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Water Delivery Performance Evaluation of a Tank Irrigated System and Best Management Practices for Paddy Agriculture

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Abstract

Objectives: To identify the current agricultural practices, challenges faced in paddy agriculture and analyse the water delivery performance of tank using RS and GIS. To review and compare the current agriculture practices with the BIS and other standards and to propose BMP's for paddy cultivation. **Methods/Analysis:** Random sampling of survey was taken and frequency analysis was done by questionnaire. The performance of irrigation system was carried out by rainfall frequency analysis by using Weibull's formula. The water delivery performance was obtained by NDVI analysis. The current practices of paddy agriculture is analysed and compared with BIS 15930 (Part 1): 2010, TNAU and FAO reports to provide BMPs for improving the productivity. **Findings:** The NDVI values classified as high, low and normal water delivery performance for years of 2002, 2006, 2009 and 2011. The percentage of area under high vegetation of paddy in the year 2002 was 28% and increased to 31% in the year 2011, because of the rainfall in 2002 was 1032 mm, whereas it was 1499.6 mm in 2011. The drought year 2009, is characterized by a very drastic change of 0% percent vegetation in the tail end region of Navarai season. But, in the Samba season, the vegetations decreased as much as 9.8% when compared to vegetation in the Samba season of 2002. It can be inferred from the NDVI map of the Samba season of 2009, there is an increase in the high paddy vegetation in the tail end. The reason is an increase in the number of bore wells dug for paddy cultivation because of poor water delivery performance. Best management practices have been recommended, for the paddy cultivation. **Conclusion:** The farmers faced problems in water sharing, fragmentation; non-maintenance of supply system, non-availability of labours; consequently people involvement in agriculture is decreasing. By enhancing the water delivery performance and adopting best management practices, the productivity and farmers livelihood will increase.

Keywords: BMP, NDVI, Paddy, Performance, Water Delivery

1. Introduction

India holds about 1,20,000 tanks irrigating about 43 Mha. There are about 5 lakhs big and 50 lakhs small tanks irrigating over 25.24 lakhs hectares of agricultural land. In Tamil Nadu have 39,000 tanks and 589 thousand hectares under tank irrigation. Geographic Information Systems and Remote sensing techniques are incredibly helpful in being able to map and project in present and future fluctuations in precipitation, temperature, crop output, delivery system and more. The historical farming practices to determine the best practices for promoting crop yield, increase water use efficiency and to maintain tank system.

In Tamil Nadu 2.05 Mha area under paddy cultivation is 34% of total cultivable area. Reducing area of paddy cultivation is not possible since large number of population need to be supplied. With available resource there is a necessity of increasing both production and effective utilization of tank system in order to augment the water

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supply. Best management practices will be a better remedy to increase the production.

The challenges in rice production are the aspects of technological, socio economic challenges and policy issues. Technological challenges includes technology transfer problem, poor extension network, problems of selecting suitable technology and no enough feedback from farmers about the appropriateness of the introduced technology[1]. To explore and investigate the issues and challenging facing in rice production and food security was identified as raising food prices, increasing input cost, uncertainty of climatic condition, overpopulation, labour availability and resources limitation[2]. The performance of the tank was evaluated using indices like adequacy, timeliness, equity, accountability of the irrigation staffs, repair and maintenance. The indicators evaluated by the help of questionnaire and identified it is vital to estimate the indicators. Based on primary and secondary data collected the indices were estimated and suggestions were given to improve the tank performance[3].

The remote sensing and geographic information system techniques used to analyse the agricultural performance and sustainability of the Bhakra Irrigation System in India. Analysis of multi date satellite on total cropped area, area under wheat and wheat productivity per unit area[4]. The problems of the irrigation tanks such as reduction of design discharge as a result of silting of channel and tanks, deterioration of stone masonry channel and encroachment of drainage course and tank water spread leads to the decline of tank performance[5]. The paddy cultivation under water saving techniques like SRI and SDI is experimented in three different plots, the crops grown and impact of these water saving method on productivity have been analyzed. It has been found that yield from the plot in which saturation soil moisture condition showed increased productivity[6].

2. Study Area and Methodology

The Vengal tank is situated in Kosathalaiyar Sub Basin of Thiruvallur district in the Northern part of Tamil Nadu and its co-ordinates are latitude 13°26'N and longitude 79°89'E Vengal tank is fully rain fed that depends on its catchment for the water resources and irrigating a command area of 178.04 ha by two sluices.

The flowchart 1 shows in portrays of methods applied in this study for analysing the performance of distribution networks of the Vengal tank and to suggest best management practices for paddy agriculture.

3. Analysis

3.1 Questionnaire Survey

The questionnaire was constructed with five sections covering the aspects of farmer details, cropping practices, irrigation supply and quality, marketing, awareness of techniques and challenges faced by the farmers in the Vengal tank. The total farmer's population accounts about 75 of which nearly 25 farmers were surveyed which is about 33% of farmer's population. Random sampling of survey was taken in the study area and frequency analysis of the respondents was carried out.

3.2 Rainfall Frequency Analysis

The rainfall frequency analysis was carried out to find the performance of irrigation system. The Weibull's formula used to calculate the dependability of rainfall is

Percentage probability P = (1/T)*100%;

Where, Recurrence interval T = (n+1)/m; Where m = rank and n = no. of data.

From Table 1, it is observed 75% dependable rainfall is occurred in the year 2006, average rainfall identified in the year 2002, drought year is occurred in 2009, and recent year rainfall more average in 2011. The water delivery performance analysis of the tank irrigation system using Remote Sensing data and GIS was carried out for the above identified years.

3.3 Delivery System Performance Analysis

The NDVI (Normalized Difference Vegetation Index) ratio is calculated by dividing the difference in the Near-Infrared (NIR) and red colour bands by the sum of NIR and red colours bands for each pixel the image is calculated by:

NDVI = (NIR-RED)/(NIR+RED)

For the NDVI analysis, the command area map was created from the base map of Vengal tank. The command area map and Lands at data were imported into ARCMAP 10 to bring the images WGS1984 geographic coordinated system and the output layer was extracted by mask. The NDVI values are obtained by the above formula and classified as high low and normal water delivery performance for years of 2002, 2006, 2009 and 2011.

Table 1. Rain fall frequency analysis

Weibull's Method				
Year	Annual Rainfall	Rank (m)	Recurrence Interval T = (n+1)/m	Percent Probability P = (1/t)*100%
1996	1980	1	35	2.85
2005	1951	2	17.5	5.71
2010	1728	3	11.66	8.57
1985	1662	4	8.75	11.42
1988	1648.8	5	7	14.28
1990	1564	6	5.83	17.15
2008	1549	7	5	20
2011	1499.6	8	4.375	22.85
1983	1427	9	3.888	25.87
2007	1369	10	3.5	28.57
1991	1360	11	3.18	31.44
1993	1356.2	12	2.916	34.36
1997	1354.9	13	2.62	38.16
1980	1349	14	2.5	40
1986	1333.4	15	2.33	42.19
1994	1257	16	2.18	45.87
1998	1250	17	2.05	48.78
2002	1212	18	1.94	51.54
2013	1193.2	19	1.84	54.34
1995	1179.9	20	1.75	57.14
1987	1117.4	21	1.66	60.24
1984	1106.9	22	1.59	62.89
2004	1053	23	1.52	65.78
2012	1051	24	1.45	68.96
2001	1050	25	1.4	71.42
2006	1032	26	1.34	74.62
1981	1018.4	27	1.29	77.52
2000	980	28	1.25	80
1999	922.4	29	1.20	83.33
1989	884	30	1.16	86.20
1982	843	31	1.12	89.28
2009	838	32	1.09	91.74
1992	804.7	33	1.06	94.33
2003	689.5	34	1.02	97.14
N = 34				

3.4 BMP for Paddy Agriculture

The main crop of the tank system is paddy. The current practices from land preparation to harvesting and finally marketing are analysed. These are compared with BIS 15930 (Part 1): 2010, TNAU and FAO reports to provide BMPs for improving the productivity.

4. Results and Discussions

4.1 Key Findings from Questionnaire

The questionnaire survey brings out the views of the farmers on the aspects of agriculture, irrigation, marketing, awareness about the technology and the challenges faced by the farmers in the study area. The Farmers response is highlighted in the following section on various aspects.

4.1.1 Agricultural Practices

- Two cropping seasons in a year is practiced.
- Paddy is the major crop.
- Land levelling is performed.
- Paddy cultivation is done by Conventional method.
- Most of tail reach farmers have left farming activity.
- Harvesting is done with the help of Combine Harvester.

4.1.2 Irrigation Aspects

- Entire agricultural activity depends on water available in the tank and part of tail reach farmers having ground water.
- Irrigation water quality is good (i.e. no salinity problem).
- Even though when the tank is filled, the tail end farmers is not getting adequate water access therefore no equity in water distribution.
- Conjunctive use of water is practiced in part of tail reach farmers.
- Micro-irrigation is not practiced.
- Ridge and furrow irrigation has been carried out.
- Irrigation of farm field is done in daily basis.

4.1.3 Awareness of Modern Techniques and Schemes

- Farmers are aware of farming scheme and some subsidy like, buying machinery, seeds, fertilizers, etc.
- They have knowledge about the water saving techniques like SRI, micro-irrigation, crop diversity etc.
- Awareness on farming machineries through IAMWARM scheme is created and covered in IAMWARM project.

4.1.4 Marketing Aspects

- The harvested produce is sold to the market which is located in red hills.
- Market is non-regulated.
- No post harvesting is followed.
- Intervention of middleman is there.

4.2 Performance of Water Delivery System

The performance of water delivery system is analysed based on the annual rainfall data of 34 year from 1981 to 2013 which subjected to frequency analysis.

4.2.1 NDVI Analysis

The NDVI image is a graphical indicator can be used to analyse and assess whether the target being observed contains live green vegetation or not by remote sensing.

The NDVI value varies between -1.0 to +1.0. The Green leaves have a reflectance of 20% or less in the 0.5 to 0.7 micro ranges (green to red) and about 60% in the 0.7 to 1.3 micron range (near-infrared). The spectral reflectance is the ratios of the reflected over the incoming radiation in each spectral band individually; hence they take on the values between 0.0 to 0.1. The negative values of NDVI (approaching-1) correspond to deep water. Values to zero (-0.1 to 0.1 generally correspond to barren areas of rock, sand or snow. Low, positive values represent shrub and grassland (0.2 to 0.4) while high values indicate temperate and tropical rainforests (approaching 1). The typical range is between -0.1 to 0.6 (for a not very green area).

A comparative analysis of NDVI for 4 different years of 50%, 75% dependable, normal and drought years are carried out. The percentage change of land under paddy cultivation in each year was identified, and was used as an indicator of performance of water delivery system. The NDVI was considered for two cropping seasons namely Samba and Navarai in all four years was used for the NDVI analysis. The output was classified into two categories as high and low. High percentage of paddy shows

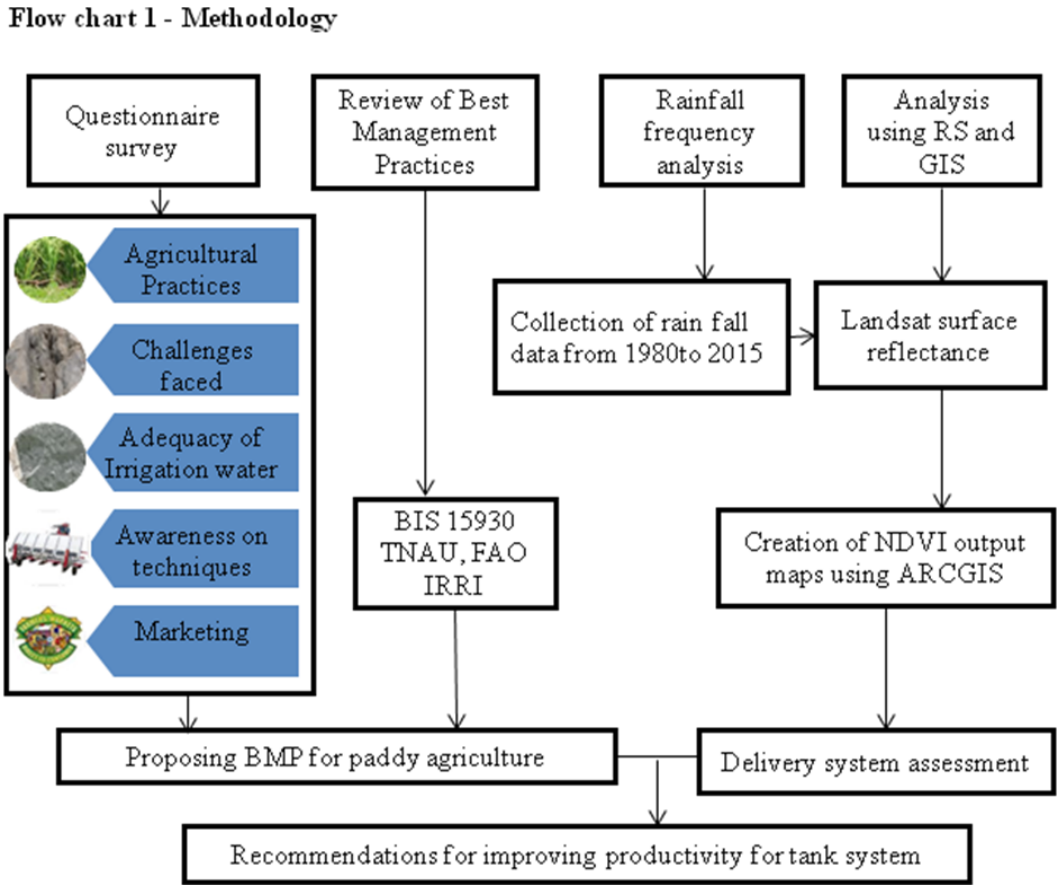

Figure 1. Key findings from Questionnaire.

more land under cultivation and the water delivery performance is good. If the NDVI is low the performance of water delivery system is poor.

Hence the analysis gives the picture of the performance of water delivery system of Vengal tank and it change over the years, leading to better management of water. The Figures 1a and 1b are the created water delivery performance maps for the average rainfall year – 2002. The Figures 2a and 2b are the water delivery performance maps for the 75% rainfall dependable year – 2006. The Figures 3a and 3b are the water delivery performance maps for the drought year – 2009. The Figures 4a and 4b are the water delivery performance maps for the recent year rainfall more than average – 2011. From the DVI maps, the water delivery performance analysis of the Vengal tank irrigation system was carried out.

4.2.2 Interpretation from NDVI Maps

The interpretation of the NDVI maps was done in Table 2, on the comparison of the land covered by both high and low paddy cultivation for all the four rainfall years. It is inferred that the area under paddy cultivation is decreased in the tail end, which indicates that the water delivery performance of Vengal tank is reduced over the years.

4.3 Best Management Practices

4.3.1 Agriculture

Best management practices in agriculture involve the practices which increases the productivity. It includes the practices right from land preparation to marketing the produce. The Table 3 gives the best management practices for paddy cultivation.

The major drawback is the labour constraint for the reduction in the area of crop cultivation. In addition, fragmentation of land is another major challenge for not adopting water conservation techniques. Farmers are adversely affected by the Mahatma Gandhi National rural Employment Scheme which caused the non-availability

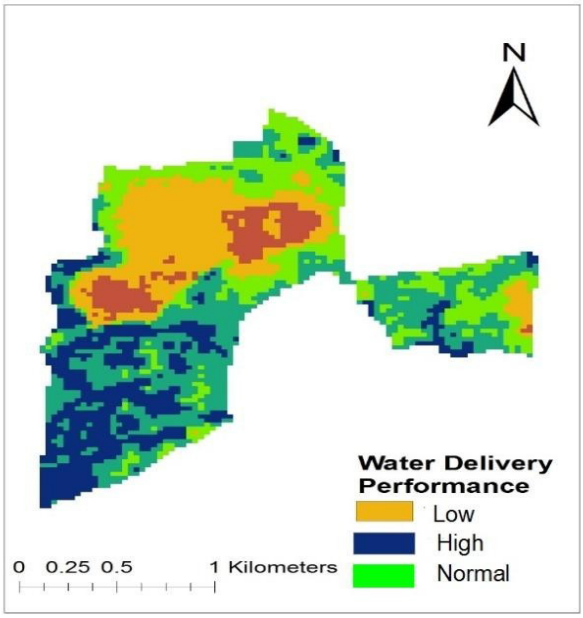

Figure 1. (a) Samba Season 2002.

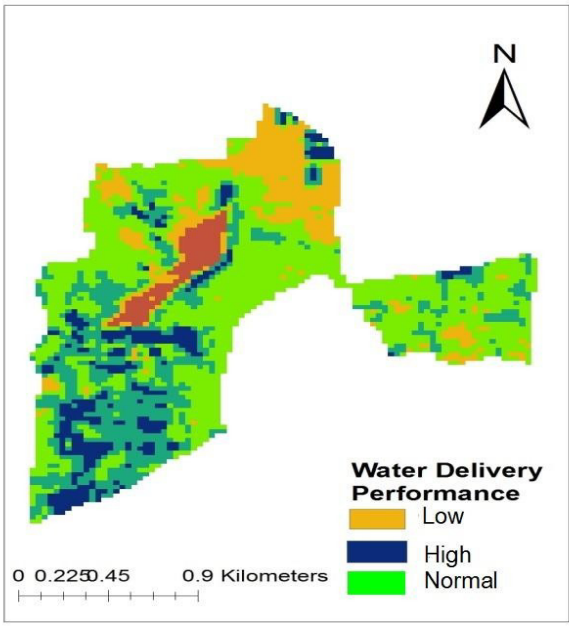

Figure 1. (b) Navarai Season 2002.

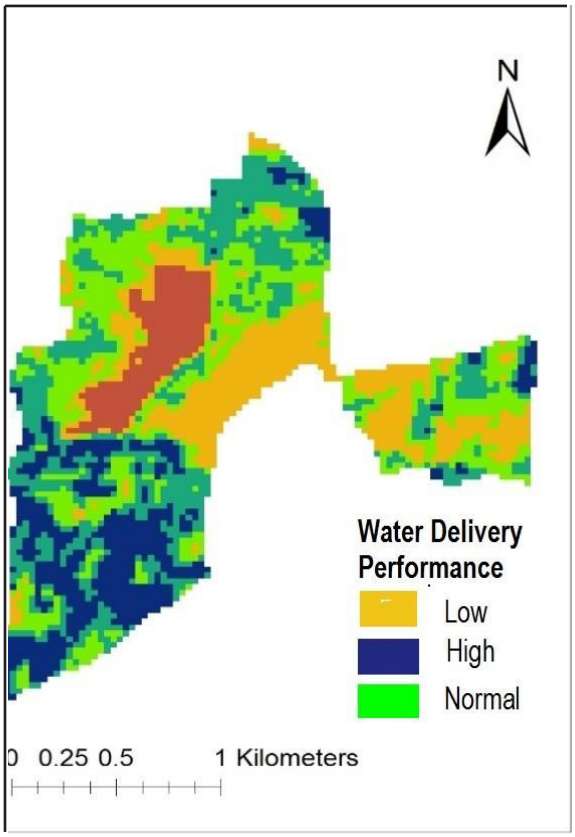

Figure 2. (a) Samba Season 2006.

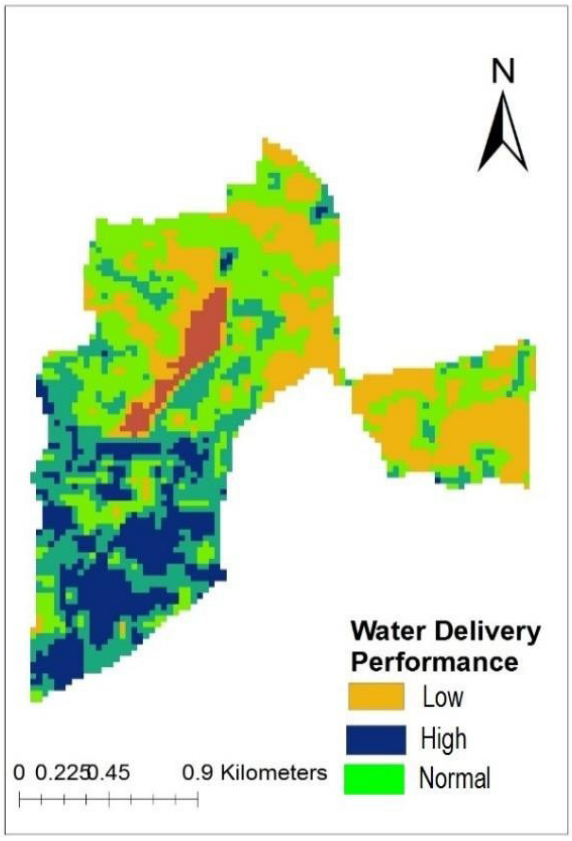

Figure 2. (b) Navarai Season 2006.

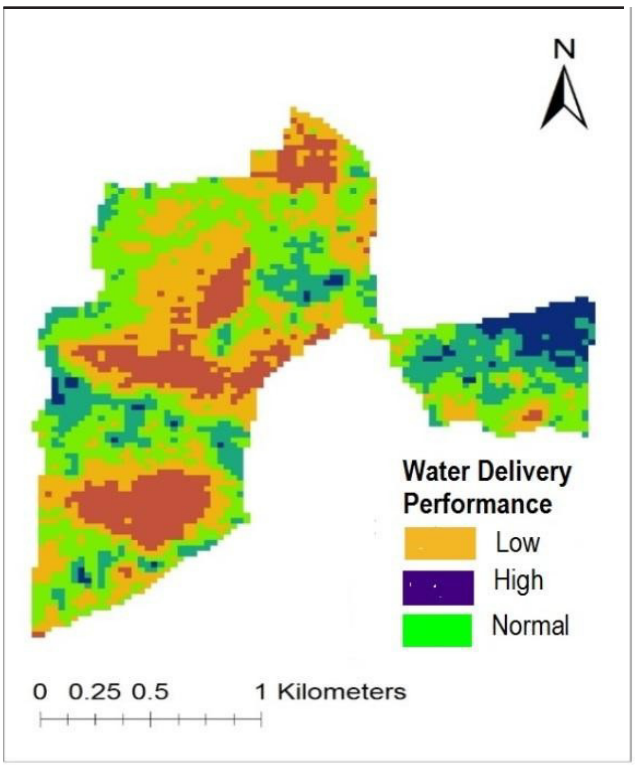

Figure 3. (a) Samba Season 2009.

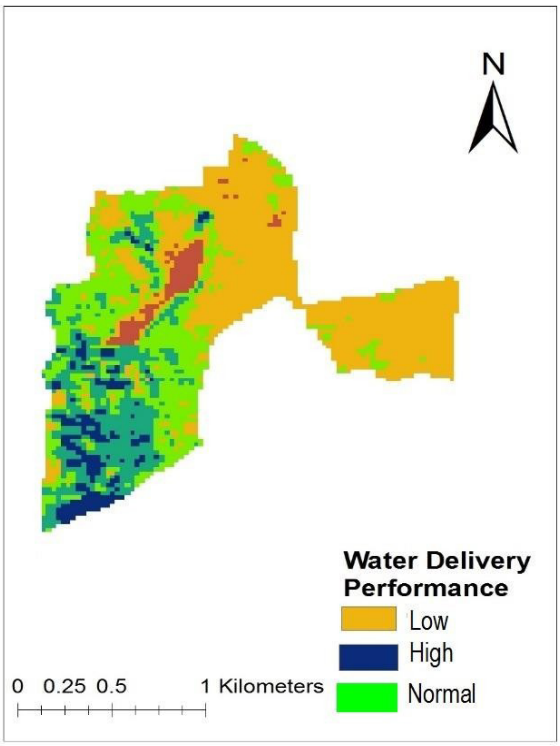

Figure 3. (b) Navarai Season 2009.

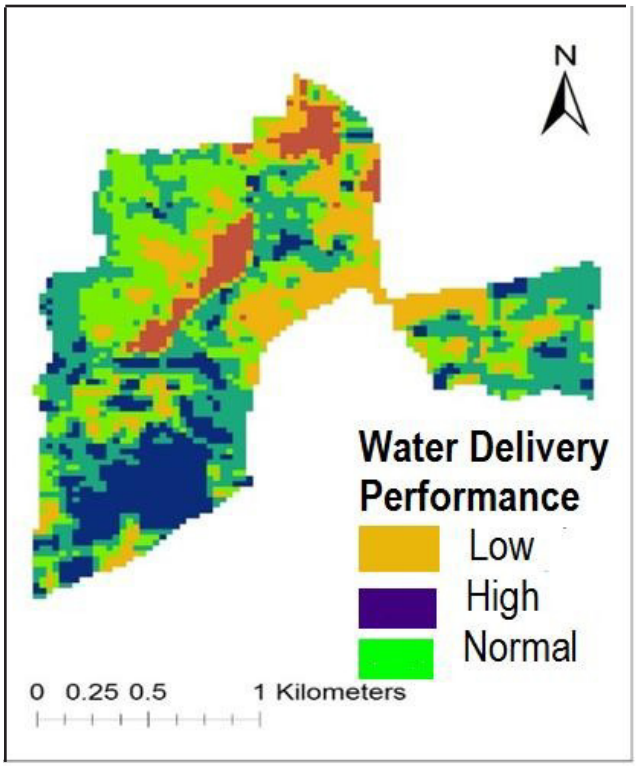

Figure 4. (a) Samba Season 2011.

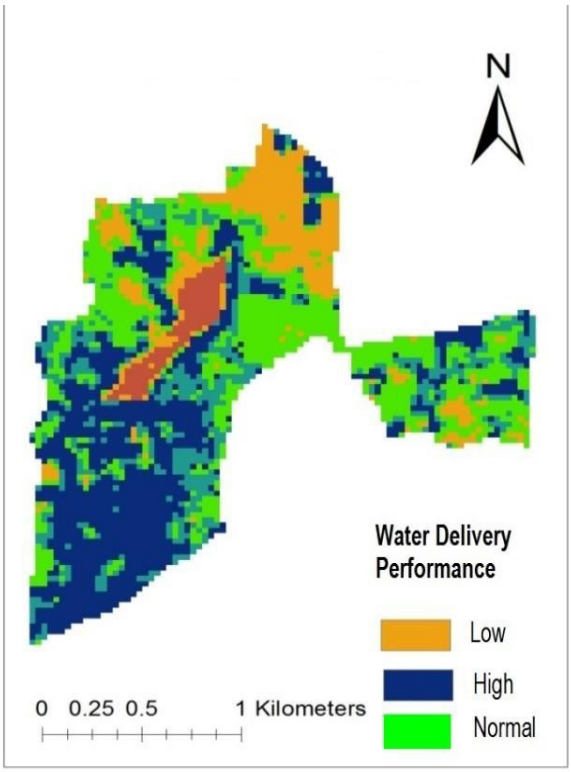

Figure 4. (b) Navarai Season 2011.

of the labours. Grazing of cattle is the reason for not opting horticultural crops.

4.3.2 Irrigation

Best management practices in irrigation involve the practices which increases the water productivity. It includes the practices that improve the condition of structures that supply water to the command area. It also includes the role of the Water User Association and Public Works Department. The Table 4 gives the best management practices for irrigation.

No conjunctive use of water is practiced since agriculture water dependency is mainly on tank irrigation. Conventional method of irrigation is practiced and there is a lack of equity in water distribution. This is mainly due to improper maintenance of tank, silting of channels as well as damages.

5. Conclusion

It is evident from the survey, that the water delivery performance of the Vengal tank is poor, since the water is not delivered in the tail region. As a result of this inequitable supply of water, the area under agriculture drastically reduced, and were converted into commercial plots. The inhabitants of the village started moving out the village in search of jobs for high income.

5.1 Water Delivery System

The NDVI analysis showed that:

- The percentage of area under high vegetation of paddy in the year 2002 was 28% out of the total area which increased to about 31% in the year 2011. This is because the amount of rainfall in 2002 was 1032mm (75% dependable rainfall), whereas it was 1499.6 mm (more than average) in 2011.
- The drought year 2009, is characterized by a very drastic change of 0% percent vegetation in the tail end region of Navarai season. But, in the Samba season, the area under high paddy vegetation s decreased as much as 9.8% when compared to high paddy vegetation in the Samba season of 2002. It can be inferred from the NDVI map of the Samba season of 2009, there is an increase in the high paddy vegetation in the tail end. The

Table 2. Interpretation from NDVI maps

Year	Samba Season	Navarai Season
2002	Water delivery performance is high in some parts of tail end and covering 28% of high vegetation of total area.	Water delivery performance is high in some parts of tail end and covering 18% of total vegetation, but predominant by low vegetation covering 27% of total area.
2006	The water delivery system was good, accounting vegetation of 24% of total area.	There is no high vegetation in the tail end of the study area.
2009	There is high vegetation in tail end even in drought year. When analysed, the no. of bore wells increased in the tail region, to counter the poor delivery system.	There is no high vegetation in the tail end of the study area.
2011	Since the rainfall was above normal, the vegetation is good, accounting for about 31% of the total area.	The water delivery system is good in this year as the rainfall was above normal.

Table 3. BMP for agriculture

Activities	Current Practices	BMP	Recommendation	Source
Land preparation	Ploughing	Levelling	Ploughing of farm field is adequate, since topography is even	Louisiana State University (LSU) college of Agriculture - Center research and extension, TNAU
Nursery preparation	Wet bed seedling	Modified mat nursery and bubble tray nursery	It is better to go with modified mat nursery, since bubble tray requires large no of trays may hinder the maintenance.	TNAU
Days required to transplant	20-25 days	12-15 days	15 days	FAO
Spacing	10-15 cm	20 or 25 cm	25 cm	Assessment of different methods of rice (Oryza sativa) cultivation affecting growth parameters, soil chemical, biological and microbiological properties, water saving, and grain yield in rice–rice system
Irrigation depth	30 mm	15-20 mm	Recommended as in BMP	Flood Reduction Function of Paddy Rice Fields under Different Water Saving Irrigation Techniques
Irrigation interval	Daily	Saturation condition	Recommended as in BMP	Above mentioned source
Method to transplant	Manual	Trans planter	SRI trans planter is recommended because of its plant spacing of 25*25 cm	TNAU
Intercultural operation	Manual weeding	Rotary or cono weeder	Recommended as in BMP	TNAU and FAO

Fertilization	Lumped application of fertilizer.	Distributed application of fertilizer	1st one-third fertilizer in soil before sowing. 2nd one-third after early tillering stages. 3rd remaining during the panicle initiation.	FAO and IRRI
Time of harvest	Not specific, mature grains are subjected to field drying.	100-110 days	Harvesting in 100-110 days will reduce harvesting losses.	FAO
Harvesting method	Combine harvester	Combined harvester	Nil	TNAU
Post harvesting techniques	Nil	Establishment of food processing centre	The food processing centre with husk removing facilities, drying yard, solar drying yard and farmers and traders rest room. Can also include marketing hall.	BIS 15930: 2010
Marketing	Non- regulated market and the produce is sold by means of middleman	Regulated markets	Regulated markets with trading hall, electronic weighing equipment, auction of agricultural produce.	BIS 15930: 2010

Table 4. BMP for irrigation

Activities	Current Practices	BMP	Recommendation	Source
Catchment	Nil	Desilting tank and at entry points	Recommended as in BMP	Towards improved performance of irrigation tanks in semi-arid regions of India: modernization opportunities and challenges
Tank bund	Insufficient and rapid erosion of top width	Widening of top width	Recommended as in BMP	Famer's opinion
Supply channel	No periodical proper maintenance, silting, leakage. Damages in the channel	Periodical desilting, clearing vegetation.	Recommended as in BMP and provide facilities for cattle and vehicle crossing.	IRRI

Irrigation management	Continuous withdrawal without relevance to actual need	Irrigation scheduling based on crop water requirement, Land consolidation and effective rainfall	Recommended as in BMP	Water management in irrigated rice coping with water scarcity
WUA	Periodic meeting have been conducted. But there is a lack of knowledge about equity and water allocation according water requirement of the crops.	An integrated approach is needed to create awareness about equity and water allocation. Capacity building is also necessary	Hence an extension activity services is needed to achieve the BMP.	Nil
PWD	Lining and desilting of channel, strengthening of tank bund. Maintenance of sluice, weirs, etc.	More frequent inspection is recommended as the channel has been damaged and contaminated by the villagers	Recommended the same in BMP.	NIL

reason is an increase in the number of bore wells dug for paddy cultivation because of poor water delivery performance.

- Apart from decrease in the water delivery performance, it can also be cited that the area under low paddy cultivation increased from 32% in the year 2002 to about 36% in the year 2011. Thus much of the agricultural land has been converted to plots.

5.2 Best Management Practices

Best management practices are the methods or practices which are applied to increase the productivity of the crops. Thus best management practices have been recommended, for the paddy cultivation. The above results were due to the problems in water sharing, fragmentation of land, non-maintenance of supply system, non-availability of labours. Thus, the percentage of people involved in agriculture is decreasing and also the productivity. Hence, best management practices for paddy cultivation from sowing to marketing have been proposed to improve the agricultural productivity. By enhancing the water delivery performance and adopting best management practices, the overall productivity of the crop will increase.

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