CROP WATER REQUIREMENT ANALYSIS OF A WATERSHED USING REMOTE SENSING DATA & GIS

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Abstract

Water in the modern world is a highly valuable resource. So it is very necessary to use this very precious resource wisely. One of the major users of water is agriculture either in form of direct use or through irrigation. So it becomes very important to note the various requirements and their amount of supply. In this case an important tool can be useful to the calculation .i.e. IRRIGATION EFFICIENCY and with this crop water requirement can also be an effective tool. Irrigation efficiency is highly useful data in calculation the actual water requirement at the field and the amount of water that is supplied to the farm lands. There are many techniques usually applied for calculation of such process but ArcGIS was taken into consideration with high satellite images because a large area can be covered with ease a thematic map can be usually designed, land use and land cover map can be used too. The study area was KUANRIA medium irrigation, NAYAGARH, ODISHA. This study is focused on estimating the water demand for paddy crop during kharif cropping season within the study area. High quality satellite images were taken into consideration to identify the irrigated areas and the fallow land. In addition to this interpretation process the help of ORSAC was taken into consideration. After calculating the area, with the help of agricultural data the actual volume of water required for the crop has to be determined. Now the actual volume was to be compared with the data that is provided by the WATER RESOURCE DEPARTMENT. Now following remedies has been provided to increase the irrigation efficiency.

Introduction

Water resource in India are examined in the context of the growing population and natural ambition to become and be seen as a developing nation. With rapid growth and rising expectation for a better life, the natural resources of our earth face increasing pressure. Water management decisions can have environmental, physical, social and economic impact that are wide spread and pervasive. It is therefore necessary to have most relevant information for arriving at rational decisions that will result in the maximum amount of benefit to most people. Accurate and reliable information to the water resource system can therefore be a vital aid to strategic management of resource. To appreciate this, an overview of different efficiency and potential are measured.

Irrigation has always played an important role in supporting the establishment and development of human societies through securing and fostering agricultural production. An interesting example that demonstrates the importance of irrigation in increasing the crop yield is a historical documents from the ancient Mesopotamia –the area known as a cradle of civilization-that dates back to 439 B.C .As these documents states that the seven local farmers agreed to pay for 1/10th of water share by a certain amount of silver plus 1/3rd of their harvest to the great Persian empire(Dandamayev,1992).The agricultural sector of Mesopotamia failed due to various factors such as soil salination etc.(Khan et.al.2006).

In a fast growing world with over a billion people, there is enormous pressure on the agricultural sector to not only increase food production, but also to do so by using less water and consider the environmental concerns at the immediate time. A sustainable management of agricultural water resource in such an environment is impossible without having appropriate knowledge on the water balance components. A major part of water in our country is invested in the form of irrigation. The net amount of water i.e. applied to the agricultural fields and the gross output that they yield are major efficiency.

Agricultural water balance study can be performed on three different standards:

1) Crop root zone.

2) Field

3) Irrigation scheme.

In the first case the analysis is focused on the amount of water which enters or exists as specific region of soil profile. The boundaries for type of analysis are mainly analyzed by the depth of the soil and the effective root depth. Irrigation performance and water accounting are useful tools to asses water used and related productivity.

Irrigated agriculture is a large consumer of water. As water is highly manageable in an irrigation system, it is an application typically suitable to establish improvement in resource utilization. Another important aspect to be taken care of is evapotranspiration (ET) from crops, native vegetation, forests, weeds, baresoil and open water bodies for a major components of water balance .The assessment of water resource utilization not only requires quantification of the ET but also the use of water.

Adequacy, efficiency, dependability and equity were defined by Molden & Gates (1990) as objective for irrigation water delivery performance. They defined these as follows:

- Adequacy: The desire to deliver intended volumes of water needed for irrigation of crops to delivery points in the system.
- Efficiency: the prevention of over delivery of water in the delivery process.
- Dependability: Achievement of temporal uniformity in the ratio of delivered volume of water to intended volumes.
- Equity: Fair distribution of water among users.

The area of land from which the runoff comes into a stream is called the catchment area of the stream. It is also called as drainage basin or drainage area or water shed. The area of land drainage into a stream or water course at a given location is known as catchment area. A catchment area is separated from its neighboring areas by a ridge called divide or watershed. If the catchment has no outlet point then it is called a closed catchment. In closed catchment water converges to a single point inside the basin known as sink, which may be a permanent lake or a point where surface water is lost underground.

Water budget equation for a catchment:

For a particular time (t):

P-R-G-E-T=S

Volume of water –Volume of outflow water=Change in storage volume of water.

Due its path catchment to irrigated fields, water is diverted from its natural course, conveyed and then distributed to farmlands through various networks. The success of irrigation – water delivery system can be known by how well it meets the objectives of delivering an adequate and dependable supply of water in an equitable, efficient manner to the farmers. If water doesn't reaches in proper time and adequate amount then it may affect the crop growth. In its path from catchment to irrigated fields water is diverted from its natural path, conveyed and then distributed through water delivery network.

Irrigation efficiency is an important point in measuring of irrigation performance in terms of the water required to irrigate afield, a farm, basin, irrigation district or an entire watershed. The importance of irrigation efficiency are most valid to society for irrigated agricultural land and its benefit in supplying high quality and abundant food supply to meet the requirement of our growing population. Irrigation efficiency is a basic civil engineering term that is used in day to day life to characterize irrigation performance, evaluate irrigation water use, to enhance better use of water resource and use of better resources (i.e. is management of agricultural and landscape management).

Irrigation efficiency defined in terms of these criteria:

- Irrigation system performances
- Uniformity of water application
- Response of crop to irrigation.

Irrigation efficiency affects the economics of irrigation, the spatial uniformity of crop and its yield, the amount of water may percolate beneath the crop root zone, the amount of water that can return to surface source for downstream use or to ground water aquifer that might supply other water uses. The volume of water for various irrigation components are typically given in unit of depths (volume per unit area) or simply the volume for the area being evaluated. Irrigation water application volume is difficult to measure, so it is usually computed as the product of water flow rate and time. This place emphasis an accurately measure water percolation volume, ground water flow volume and water uptakes.

GIS & Importance

GIS got a major role in developing the information system that is being adapted to the kind of decision and management functions that lie at the heart of the planning process of any development activities. Handling and analyzing data that are referenced to a geographical location are key capabilities of a GIS system, the power of the system is most apparent when the quantity of data involved is too large to be handled manually. There may be hundreds of factors or thousands of features to be considered. These data may be in forms of maps, tables or even list of names and data.

The catchment of a given river/dam can easily be traced down using GIS. GIS can provide variable for input to catchment modeling. Using spatially data input management, analysis and display functions. It is used to locate all the terrains, slopes as well as the land use in the area. When defining a realistic stream network one problem, is choosing an appropriate threshold so that the density of the derived network matches as near as possible, the density of real stream network. It is also important to recognize the density from place to place and from time to time will be affected by differences in hydrological process rates and temporal changes in variables such as soil moisture.

Study Area

The In this thesis work it is being tried to calculate the net potential and efficiency of a canal system by taking the help of ARC GIS. Kuanria irrigation project is medium irrigation project that is present in the district of Nayagarh. The dam is built over Kuanria River which is a tributary of Kusumi River which drains into Mahanadi River. The exact location can be traced on the base of coordinates $20°20'32"N$ $84°48'1"E$. The nearest city to the dam is Nayagarh. The whole catchment comes under Mahanadi basin. It has a catchment area of about 124 square kilometers. The whole construction was completed in the year 1971.

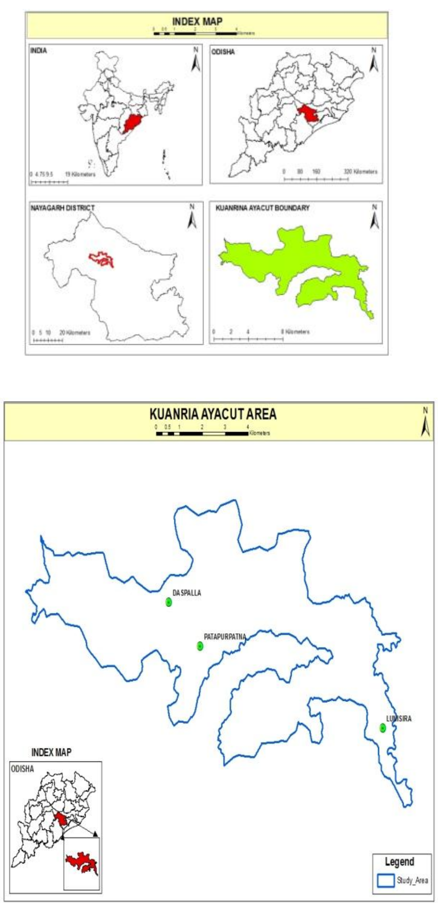

Fig: Index map of kuanria

Irrigation performance measures: Building a good understanding of the hydrological water balance is an important first step in analyzing irrigation performance .Once the components of the water balance are quantified, one can make rational decisions about the appropriateness of the water uses and whether they have a positive or negative effect on crop production, the economic health of the region, the environment, or any other issues of importance

Literature review

et.al: DAVID.J.MOLDEN; TIMOTHY K.GATES; ASSOCIATE MEMBERS, ASCE (1990):

Performance measures are developed that facilitate analysis of irrigation-water delivery system in terms of adequacy, efficiency, dependability and equity of water delivery. The measures provide a quantitative assessment not only of overall system performance, but also of contributions to performance from the structural and management component of the system. Spatial and temporal distributions are required, scheduled, deliverable and delivered water are used to calculate the performance measures. These variables may be estimated by a combination of field measurement and simulation technique. The performance measures can be incorporated in an irrigation system monitoring program and can provide a frame work for assessing system improvement alternatives. They are amenable to decomposition of analysis of system, allowing assessment of trends in performance among distinctly defined sub regions or comparisons of performance at different levels of system –network hierarchy. Example application to system typically of Sri-Lanka and Egypt indicate the usefulness of the measure in system evaluation. Some of the parameters that were checked in the following study adequacy: delivery of required amount, efficiency: conservation of water resource, dependability: uniform delivery over time, equity: delivery of fair amount.

et.al: A. J. CLEMMENS; C. M. BURT; ASCE (1997):

This paper was an attempt of the ASCE committee on describing irrigation efficiency and uniformity. They have briefed irrigation performance measures from a hydrological standpoint. Irrigation performance measures are defined in terms of ultimate destination (i.e. use) of applied irrigat5ion water. Irrigation water that enters and leaves the boundaries (i.e. representing a particular use) is separated from the other inflows and outflows. Another important consideration of the ASCE task committee in viewing irrigation system performance was separating consumptive use from beneficial use.

et.al: PETER DROOGERS & WIM BASTIAANSSEN (2002):

Development of water saving measures requires a thorough understanding of the water balance. Irrigation efficiency and water accounting is useful tool to assess water use and related productivity. Remote sensing and hydrological modeling were used to estimate the water balance to support water use and productivity analysis. Remote sensing techniques can produce high spatial coverage of important terms in the water balance for large areas, but at the cost of a rather sparse temporal resolution.

The increasing scarcity of water is a real threat for a sustainable development of large areas in the world. Irrigated agriculture is a large consumer of water. As water is highly manageable in irrigation system, it is an application typically suitable to establish improvements in resource utilization. Although knowledge of all terms of the water balance is essential to understanding how the system functions hydrologically and how productivity and sustainability can be improved.

Actual evapotranspiration for an irrigation area was calculated using the surface energy balance algorithm for land (SEBAL) remote sensing land algorithm for two land sat images. The hydrological model soil-water-atmosphere-plant (SWAP) was setup to simulate the water balance for same area, assuming a certain distribution in soil properties, planting dates and irrigation practices. A comparison between evapotranspiration determines from SEBAL and from SWAP was made and differences were minimized by adopting the distribution in planting date and irrigation practices.

et.al: MD. HAZRAT ALI; LEE TEANG SHUI; W.R. WALKER (2003):

This was an analysis conducted in the MUDA irrigation project, MALASYA. In this study, a water balance equation was derived to evaluate the performance of the project. The water balance data were found out without any calibration and was checked with the data obtained. A reservoir simulation model was designed which was checked with observed storage reserve. An optimization model was designed for the reservoir management in satisfactory manner trough computation. The optimal reservoir storage, optimal irrigation demand and optimal reservoir release were computed. The optimal demand for water in the dry and wet season was compared with the actual optimal contribution by rainfall, reservoir, uncontrolled river flow and recycled water. The GIS was used to store data for monthly mean water balance components. Different formulas and computational values were designed to calculate the water balance components, estimate overall project efficiency, calculate total water requirement for rice, simulate the storage of reservoir system, to optimize water withdrawal from the reservoir system, factors such as potential evapotranspiration, infiltration, surface runoff, seepage, Distributed channel flow routing, efficiency were calculated through formulas.

Et.al: SALCH TAGHVACIAN, CRISTOPHER M.U. NACLE (2011):

For an efficient management of our precious water resource is not possible without acquiring a comprehensive and detailed understanding on water fluxes at irrigated areas. Agricultural water balance study has been carried out at a wide variety of temporal and spatial scales. Scheme wide water balance analysis in particular, provides information about amount of water supplied to irrigated scheme and its fate. This paper initially focuses on use of remote sensing in irrigation purpose. Remote sensing can be acted as a very powerful tool in analyzing the classification map, image of land surface, soil classification etc. In irrigation it is important to know the water flux in irrigation area. It is useful in getting the details of the vegetation and cropping pattern with respect to irrigation.

Et.al: FRANCESO VOUOLO; GUIDO D'URSBO, CARLO DC MICHELLE, BIAGIO BIANCH; MICHAEL CUTTING (2014):

In this research paper work Earth observation techniques are highlighted. These technique are widely recognized in supporting the management of land and water resource and they are now being transferred to operative applications. In this paper web GIS has been used to present the current status of a satellite based irrigation advisory system. It was analyzed in three different agricultural system and environments; Southern Italy, Austria and Southern Australia. The maps of canopy development (leaf area index, albedo and soil cover) are derived from high resolution spectral image, delivered in real time and processed by in-situ agro meteorological data. The outputs of this procedure are provided as a personalized irrigation advice, time delivery of information, consisting of maps, information. In this paper a whole total of guide is provided to the farmers for their better control of irrigation process and understanding of soil and other physical features.

From the above literature review it is clear that the irrigation efficiency has a great role to play in the irrigation system. So an effective irrigation efficiency for crop water balance is required for an effective irrigation system. The various losses are also considered but the important point that is to be noted is that how efficiently we can transmit that water to the fields as so that the crops can use it. In this case technology can be a boon to our society using software like ArcGIS can reduce the tediousness of work as well as more and more area can be covered and utilized. It has got a very brief history but still it can be a vital tool to analysis of efficiency.

Objective

- To assess the performance and potential of the canal system.
- To attempt the calculation of the crop water requirement in that area.
- To chart the chance of improvement in the present system.

  ARC GIS is used to digitize different prospective of the given ayacut area such as canal system, river, area under agricultural influence, roads sustaining in that area, ayacut boundary.

Methodology

In the initial stage of the thesis a study area has been selected i.e. Kuanria command area. Kuanria is a medium irrigation project that is situated in the district of Nayagarh. The ayacut area map of Kuanria command area has been collected from Water Resource department of Odisha by ORSAC through proper channel. The command area initially provided was in form of raster data in the form of .dwg format.

The command area then was geo- referenced with the world view-II. Apart from this high resolution satellite image were taken into consideration in addition to the survey of India Topo sheet no. .Then the given ayacut area was demarcated as a study area through arc GIS 10.3.

In the meanwhile the ayacut area was converted into appropriate form of working that is converting from .dwg to .mxd so that it can be worked on arc GIS 10.3.Now using the high resolution data and the topo sheet of survey of India a proper image interpretation was analyzed done to the best of our knowledge because in arc GIS perception of one plays a bigger role.

The Kuanria dam and the reservoir area has been mapped from the satellite image with verification to the topo sheet of India. Then the main canal, branch canal, minor and sub minor canals has been interpreted and digitized through proper interpretation of satellite images and topo sheet. In addition to this the major road and settlement has been interpreted from the satellite image.

In the next stage georeferenced cadastral maps of villages of the command area provided by ORSAC was used to identify the croplands in the command area and are compared with the gross command area as provided by the Water Resource department. The total identification process was done in phases that is village wise .About 52 villages of two blocks that are Daspalla and Nuagaon has been studied and interpreted plot wise .i.e. the plot covering roads, canals, river ,nalas, upland , vegetation cover ,scrub lands were distinguished and were properly added in the attribute table over the study area. So now once all other than the agricultural land that are to be irrigated are distinguished it has been quite easy to demarcate the agricultural land that are really benefitted by the irrigation networks.

In addition to this the schematic diagram of the canal network was provided by water resource department. Taking into consideration the various 18 canals were interpreted and distinguished.

In the meanwhile to have a cross reference several field visits has been done to the study area and nearby places. The various important points are located and has been seen what other features needs to be added.

Now since the total volumetric use or working volume chart has been provided by water resource department. It is easier to calculate the depth of water that is supplied to the agricultural land.

In the next step the various crop that are cultivated in that area has been identified. From this data there will be a comparative study on the water requirement by the crop and the actual amount of water available to the crop.

As a result a crop water balance need will be full filled. The precipitation in that area and the water storing capacity has been analyzed. A part from this the irrigation efficiency would also be calculated.

Discussion

In this project a brief study of the efficiency of canal has been studied. Apart from this the irrigation efficiency has been also calculated on volume basis. Other than this the crop water requirement for a paddy crop has been taken into account. Every crop requires a definitive quantity of water after a definite period throughout its period of growth. If the water requirement is fulfilled naturally then there is no need for extra watering to the crop. For example in case of England the normal rain is quite sufficient for its agriculture. Where in case of country like India the rainfall is not sufficient or sometimes it does not fall in adequate time. Here various crops have different requirement at various stages of year. So it is a very important aspect of that area to have a good irrigation network.

The term "WATER REQUIREMENT" means the total quantity and the way in which a crop requires water, through its growing period.
Irrigation efficiency is a critical measure of irrigation performance in terms of the water required to irrigate a field, farm, basin, irrigation districts or an entire watershed.

Here in this project an entire ayacut area was taken into consideration. The Kuanria irrigation project is a medium irrigation projectthat is located in Nayagarh district of Odisha. The project is surrounded by rich vegetation all around it due to the presence of Daspalla forest range.

The study area and ayacut boundary were specified by the water resource dept. of Odisha. Then by the help of ORSAC an appropriate liss3 image was taken into consideration. This satellite image was taken into consideration because of its ease for image interpretation. In the image interpretation process various element were taken into consideration such as shape, size, tone, texture, shadow, site, association, pattern etc... Visual image interpretation is the process of examining an aerial photo or digital remote sensing image and manually identify the feature of that images.

This image was later used in Arc GIS 10.3 using this image the various landscape features were identified. Arc GIS was considered here because of its ability to interpret, digitize and store the data. By using the data we are able to know the actual land that are irrigated by the canals. The rest part may be uplands, covered by vegetation, settlements etc.… So by knowing the interpreted irrigated agriculture land now comparison was made between the actual area and the interpreted images. In the next step this area was used along with the volume of water supplied by the canals. This data was used to calculate the actual depth of water required by the crops. Hence a brief comparison was made between the actual depth of water in the lands and the water required by the cops actually. The water volume is the actually water that is stored over the surface apart from the water that is evaporated, transpired or the water that is percolated downwards.

RESULT & CONCLUSION:

From this study it was clear that irrigation efficiency has a major role to play in the irrigation system of the society. In this fast growing world there is an ever increasing demand of food crops to feed the increasing population but at the same time it is pressuring the available irrigation system to feed more water. Hence irrigation efficiency can be an important tool to understand the crop water requirement as well as the required volume of water that is to provide by the reservoir for a given crop yield. In the early studies as done by others basic field data and formulas were mainly used but in this work an attempt has been made to use earth observation techniques were used .i.e. use of arc GIS 10.3 and satellite images. The study as has been tried is very simple and can be analyzed and computed easily from any part of the world.

The KUANRIA medium irrigation project is located in the district of NAYAGARH. It is under the MAHANADI basin. The river that constitute the whole project is KUANRIA River. With a maximum annual rainfall of 2295.00mm and a minimum of 906.30mm annual rainfall. The mean annual rainfall hence can be concluded as 1400mm.

The gross command area as provided by the WRE department, ODISHA was 4800 hectares and the cultivable command area was given as 3780 hectares. The intensity of irrigation as during kharif season is 100%. The total area irrigated during the kharif season is 3780 hectares approximately The length of the main canal and branch canal are 18.20 km and 16.50 km respectively. The total lengths of minor and sub minor is 49.86km.

Now using ArcGIS 10.3 over a liss-III image the image was interpreted. By the image interpretation it was found that the C.C. Area was found out to be 3676.708877 hectares. The difference was of 103.291123 hectares from the original provided area. This loss may be due to some of natural factors during image capture or due to loss of data. The soil type in these areas are of red sandy soil, laterite soil, red brown soil, mixed brown soil, alluvium soil.

The KHARIF crop pattern as provided by WRE department as follows:

Table No-1

CROP TYPE(PADDY)	INTENSITY OF IRRIGATION	AREA
Early paddy	30%	1134 HA
Medium paddy	70%	2646 HA
TOTAL	100%	3780 HA

But the actual area was found out to be 3676.708877 hectares. So now in the next step the actual volume is to be found out for the crop requirement. The crop coefficient value for paddy is given as 0.70 to 0.80. As there are two types of paddy that is early paddy and medium paddy there are their own requirement of water for their consumptive use.

The early paddy requires a maximum of 0.75m of water and the crop period for its growth is 100 days whereas for medium paddy a maximum of 1.00m of water is required for its growth and a growth period of 135 days is required.

Table No-2

PADDY TYPE	AREA IN HA	AREA IN M^2	WATER REQUIREMENT OF CROP IN M	VOLUME OF WATER REQUIRED
Early paddy	1134	11340000	0.75	8505000
Medium paddy	2646	26460000	1	26460000

GRAPH

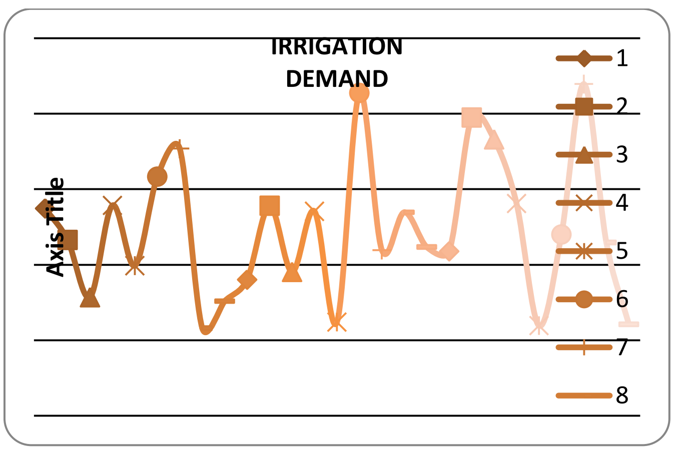

Table No-3

FOR THE YEAR	IRRIGATION DEMAND
1989-1990	54.91
1990-1991	46.58
1991-1992	31.41
1992-1993	55.71
1993-1994	39.75
1994-1995	63.31
1995-1996	70.74
1996-1997	23.22
1997-1998	30.37
1998-1999	36.05
1999-2000	55.64
2000-2001	38.12
2001`-2002	54.15
2002-2003	24.82
2003-2004	85.51
2004-2005	43.9
2005-2006	53.89
2006-2007	44.69
2007-2008	43.56
2008-2009	78.99
2009-2010	73.21
2010-2011	56.22
2011-2012	23.87
2012-2013	48.02
2013-2014	87.84
2014-2015	45.89
2015-2016	24.25

Hence a total of 34965000 m*m*m volume of water is required .i.e. 34.96 HAM. As per the requirement during the draught year the maximum water requirement can exceed upto 87.84 HAM and during wet season as low as 23.22 HAM. On an average 49.430 HAM is the requirement of the volume of water requirement.

PICTURES & MAPS:

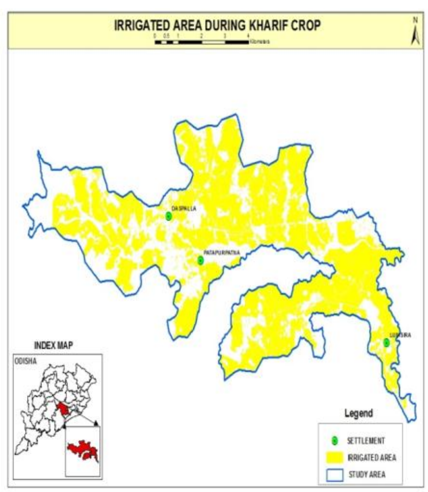

Figure represents irrigated area during kharif season

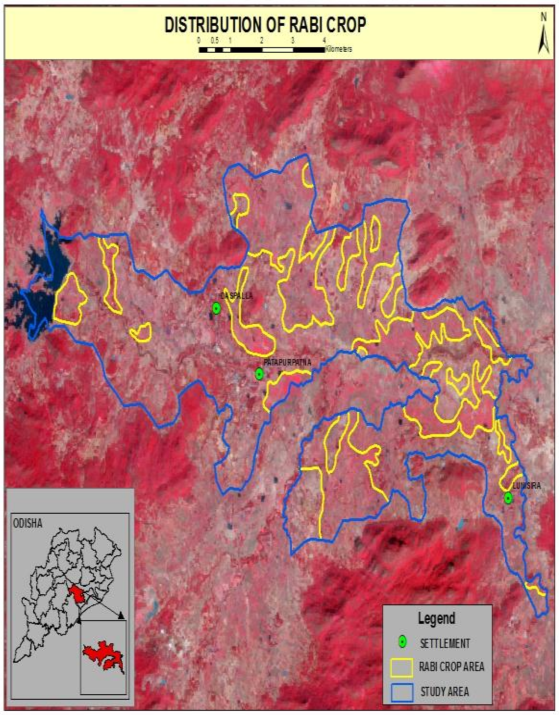

Figure represents irrigated area during rabi crop

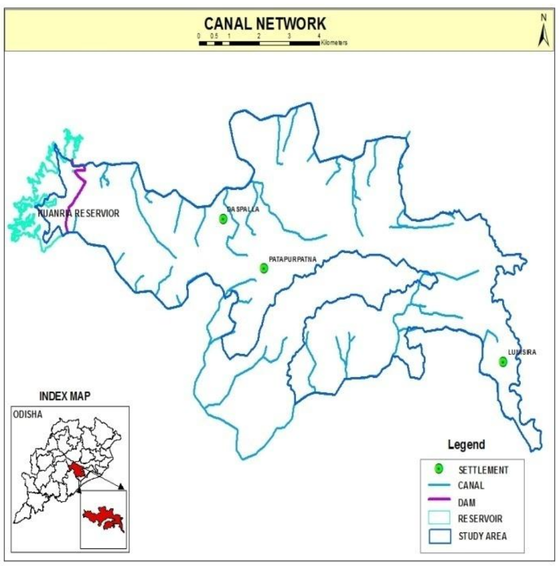

Figure represents canal networking in the area

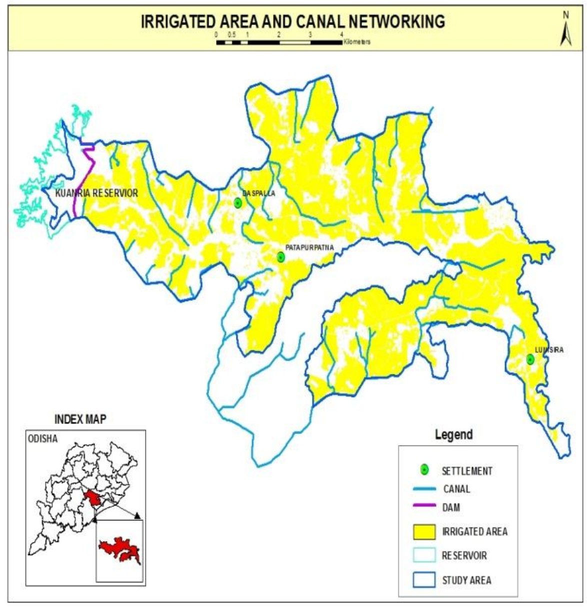

Figure represents irrigated area and the canal networking

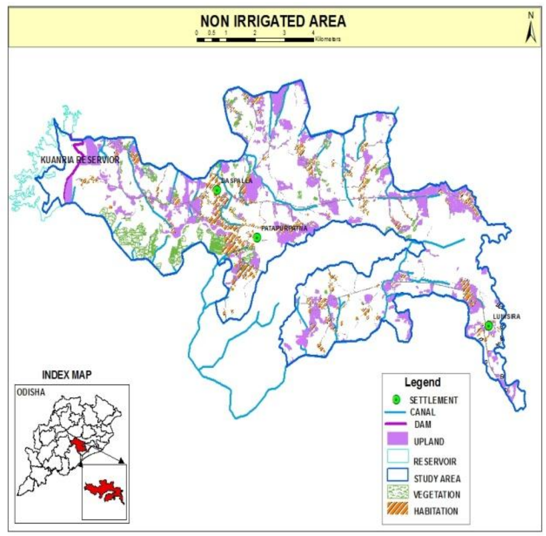

Figure represents non irrigated area

SCOPE OF THE WORK:

In this study, an attempt has been made to know then net requirement of water by an agricultural field and the amount of water that is supplied to the crop lands. Apart from this the amount of water supplied by the canal system are evaluated on the basis of analytical calculations. There is a huge scope of developing the efficiency of the canal system by using different software available and a brief study of the ongoing details. The canal system are very important in a country like that of in our country where there is no assurance of the amount of water and the intensity of water in precipitation. Hence irrigation plays an important role in those areas but efficiency should be kept in mind of the canal system. In this irrigation system it is surrounded by rich amount of vegetation all around. Hence it was a very tricky job for the officials to define an irrigated boundary. The depth of water was checked for the requirement of the crop. Apart from this many other things can be done like adjusting the volume that can be stored in the reservoir, canal improvement techniques etc.… Regarding this work additional work can be done over crop root zone water storage, amount of water required for each crop and the actual amount of water required for each crop, improving agricultural techniques.

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