the area of interest which clearly defines nonavinakere waterbody and its catchment for further analysis (Images 9, 10 & 11).

5.2 Data analysis & results

5.2.1 Surface water body (Nonavinakere water tank) - time series analysis

Considering the primary focus of the study on Nonavinakere water tank, multi-temporal satellite data covering the water tank and surroundings was acquired to analyse the water spread area and related details. As kharif time image acquisition is not possible due to the presence of clouds, it was decided to focus on non-cloudy season data for image analysis. On detailed search for satellite data, images of December and April were of better quality and hence such images were selected for the analysis. The data, being multispectral in nature, was georeferenced to a common base and a systematic water body extraction algorithm was used to obtain the water spread or extent for all the selected data sets. Following table 9 shows the outcome of the analysis.

Table 9: Multi-temporal satellite images of Nonavinakere water tank

Sl. No.	Pre monsoon data	Post monsoon data
1	Mar1995 	Dec 1995 
2	Mar1998 	Dec 1998 
3	Mar1999 	Dec 1999 

4	April 2000 	Dec 2000 
5	Mar 2007 	Jan 2007 
6	Apr 2009 	Nov 2009 
7	Apr 2013 	Dec 2013 
8	Apr 2014 	Dec 2014 
9	Mar 2015 	Dec 2015 
10	Apr 2016 	Dec 2016 
11	Apr 2017 	Dec 2017 
12	Mar 2020 	Dec 2020 

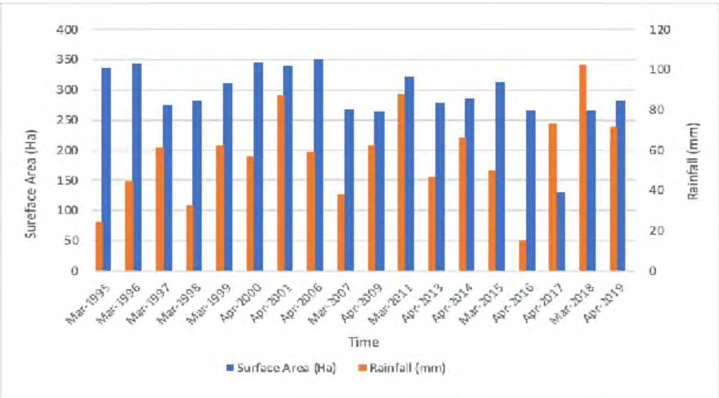
The above illustration clearly brings out the dynamic changes that can be visualised in the nonavinakere water body surface area across 25 years. The following table provides the quantitative estimation and analysis of the surface area of the waterbody using time series satellite data of the water body.

As part of the analysis, the pre and post monsoon satellite data are analysed to understand the status of water body in both these conditions, as the rainfall is the main source for nonavinakere tank. Historical cumulative rainfall data have been considered for both these seasons, using the IMD data as the source to understand the rainfall v/s surface area of waterbody in different seasons. Accordingly, available satellite data of March/April and Dec (Nov/Jan in come cases) are used to understand the outcome of rainfall in the form of surface area of the water body for about 25 years.

Satellite images, estimated surface water body area and also rainfall data, are organised in the form of tables and graphs for both pre-monsoon and post-monsoon periods. The pre-monsoon data shows a small quantity of rainfall during Jan - Apr time period, while the surface water area gradually decreases towards summer months. The correlation coefficient value of the rainfall data and surface area is -0.098 summarise as rainfall increases surface water body in the tank increases (Table 10).

Table 10**:** Time series data on surface water body area and also rainfall data

Time	Surface Area (Ha)	Rainfall (mm)
Mar-1995	336.51	24.59
Mar-1996	343.35	44.18
Mar-1997	274.41	61.07
Mar-1998	283.59	32.66
Mar-1999	311.94	62.13
Apr-2000	344.88	57.34
Apr-2001	339.75	87.43
Apr-2006	351.81	59.45
Mar-2007	267.48	38.36
Apr-2009	263.52	62.79
Mar-2011	322.83	87.94
Apr-2013	278.19	47.02
Apr-2014	285.12	66.21
Mar-2015	313.29	49.98
Apr-2016	265.86	15.33
Apr-2017	130.68	73.16
Mar-2018	266.04	102.44
Apr-2019	281.88	71.79



Graph 1: Time-series on rainfall & surface waterbody area (Mar-Apr) period

Time-series on Rainfall & Surface waterbody area (Mar-Apr) The rainfall data shows a typical trend of a sinusoidal pattern for the entire period of 1995 - 2019. Surface waterbody is almost constantly maintained above 250 Ha and up to a maximum of about 350 Ha throughout the time period, except for Apr 2017 (Table 10).

Table 11: Surface waterbody of the tank

Sl. no.	Date	WB area (Sq. km)	Ha
1	22/12/21	4.1027	410.27
2	11/01/22	4.1043	410.43
3	10/02/22	3.995	399.5
4	12/03/22	3.1964	319.64
5	01/04/22	2.2666	226.66

Further analysis of the water-spread data shows a steady decline in nonavinakere capacity in 2022 during the timeframe Jan – April as part of the pre-monsoon data analysis. Water spread in April 2022 is significantly low (226.66 Ha) (**Annexure -1**)

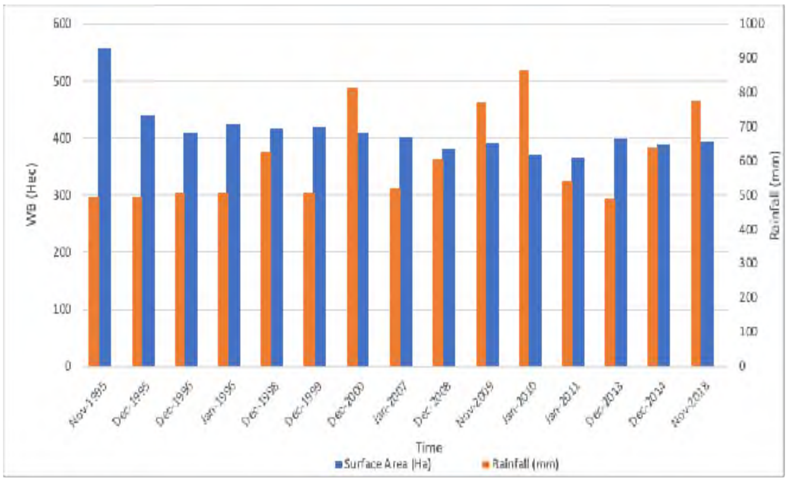
However, the monsoon season brings in lot of rainfall and hence the surface waterbody area increases and it remains fairly consistent as reflected in the table 12 and graph 2. It is evident from the value of correlation coefficient -0.0406 that there is a negative relationship between the rainfall and surface water body in the tank. It is also observed that there is a general decreasing trend in surface water area of the nonavinakere waterbody from 1995 to the 2018 data (Table 12). This is an important information that need to be carefully analysed with regard to tank capacity and its dynamics.

The Time series data from both pre and post monsoon season brings out the importance of the presence of water in nonavinakere water body. It can be observed that monsoon rains are consistently high and are always about 600 mm (cumulative seasonal data). However, the storage capacity with regard to surface area of the water body is not consistently the same across the years.

There is a gradual decreasing trend observed from 1995 to 2018. It is seen that 2008 onwards the surface water body area has not crossed 400 Ha, while a maximum of about 555 Ha was noted in 1995. This may also reflect on the silt accumulation in the water body and the need for desilting. This may not only help in increasing the capacity of the water body, but also helps in recharging the ground water potential in the region (Table 12).

Table 12**:** Time series data on surface water body area and also rainfall data

Time	Surface Area (Ha)	Rainfall (mm)
Nov-1995	555.93	494.06
Dec-1995	438.12	494.06
Dec-1996	408.33	505.63
Jan-1996	424.08	505.63
Dec-1998	416.07	626.66
Dec-1999	419.04	506.20
Dec-2000	408.24	813.36
Jan-2007	401.58	519.87
Dec-2008	379.80	606.29
Nov-2009	391.32	769.82
Jan-2010	369.00	862.10
Jan-2011	365.49	542.25
Dec-2013	398.25	487.98
Dec-2014	388.08	637.43
Nov-2018	394.38	774.41



Graph 2: Time-series on rainfall & surface waterbody area (Nov-Dec) period

Time-series on Rainfall & Surface waterbody area (Nov-Dec)

The rainfall data shows a consistent trend of at least 500 mm for the entire period of 1995 - 2019. Surface waterbody is almost constantly maintained above 350 Ha and up to a maximum of above 500 Ha in the time period, which is well sustained throughout the time period. However, volume estimation would give better idea of the local scenario of water use (Table 12).

5.3 Season-wise cropping in the catchment

While it is well established from the above analysis that nonovinakere water body is one of the major waterbodies in the area and can support agricultural activities for reasonably large area. It is essential to make a seasonal assessment of crops grown in the area, but optical remote sensing data is not available during monsoon cloud period. Hence, best available satellite data is used to make an assessment of agricultural activities in the area around nonovinakere and surroundings. Satellite images are digitally analysed using pattern recognition techniques that results in image classification outputs or digital maps. This is done, based on supervised image classification that uses the known signatures of crops and plantations to provide visual image of crop maps and also the statistics of the area coverage. The classification accuracies are also computed with the assessment of accuracies of the training sets of different categories of themes and fitting of Kap pa Coefficient that provides mapping accuracy for a given seasonal image.

Two-time data in the post-monsoon season are analysed for the time period of 1995 to 2020, at three different times to establish the agricultural land use of the area. Following are the details of the multi-date and multi-season image classification

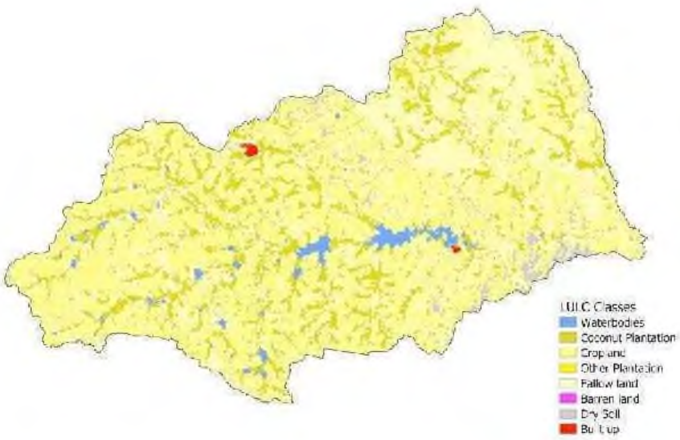


Image 12: Satellite image of Feb 1995

Image 13: Satellite image of Dec 1995

Images 12 & 13 represent two different seasons, majority of the area falls under cropland or plantations, including coconut plantations. Similar analysis is done for 2014-15 below.

The above images 14 & 15 show the status of the land use after 10 years, as compared to the 1995 land use/ cover. As can be seen, the images show additional areas under plantations, particularly the coconut plantations during past 10 years and also the urban areas around Tiptur and Nonavinakere has increased. The entire area under consideration is prominently used for cropping and agriculture activities. However, the waterbody status is always dependent on the rainfall in the respective season. Similar analysis is done for 2020 below.

Image 14: Satellite Image of Feb 2014

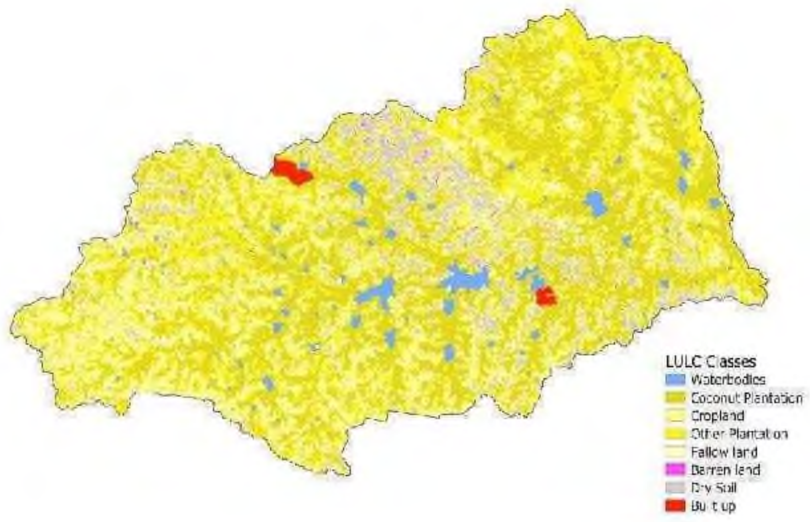


Image 15: Satellite image of Dec 2015

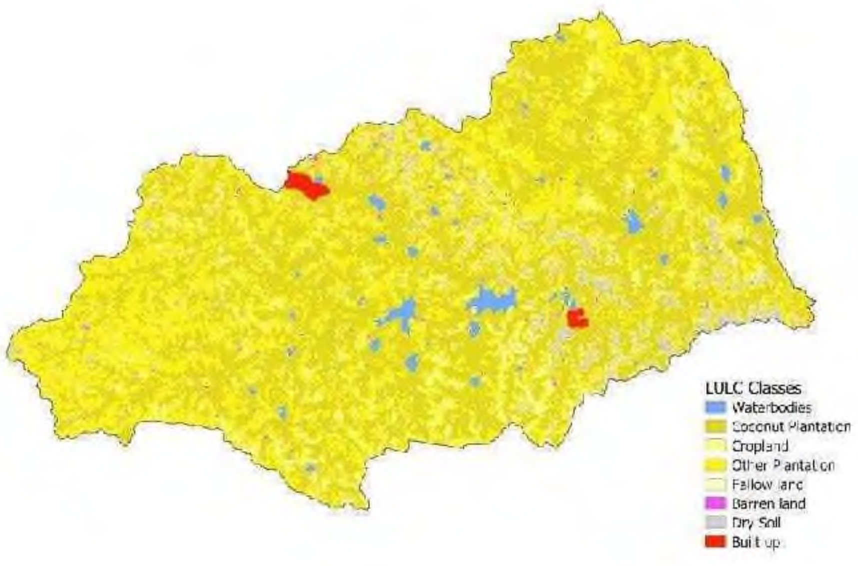
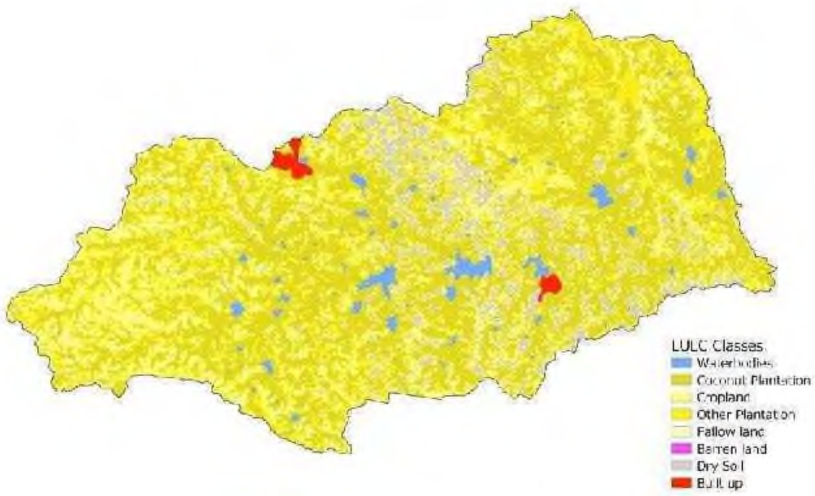


Image 16: Satellite Image of Feb 2020



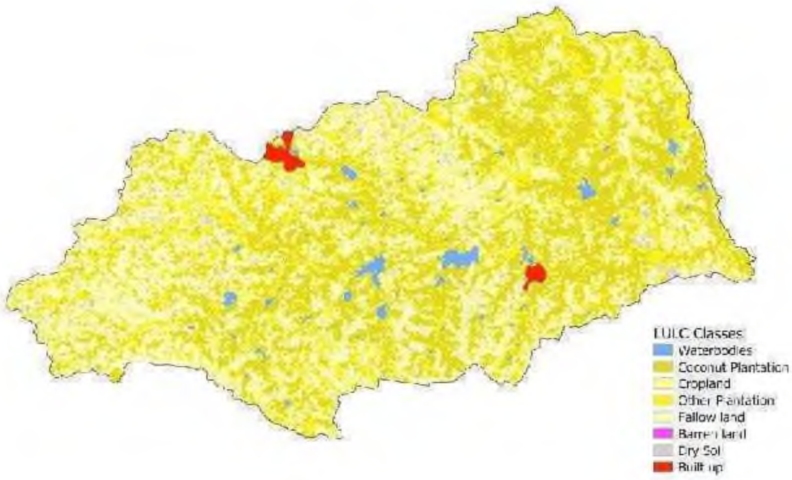


Image 17: Satellite Image of Dec 2020

The recent satellite images of 2020 from February and December show a similar trend of the crop land and plantation areas in Nonavinakere, while there is an increase in the urban patches both in Tiptur and Nonavinakere. As Coconut is the most popular and well-established plantations in this area for the time immemorial, the images also show higher manifestation of coconut trees in the entire area (Images 16 & 17).

5.3.1 Statistical analysis

As can be seen from above, a three time-frame satellite data analysis has been done spanning about 25 years of land use changes in the catchment area of nonovinakere water body. The classified image displays have been illustrated in the above sections for which a detailed statistical analysis has also been carried out, as follows.

Table 13: Vegetation dynamics of the catchment area of Nonavinakere (Feb 1995-Feb 2020)

Classes	Feb 1995	Feb 2014	Feb 2020
Waterbody	29.07	42.18	32.52
Other plantations	No value	370.84	260.03
Coconut Plantation	236.98	503.21	637.94
Current Fallow	556.78	164.33	No value
Cropland	530.66	225.39	361.53
Eroded soil	29.39	68.68	84.44

Graph 3: Vegetation dynamics of the catchment area of Nonavinakere

(Feb 1995-Feb 2020)

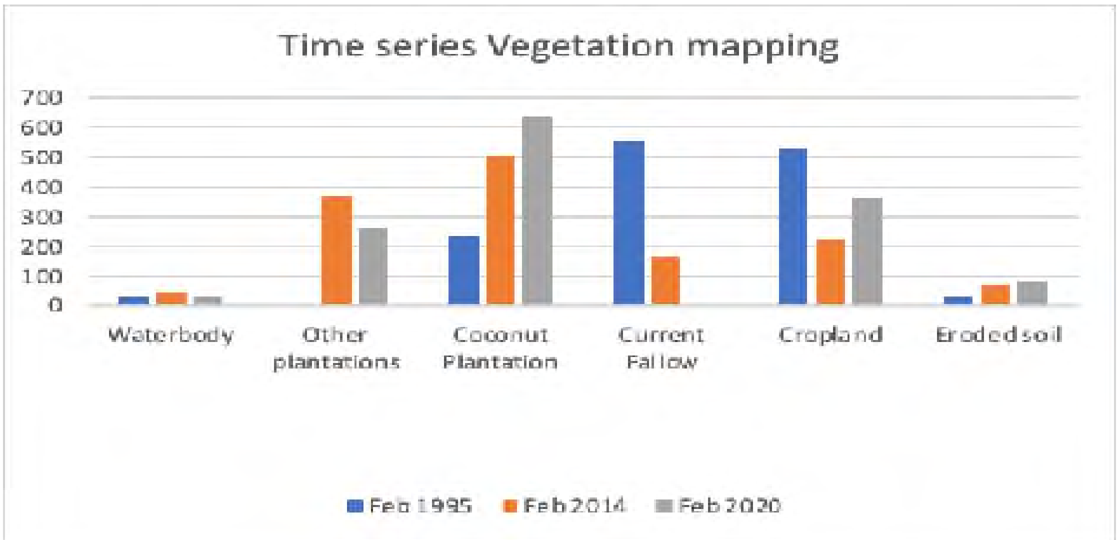
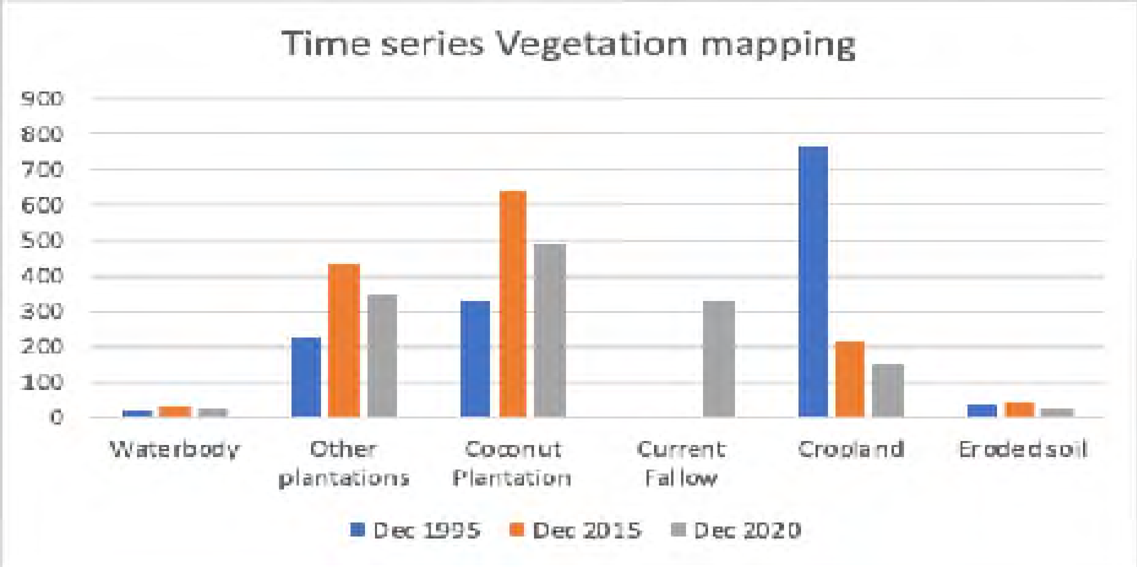


Table 14: Vegetation dynamics of the catchment area of Nonavinakere

(Dec 1995-Dec 2020)

Classes	Dec 1995	Dec 2015	Dec 2020
Waterbody	23.36	31.28	26.26
Other plantations	227.20	436.72	347.10
Coconut Plantation	330.52	643.76	491.59
Current Fallow	No value	No value	329.63
Cropland	765.13	218.27	153.05
Eroded soil	36.68	42.57	28.88

Graph 4: Vegetation dynamics of the catchment area of Nonavinakere
(Dec 1995-Dec 2020)

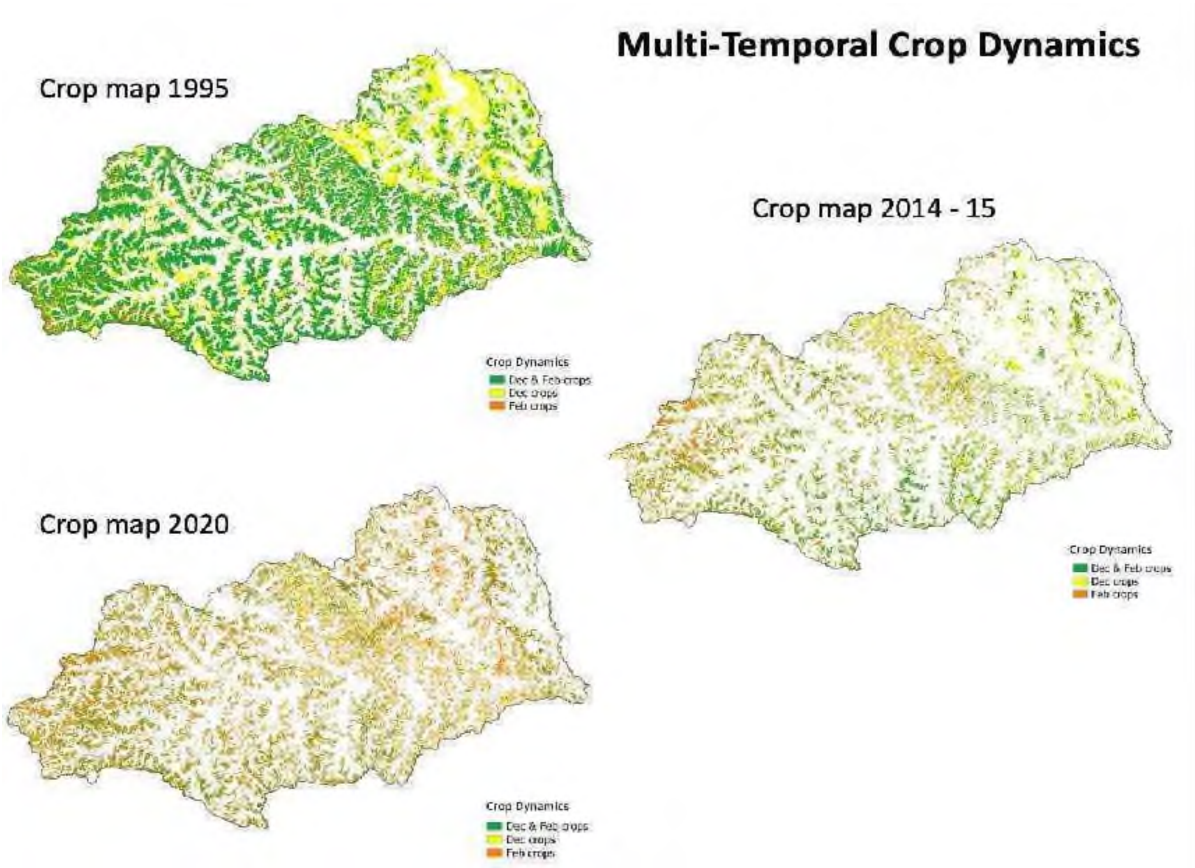


The data presented here provides details on the vegetation dynamics in a span of 25 years in the catchment area of nonavinakere. A careful analysis of the data and the graphs shows that agricultural cropland covered major portion of the area during 1995, while in comparison the plantations were not dominant. However, by the year 2015 and 2020, the plantations have occupied larger area amongst the land use / cover categories as against others, particularly the coconut plantations. During the same time frame the agricultural area coverage has reduced, possibly giving way to more plantations. This is evident from the above graph that provides the summary of 25 years of agricultural land use in Nonavinakere catchment area. A small area of eroded soils is also noticed with an increasing trend by 2020, primarily due to high slopes and gradients, as seen in the satellite images. Agricultural fallow and cropland together form the area under cultivation and both these have significantly reduced during the past two decades, while plantations, including coconut coverage have increased, which is evident from the above tables and the graphs (Tables 13 & 14) (Graphs 3 & 4). Following time series analysis on the vegetative classes gives more details on the dynamics of plantations and crop coverage below.

5.3.2 Cropland dynamics & timeseries

Two seasons crop dynamics maps are prepared for all the three seasons to bring out the dynamically changing scenario in the Nonavinakere catchment area. The classification coding scheme recoded to run a rule-based model to assess the two-seasons crop coverage maps in three different years to spatially highlight the cropland dynamics, as shown in the above statistics and graphs.

Image 18 Multi-temporal crop dynamics



The above analysis shows that there has been a shift from traditional agricultural practices to that of coconut and other plantations during the past 25 years. This was further substantiated by analysing some more satellite data sets from Bhuvan Geoportal (Image 18).

5.4 Statistical analysis from Bhuvan Geoportal

Bhuvan geoportal provides classified image data for visualisation and could also be used by customising the portal to our requirements using APIs. Major classes, such as Agriculture cropland, Agriculture plantation and Agriculture fallow were considered for this analysis for the year 2005-06 and 2011-12 to study the trends of agricultural practices in the study area. Following are the outputs obtained and the analysis of the data.

Image 19: Agricultural land use 2005 - 06

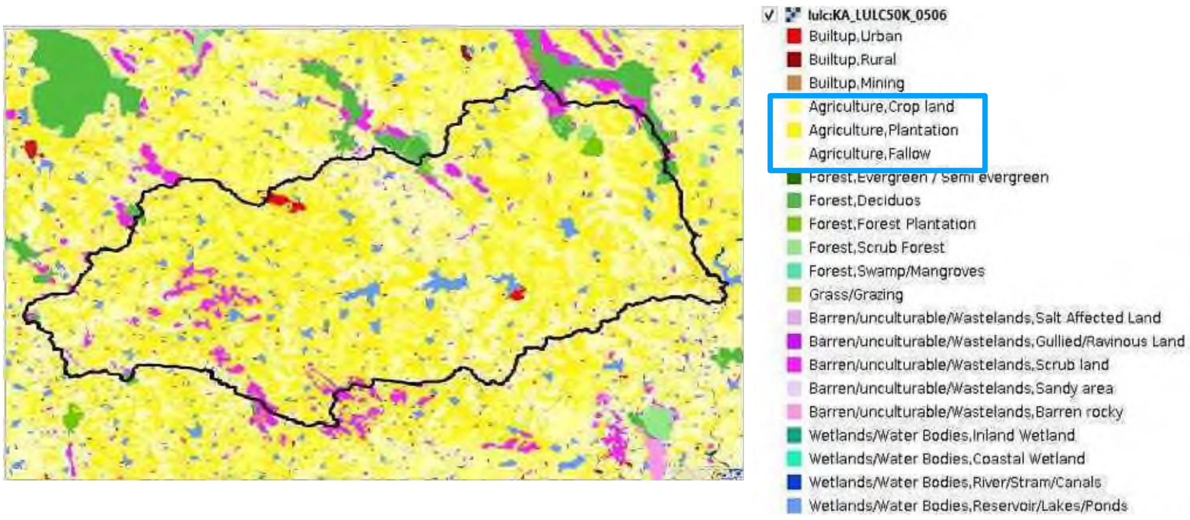
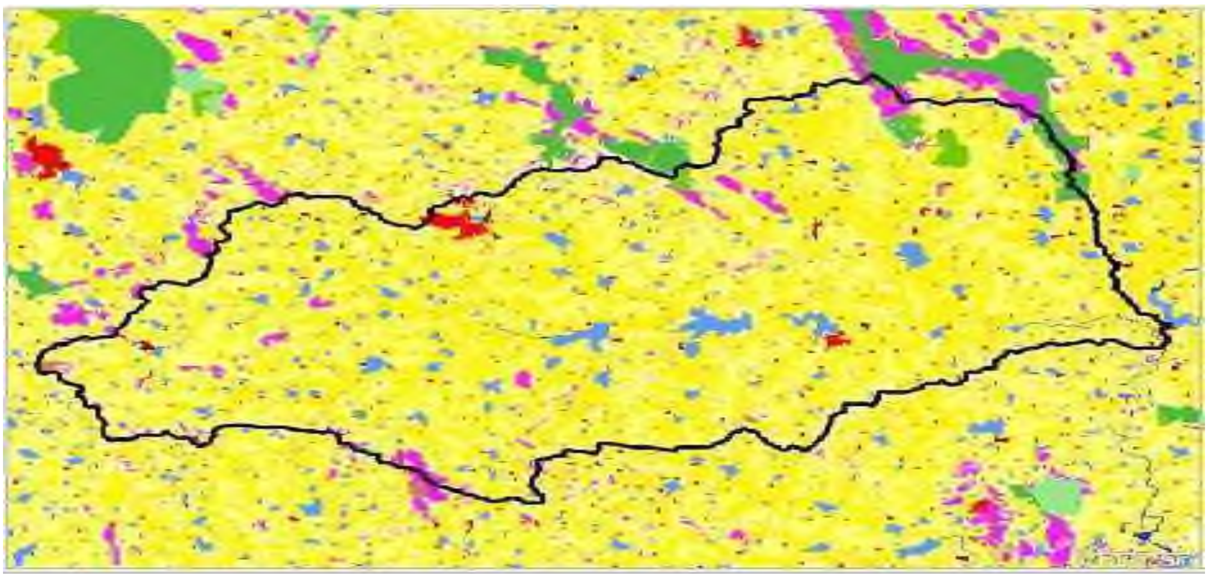


Table 15: Status of agricultural land use 2011 - 12

Agri. Land use Classes	2005-06	2011-12
Agriculture, Crop land	304.99	490.52
Agriculture, Plantation	652	763.75
Agriculture, Fallow	297.13	8.25

Image 20: Agricultural land use 2011 – 12 (area in Sq. Km)



The classified images clearly highlight the major portion of the catchment area being actively used for agricultural use (Images 19 & 20). The classification shows many classes, as shown in the legend, but as the focus of the present study is on the agricultural areas and the plantation, the statistics is extracted for only those classes. The vegetation dynamics in terms of trends is already highlighted in the previous section and above observations further add to the trend beyond 1995. The above data also shows increasing trend of plantations and marginal reduction of agricultural crops, as noticed earlier (Table 15).

5.4.1 Agricultural land use for 2022

Considering the changing ground situations due to Pandemic related issues, Lockdowns and hence impact on the general environmental conditions, it was decided to carry out a pre-monsoon land use/ landcover mapping of the study area. Accordingly, satellite data of February 2022 was used for the analysis. Due to the lockdown situation, there were subtle changes in the general climatic conditions that also resulted in good rain fall throughout the 2021 and extended to early 2022 also. As a result of this, it was observed that there were increased field activities in the District and also the area of interest.

Two data sets were analysed to confirm these findings, namely, one in Febraury 2022 and one more satellite data set in May 2022. Both these data sets have shown similar land use/ cover trends. The images are provided below with associated statistics of the same.

These two months Agriculture and Plantations statistics shows a marginal change with respect to the previous years' trends, primarily due to the subtle change in the weather pattern and increased rainfall conditions (Images 21 & 22). Following table analyses the details on Statistics and also the trends in the area of interest.

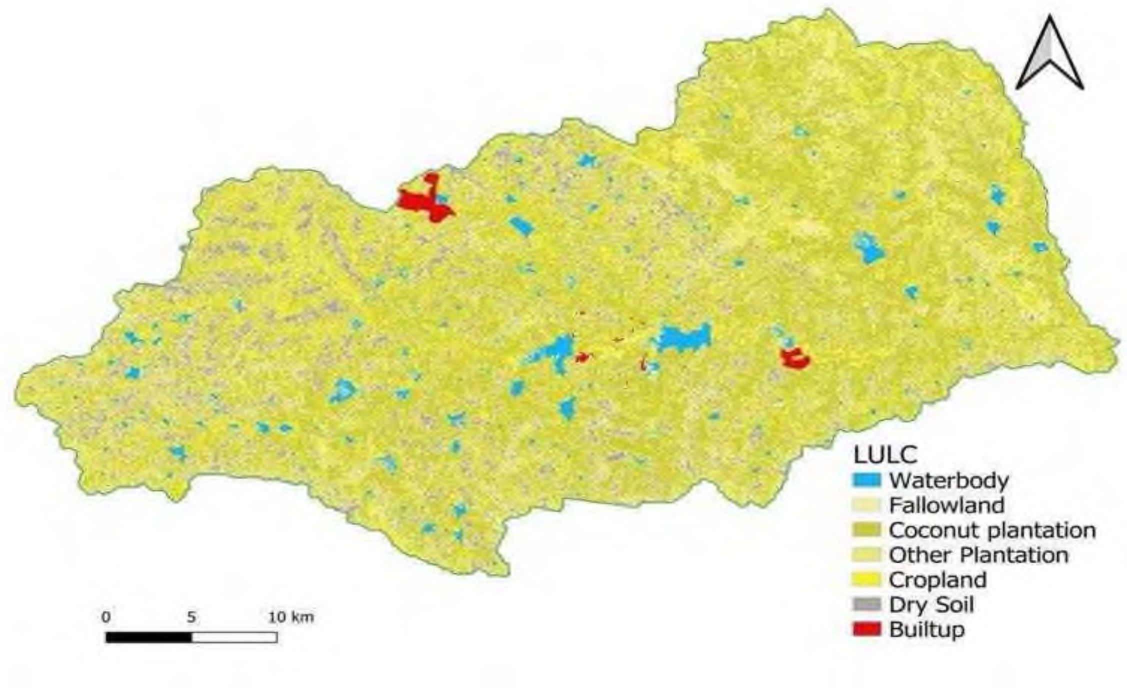


Image 21: Land use/ cover trends in February

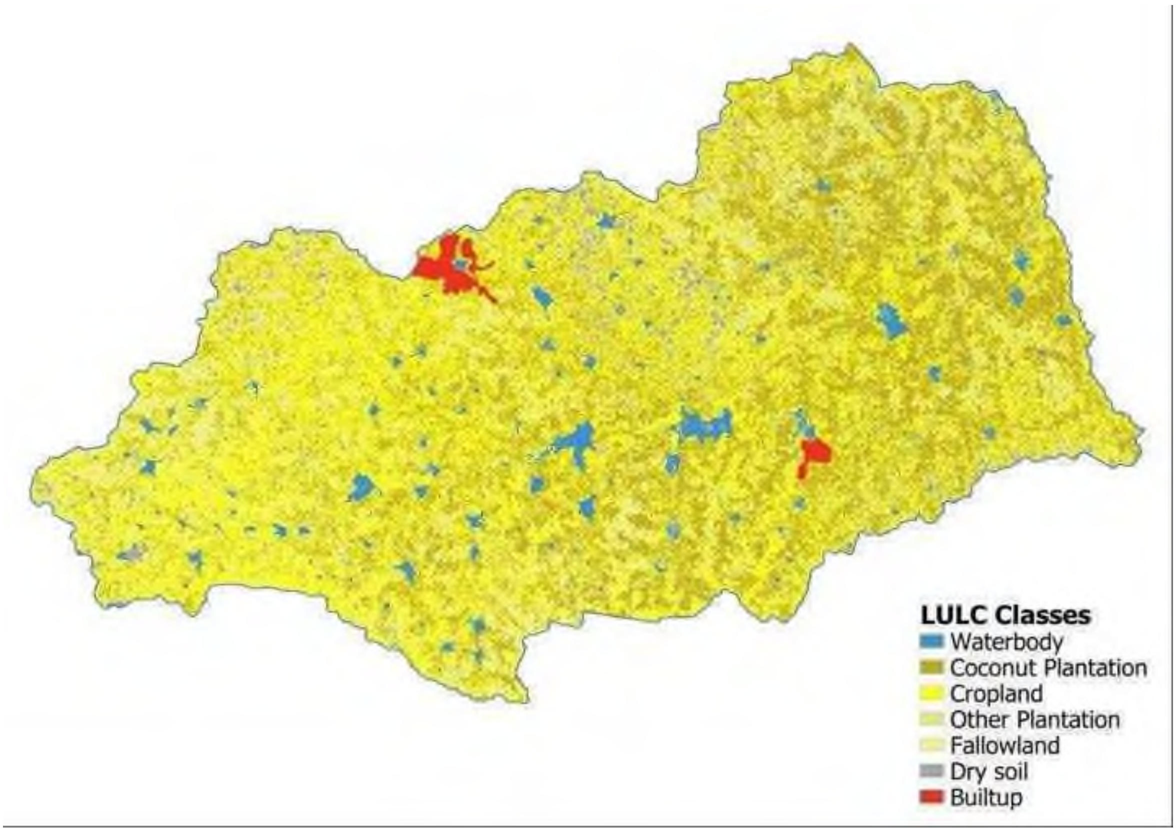


Image 22: Land use/ cover trends in May 2022

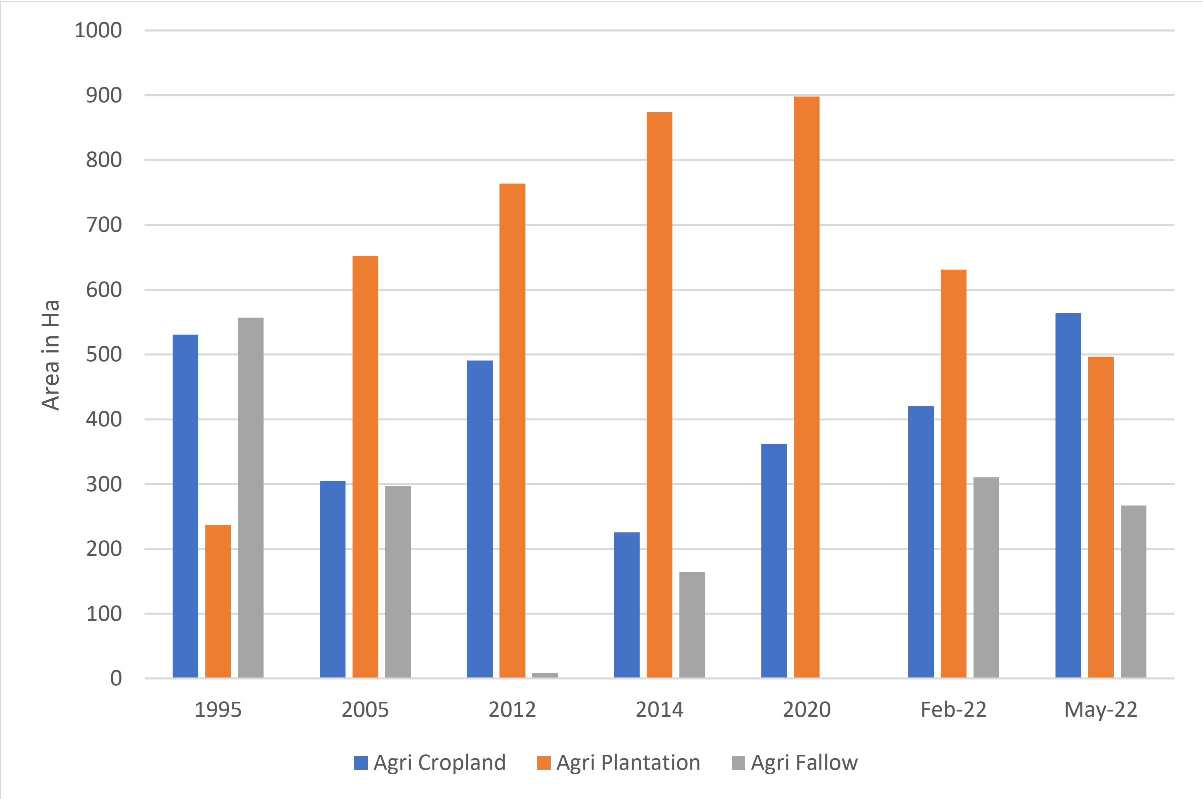
5.4.2 Overall land use/ land cover statistics

Using all the above data sets, table 16 is computed to understand Land-use use trends.

Table 16: Over Land use/land cover statistics

Sl. No.	Description	1995	2005	2012	2014	2020	Feb 2022	May 2022
1	Agri Cropland	530.66	304.99	490.52	225.39	361.53	420.20	563.83
2	Agri Plantation	236.98	652.00	763.75	874.04	897.97	631.10	496.41
3	Agri Fallow	556.78	297.13	8.25	164.33	- -	310.28	266.94

Graph 5: Land use trend and shift in preferences



The time series data on the cropping shows that there has been an increasing trend in the farmers adopting plantations, with a gradual reduction in agricultural activities up to 2014. Subsequently, there is a marginal shift in this trend and gradual increase in agricultural activities. This again is with regard to dynamic changes that is seen with regard to agricultural fallow land area, which either get used for cropping or left unattended based on rainfall events. Depending of its usage for cropping it might have got added to agricultural activities at times, which is typically the case during Feb and May 2022 and similarly in the earlier time periods. The plantation area has been continuously on the increase up to 2020, while for 2022 there is a change in the pattern due to change conditions on the ground. The pandemic has driven many people from cities back to the villages, due to lockdowns there has been some impacts on the general climatic parameters, due to some of these factors more rains have been seen in the past two years etc. These have impacted the agricultural activities at field level which has, in general, resulted in change in land use pattern. The waterbody analysis, however, has been separately carried out above. As seen from the above Chart, the current agricultural cropping area coverage is almost matching with that of 1995 with a marginal decrease in plantation area which need to be validated from additional ground work and also towards the harvest and crop yields (Graph 5). This also needs further confirmation as to how many migrated individuals have returned back to villages due to Covid/ Pandemic situations in the cities during the last two years. The sudden change in cropping pattern seems to suggest such a probability as more manpower is available at field level and hence the impact on the cropping preferences. These are inferences drawn from the satellite data analysis and needs ground survey and assessment.

5.5 Erosion process

The entire terrain is undulating with rivers and valleys and hence nonavinakere gets a lot water from many of the nearby streams and rivers. The satellite images, Digital terrain models and the agriculture land use/ cover maps indicate the active erosion process, especially in the monsoon season, that is prevalent in the area of interest. Initial analysis of the satellite data and the digital elevation model shows that are many pockets that show erosion due to water and hence may need correction measures at field level. The erosion is primarily due to higher intensity of runoff through the slopes and gradients during rainy conditions. A series of erosion maps have been generated using satellite imageries of relevant seasons in the past by NRSC, ISRO. The maps published under Bhuvan Geoportal is referred and highlighted here to get a spatial feel of the erosion around the catchment area of nonavinakere water body. It is essential that necessary counter measures with regard to soil and water conservation is properly sensitised to the farming community in this region to arrest the soil loss, which is detrimental to the agricultural activities in the area. Following satellite images and the erosion maps demonstrate the intensity of this problem in the area.

Image 23: Flow Direction image derived from satellite stereo based Digital Surface Model

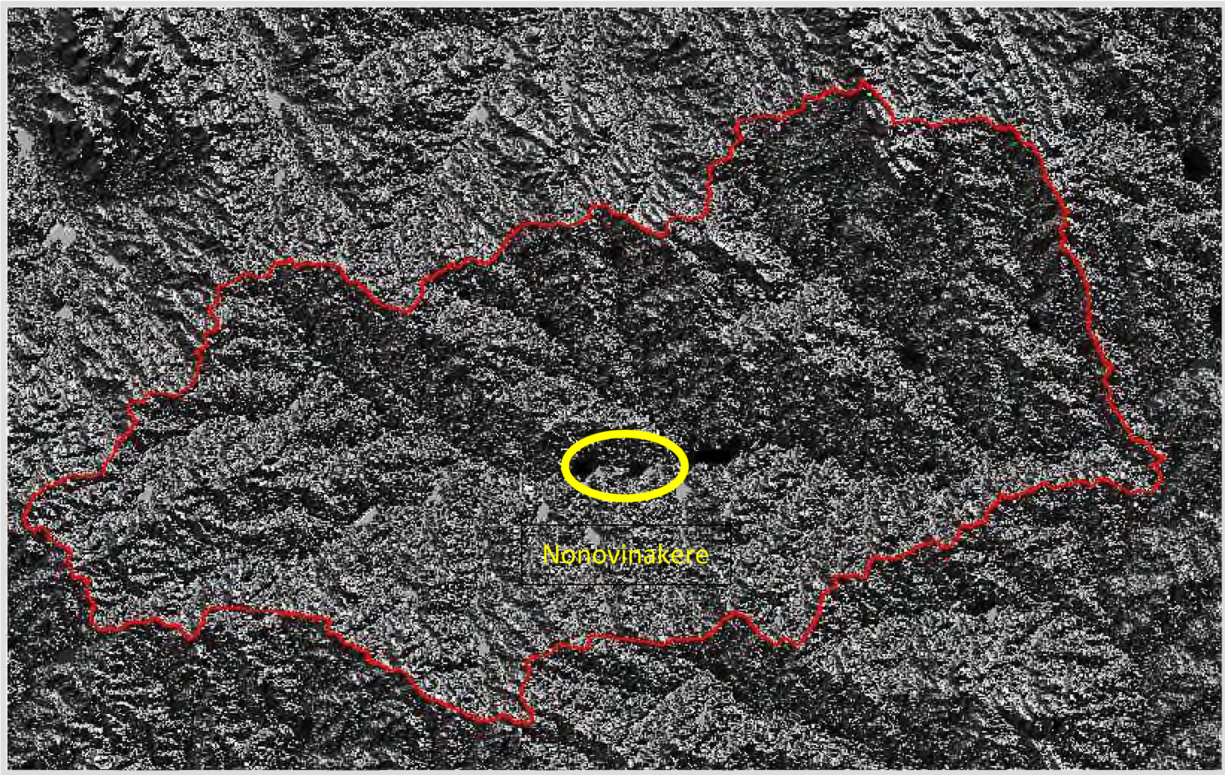
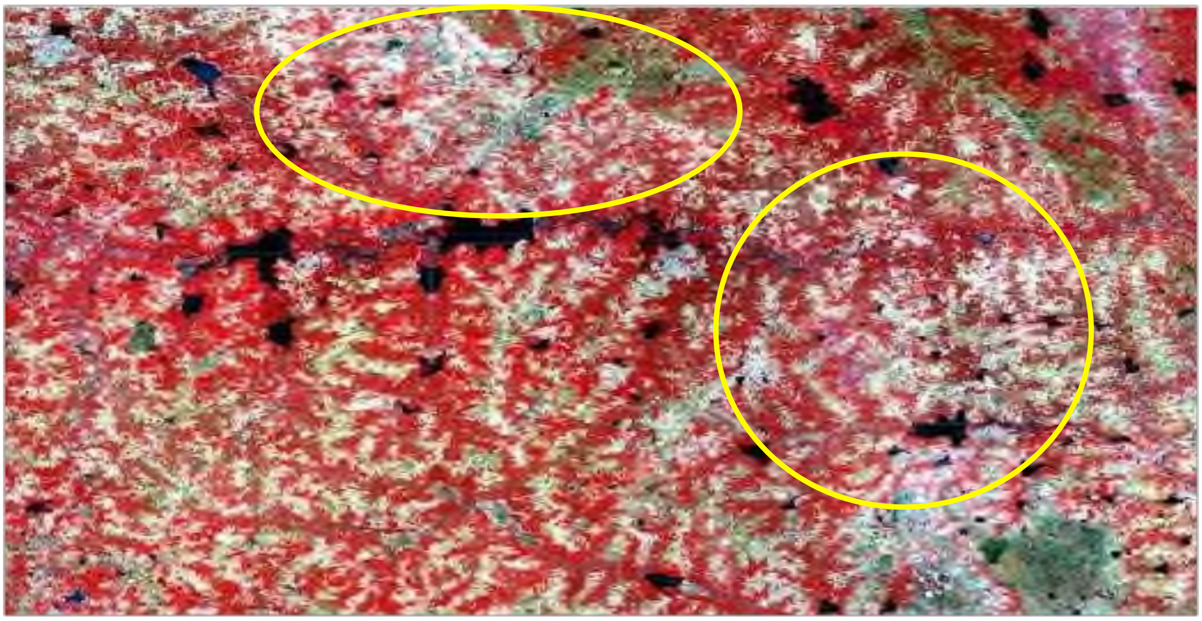


Image 23 gives a clear perspective of the undulations in the terrain and also with in the catchment area of nonavinakere. The ruggedness and the undulations are quite pronounced, which has resulted in such huge waterbodies, such as nonavinakere and mallaghattakere, situated almost in the middle of the area of interest. It is obvious that most of the natural drains bring large amount of water to these waterbodies, but along with that even silt is brought to the tank. Water Erosion is quite pronounced in the region during monsoon season, especially whenever there are heavy rains. Following image demonstrations, the same.

Image 24, the False Colour Composite (FCC), depicts vegetation in red colour and the deep waterbodies in dark colour. There are many white/grey high-reflecting patches shown along the drainage networks which are basically flow directions of the rain water, as depicted in the above images. These are typical images taken in the post monsoon season after the crop harvest and the eroded patches are quite clearly visible in large chunks. Following maps depict the water erosion, derived from RESOURCESAT LISS 3 sensor data in 2015-16.

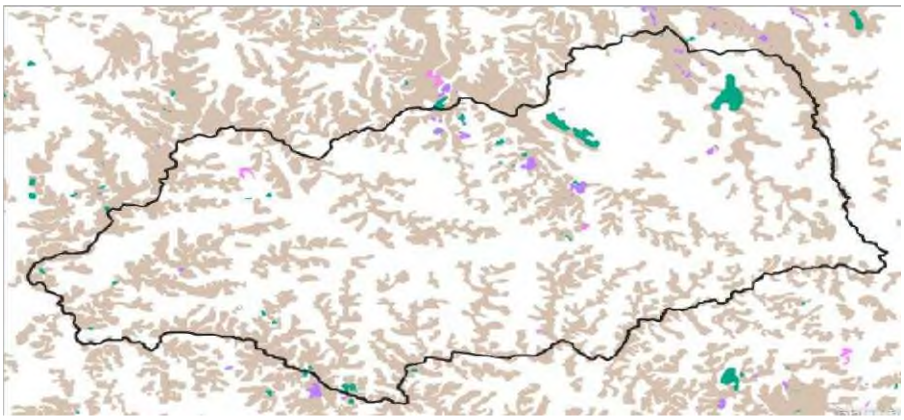
Image 24: Vegetation and deep waterbodies of Nonavinakere



5.6 Water erosion

It is necessary to estimate the amount of silt that is accumulated in the nonavinakere, to immediately take up the activity of desilting. Accumulation of silt over a long period of time results in storage loss of such a huge waterbody that would drastically affect the agricultural activity in the tank-fed agricultural areas. Desilting would be advantageous, as this would restore its original capacity to store large volumes of water and at the same time helps in percolation of water into ground water aquifers (Map 1).

Map 1: Erosion status of Nonavinakere



Erosion map as extracted from Bhuvan Geoportal, for the Area of Interest. The map clearly highlights many areas of erosion that needs to be properly treated and the erosion to be arrested

5.7 Village-wise statistics

Considering the recent cropping season data, an analysis is done to find out village-wise statistics with regard to cropland, plantations and fallow-land. The village boundaries considered are as per the census boundary definitions. A set of village boundaries are used as Area of Interest and statistics are computed for each of the boundaries. Following village boundaries are used in the present computation, namely, Agrahara, Alburu, Basavanahalli, Chiggave, Gopalapura, Kodihalli, and Nonavinakere. The statistics of the land use/ land cover are given below with a brief analysis.

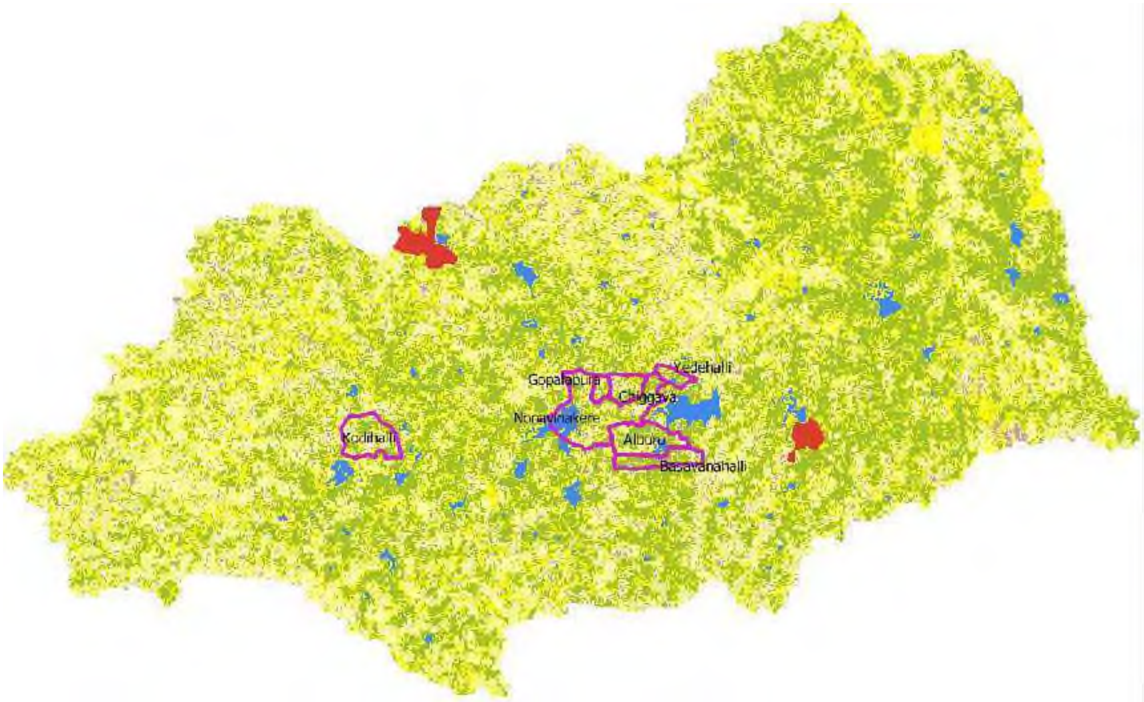


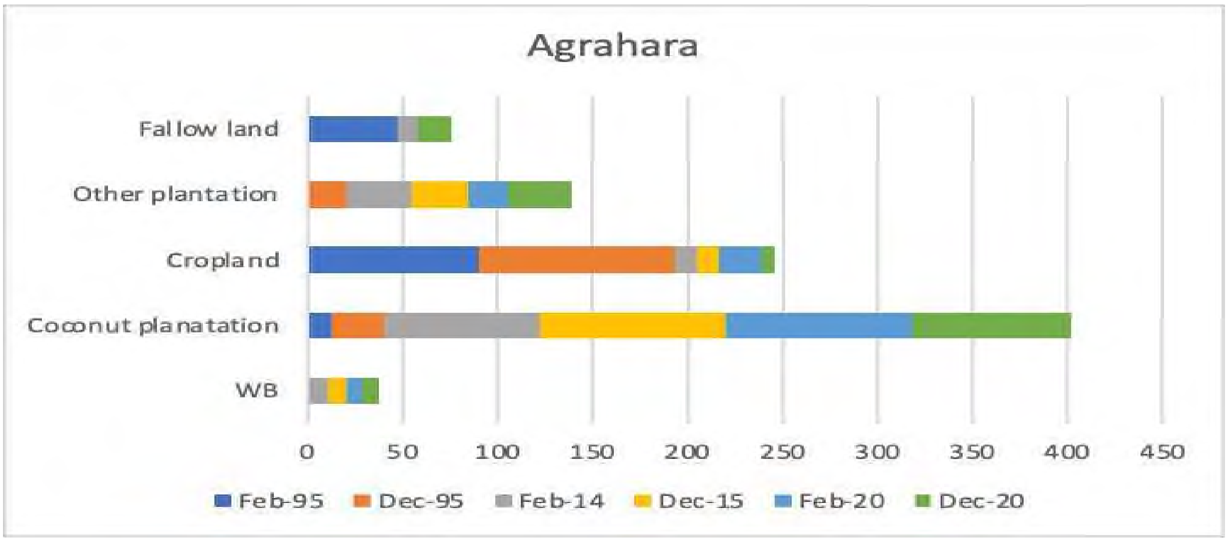
Image 25: Study area showing the Village boundaries considered for Statistics

As it can be seen from image 25, majority of the villages considered for the analysis are in the command area of Nonavinakere, which shall give an idea on the way the water is utilized in the command area, while a sample village is also considered towards the catchment area for statistical analysis for comparison. Following are the details of the village-wise statistics and brief analysis.

5.7.1 Agrahara

The village statistics for Agrahara village shows that cropland area has reduced and majority of the farming community have shifted to coconut plantations. After 1995, consistent increase in the area of coconut and other plantation is observed from the following graph. Cropland and fallow land areas have reduced during the same period (Graph 6).

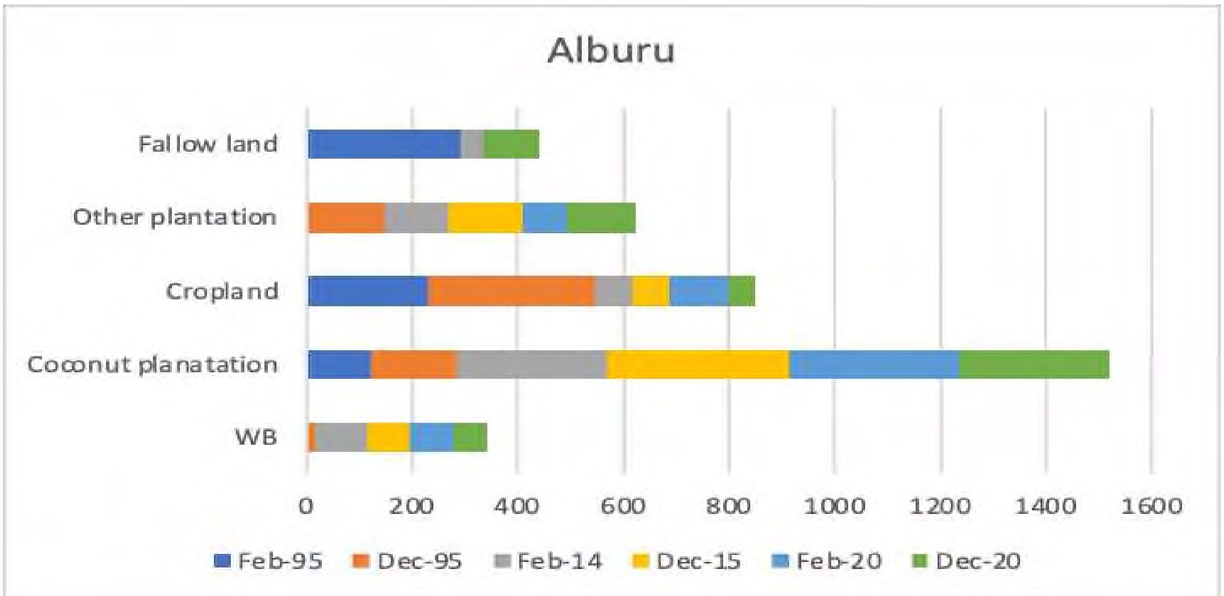
Graph 6: Village statistics for Agrahara village



5.7.2 Alburu

The village statistics of Alburu shows a similar trend as in Agrahara above. Consistent and significant shift to coconut and other plantations is observed in this village too. The shift is even more pronounced in Alburu village. The x-axis shows a larger area coverage (sq. km) for this village (Graph 7).

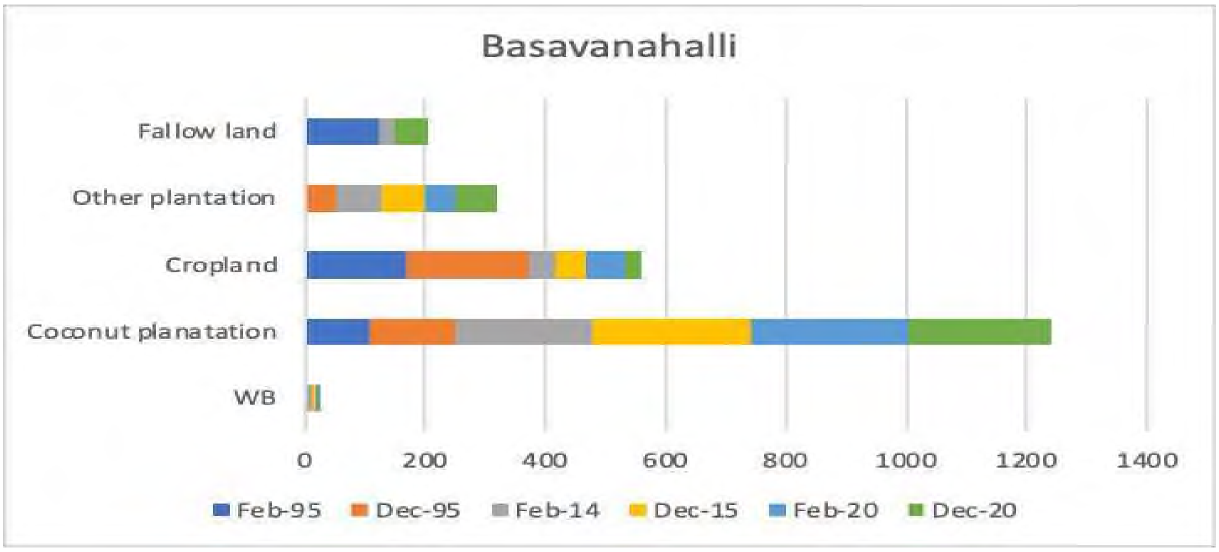
Graph 7: Village statistics for Alburu village



5.7.3 Basavanahalli

The village statistics of Basavanahalli shows a similar behaviour as in Agrahara and Alburu. Consistent and significant shift to coconut and other plantations is observed in this village too. The x-axis shows a larger area coverage (sq. km) for this village too (Graph 8).

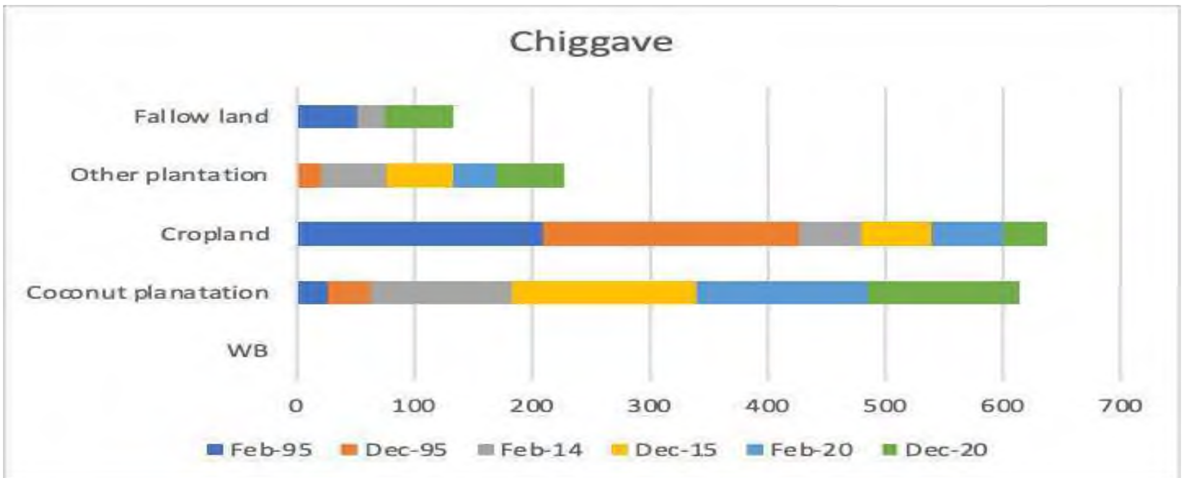
Graph 8: Village statistics for Basavanahalli village



5.7.4 Chiggave

The village statistics here is similar to the previous ones, as plantations dominate the area coverage in the recent years. It can be clearly seen that 1995 areas shows a significant coverage in 1995 while the plantations are very minimal. Gradually, the cropland has shown regular

Graph 9: Village statistics for Chiggave village

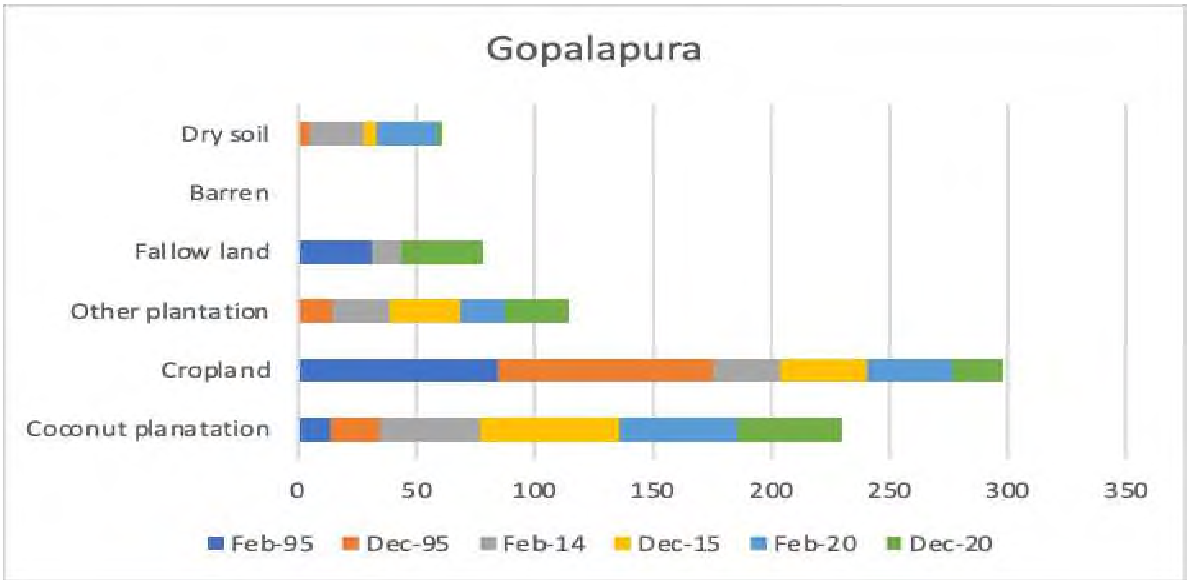


decrease while the coconut and other plantations have increased on a year-to-year basis. Even though the agriculture related activities have come down, compared to other villages above Chiggave still has better cropping related activities (Graph 9).

5.7.5 Gopalapura

The village statistics here is very similar to the Gopalapura village. While the cropping activities have reduced and the plantations have gone up, there is still reasonable agricultural activities being continued as observed in Gopalapura (Graph 10).

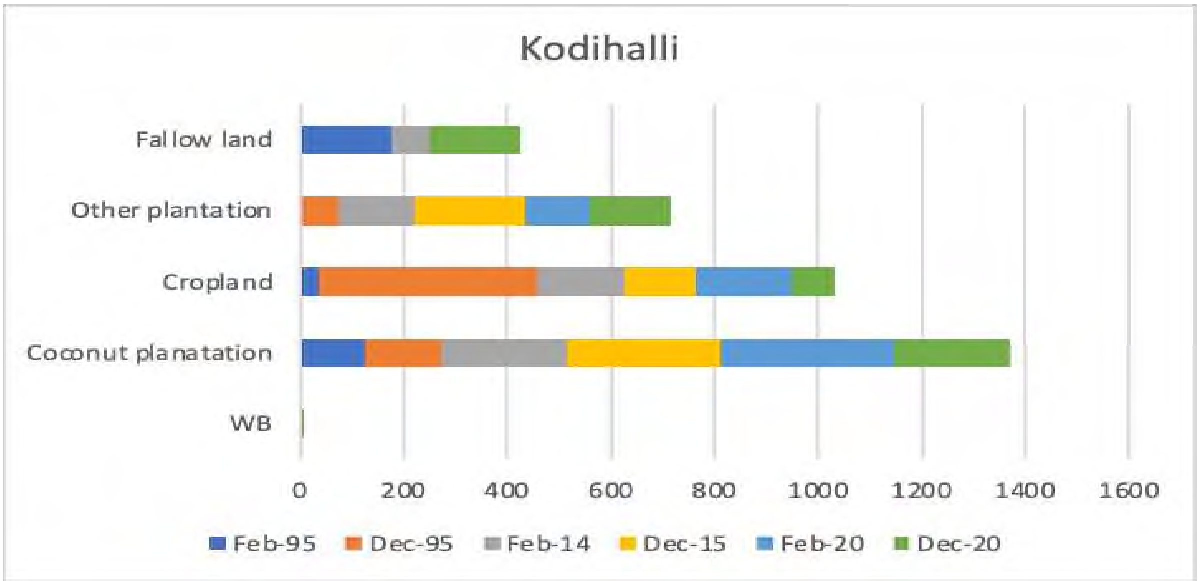
Graph 10: Village statistics for Gopalapura village



5.7.6 Kodihalli (at far left of Nonavinakere)

The village statistics shows that the coconut and other plantations dominate the village area, which was not so in 1995. The cropland area in December 1995 is quite significant and in subsequent time frames the areas have reduced, while at the same time coconut and other plantations have increased and remains to be stable across past more than a decade. It may also be seen from the graph that the area coverage is much larger as compared to the above villages, which shows that this village has much larger area coverage for agriculture/ plantation related activities (Graph 11).

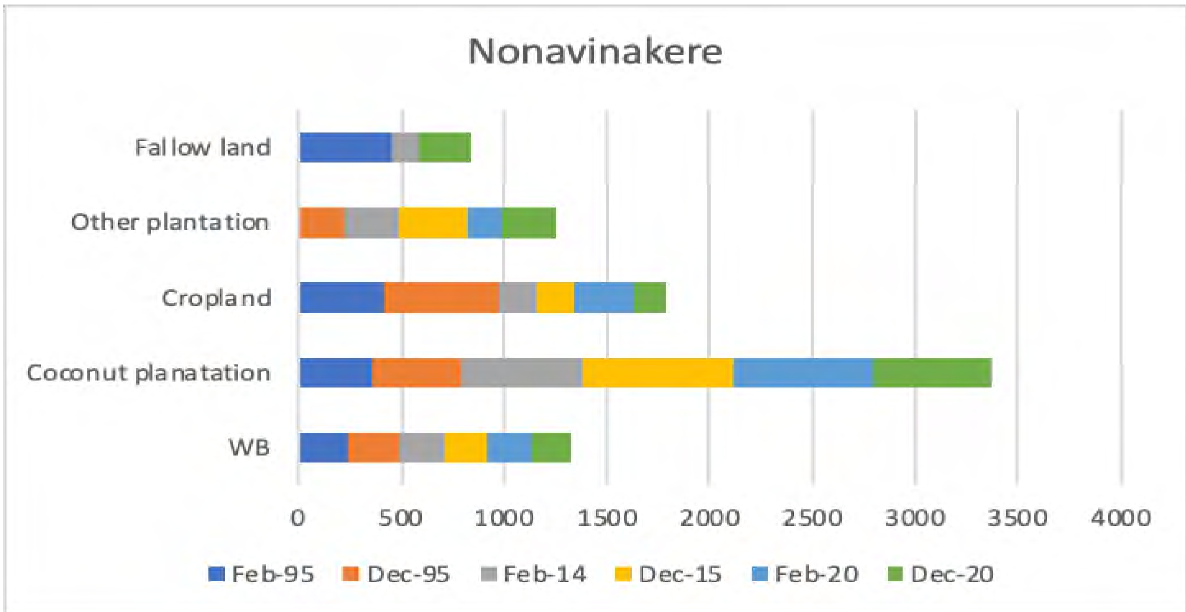
Graph 11: Village statistics for Kodihali village



5.7.7 Nonavinakere

The village statistics shows that agriculture and plantations have co-existed even during 1995, while the area under coconut and other plantations have increased in the later years, while the cropping areas do exist in smaller numbers (Graph 12). It may also be seen that the total area covered is much larger than all others, as described above.

Graph 12: Village statistics for Nonavinakere village

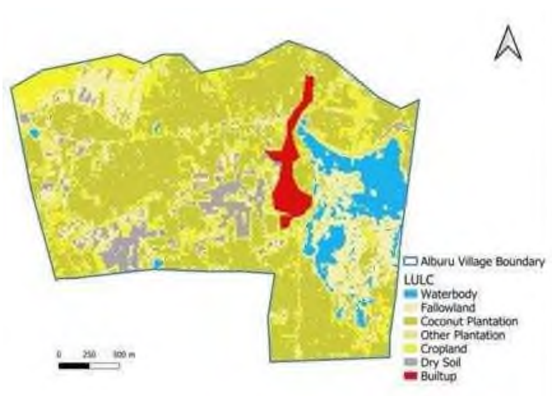


5.7.8 Village statistics for 2022

Following are the crop maps that are generated with regard to different villages in the study area and their corresponding area statistics with regard to the land use as observed from satellite during Feb 2022 (Images 26 & 27).

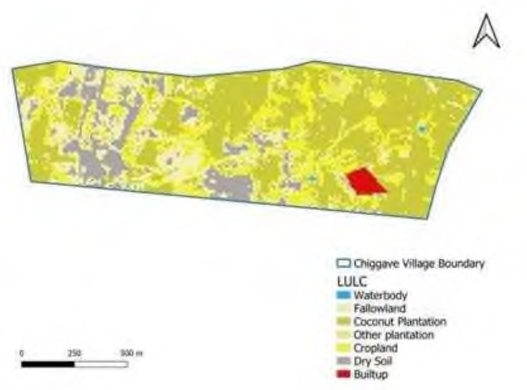
Image 26: Area statistics of different villages during Feb 2022

Alburu



Basavanahalli

Chiggave



Gopalapura

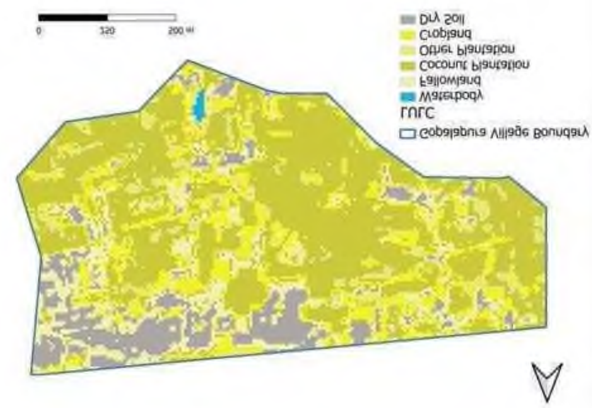


Image 27: Area statistics of Nonavinakere during Feb 2022

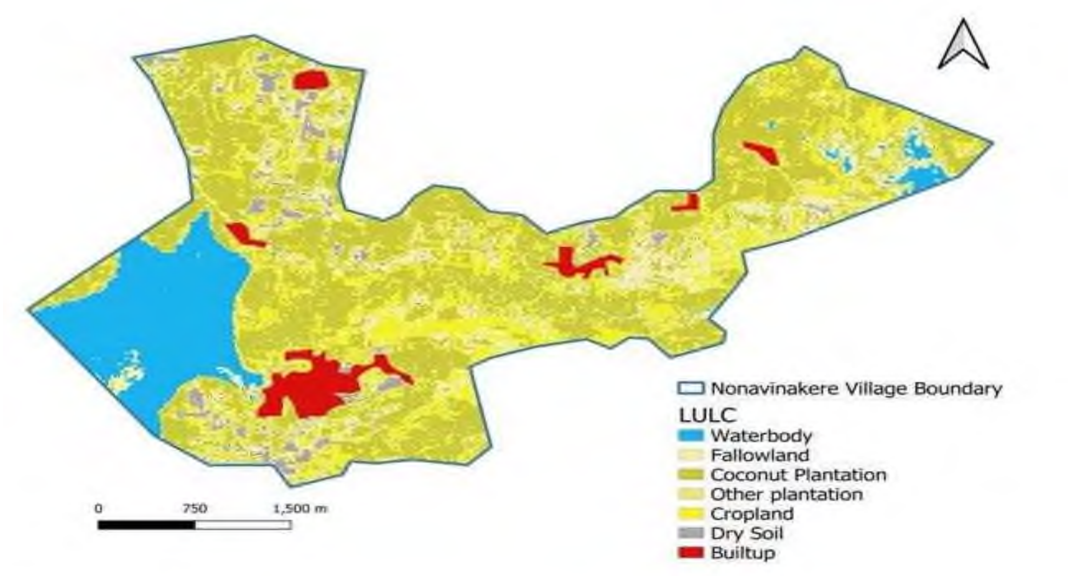
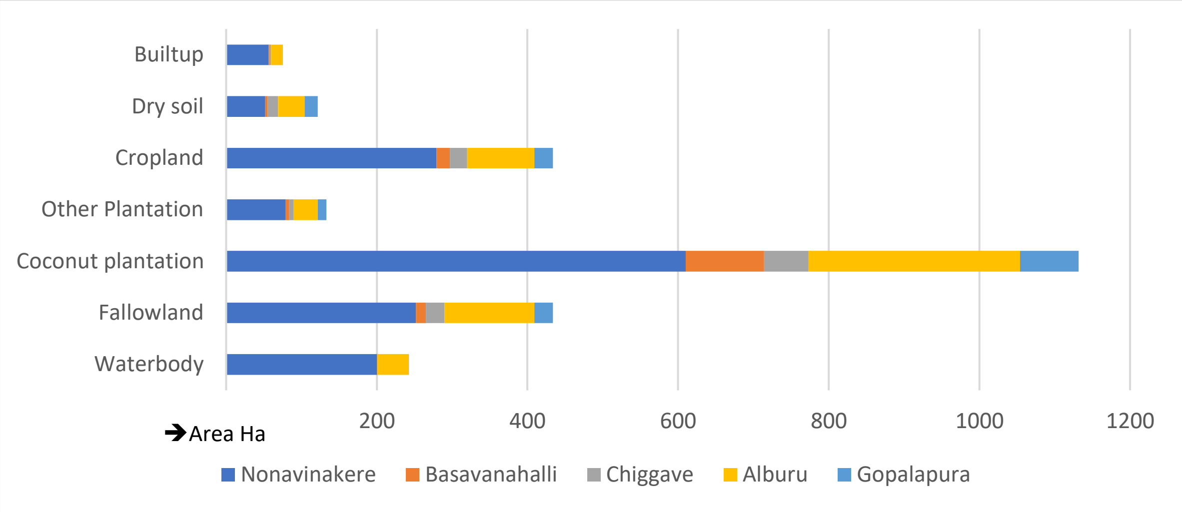


Table 17: Village statistics (area in ha)

Villages	Waterbody	Fallow land	Coconut plantation	Other Plantation	Cropland	Dry soil	Built up
Nonavinakere	200	252	610	79	279	52	56
Basavanahalli	0.3	13	104	4.8	18	2.9	1.9
Chiggave	0.1	25	59	6	23	14.1	1.5
Alburu	42	119	281	32	89	35	16
Gopalapura	0.3	24.9	77.8	11.1	24.7	17.5	--

Note: *The Village boundary for Nonavinakere includes kodihalli, konegowdanapalya, kuduvanaghatta, Basthihalli, Yadehalli, as separate boundaries for these villages are not available.*

Graph 13: Village statistics (area in ha)



As can be seen from table 17, even though the overall statistics for the entire catchment shows that there is increased agricultural cropping activities and reduced plantations, the data for all villages around Nonavinakere shows the other way round. The previous years trend continues even 2022, especially the coconut plantations dominate the agriculture/ horticulture activities in and around nonavinakere.

Overall village level trend shows increased plantation activities as compared to the agricultural cropping activities (Graph 13).

5.8 The role of water tank management on equal and efficient use of water

The tank water is managed by the sub-division of Cauvery Neeravari Nigam Limited (CNNL) - a corporation established in 2003, as a special purpose vehicle for speedy implementation of irrigation projects. The sub-division managing Nonavinakere tank is located near the city of Tiptur. We have conducted multiple key informant interviews with the officials of CNNL and collected information on the salient features of the tank and canals, the overall management and distributional structure and challenges faced by the management authority and other information on set of indicators mentioned in the table 7.

The officials of CNNL mentioned that the overall area irrigated (also referred to as atchkat in local language) is around 540.92 ha. However, considering the total capacity of the tank, it is estimated that the water can be used to irrigate approximately 730 ha of land. Nonavinakere has two main canals; first is the right bank canal which is around 4.5 km long and second is the left bank canal which is around 7 km long. Moreover, 11 villages around the tank benefit from the tank's water. It should also be noted that the tank water is essentially for the irrigation of Semi-dry crops like Ragi, green gram, pulses etc. However, most of the farmers tend to grow paddy using the tank water. Furthermore, the water from the tank is released from mid-January to April every year, which can be extended to another month based on prevailing weather conditions. The water releasing schedule is, however, subject to varying rainfall and other environmental parameters.

Photograph 3: Cauvery Neeravari Nigam Limited

Photograph 4: IIMB team interacting with officials of CNNL

As noted earlier, there are two main canals of the tank through which the water is distributed to around 12 villages around the area. While the left bank canal is lined up-to 1.5 km, the right bank canal is not lined. Before releasing the water, these unlined canals are cleaned, which are overgrown with weeds and other unwanted plants. The management authority is tasked to hire contractors for this and also provide further canal access from the main canal to the farms. In other words, before the water release, minor and sub-minor canals are dug out to allow the beneficiary farms to receive the water.

Surface irrigation system often suffers from water shortage at the canal tail-end. This is often caused due to myriads of reasons, for instance, the conveyance system is often not capable of taking it into the farms through the minor, sub-minor canal system; or obtaining insufficient water at the canal intake. To avoid a shortage of water for the tail-enders, the CNNL authorities have adopted a 'half-and-half system' of water distribution. Precisely, the water is released till the middle of canal in the day and later at night the water is allowed to flow across the rest of the canal. Thus, maintaining an equal distribution of the water across the beneficiary villages. However, this 'half-and-half' system requires that the water flow is adjusted manually.

5.9 Key observations from the multiple field visits in the study area

These observations indicate a need to improve the management regime of the water tank management authority. The inter-departmental coordination and communication is a crucial factor for efficient implementation any activity. The villagers have been getting the water from tank regularly from January to May, every year. However, during some years the water is not released. In the recent past, this has happened 2 years ago and entire summer season were idle for the farmers and there were no farming activities from January to May. Due to improper inter-departmental coordination and communication, in this year similar trend is observed and there is a delay in water release from management authority to the command area. As we have observed there is no agricultural activities from January to mid- March in the command area this year. Water is released on 19th March so the crop season for paddy is almost over and farmers are uncertain about the farming till end of the March month.

The management authority is not properly maintaining the data of inflow water to the water tank, the volume of water in the tank in different seasons, diameter and depth of the tank. There is no proper measurement and control system for overflow water. Moreover, they are using outdated and manual system to release the water in the command area. As we have observed the condition of the gates is very poor and leakage in the gates. Gates of the left bank and right bank do not have any measurement structure and as of result of which data on amount of water released to the command area is not available.

Photographs 5 & 6: Right bank canal

Photographs 7 & 8: Left bank canal

There is need to improve the infrastructural arrangements like lining of the canals, using pipes or pumps to extract water from the canals instead of natural drains dug out for them. Considering how the canals are not lined and the soil type, despite employing a half-and-half system, there would be considerable amount of water loss due to seepage. Proper cleaning of the canals is essential before releasing the water to the command to ensure efficient flow of water through the canals. The conditions of the minor and sub-minor canals which interlink the main two canals to the farm lands are also not maintained and some of the interlink canals die out due to lack of proper maintenance. As a result of which some farmers unable to access the water from the main two canals and keep their land as fallow during summer season. The gates of the minor and sub-minor canals usually used to divert the water flow and maintain the equal distributions of intake canal water among the farmers, do not exist.

Photograph 9: Left bank canal

Photograph 10: Right bank canal gate

Photograph 11: Left bank canal main gate   Photograph 12: Overflow water from the tank

The observations reveal that engagement of the farmers in the water releasing planning process and other decision-making process is negligible. The management authority is not properly communicating the water releasing schedule with the farmers of the command area. Due to improper and uncertain information about the water releasing schedule farmers could not suitably adopt crop varieties and other agricultural activities. Therefore, crop season as well as water will be wasted.

The table 18 reveals the remote sensing time series data of the surface water body of the water tank. It indicates that a significant amount of water body was available from December. Table 19 represents the time series data of volume of water in the water tank. The following formula is used to calculate the volume of water in the water tank in different period of time:

Surface water body of the water tank x **Average depth of the tank = Volume of water**

Table 18: Time series data of water body area of Nonavinakere water tank

Sl. No.	Date	WB area (Sq. km)	Ha
1	22/12/21	4.1027	410.27
2	11/01/22	4.1043	410.43
3	10/02/22	3.995	399.50
4	12/03/22	3.1964	319.64
5	01/04/22	2.2666	226.66

Table 19: Time series data of volume of water in Nonavinakere water tank

Sl. no.	Date	Water body area (Sq. km)	Average depth (in meter)	Volume of water (in liter)
1	22/12/21	4.1027	5	20513500000
2	11/01/22	4.1043	5	20521500000
3	10/02/22	3.995	5	19975000000
4	12/03/22	3.1964	5	15982000000
5	01/04/22	2.2666	5	11333000000

The amount of water requirement to produce 1 kg of rice is 1432 litre (FAO). The productivity of rice in the command area is 32 quintals. The estimated water volume on 22/12/21 can be used to irrigate approximately 1811 ha of land (Table 20).

Table 20: Time series data of estimated irrigable land using Nonavinakere water tank

Sl. no.	Date	Volume of water (in liter)	Estimated irrigable land (in hectares)
1	22/12/21	20513500000	1811
2	11/01/22	20521500000	1812
3	10/02/22	19975000000	1764
4	12/03/22	15982000000	1411
5	01/04/22	11333000000	1000

Having known the water level in October, the authority can compute the irrigable land and immediately inform the farmers in the command area. If the water is released during rabi season the amount of water needed for crop is lower due to residual moisture from kharif season. With proper crop planning it would be possible to take up both rabi and summer crop.

6. The initiatives taken individually and by the community to improve the management of water resources

The FGDs was conducted to get more insights about participation of the farmers in decision making process and initiatives taken by farmers at individual and community level in system design and management of water resources. We have conducted two focus group discussions with the farmers from two different beneficiary villages namely Gopalpura and Alburu. Each focus group discussion consisted of 8 to 10 farmers. Most of the farmers do get the same amount of water every year. However, this is not based on some calculation or measurement. There are no fees that the farmers have to pay for using this water. However, they do they to pay a water tax, which is included in the land.

Photographs 13 & 14: Focus group discussion

Farmers don't have any idea how much water they receive. All of the farmers in the discussion noted that the constant supply of water is more than enough and in fact, they receive an excess amount of water. The farming fields of the farmers who were involved noted that their farms

> *"We are interested to adopt other crops instead of paddy. Paddy is not profitable for us. We are growing it because we do not know what are the others crops suitable for summer season. Most of the farmers are interested about the coconut plantation so in the village they are less interested about other crops."*
>
> -- **Farmer from Alburu village**

were adjacent to the canal, and a few noted that they were around 1 or 3 kms away from the main canal. The farms close to the canal have natural drains. Farms further use a combination of different equipment like pipes and pumping machines. Moreover, these farms (further away from the canal) use different equipment and share water amongst themselves. That is, if one

> *"We usually grow paddy and most of the farmers from the village grow paddy from January to May but this year we have not got the water from the tank. The whole agricultural activities are affected because of the delay in the water release schedule. We are certain what to grow, no one is ploughing their land in the month of March also."*
>
> -- **Farmer from Gopalpura village**

farm has equipped pumping machine/pipe to extract water from canal, then this water is also used by the adjacent farms. In the village of Gopalpura, almost all farmers used to grow paddy, not many farmers keep their land fallow. However, due to recent construction of new road, many farmers could not dig the natural drains to extract the water from main canal, as their farms were further away and the elevation of the land did not support the natural drain water to reach. None of the farmer knew much about the requirement of the water for their crops. Based on availability, the water is being used for crops. However, since they receive an excess amount of water, they all never considered to know more about the actual crop-water requirement. Many big farmers grow both coconut and paddy, however, all of them noted that they have only been growing paddy. Most of the farmers felt that growing paddy is not profitable for them. The nearest market to this area for paddy is Davangere market. The farmers sell their produce to the agents (middlemen) and not in the agriculture produce market committee (APMC). While many young farmers do access the internet for market price etc. however, they still sell their produce at a lower price, which always makes it unprofitable for the farmer considering the cost of cultivation. Moreover, free rice they are getting from the ration is discouraging them to go for paddy. Therefore, there is a need for proper advice on the cropping pattern changes in the area. Establishment of Water User Association (WUA) amongst or within the beneficiary villages can help bring in improvements in management, distribution and maintenance of tank water.

7. Analysis of FGDs

Table 21: Interpretation of the indicators of the FGDs

Sl. No.	Indicators	Interpretation
1.	Knowledge and awareness about water management	
	a) Farmers' knowledge about water tank management authority	They do not have any proper knowledge
	b) Information and awareness about water releasing schedule	Unaware about water releasing schedule
	c) Information about the availability of water in the tank	No knowledge about water volume
	d) Information about the water distribution procedure	Few farmers have the information
	e) Information about the condition of the canals system	Well aware of conditions the canals
	f) Knowledge about water scarcity	No knowledge
	g) Knowledge about innovative irrigation or water saving irrigation systems	Minimal knowledge
	h) Knowledge about the importance of water and its sustainable use	Not aware of sustainable use of water
	i) Knowledge about ground water, surface water, rainfall, moisture, and seasonal variations	Few educated farmers have the knowledge
2.	j) Formation of water user association	No water user association formed
	k) Member of farmer association	Few farmers have the membership
	l) Interaction with the officials of water tank management authority	Lack of Interaction with the officials of water tank management authority
	m) Participation in decision making process related water tank management	There is no participation
	n) Participating in extension classes to resolve water problems	No extension classes organized
	o) Participate in group activities to construct canals	No participation
	p) Participating in maintenance of canals	Some of the farmers participated

3.	Obstacles for farmers participation	
	q) Dissatisfaction with water tank authority operators	Most of the farmers are disappointed
	r) Delay in water release schedule	This is year there is delay
	s) Unequal distribution of water among farms	Tail enders' farmers face the problem of unequal distribution
	t) Suspension of cultivation due to delay in water release	This year most of the farmers keep their land idle

8. Analysis of the primary data (200 respondents)

Table 22 describes the descriptive statistics of 200 farmers. The descriptive statistics reveal that average age of the farmers is 52 years. The average educational attainment is higher primary and primary occupation is farming. Average experience and farm sizes are more than 21 years and 2.84 acres respectively. The average income of the farmer is INR 40,605. Average household expenditure lies in the range INR 3001–5000.

Table 22: Descriptive statistics of socio-economic factors (For 200 respondents)

Variables	Unit of Measurement	Mean (Std. Dev.)	Min.	Max.
Age	Year	52.34 (13.52)	22	69
Education	Categorical: (Illiterate = 1, Lower primary (I-IV) = 2, Higher primary (V-VII) = 3, High School = 4, PUC = 5, Graduate & above = 6, Other technical degree = 7)	3.28 (Higher primary)	Illiterate	Graduate
Primary occupation	In percentage	100.00	-	-
Experience as a farmer	Categorical: (Less than 5 years = 1, 5 to 10 years = 2, 11 to 15 years = 3, 16 to 20 years = 4, More than 21 years = 5)	5.01 (More than 21 years)	5 to 10 years	More than 21 years
Income of the respondent	in INR	40,605 (35,419.08)	10,000	250,000
Monthly expenditure	Categorical: (Less than INR 3000 = 1, INR 3001–5000 = 2, INR 5001–7000 = 3, INR 7001–10,000 = 4, More than INR 10,000 = 5	2.97 (INR 3001–5000 = 2)	Less than INR 3000	More than INR 10,000
Average cultivable land per farmer	in Acres	2.84 (1.91)	0.25	15

Tables 23 & 24 represent the crop wise distribution of the number farmers and crop wise distribution of the number farmers during summer season respectively. The percentage of the farmers growing Coconut, Areca nut, Ragi, and Paddy are 97.50, 36.18, 86.50, and 97.50. Most of the farmers are growing paddy during January to May.

Table 23: Crop wise distribution of the number of farmers

Crops	Number of farmers	Percentage of farmer
Coconut	**195**	**97.50**
Areca nut	72	36.18
Ragi	173	86.50
Paddy	**195**	**97.50**

Table 24: Crop wise distribution of the number of farmers (From January to May)

Crops	Number of farmers	Percentage of farmer
Paddy	**193**	**96.50**
Ragi	4	2.00
No crop	3	1.50
Total	200	100.00

The table 25 shows the average area under paddy is 0.78 acres and maximum land holding under paddy cultivation is 2 acres. The average production and productivity of paddy are 25.75 and 32.30 quintals respectively. All farmers growing paddy for self-consumption and for selling. Average amount of paddy sold in the market is 14.15 quintals. The average income generated from paddy farming is INR 21,615.03.

Table 25: Information related to paddy farming (During January to May)

Variables	Unit of measurement	Observation	Mean (SD)	Min	Max
Area under paddy	In acres	193	0.78 (0.42)	0.15	2
Production level	In quintals	193	25.75 (14.73)	4.8	75
Productivity	In quintals per acre	193	32.30 (4.16)	22.5	41.67
Own consumption	In quintals	193	11.60 (7.34)	8.3	47
Amount of paddy sold	In percentage	193	14.15 (12.33)	0	60
Income from paddy	In INR	193	21,615.03 (19,849.93)	0	90,000

Table 26 represents the average costs of seeds, fertilizers, labour, irrigation, along with the average total cost of production INR 33,085.46.

Table 26: Cost of paddy cultivation

Variables	Unit of measurement	Observation	Mean (SD)	Min	Max
Cost of seeds	In INR	193	1,059.55 (475.39)	200	2,500
Cos of fertilizer	In INR	193	5939.64 (3,306.73)	300	15,000
Cost of labour	In INR	193	16,300.78 (10,738.09)	2,000	60,000
Cost of irrigation	In INR	193	3,845.86 (2,389.39)	500	9,000
Other cost	In INR	193	3,335.04 (2,222.13)	200	8,000
Total cost of production	In INR	193	33,085.46 (17,084.10)	6,750	95,800

Table 27 depicts the average costs of seeds, fertilizers, labour, irrigation, along with the average total cost of production INR 56,043.98 per acre and income from the paddy INR 57,600.39.

Table 27: Cost of production and income from paddy cultivation per acre

Variables	Unit of measurement	Observation	Mean (SD)	Min	Max
Cost of seeds	In INR	193	1,512.77 (652.06)	900	2,500
Cos of fertilizer	In INR	193	8,255.00 (3,440.754)	2,300	12,000
Cost of labour	In INR	193	21,803.73 (12,577.45)	5,040	38,000
Cost of irrigation	In INR	193	6,124.08 (4,574.72)	890	11,230
Other cost	In INR	193	5,607.714 (2,222.13)	2,320	7,790
Total cost of production	In INR	193	56,043.98 (18,072.17)	29,250	62,834
Income from paddy	In INR	193	57,600.39 (36,851.62)	38,645	62,973.56

The average cost of production of paddy farming per acre is INR 56,043.98 and income from the paddy farming per acre is INR 57,600.39. It is observed from the data that paddy farming is not so profitable for the them and the average profit of the paddy farming is only INR 1,556.41.

There are 3 major reasons for growing paddy: own consumption; as a fodder for their cattle; and market. Most farmers grow paddy during summer season for self-sustenance (especially small-holders). Farmers with bigger land holding, kept half of it for their own purpose, and then sold the rest in the market.

The 97.00 percentage of farmers used canal water and 78.00 percent are using borewell as a source of irrigation. The farmers use borewell water as a source of irrigation are Coconut and Areca nut farmers. Most of the paddy farmers are using canal water as a source of irrigation. Only 69.50 percent of the farmers are using pumping machine and pipes to extract water and irrigate their land. The study reveals that there are positive correlations between the distance of the farm land from the canals and use of pumping machine and pipes. As a result of this their cost of irrigation also increases for paddy cultivation. On the other hand, 77.00 percent farmers are using natural drainage system or gravitational flow to extract water from the canal to the farm land. Most of the farmers used flood irrigation system and only 1 percent (2 farmers) used drip and 0.5 percent (1 farmer) used sprinkle irrigation system (Table 28).

Table 28: Status of sources of irrigation and type of extraction

Variables	Unit of measurement	Observation	Frequency (percentage)
Source of irrigation			
Canal	In percentage	200	194 (97.00)
Borewell	In percentage	200	156 (78.00)
Type of irrigation			
Flood irrigation	In percentage	200	197 (98.50)
Drip irrigation	In percentage	200	2 (01.00)
Sprinkle irrigation	In percentage	200	1 (0.50)
Type of extraction			
Pumping machine and pipe	In percentage	200	139 (69.50)
Natural drain	In percentage	200	154 (77.00)

Only 17 percent of the farmers farm land visited by the water tank management authority, 29 percent of farmers farmland visited by the water man, and 26 percent of farmers farm land visited by agricultural officials (Table 29). There is lack of communication between the water tank management authority and farmers as frequency of visit from the water management authority is very less. As a result of this farmers are not well aware of water releasing schedule and amount of water release. Farmers face problem for land preparation and other farming activities accordingly for the crop season.

Table 29: Field visit and monitoring status of different officials

Variables	Unit of measurement	Observation	Frequency (percentage)
Visit from water tank management authority	In percentage	200	34 (17.00)
Visit from waterman	In percentage	200	58 (29.00)
Visit from Agricultural officials	In percentage	200	58 (26.00)

The awareness and attainment of the government schemes is also minimal among the farmers. Only 9 percentage of farmers have crop insurance, 2 percent farmers availing the minimum support price, 4 and 61 percent farmers are availing subsidies fertilizers and seeds (Table 30).

Table 30: Participation in government programs

Variables	Unit of measurement	Observation	Frequency (percentage)
Crop insurance	In percentage	200	19 (09.50)
Availing MSP	In percentage	200	5 (2.50)
Subsidies fertilizer	In percentage	200	9 (4.50)
Subsidies seed	In percentage	200	122 (61.00)
Availing free rice scheme	In percentage	200	194 (97.00)

There is no water user association exists in the study area. The membership of the farmer producer organization is 24 percent and 21 percent farmers are member of Self-help groups (SHGs) (Table 31).

Table 31: Membership status of farmers in organizations

Variables	Unit of measurement	Observation	Frequency (percentage)
FPO	In percentage	200	48 (24.00)
Cooperative society	In percentage	200	45 (22.50)
Water user association	In percentage	200	0 (0.00)
SHG	In percentage	200	42 (21.00)

The awareness about the water scarcity and sustainable use among the farmers is nominal. Only 29 percentage of the farmers are aware about the water scarcity problem in the World. Very less farmers have knowledge about the sustainable use of water. The 64 percent of the farmers of are not aware of water releasing schedule during summer season. This reveals that lack of communication between the water tank management authority and farmers (Table 32).

Table 32: Knowledge and awareness about the water issues

Variables	Unit of measurement	Observation	Frequency (percentage)
General awareness			
Water scarcity	In percentage	200	59 (29.50)
Sustainable use of water	In percentage	200	26 (13.00)
Crop damage due to water scarcity	In percentage	200	48 (24.00)
Tank related awareness			
Knowledge about water releasing schedule (January to May)	In percentage	200	72 (36.00)


Photograph 15: Weather station

Photograph 16 : Gateway


Photograph 17: Soil moisture sensor

Photograph 18: Water level sensor

The results of the stochastic production frontier analysis are represented in Table 33. The coefficient value of all the inputs is positively significant and reveals that all the inputs have a positive influence on output. The null hypothesis is rejected at a 1 percent significance level that implies the existence of TI among households. This validates the importance of inefficiency analysis of the farm households in the study area.

Table 33: Results of the stochastic production frontier model

Variables	Coefficient
Ln(total land)	1.121*** (0.030)
Ln(total wages)	0.166*** (0.057)
*Ln(*capital)	0.283*** (0.110)
Ln(fertilizers used)	0.213*** (0.037)
Ln(irrigation used)	0.189*** (0.015)
Ln(seed used)	0.163**(0.039)
Constant	4.874*** (0.203)
Number of observations	193
Wald chi-square (6)	2266.09***
H_0: No inefficiency	prob <z = 0.000

Source: Estimation is based on primary data.
Notes: (i) ***, **, and * represent significant at 1 percent, 5 percent, and 10 percent respectively.
(ii) Figures in parentheses represent standard error.

8.1 Determinants of technical inefficiency of the rice farming household

The marginal effect of the factors that influence the TI level of paddy farms is shown in Table 34. The coefficient of the determinants like the having a coconut farming and farm distance from the canal are found to be positively significant. Whereas, the coefficient of education, farming experience of the farmers, amount access to extension services, income from paddy, and farm size are negatively significant.

Table 34: Estimated values of the determinants of technical inefficiency

Variables	Marginal effect
Experience	- 0.236**(0.078)
Family size	-0.016 (0.033)
Education	-0.024** (0.048)
Coconut farming	0.047** (0.021)
Income from paddy	-0.097* (0.134)
Distance from the canal	0.079** (0.048)
Access to extension services	-0.063**(0.043)
Size of the farm	-0.082(0.031)
Constant	-0.051 (0.181)

Source: Estimation is based on primary data.
Notes: (i) ***, **, and * represent significant at 1 percent, 5 percent, and 10 percent respectively.
(ii) Figure in parentheses represents standard error.

The positive and significant coefficient value of the variable like coconut farming indicates that the inefficiency increases as the farmer is a coconut farmer. As the farmer is a coconut farmer, he may be more concerned about coconut farming as he has stable source of income from coconut farming. Therefore, the farmer who has coconut farming as a primary source income are not getting proper incentives to adopt new technologies and use other inputs efficiently in paddy farming. The education status and farming experience of the farmers are negatively significant on the inefficiency level. This indicates that the farmers who have more farm experience and educational attainment are more technically efficient. More farm experience and educational attainment of the farmers enhance the farmers' ability to adopt new technologies, increase their awareness and managerial skills that results in efficient use of agricultural inputs. The income from the paddy farming has a positive significant impact on the farm efficiency. Paddy farming is source of income enhance the farmers to adopt new technologies, improve their managerial and farming skills that results in efficient use of inputs.

The study found that, with an increase in the distance of farmland from the canals increases the inefficiency of the farmers. As most of the paddy farmers in the study area are extracting the water from the canals using gravitational flow or natural drain system to their farmland. The use of natural drain system is not an efficient water extracting method for long distance farmland from the canal. It is observed that the amount of water wastage is more in this system and farmers are not getting sufficient amount of irrigation water. Hence it may influence the efficient use other inputs level as well as their productivity level. The variable access to extension services has significant and negative influences on farm inefficiency. In any production activities, extension services play a vital role. In agriculture, the government provides different inputs at a subsidized rate and different training facilities to improve farming skills. As the most of the farmers are small farmers in the sampled area, subsidized seeds, fertilizer, irrigation and electrification facilities, and skill development programs enhance the farm efficiency and productivity.

The average TI of the farm is as low as 8.731 percent (92 percent efficient), and the maximum and minimum technical inefficiencies of the paddy farming households are 11.63 and 5.35 respectively (Table 35).

Table 35: Summary statistics of the estimated technical inefficiency

Parameters	Value (in percentage)
Mean	8.731
Standard Deviation	0.561
Minimum	5.356
Maximum	11.634

Source: Estimation is based on primary data.

A major fraction of the farmers in the sampled area is poor and marginal. Thus, subsidized inputs and extension services have a vital role in improving efficiency and productivity. As education, government support, and have positively significant impacts on farm efficiency, policymakers should give more emphasis on formal as well as technical education. Moreover, the frequent and productive interaction of the government officials with the farmers in the form of workshops and training may improve the efficiency more. Efficient distribution of canal water with proper follow-up mechanism may have some positive impact on farm productivity. Cooperative farming and awareness camps related to different modern farming practices may also be helpful in increasing the technical efficiency of the farmers.

8.2 Factors affecting farm-level (resource) allocative efficiency

Results of the factors affecting farm-level (resource) allocative efficiency are presented in Table 36. The results revealed that several factors influence the AE of paddy farming. AE has a significant relationship with the experience of the farmer ($p < 0.05$), educational level of the farmer ($p < 0.01$), access to extension services, access to market, and size of the farm.

Table 36: Factors affecting allocative efficiency of rice production

Allocative efficiency	Coefficient (robust standard error)
Experience	0.0325** (0.0141)
Education	0.0561*** (0.0231)
Access to extension services	0.0163*** (0.0083)
Access to market	0.0527** (0.0163)
Size of the farm	- 0.0481** (0.0271)
Constant	0.0629*** (0.0146)
Sigma	0.0749 (0.0068)
F (5, 193)	15.430
Pseudo R square	- 1.2541
Log-likelihood	163.3129
N	193

Note: ***, **, and * represent significant at 1 percent, 5 percent, and 10 percent, respectively.

There is also an inverse relationship between farm size and AE of paddy. Specifically, an increase in farm size is likely to reduce AE for paddy production. It provides more evidence on the inverse productivity hypotheses. In addition, access to the market is an important indicator of market accessibility for both input and outputs for smallholder farmers. The present study found a positive relationship between access to market and AE for paddy farming. The study also suggests that there is a positive relationship between access to extension services and AE. In other words, farmers who had access to extension services have higher AE. Farmers efficiency in the allocation and use of inputs ensure the optimal level of productivity by using a minimum level of inputs.

Photographs 19 & 20: Interaction with officials of Raita Samparka Kendra

9. The programs to create awareness among farmers to enhance equal and efficient use of water

There is a delay in water release from management authority to the command area. As we have observed there is no agricultural activities from January to mid- March in the command area. Water is released on 19th March so the crop season for paddy is almost over and farmers are uncertain about the farming till end of the march month.

As we have already mentioned earlier 30 farmers are selected from the Goapalpura village for the installation of soil moisture sensors. We are interacting with these farmers from January onwards to observe their agricultural activities. We conducted FGDs with the farmers to understand the challenges faced by them due to delay in water release. Farmers are mostly dependent on the Nonavinakere water tank for irrigation in the summer season. Farmers are uncertain about the paddy farming or other crops in this season as there is no water release till mid-March. In the focus group discussions farmers mentioned that due to lack of rainfall and canal water they are unable to prepare their land for paddy cultivation. Moreover, they mentioned that it is already late to start paddy cultivation.

We interacted with the officials of CNNL and enquired about the delay in water release and inform them about the timely release of water in the command area for cultivation. Moreover, we communicated with CNNL on behalf of farmers to release the water beginning of January month so that farmers can start the paddy cultivation on a timely basis. Moreover, we are encouraging the farmers to interact with the managing authority and enquire and demand the water for farming.

We organised a preliminary consultation program in the Gopalpura village among the farmers. Farmers discussed the requirements and challenges of the farming with the KVK scientist, Officials of Raita Samparka Kendra, and Agriculture development officer. Moreover, experts encouraged the farmers to adopt pre-monsoon crops like green gram, black gram, and cowpea crops package of practices. To create awareness among the farmers as suggested by KVK scientist a WhatsApp group was created to provide timely advisory to the farmers. KVK scientists is providing advisory to the farmers twice a week about uses of fertilizer, pesticides, irrigation schedule, crop recommendations, use of cost effective and modern machineries, efficient use of water irrigation practices. A crop advisory training program was organized in association with KVK, CulTyvate, and Raita Samparka Kendra and distributed the crop advisory related to Maize farming among the farmers. We have collected the soil samples of 30 selected farmers from Gopalpura village and analysed the soil samples in Cryogen lab. On the basis of soil testing result, KVK recommended fertilizer packages to the farmers.

Photograph 21: Crop advisory training for water use efficiency in agriculture

Photograph 22 & 23: KVK scientist explaining the advisory and use of soil moisture sensor

Photograph 24 & 25: Cultyvate official explaining the use of soil moisture sensor

Photographs 26 & 27: Preliminary consultation programme

Photograph 28: CulTyvate team tank inspection

Photograph 29: Interaction with FPO

Photographs 30 & 31: Soil sample collection from Gopalpura village

Photograph 32: Land preparation baby corn cultivation


Photograph 33 & 34: Fallow land during April 2022

Photograph 35: Farmers extracting water from canal

Photograph 36: Farmers using natural drain to irrigate their land

Photograph 37: Flood irrigation for germination

Photograph 38: Treatment farmer sowing baby corn seed

Photograph 39: Baby corn farming in treatment farmer farmland

Photograph 40: Baby corn farming in treatment farmer farmland

CONCLUSION AND POLICY SUGGESTIONS

10. Conclusion

The sustainable use of irrigation water is a priority for agriculture across India. Over the years, considerable effort has been devoted to introducing policies and technologies aiming to increase water efficiency based on the assertion that more can be achieved with less water through better management. With a focus on exploring how irrigation tanks are managed efficiently, this study considers the case of Nonavinakera water tank in Tumkuru district of Karnataka. Using both qualitative and quantitative methods, the study summarized and concluded the findings below.

The satellite image-based analysis brings out various dimensions of agricultural activities in and around Nonavinakere catchment area. The time series data analysis has shown a major shift of agricultural practice. As compared to 1995 agricultural practices, there is a major shift from field crops towards coconut and other plantations. The reasons for such a shift could be many, such as, increading labour cost, ease of management, and better returns. Tiptur taluk and surroundings area are well known for coconuts and other plantation crops, hence the farmers may find better gains in cultivating these crops.

Nonavinakere is very large waterbody but not maintained well for long time. Data analysis on water erosion shows large areas under erosion and hence the accumulation of silt in the waterbodies in the area is quite natural. More detailed study is required to establish a quantitative estimate of the amount of silt accumulation and the resulting storage loss in nonavinakere. If desilting is not done for a long time, as part of management practice of any waterbody, it is necessary that such an action is taken up immediately so as to store more water. The silt removed can be distributed to the local farmers for application in their farms. Desilting shall ensure restoration of original status of nonavinakere and restoration of its original capacity to store water. Also, this would effectively help in better water percolation and improvement in the ground water levels in the surrounding villages. Hence, desilting would be an important activity to be taken up on priority.

Analysis has also been done with regard to satellite stereo data in view of the terrain heights and gradients. There are quite a few areas with steep slopes that could contribute to larger proportion of silt if proper interventions are not done. Some of the illustrations on the derived parameters from digital terrain model clearly shows the gradients and slopes that need to be addressed. Best approach would be to go for a comprehensive watershed development by considering about 1000 Ha area per watershed. Various terrain-based activities could be implemented in terms of soil and water conservation measures, particularly the check dams, nala bunds, farm-level bunds and others to check the runoff and silt transportation to waterbodies like Nonavinakere. Large scale watershed development in the area would also reduce the water erosion, that is prevalent, in the area.

On the Cropping aspects, the time series data analysis for recent dates shows that agricultural cropping takes a back seat as compared to plantations. However, the overall catchment shows a different trend for the year 2022, wherein agricultural areas have increased. This could be related to the pandemic and people who had migrated to cities for better opportunities perhaps have moved back to villages and back to agriculture. However, this need to be substantiated with strong data from the field.

The majority of the farmers are not aware of the water releasing schedule and amount of water they receive. Farmers are unaware of modern technology practices and irrigation methods. None of the farmers knew other crops which can be grown in rabi season and summer season instead of paddy. Most of the farmers grow paddy during the summer season using flood irrigation system. Usually, farmers use drain or gravitational flow to extract water from the canals for irrigation purposes. Knowledge and awareness of the farmers about the efficient and sustainable use of water is very less.

The tank water is managed by the sub-division of Cauvery Neeravari Nigam Limited (CNNL). The interaction with the officials of the tank management authority and field observation reveals that there is a need to improve the management regime of the water tank management authority. Due to improper inter-departmental coordination and communication, this year it is observed that there is a delay in water release from management authority to the command area. As we have observed there are no agricultural activities from November to mid- March in the command area this year. Water is released on 19th March so the crop season for paddy is almost over and farmers are uncertain about the farming till the end of the March month.

The inflow and outflow data of water tank, the volume of water in the tank in different seasons, diameter and depth of the tank are not maintained. There is need to improve the existing infrastructure of the canals, sub-canals, and gates. The outdated and traditional systems of releasing the water are currently followed. These systems need to be replaced by the modern technology and automation for efficient and equal distribution of water in the command area.

The study determines the influences of a combination of economic, personal, institutional, and physical factors on the farm-level inefficiency in the study area. The study explores the efficiency level of paddy farms based on primary data. The average TE of the farms is 91.27 percent, and the most efficient farm has 94.65 percent TE in the study. A change in the exogenous factors that adversely influence the productive efficiency of the farmers and the improvement of managerial practices may increase the scope for productivity enhancement. The rejection of the null hypothesis shows the existence of TI among the farms. The estimation of the generalized production frontier model shows that all the inputs are significant and positive.

The result of the determinants of the TI model reveals that the technical efficiency level of the paddy farmers who have coconut farming is less. They have a stable source of income from coconut farming as a result of which they give more preference to coconut farming as compared to paddy farming. Whereas, an increase in the educational attainment, the farming experience of the farmers, access to extension services, income from paddy, and farm size significantly reduce the farm-level inefficiency. Education is playing a critical role in the improvement of farm efficiency and productivity. Higher levels of educational attainment improve the farmers' knowledge about new farming techniques and efficient use of inputs. An experienced farmer may improve the TE level of his/her farm by using his experiences, and such farmer may quickly be acquainted with the different problems of farming and different techniques of farming which become helpful for efficient use of inputs. The extension services has positive and significant impacts on the farm efficiency; policymakers should give more emphasis on formal as well as technical education. Moreover, the frequent and productive interaction of the government officials with the farmers in the form of workshops and training may improve the efficiency more.

The sustainability of resources depends on the efficient usage of the resources in producing the crop. The results of the determinants of allocative efficiency revealed that experience of the farmer, educational level of the farmer, access to extension services, and access to market had a positive and significant influence on allocative efficiency level of the farms. Whereas, size of the farm had a negative and significant influence on the allocative efficiency level. In the study area, the majority of the farmers are small and marginal farmers. Thus, access to extension services and subsidized inputs play a vital role to improve efficiency and productivity. Sustainable production of paddy will be achieved by increasing AE in paddy production. The policymakers/government should give more emphasis on government support through subsidized inputs and formal as well as technical education. Moreover, the frequent and productive interaction of the agriculture officials with the farmers in the form of workshops and training may improve the efficiency further. Awareness camps and training programs related to different modern farming practices may also be helpful in increasing EE.

We conducted FGDs with the farmers to understand the challenges faced by them due to delay in water release. Farmers are uncertain about the paddy farming or other crops in this season as there is no water release till mid-March. We organised a preliminary consultation program and a crop advisory training program in the Gopalpura village among the farmers to create awareness among farmers to enhance equal and efficient use of water. In the preliminary consultation program KVK scientist, Officials of Raita Samparka Kendra, and Agriculture development officer encouraged the farmers to adopt pre-monsoon crops like green gram, black gram, and cowpea crops package of practices. Moreover, they suggested modern irrigation systems, less water requirement crops, and agricultural methods for efficient use of water and other resources. The KVK scientists created a WhatsApp group and provide timely advisory about uses of fertilizer, pesticides, irrigation schedule, crop recommendations, use of cost effective and modern machineries, efficient use of water irrigation practices to the farmers. A crop advisory training program was organized in association with KVK, CulTyvate, and Raita Samparka Kendra and distributed the crop advisory related to Maize farming among the farmers. We have collected the soil samples of 30 selected farmers from Gopalpura village and analysed the soil samples in Cryogen lab. On the basis of soil testing result, KVK recommended fertilizer packages to the farmers.

Overall, it indicates that the proper management of water tank and communication with farmers will improve the water distribution system in the command area. Creating awareness and encouraging farmers to adopt modern irrigation practices and other varieties of less water requirement crops will ensure sustainable use of water. Moreover, efficient use of water and other resources will help farmers to improve their food grain productivity and profitability.

11. Policy suggestions

The results reveal that there exists a host of constraints and challenges in the study area. The findings motivate us to draw the following policy implications:

1. Stakeholder engagement and farmers participation in the planning and execution process should be encouraged. Participation of the farmers in the decision-making process will ensure effective implementation of the action plan.
2. Conducting survey and public hearing among the beneficiary group and review the feedback before planning the release of the water will ensure an equal and efficient water distribution system in the command area. The formation of a water user association may be helpful in creating access to all information related to the management of the water tank and water releasing schedule.
3. Proper monitoring system, coupled with water budgeting will help the management authority to better utilization of the tank water. The authority will be able to plan the water resource judiciously if they have a proper dashboard and online monitoring system in place for use of water efficiency. The authority needs to compute the volume of water available in the tank and the irrigable land. Based on these data authority needs to provide information about the water releasing schedule to the farmers in the command area. If the farmers will get the proper information, they can plan accordingly for cultivation in the summer season as well as other seasons.
4. The dashboard data from the weather station, gateway, water level sensor and soil moisture sensor can enable a proper prediction system. These data can be shared with KVK scientists and other agricultural experts, so that they can recommend proper crop selection for summer as well as other seasons also. Moreover, as per the crop selection they can provide advisory regarding irrigation and other technology which will ensure sustainable and efficient use of water and other resources. With proper crop selection and by following efficient irrigation and cropping method farmers can optimize the use and allocation of inputs. Thus, thereby increasing the productivity and profit which will enhance the farmers livelihood.
5. Promotion of training programs related to the efficient irrigation systems and cropping methods among the beneficiary group and farmers in collaboration with experts from various agriculture institutes, KVK scientists, officials of Raita Samparka Kendra, and other officials of agriculture and irrigation departments will create awareness about sustainable use of water resources.

6. The extension services should be strengthened, as this is an important aspect of farmers' adoption behavior. In spite of the reorientation program of the government extension services over the years, there are still enough limitations on the coverage of extension agencies in the region. The problem of inadequate coverage and intensity of extension services need to be addressed. The study has found that the farmers' contact with the extension agents is minimal as has been reported by the respondents. Keeping in view of the findings of this study, the government should focus on improving the capability and effectiveness of the extension services.
7. The present study indicates that education has a significant role in influencing technology adoption and helps to raise the yield per hectare of land. Thus, adequate measures should be taken by the government to facilitate the rural population with education mainly of vocational training. The farmers should be made aware of the relevance of modern technologies to encourage adoption through various training programs.
8. Developing market infrastructure and market linkages for the major crops should be a policy priority to promote different farming activities in the agriculture sector.

REFERNCES

Bhalage, P., Jadia, B. B., & Sangale, S. T. (2015). Case studies of innovative irrigation management techniques. *Aquatic Procedia*, *4*, 1197-1202.

Census of India (2011). Census of India 2011: Instruction Manual for Houselisting and Housing Census. Retrieved from http://censusindia.gov.in/2011-Documents/Houselisting%20English.pdf

FAO, 1999. The state of food insecurity in the world. Rome, Italy

Farrell, M. J. (1957). The measurement of production efficiency. *Journal of Royal Statistical Society*, *120*(3), 253-290.

Isoto, R. E., Sam, A. G., & Kraybill, D. S. (2017). Uninsured health shocks and agricultural productivity among rural households: the mitigating role of micro-credit. *The Journal of Development Studies*, *53*(12), 2050-2066.

Jensen M.E., 1993. The impacts of irrigation and drainage on the environment. 5th Gulhati Memorial Lecture. 15th ICID Congress, The Hague, ICID, New Delhi.

Kopp, R. J., & Diewert, W. E. (1982). The decomposition of frontier cost function deviations into measures of technical and allocative efficiency. *Journal of Econometrics*, *19*(2-3), 319-331.

Mollinga, P.P., 2008. Water, politics and development: Framing a political sociology of water resources management. *Water alternatives*, *1*(1), p.7.

Ogundari, K., & Ojo, S. O. (2007). Economic efficiency of small scale food crop production in Nigeria: A stochastic frontier approach. *Journal of Social Science*, *14*(2), 123-130.

Postel S., 1999. Pillar of sand: Can the irrigation miracle last? New York, USA, W.W. Norton& Co.

Rosegrant M.W. and Cai X., 2002. Global water demand and supply projections: Results and prospects to 2025. Water Intern., 27: 170-182.

Yin, R.K., 1992. The case study method as a tool for doing evaluation. *Current sociology*, *40*(1), pp.121-137.

Annexure – 1

Nonavinakere surface water in recent months

This is with reference to the recent exchanges and the communication that I received on the additional inputs required for the Nonavinakere Study. Following two points have been analysed using the available satellite images and the following results are brought out. The images clearly highlight the status of surface water on different dates and at the same time the corresponding area figures are also highlighted.

1. Surface water area or surface water body of the tank during December 2021 and from 1st January to 15th May 2022. If you can provide month-wise data it would be very helpful for us.


December 2021


January 2022

February 2022

March 2022

April 2022

From the above images and the classification results on the water spread area from these images a clear interpretation is arrived at. December 2021 data clearly shows the status of water spread as part of the post monsoon situation at the end of the year 2021. The water spread is significant as it can be observed that the nonavinakere is visually full, as interpreted from the satellite data.

Subsequently, the monthly images of same water body are considered and analysed for the water spread area as depicted above. The monthly images (false colour composite on the left-hand side and mapped area on the right) clearly show a gradual reduction in the water content and the same is shown quantitatively in the following table in terms of water spread area.

Table 19: Time series data of water body area of Nonavinakere water tank

Sl. No.	Date	WB area (Sq. km)	Ha
1	22/12/21	4.1027	410.27
2	11/01/22	4.1043	410.43
3	10/02/22	3.995	399.50
4	12/03/22	3.1964	319.64
5	01/04/22	2.2666	226.66

The water spread of about 410 Ha, that was observed during Dec 2021, has come down to about 227 Ha by April 2022. This clearly shows the amount of water that is consumed in a span of about 4 months' time.

Appendix 1: FDG – questions

1. How many years have you been irrigating your field using Nonavinakere water?
2. What is the period during which you receive the water?
    a. Are you paying any water fees for the same?
        i. If we charge, will you still use the water? (To understand how much they depend on this water during this period).
    b. Do you get the same amount of water that you always get? Or does it vary with each year?
    c. Do you have an idea of how much water you receive?
        i. Do you receive excessive water?
        ii. Are you satisfied with the amount of water you get?
        iii. Do you think sometimes the water is wasted?
3. How far is your field from the main canal?
    a. Do you find it difficult to take the water?
4. How do you extract/take the water from main canal? (- pipe/natural drain/pumping machine)
    a. Do you pay any maintenance charge for the pipes etc.?
    b. Does the canal require any repair (due to siltation/weed growth etc.) every year? How do you manage?
5. What are the crops you usually grow during this period (during which you receive the water from tank?)
    a. What are the irrigation practices you use during this period for these crops?
        i. Have you heard of irrigation practices like drip irrigation, sprinkle irrigation etc.?
    b. Do you keep the land fallow during the period? If yes, why?
    c. Is it always the same crop that you grow? Or do you keep changing the kind of crop each year?
    d. Do you flood your field when you receive the water?
    e. Do you know how much water is required for the crop you are growing?
6. Is the crop you grow profitable? (Why do you grow only this crop?)
    a. Did you change the kind of crop you are growing?
    b. How do you know the market value of these crops?
7. Does someone check how much water you are using?
8. Any training about irrigation techniques to use water efficiently?
9. Are you part of any committee related to tank irrigation?
10. Do you feel there are any changes required in terms of management of the water? (Proper canal lines, pumping machines, pipes etc.)

Appendix 2: Interview Schedule

Interview Schedule

Developing sustainability related knowledge and capability for farmers

Case Study of an Irrigation Tank

1. Name of the respondent: ……………………………. 2. Respondent no: …………

1. Village name: ……………………………… 4. Telephone No: ……………………

5. Marital Status: Married = 1, Unmarried = 2, Widow = 3, Widower = 4, Divorced = 5

6. Level of education: ………….. (Illiterate = 1, Lower primary (I-IV) = 2, Higher primary (V-VII) = 3, High School = 4, PUC = 5, Graduate & above = 6, Other technical degree = 7)

7. Occupation and income of the respondent: (Farmer)

Primary occupation	Income from primary occupation (Yearly)	Secondary occupation	Income from Secondary occupation (Secondary)

(Farmer = 1, Government service = 2, Private service = 3, Casual labour = 4, Others specify………………………… = 5)

8. Number of family members:

9. Information related to family income:

Sl. No.	Earning members of the family	Primary occupation	Income	Secondary occupation	Income
1					
2					
3					
4					
5					
Total					

(Farmer = 1, Government service = 2, Private service = 3, Casual labour = 4, Others specify………………………… = 5)

10. What is the current expenditure of your family?				
Less than INR 3000 = 1	INR 3001–5000 = 2	INR 5001–7000 = 3	INR 7001–10,000 = 4	More than INR 10,000 = 5

11. Experience as a farmer:				
Less than 5 years = 1	5 to 10 years = 2	11 to 15 years = 3	16 to 20 years = 4	More than 21 years = 5

12. Land utilization pattern:

Sl. No.	Items	Area (in acres)
1	Homestead	
2	Details of cultivable land	
a)	Owned	
b)	Leased in	
c)	Leased out	
d)	Fallow land	
e)	Land under Miscellaneous Tree Crops	
g)	Any others (specify………………….)	
3	Total	

13. What are the crops you grown in your field?						
Crop name						
Duration						
Total land						

Duration: Early Kharif (April - August) = 1, Kharif (July - November) = 2, Late kharif (August - November) = 3, Rabi (October - September) = 4, Summer (January - May) = 5

14. Cost of production (per acre):

Crop name	Use of HYV seeds	Cost of seeds per acre	Use of fertilizers	Cost of fertilizer	Cost of irrigation	Labour cost	Total cost of production	Yield (in quintals per acre)	Amount sold in the market (in quintals)	Income (in INR)

15. Source of irrigation: Water tank = 1, Other source = 1

16. If you get water from the water tank:

a) How many days do you get water from the canal?

b) What is the time period in a day you get water from the canal?

c) In a day for how many hours do you get water from the canal?

17. Source of irrigation: Water tank = 1, Other source = 1

18. If you get water from the water tank:

d) How many days do you get water from the canal?

Ans:

e) What is the time period in a day you get water from the canal?

Ans:

f) In a day for how many hours do you get water from the canal?

Ans:

19. All your farm lands are in one plot or it is in different plots.

Ans: One plot = 1, Different plots = 0

20. If different plots how many plots do you have (in numbers):

Details of the crops grown during water realising period:

21. Plot wise details:

Plot no	Plot area (in acres)	Distance from the canal (in km)	Ownership (Own = 1 & leased in = 2)	Crop name	Duration of crop (in Months)

Duration: Early Kharif (April - August) = 1, Kharif (July - November) = 2, Late kharif (August - November) = 3, Rabi (October - September) = 4, Summer (January - May) = 5

For Plot 1 details

22. Source of irrigation water:			
Directly from Canal = 1	From canal to community pond then to farm = 2	From canal to own pond or reservoir = 3	Other source = 4 (If 4 specify)

If water source is canal:

23. Plot distance from the canal:			
24. How do you extract water from canal to your plot?			
a) Pumping machine and Pipe = 1	b) Pumping machine and Drain =2	c) Natural drain = 3	d) Other ways = 4 (If 4 specify)

a) If pumping machine and pipe used:

I. Details of pipe:

Type of pipe:	Diameter of the pipe (in inches)	Length of the pipe (in meters)
Rubber pipe = 1, PVC pipe = 2, Others = 3, Specify		

II. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

III. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

b) If pumping machine and drain:

I. Details of the drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

II. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

III. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

c) If natural drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

25. Type of irrigation in the farm:			
Surface water irrigation = 1	Drip irrigation = 2	Sprinkle irrigation = 3	Other = 4 Specify

26. If you have drip irrigation facility cost of drip irrigation:

27. If you have sprinkle irrigation facility cost of sprinkle irrigation:

31. Do you have any ground water irrigation facility in your field:			
Bore wells = 1	Open dug well = 2	Other = 3 Specify	Other = 4

28. If farmer has bore well:

Depth of the well	Hours of pumping	Cost of extractions	Area used for irrigation

29. Do you have any reservoir in your field?	30. If yes what is the size of the reservoir? (in acres)
Yes = 1 No = 0	

31. Do you attend any workshop or training regarding irrigation system?	32. If yes who organised the workshop or training
Yes = 1 No = 0	

33. Any from the list visited your field during the time of water extraction and irrigation?

	Response	
a) Water tank management authority	Yes = 1	No = 0
b) Water man	Yes = 1	No = 0
c) Agriculture development officer	Yes = 1	No = 0
d) Any other officials	Yes = 1	No = 0

34. Schemes:

Items	Response	
a) Crop insurance	Yes = 1	No = 0
b) Any Agri-scheme	Yes = 1	No = 0
c) Availing Minimum Support Price (MPS)	Yes = 1	No = 0
d) Availing subsidised seed	Yes = 1	No = 0
e) Availing subsidised fertilizers	Yes = 1	No = 0
f) Other farming facilities	Yes = 1	No = 0

35. Membership of any association:

Associations	Response	
a) FPO	Yes = 1	No = 0
b) Farming society	Yes = 1	No = 0
c) Water Users Association	Yes = 1	No = 0
d) Self Help Groups (SHGs)	Yes = 1	No = 0
e) Any community	Yes = 1	No = 0

36. Awareness:

	Response	
a) Aware about water realising schedule	Aware = 1	Not aware = 0
b) Aware about the scarcity of water in the World	Aware = 1	Not aware = 0
c) Awareness about sustainable use of water	Aware = 1	Not aware = 0
d) Awareness about the water tank	Aware = 1	Not aware = 0

37. Awareness:

	Response	
a) Do you think you use more water than the requirement?	Yes = 1	No = 0
b) Amount of water you received is it enough for good production	Yes = 1	No = 0
c) Crop damaged due to scarcity of water	Yes = 1	No = 0
d) Do you flood your field with water?	Yes = 1	No = 0
e) If we charge some money on water, will you use same level of water or less?	Yes = 1	No = 0

For Plot 2 details

22. Source of irrigation water:			
Directly from Canal = 1	From canal to community pond then to farm = 2	From canal to own pond or reservoir = 3	Other source = 4 (If 4 specify)

If water source is canal:

23. Plot distance from the canal:			
24. How do you extract water from canal to your plot?			
e) Pumping machine and Pipe = 1	f) Pumping machine and Drain =2	g) Natural drain = 3	h) Other ways = 4 (If 4 specify)

d) If pumping machine and pipe used:

IV. Details of pipe:

Type of pipe:	Diameter of the pipe (in inches)	Length of the pipe (in meters)
Rubber pipe = 1, PVC pipe = 2, Others = 3, Specify		

V. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

VI. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

e) If pumping machine and drain:

IV. Details of the drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

V. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

VI. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

f) If natural drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

25. Type of irrigation in the farm:			
Surface water irrigation = 1	Drip irrigation = 2	Sprinkle irrigation = 3	Other = 4 Specify

26. If you have drip irrigation facility cost of drip irrigation:

27. If you have sprinkle irrigation facility cost of sprinkle irrigation:

31. Do you have any ground water irrigation facility in your field:			
Bore wells = 1	Open dug well = 2	Other = 3 Specify	Other = 4

28. If farmer has bore well:

Depth of the well	Hours of pumping	Cost of extractions	Area used for irrigation

For Plot 3 details

22. Source of irrigation water:			
Directly from Canal = 1	From canal to community pond then to farm = 2	From canal to own pond or reservoir = 3	Other source = 4 (If 4 specify)

If water source is canal:

23. Plot distance from the canal:			
24. How do you extract water from canal to your plot?			
i) Pumping machine and Pipe = 1	j) Pumping machine and Drain =2	k) Natural drain = 3	l) Other ways = 4 (If 4 specify)

g) If pumping machine and pipe used:

VII. Details of pipe:

Type of pipe:	Diameter of the pipe (in inches)	Length of the pipe (in meters)
Rubber pipe = 1, PVC pipe = 2, Others = 3, Specify		

VIII. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

IX. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

h) If pumping machine and drain:

VII. Details of the drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

VIII. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

IX. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

i) If natural drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

25. Type of irrigation in the farm:			
Surface water irrigation = 1	Drip irrigation = 2	Sprinkle irrigation = 3	Other = 4 Specify

26. If you have drip irrigation facility cost of drip irrigation:

27. If you have sprinkle irrigation facility cost of sprinkle irrigation:

31. Do you have any ground water irrigation facility in your field:			
Bore wells = 1	Open dug well = 2	Other = 3 Specify	Other = 4

28. If farmer has bore well:

Depth of the well	Hours of pumping	Cost of extractions	Area used for irrigation

For Plot 4 details

22. Source of irrigation water:			
Directly from Canal = 1	From canal to community pond then to farm = 2	From canal to own pond or reservoir = 3	Other source = 4 (If 4 specify)

If water source is canal:

23. Plot distance from the canal:			
24. How do you extract water from canal to your plot?			
m) Pumping machine and Pipe = 1	n) Pumping machine and Drain =2	o) Natural drain = 3	p) Other ways = 4 (If 4 specify)

j) If pumping machine and pipe used:

X. Details of pipe:

Type of pipe:	Diameter of the pipe (in inches)	Length of the pipe (in meters)
Rubber pipe = 1, PVC pipe = 2, Others = 3, Specify		

XI. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

XII. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

k) If pumping machine and drain:

X. Details of the drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

XI. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

XII. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

l) If natural drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

25. Type of irrigation in the farm:			
Surface water irrigation = 1	Drip irrigation = 2	Sprinkle irrigation = 3	Other = 4 Specify

26. If you have drip irrigation facility cost of drip irrigation:

27. If you have sprinkle irrigation facility cost of sprinkle irrigation:

31. Do you have any ground water irrigation facility in your field:			
Bore wells = 1	Open dug well = 2	Other = 3 Specify	Other = 4

28. If farmer has bore well:

Depth of the well	Hours of pumping	Cost of extractions	Area used for irrigation

For Plot 5 details

22. Source of irrigation water:			
Directly from Canal = 1	From canal to community pond then to farm = 2	From canal to own pond or reservoir = 3	Other source = 4 (If 4 specify)

If water source is canal:

23. Plot distance from the canal:			
24. How do you extract water from canal to your plot?			
q) Pumping machine and Pipe = 1	r) Pumping machine and Drain =2	s) Natural drain = 3	t) Other ways = 4 (If 4 specify)

m) If pumping machine and pipe used:

XIII. Details of pipe:

Type of pipe:	Diameter of the pipe (in inches)	Length of the pipe (in meters)
Rubber pipe = 1, PVC pipe = 2, Others = 3, Specify		

XIV. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

XV. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

n) If pumping machine and drain:

XIII. Details of the drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

XIV. Details of pumping machine:

Type of pumping machine (Diesel = 1 & Electric = 2)	Hours of pumping (in hours per day)	Total number of days pumping (in days per month)	Number of months pumping (in months for plot 1)	Pumping machine model name

XV. Cost of pumping:

Diesel pump (in INR per hour)	Electric pump (in INR per hour)	Maintenance cost (in INR)	Other cost (in INR)

o) If natural drain:

Type of drain:	Diameter of the drain (in meters)	Length of the drain (in meters)

25. Type of irrigation in the farm:			
Surface water irrigation = 1	Drip irrigation = 2	Sprinkle irrigation = 3	Other = 4 Specify

26. If you have drip irrigation facility cost of drip irrigation:

27. If you have sprinkle irrigation facility cost of sprinkle irrigation:

31. Do you have any ground water irrigation facility in your field:			
Bore wells = 1	Open dug well = 2	Other = 3 Specify	Other = 4

28. If farmer has bore well:

Depth of the well	Hours of pumping	Cost of extractions	Area used for irrigation

Appendix 3: Crop advisory

❖ **ಬೀಜೋಪಚಾರ:** ಅರ್ಝೋಸ್ಪೈರಿಲಂ ಮತ್ತು ರಂಜಕ ಕರಗಿಸುವ ಜೀವಾಣು ಗೊಬ್ಬರವನ್ನು ಎಕರೆಗೆ 200 ಗ್ರಾಂ.ನಂತೆ ಬೀಜೋಪಚಾರ ಮಾಡಬೇಕು.

ತಳಿಗಳು	ಕಾಲಾವಧಿ	ಬೀಜ (ಕೆ.ಗ್ರಾಂ/ಎ)	ಅಂತರ(ಅಡಿ)	ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (ಟನ್/ಎ)	ಸತುವಿನ ಸಲ್ಫೇಟ್ (ಕೆ.ಗ್ರಾಂ/ಎ)	ರಾಸಾಯನಿಕ ಗೊಬ್ಬರ (ಕೆ.ಗ್ರಾಂ/ಎ)	ಇಳುವರಿ (ಕ್ವಿ/ಎ)	
							ಕಾಳು	ಮೇವು (ಟನ್)
ಹೈಬ್ರಿಡ್-ಹೇಮ	110-120	6	2*1	3	4 ಬಿತ್ತನೆ ಮುಂಚಿತವಾಗಿ ಮಣ್ಣಿಗೆ	ಎನ್.ಪಿ.ಕೆ 40.20.10	32-34	8
ನಿತ್ಯಶ್ರೀ	110-120						30-32	8
ಎನ್ ಎ ಸಿ 6004	115-120						18-20	6
ಎನ್ ಎ ಸಿ 6002	90-95						12-14	4
ಎಂ ಎ ಹೆಚ್-14-5							32-35	12
ಎನ್ ಎ ಹೆಚ್-1137	110-120						30-32	12
ಎನ್ ಎ ಹೆಚ್ 2049								

❖ **ಬಿತ್ತನೆ:** ಬೀಜವನ್ನು 2 ಅಡಿ ಅಂತರದ ಸಾಲುಗಳಲ್ಲಿ ಬೀಜದಿಂದ ಬೀಜಕ್ಕೆ 1 ಅಡಿ ಅಂತರದಲ್ಲಿ 2 ಅಂಗುಲಕ್ಕಿಂತ ಹೆಚ್ಚು ಆಳವಿಲ್ಲದಂತೆ ಬಿತ್ತನೆ ಮಾಡುವುದು.

❖ ಖುಷ್ಕಿಯಲ್ಲಿ 20 ಕಿ.ಗ್ರಾಂ ಸಾರಜನಕ ಮತ್ತು ಶಿಫರಸ್ಸು ಮಾಡಿದ ಪೂರ್ತಿ ಪ್ರಮಾಣದರಂಜಕ, ಪೊಟ್ಯಾಷ್, ಮತ್ತು ಸತುವಿನ ಸಲ್ಫೇಟ್ ಬಿತ್ತನೆಗೆ ಮುಂಚೆ ಮಣ್ಣಿನಲ್ಲಿ ಸೇರಿಸುವುದು. ಎಕರೆಗೆ 20 ಕಿ.ಗ್ರಾಂ ಸಾರಜನಕವನ್ನು ಮೇಲುಗೊಬ್ಬರವಾಗಿ 3-4 ವಾರದೊಳಗೆ ಕೊಡುವುದು ಮತ್ತು ಮೇಲುಗೊಬ್ಬರಕೊಟ್ಟ ನಂತರ ಮಣ್ಣುಏರು ಹಾಕುವುದು.

❖ ಕಳೆ ನಿರ್ವಹಣೆ:

❖ ಅಟ್ರಜಿನ್ 50 ಡ.ಬ್ಲ್ಯೂ.ಪಿ 1 ಕೆ.ಜಿ/ಎಕರೆಗೆ 4 ಗ್ರಾಂ./ಲೀ ಬಿತ್ತನೆಯಾದ 3 ದಿನಗಳ ಒಳಗೆ 300 ಲೀ. ನೀರಿನಲ್ಲಿ.

❖ ಪೆಂಡಿಮಿಥಲಿನ್ 30 ಇ.ಸಿ 1 ಲೀ/ಎಕರೆಗೆ 3 ಮಿ.ಲೀ/ಲೀ. ನೀರಿನಲ್ಲಿ. 2,4-ಡಿ ಸೋಡಿಯಂ ಸಾಲ್ಟ್ 80% ಡಬ್ಲ್ಯೂ.ಪಿ 250 ಗ್ರಾಂ/ಎಕರೆ 2ಗ್ರಾಂ/ಲೀ. 15-20ದಿನಗಳ ಒಳಗೆ 200ಲೀ. ನೀರಿನಲ್ಲಿ.

❖ **ಅಂತರ ಬೆಳೆಗಳು:** ಅಲಸಂದೆ, ಸೋಯಾಅವರೆ ಹಾಗೂ ಅವರೆ 2:2 ರ ಅನುಪಾತದಲ್ಲಿ ಬಿತ್ತುವುದು.

❖ **ಮುಖ್ಯವಾದ ಕಡಿಮೆ ಖರ್ಚಿನ ಬೇಸಾಯ ಕ್ರಮಗಳು**

- ಬಿತ್ತನೆಯನ್ನು ಮೇ-ಜುಲೈಕೊನೆಯವರೆಗೂ ಬಿತ್ತನೆ ಮಾಡಿ.
- ರಾಸಾಯನಿಕ ಗೊಬ್ಬರಗಳನ್ನು 40:20:10 ರ ಪ್ರಮಾಣದಲ್ಲಿ ಕೊಡಬೇಕು.
- ಬಿತ್ತನೆ ಸಮಯದಲ್ಲಿ 20 ಕಿ.ಗ್ರಾಂ. ಸಾರಜನಕವನ್ನು ಮತ್ತುರಂಜಕ/ಪೊಟ್ಯಾಷ್ ಒದಗಿಸುವ ರಸಗೊಬ್ಬರವನ್ನು ಕೊಟ್ಟು ಸಾಲುಗಳನ್ನು ಏರು ಹಾಕಿ.
- ಬುಡದಲ್ಲಿ ಬರುವ ಕವಲುಗಳನ್ನು ತಪ್ಪದೇ ತೆಗೆಯುವುದು.
- ಹಾಲು ತುಂಬುವ/ ಕಾಳು ಕಟ್ಟುವ ಸಮಯದಲ್ಲಿ ಗಿಡದ ತುದಿಯನ್ನು ಮುರಿಯಬಾರದು.
- ಬೀಜ ಮೊಳೆಯುವ, ಹೂ ಬಿಡುವ ಮತ್ತು ಕಾಳು ಕಟ್ಟುವ ಸಮಯದಲ್ಲಿತಪ್ಪದೇ ನೀರು ಹಾಯಿಸುವುದು.

❖ **ವಿಶೇಷ ಗುಣಗಳು:** ವಿಶೇಷವಾಗಿ ಕಟಾವಿನ ಹಂತದಲ್ಲಿ ಗಿಡಗಳು ಹಸಿರಾಗಿ ತೆನೆಯು ಪೂರ್ಣ ಪ್ರಮಾಣದಲ್ಲಿ ಒಣಗಿರುತ್ತದೆ:

ರಸಮೇವು(ಸೈಲೇಜ್)
ಕಟಾವು ಮಾಡಿದ ಜೋಳದ ಕಡ್ಡಿಗಳನ್ನು ಸಾಧ್ಯವಾದಷ್ಟು ಸಣ್ಣದಾಗಿ ತುಂಡರಿಸಬೇಕು ನಂತರ ತುಂಡಾದ ಜೋಳದ ಕಡ್ಡಿಗಳನ್ನು ದೊಡ್ಡ ಪ್ಲಾಸ್ಟಿಕ್ ಅಥವಾ ಡ್ರಮ್‌ಗಳಲ್ಲಿ ಗಾಳಿಯಾಡದಂತೆ 3 ತಿಂಗಳ ಕಾಲ ಶೇಖರಣೆ ಮಾಡಬೇಕು. ಮೂರು ತಿಂಗಳ ನಂತರಚೆನ್ನಾಗಿ ಕಳಿತಂತಹ ಸೈಲೇಜ್ ಪಡೆಯ ಬಹುದಾಗಿದೆ. ಇದನ್ನು ಜಾನುವಾರುಗಳಿಗೆ ಬೇಸಿಗೆ ಸಮಯದಲ್ಲಿ ಮೇವಾಗಿ ಬಳಸಬಹುದಾಗಿದೆ.

ABOUT INDIAN INSTITUTE OF MANAGEMENT BANGALORE
Indian Institute of Management Bangalore (IIM Bangalore or IIMB) is a public business school and Institute of National Importance located in Bangalore, India founded in 1973. The Institute at Bangalore was set up to cater exclusively to the needs of public sector enterprises. The institute offers Post Graduate, Doctoral, Executive Education and Certificate Programmes. The MBA programme is the flagship programme of the BSchool and is offered in three modes - one year full-time, two year full-time and two years executive (weekend).IIM Bangalore provides wide network of corporate placement opportunities for its students and recently collaborated internationally for exploring students' dynamics for international experience. In addition to its academic programmes, the institute is engaged in facilitating research, offering consulting services, conducting seminars and academic conferences and publishing journals.

ABOUT HANNS SEIDEL FOUNDATION INDIA
The Hanns Seidel Foundation, founded in 1967, is a German political foundation, working "in the Service of Democracy, Peace and Development". It has been active for more than 40 years in the field of political development cooperation and is currently taking an active part in 80 projects in 60 countries worldwide.
In India, the Foundation started its work in the year 1996 and undertakes projects to support India's federal democratic structure, strengthen geopolitical relations, water governance and improved access to justice. The projects are implemented with government and non-government partners at regional, national and state level, aiming at increased systemic efficiency. The Foundation seeks to contribute to India's sustainable development by strengthening peace, democracy and rule of law. More information on the work of Hanns Seidel Foundation India can be found at india.hss.de

IIMB
Hanns Seidel Foundation India

HSS-IIMB Water Project 2022

Developing sustainability-related knowledge and capability for farmers Case Study of an Irrigation Tank

CROP ADVISORY FOR THE FARMERS
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India

During the preliminary consultation with the farmers by the IIM Bangalore team, the farmers informed that they were keen on cultivating maize rather than paddy. Therefore, with the help of the KVK scientist this crop advisory related to maize is prepared.

PACKAGE OF PRACTICES OF MAIZE

CLIMATE
Maize can be grown in temperate high lands, tropical as well as sub-tropical regions. A moderate temperature and adequate moisture are the basic need of the Maize crop. However, the crops susceptive to water logging conditions, which needs to be avoided.

SOIL
Maize requires a well-drained sandy loam soil with organic matter. It thrives well in soil pH between 5.5 to 8.0.

SOWING TIME:
1. **Kharif season crop:** Seed is sowed in the month of February/March.
2. **Rabi season crop:** Seed is sowed in the middle of October to the middle of November.

LAND PREPARATION AND MANURING
A well-prepared flat-beds which has given 4-5 deep plowing provided an ideal condition
for sowing of crops.
1. FYM or compost: 5 tons/ha
2. N: 100-120 Kg
3. P_2O_5: 60 Kg
4. K_2O/ 30-40 Kg

Urea should be applied in 3 splits, mainly at sowing, knee-high and tasseling stages. The entire dose of P & K_2O with 40 Kg urea should be applied at the time of sowing. Application of 25 Kg of $ZnSO_4$ at sowing is also recommended since maize is susceptible to Zn deficiency.

METHOD OF PLANTING
1. Seed treatment: Treated with Bavistan@ 3gm/Kg of seeds before sowing in the field.
2. Depth of Sowing: 4-6 cm, where maize is generally sown on flatbeds.
3. Spacing: 70cm x 25cm for the row to row and plant to plant
4. Plant density of 66,666/hectare.
5. Healthy seeds of 20-22Kg required for cultivation in one hectare of land.

INTERCULTURE OPERATION:
Thinning should be done after 10 days of germination keeping one plant per hill. At knee-high stage (about 35 days after germination) the crop plants should be earthed-up followed by light hand weeding. The second earthing up should be done at 60 days after germination of the crop; it may slightly vary in respective to locality.

IRRIGATION:
For Kharif Maize, irrigation at early knee-high, tasseling and 50% silking stages are to be given. For rabi Maize, first irrigation is to be applied 3-4 weak after seedling emergence, subsequently at 4-5 weeks till March and thereafter at 1-2 weeks interval. Variety: Hybrid variety – Ganga hybrid makka-5, Himalayan hybrid Makka. The compositevariety, Prabhat and Dhawal are especially recommended for cultivation in North-eastern hillregions. The variety of QPM (HQPM-3) and Baby corn (HM-4) are also found to be suitably grown in the district.

PLANT PROTECTION:
1. Maize Stem Borer: The Larvae attack the crop from June to September, first they scrap the leaves and then bore into the stem, thus resulting in dead heart of the central shoot.
   Control: Application of Endosulfan 35EC @250 ml and Monocrotophos 36 WSC @275ml/ha in 125 liters of water by starting spray 2-3 weeks after sowing. Application of Neem-based pesticides like Margosa @2 ml/liters of water are found to be beneficial.
2. Armyworm and Silk cutter: These insects feed on the leaves in the Whorl.
   Control: Spray Sevin (Carbaryl) 50 WP@ 250g in 125 liters of water.
3. Leaf Blight: Maydis leaf blight symptoms appear on leaves on the form of spindle-shaped neurotic to brown lesions. Such lesions may emerge to form large, irregular patches.
   Control: spraying of Indofil M45 @ 500g in 250 ltr of water/ha. Give the spray at 10days interval.
4. Weed control: Pre-emergence application of Atrazine @ 1 Kg a.i/ha is recommended for weed control.
5. Bird damage: To save the crop from bird damage, apply Malathion 5% dust on cobs, especially on the outer rows.

INTERCROPPING:
Growing one row of soybean in between 2 rows of maize (60 cm spacing) gave an increase in the yield of maize. The planting of one row of Maize alternating every 4 rows of Urdbean or black gram (30cm spacing) is found to be most suitable, resulting in the highest productivity.

HARVESTING AND THRESHING:
Maize is ready for harvesting even when the stacks and leaves are somewhat green but thehusk cover has dried and turned brown. Shell Maize when the moisture content ranges between 15-20%. Conventional harvester combines can be used for threshing Maize with husk to save labour involved in dehusking. The Maize ears should preferably be dried for 3-4 days after harvesting to improve grainrecoveries and reduce breakage losses during shelling.

Varieties	Duration (in days)	Seed (kg/acre)	Spacing (In feet)	Farmyard manure (tons/acre)	Zinc Sulphate (kg/acre)	Fertilizers (kg/acre)	Yield (quintal/acre)	
Hybrid Hema	110-120	6	2*1	3	4 (Before sowing soil application)	N:P:K 40:20:10	Grains	Straw
Nityashree	110-120						32-34	8
NAC-6004	115-120						30-32	8
NAC- 6002	90-95						18-20	6
MAH- 14-5	110-120						12-14	4
NAH -1137							32-35	12
NAH-2049							30-32	12

ಮುಸುಕಿನ ಜೋಳದ ಸುಧಾರಿತ ಬೇಸಾಯ ಕ್ರಮಗಳು

❖ ಮುಸುಕಿನ ಜೋಳವನ್ನು ಇತ್ತೀಚಿನ ವರ್ಷಗಳಿಂದ ಹೆಚ್ಚಾಗಿ ಬೆಳೆಯುತ್ತಿರುವ ಆಹಾರ ಬೆಳೆ.

❖ ಅಧಿಕ ಇಳುವರಿ ಕೊಡುವ ತಳಿಗಳು, ಸುಲಭವಾದ ಬೇಸಾಯದ ಕ್ರಮಗಳು, ಹಾಗೂ ಬಿತ್ತನೆ ಮತ್ತುಕಟಾವಿಗೆ ಲಭ್ಯವಿರುವ ಯಂತ್ರಗಳಿಂದ ಈ ಬೆಳೆಯನ್ನು ಹೆಚ್ಚು ವಿಸ್ತೀರ್ಣದಲ್ಲಿ ಬೆಳೆಯಲು ಸಾಧ್ಯವಾಗಿದೆ.

❖ ವಿಶ್ವದಲ್ಲಿ ಭಾರತವು ಮುಸುಕಿನ ಜೋಳದ ಉತ್ಪಾದನೆಯಲ್ಲಿ 6ನೇ ಸ್ಥಾನದಲ್ಲಿದೆ. ಅಕ್ಕಿ ಮತ್ತು ಗೋಧಿಯ ನಂತರ ಭಾರತದಲ್ಲಿ ಮುಸುಕಿನ ಜೋಳವು 3 ನೇ ಪ್ರಮುಖ ಆಹಾರ ಬೆಳೆಯಾಗಿದೆ.

❖ **ಭಾರತದಲ್ಲಿ ಪ್ರಮುಖವಾಗಿ ಜೋಳ ಬೆಳೆಯುವ ರಾಜ್ಯಗಳು:** ಕರ್ನಾಟಕ, ಆಂಧ್ರ ಪ್ರದೇಶ, ಬಿಹಾರ, ಪಂಜಾಬ್, ಹಿಮಾಚಲ್ ಪ್ರದೇಶ.

❖ **ಕರ್ನಾಟಕದಲ್ಲಿ:** ಚಿತ್ರದುರ್ಗ, ಹಾವೇರಿ, ಬೆಳಗಾವಿ

❖ **ಬಿತ್ತನೆ ಕಾಲ:** ಈ ಬೆಳೆಯನ್ನು ವರ್ಷದ ಎಲ್ಲಾ ಕಾಲಗಳಲ್ಲಿಯೂ ಬೆಳೆಯಬಹುದು, ಆದರೆ ಬಿತ್ತನೆಗೆ ಮೇ-ಜೂನ್, ಸೆಪ್ಟೆಂಬರ್-

Appendix 4: Soil testing result

Parameters	**Normal range**	**Average**	**Rating**	**Min**	**Max**
pH	6.3-8.3	7.05	Neutral	6.38	7.78
Electrical conductivity (EC)	< 1 dS/m	0.20	Normal	0.066	0.614
Organic carbon (OC)	0.5 – 0.75 %	0.75	High	0.36	1.49
Available N	112 – 224 kg/ac	91.93	Low	64	106
Available phosphorous (P2O5)	9 -22 kg/ac	7.55	Low	0.73	105.97
Available potash (K2O)	50 – 120 kg/ac	134.93	High	53.71	399.26
Available Sulphur (S)	10 – 20 ppm	45.21	Low	1.5	467.75
Available Zinc (Zn)	0.6 ppm	1.36	Sufficient	0.26	3.29
Available Manganese (Mn)	1 ppm	15.29	Sufficient	2.45	40.75
Available Iron (Fe)	4.5 ppm	21.32	Deficient	1.4	151.27
Available Copper (Cu)	0.2 ppm	1.13	Deficient	0.02	17.36
Boron (B)	0.5 ppm	0.63	Deficient	0.12	9.98
Sodium (Na)	80 – 120 ppm	89.89	Medium	22.45	193.95

1. Fertilizer recommended as per package of practice per based on soil testing result

Sl. No.	**Fertilizer**	**Prescription**				
1	N (Nitrogen) P (Phosphorous) K (Potassium)	**Normal fertilizers (Kg/Acre)**				
		Combination 1	Combination 2	Combination 3	Combination 4	Combination 5
		Urea: 110	DAP: 55	10:26:26: 40	19:19:19: 55	17:17:17: 58
		SSP: 155	Urea: 85	Urea: 100	Urea: 90	Urea: 85
		MOP: 15	MOP: 15	SSP: 95	SSP: 95	SSP: 90
		Water-soluble fertilizers (kg/ac)				
		Combination 1	Combination 2	Combination 3	Combination 4	
		00:00:50:20	19:19:19: 55	13:00:45: 25	00:52:34: 50	
		Urea: 100	Urea: 85	12:61:00: 45	Urea: 110	
		12:61:00: 45	CN: 00	Urea: 95	CN: 00	
2	Micronutrients	$MnSO_4$:	$ZnSO_4$:	$FeSO_4$:	Grade-2: **5** Micronutrients	Bio Maxx:3ml/liter
3	Biofertilizers	Bo'N:	Zen:	Bio-NPK:**10**	Bumper Crop:	
4	Organic fertilizers	DNP:**100**				
5	Specialty fertilizers	PH-50:**10**	Amino G:			