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A GIS based Sustainable Irrigation Management Plan for Ferti-irrigation of Sugarcane with Treated Spent Wash

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Abstract: With the firstly growing Industries large volumes of distillery effluent have been discharged to various natural resources. Improper disposal of spent wash, in contamination with water, land and air causes health hazard of both human and animal beings. But there are certain recalcitrant compounds present in this spent wash which can causes good effect on plants. Therefore the scientific community has taken it as a challenge to treat this stream to make a proper utilization. The present study focus on the utilization of GIS technology for the ferti-irrigation of sugarcane treated with distillery effluent. To see the effect of the diluted (with water) distillery effluent sugarcane has been chosen as it shows good results. With the help of GIS we have prepared landuse map, pipeline zonation map and network accessibility map. As a result of this analysis we concluded with a sustainable irrigation management plan for sugarcane as well as recycling of distillery effluent in agro-ecosystem will not only eliminate the pollution of water reservoirs but check price inflation in the country and maintain soil health & water management. Nevertheless, the systematic information on long term impact of use of distillery effluent as pre-sowing or standing crop irrigation are not available. So far Last but not the least the Effluent's Nutrient may has a potential of saving Rs. 200 to 300 crore of national income in terms of liquid Fertilizer and will manage water budget.

Keywords:- Spent wash, ferti-irrigation, Remote Sensing and GIS technology, sustainable irrigation.

1. INTRODUCTION

The future of the present world depends very much on how we manage our natural resources. Land and water are crucial natural resources that need a serious attention towards economical use and better management for the sustenance of mankind. In order to keep a pace with the ever growing needs, it is imperative to have comprehensive information on the spatial distribution and better understanding of rational utilization of natural resources. Water is a crucial commodity which serves both domestic as well as industrial purposes. Another important area where water is immensely used is irrigation. Irrigation is a process to supplement precipitation by applying water or wastewater through artificial means to land areas. As Water is the font of life, irrigation has been the font of civilization. Irrigation maintains the soil moisture during the growing seasons, irrigation supplies water and the nutrients needed for crops. Ferti-irrigation is a modern approach of growing crops that ensures a controlled content of the main fertilizing elements and of micro-organisms. Use of effluent water through ferti- irrigation is one of the best human efforts towards sustainable irrigation.

In India, sugarcane production contributes significant role in rural economy. So, there are large-scale distillery effluents from sugar mills. The waste products from sugar mill comprise bagasse (residue from the sugarcane crushing), pressmud (mud and dirt residue from juice clarification) and molasses (final residue from sugar crystallization section). Bagasse is used in paper manufacturing and as fuel in boilers; molasses as raw material in distillery for alcohol production while press mud has no direct industrial application. The effluents from molasses based distilleries contain large amounts of dark brown coloured molasses spent wash (MSW) (Nandy et al., 2002; Pant and Adholeya, 2007). After the treatment of spent wash, proper dilution and systematic application, it would not cause any harm to soil and in some cases the nutrient, which are exhausted by the sugarcane crop would be brought back to soil (Devarajan and Oblisami, 1995). Devamani *et al.* (2006) observed the impact of sugar and distillery wastes as nutrient, status of soil yield and quality of sugarcane.

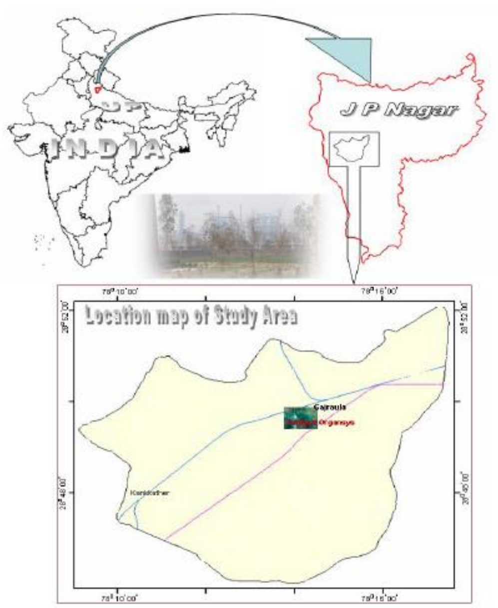
Recently, remotely sensed data have been integrated in GIS databases, such as to facilitate temporal analysis for resources monitoring. GIS can handle, manipulate and analyze data from different sources and coordinate systems, scales and formats (Navalgund, 1994 and Bouma 1989). GIS, provided with a proper set of databases of the area, and containing the related information made available from the Public Institutions and the Research (soil, water, air, flora, fauna, urban and industrial settlements, landscape, cultural heritage, socio-economic condition, etc.), is the only effective operative tool (Bertozzi *et al.*, 1999). Effective management relies on accurate and timely information. Advent of remote sensing technology and its great potential in the field of agriculture have opened newer possibilities of improving agricultural statistic system as it offers accelerated, repetitive and spatial – temporal synoptic view in different windows of the electromagnetic spectrum from its vantage point in space. In the last few years, remote sensing technology has been increasingly considered for evolving an objective, standardized and possibly cheaper and faster methodology for crop production estimation (Bauman, 1992). The use of remotely sensed data in crop acreage estimation has been demonstrated by various researchers in different parts of the world (Saha and Jonna, 1994, Syam and Jusoff, 1999 and Arnoldi and Zampedri 1997). Remote Sensing and GIS are providing new tools for advanced irrigation management, agricultural planning and continuous monitoring of natural resources etc (Wilkie and Finn, 1996). The coordinated use of GIS, GPS and simulation models has been applied by Olteanu and Dudui (1997) to monitor agricultural resources and manage potato crops in a precision farming approach. In addition, Hijmans (1997) has proposed GIS-linked simulation models to study the effect of yield-limiting factors on potato production, and to compare different varieties in order to guide crop improvement efforts.

Geographic information system (GIS) is recognized as an important tool for geographical surveys and has been applied in agronomic surveys, such as those for sugarcane (Jhoty *et al.*, 1994). The technique has been used in a number of countries such as Australia (Lee-Lovick and Kirchner, 1990, 1991; Lee-Lovick *et al.*, 1992), South Africa (Platford, 1990) and Mauritius (Jhoty *et al.*, 1994). Thailand started a project on application of remote sensing for agronomic purpose have been conducted for cassava and sugarcane since 1995 (Hadsarang and Sukmuang, 2000). In India, In past two decades studies on RS based crop inventory of more than 20 crops at various spatial scales (village to national) have been conducted (Dadhwal *et. al*, 2002).

In the present study an attempt has been made to create a geo-database of efficient usage of effluent water for ferti- irrigation by examining existing landuse pattern in and around the environs of industrial estate Gajraula.

2. STUDY AREA

Fig. 1 Location of Study Area



Gajraula is a prominent industrial area of district Jyotiba Phule Nagar (J P Nagar) in western Uttar Pradesh. It has a diverse group of industries, which include large distillery and its associated Chemical and pharma units, Paper, Phosphatic Fertiliser Plant etc. The geographical extend of Gajraula is 28° 49' north to 28° 51' north latitude and 78° 14' east to 78° 16' east longitude. The maximum & minimum height from sea level is 240 ft & 177 ft respectively. The climate is hot in summer and dry & cold in winter. Ganga is the main river and Bagad, Chhoya and Matwali are the seasonal rivers in Gajraula. Fig.1 showing the location map of the study area. The study area consists of 30 villages.

3. MATERIAL & METHODS

3.1 Remote Sensing Data and Survey of India Topomaps:

For the present work high resolution multispectral imagery of Resourcesat (IRS-P6) LISS IV of 27 June 2004 was used. Survey of India Topomaps 53 L/1 and 53 L/5 on 1: 50,000 scales pertaining to Moradabad district were used for reference only.

Table : 1 Details of IRS P6 are given below:

Payload	Resolution in meters	Swath (km)	Revisit in days	Image size (km x km)	Overlap (km)	Side lap quator (km)
LISS III						
Visible	23.5	14 1	2 4	142 x 141	7	23.5
SWIR	23.5	14 1	2 4	142 x141	7	23.5
LISS IV						
Mono	5.8	70	5	70 x 70	2.5	
MX	5.8	23	5	23 x 23	14.2	
A WiFS	50 (Nadir) 70 (End) Pixel	73 7	2 4	738 x 737	82%	84%

3.2 Materials Used: The equipments and materials used for data collection and analysis are listed below: Table 2 gives the details of Equipments Used

Table: 2

Equipment	Source/Purpose
Satellite Image	IRS-P6, LISS IV (27 June 2004)
Topographic Map No. 53 L/5. 53 L/1 and 53 L/5	Field reference (1: 50,000)
Hand Held GPS (Garmin eTrex)*	Positioning and receiving from satellites for on data fields digitizing with computers.
ERDAS 8.7, Arc GIS 9.0	Software for analysis
MS Excel	Spread sheet for data entry and analysis
MS Word	Word processing

3.3 Methodology

Methodology adopted for the present work has been divided into three phases i.e. pre-field interpretation, field-investigation and Post-field interpretation. The methodology followed for database creation and mapping has given in a flow chart (Fig. 2).

Pre-field interpretation

The satellite data of study area was procured pertaining to LISS IV sensor of IRS-P6. The image was geometrically rectified with top maps by the method of proper identification of ground control points (GCPs) with minimum root mean-square (RMS) error. The image was radio metrically corrected using dark pixel subtraction technique followed by co-registration with topomaps using polyconic projection system and nearest-neighbour resampling algorithm (Jensen, 1996).

The FCC image was interpreted digitally and visually using various digital images processing techniques. Supervised, unsupervised, and knowledge base layers were used for hybrid classification and all operations were carried out using ERDAS IMAGINE software. The general procedure for classification involved, the following important steps viz., enhancement of scene, rectification and classification technique. These were given in Fig.2.

Field-investigation

It has been observed, the water that is being used for pipeline irrigation passes through various phases. The waste water was treated at the treatment plant where the major emphasis was on anaerobic digestion. During the field work GPS was extensively used. The ground verification was done by taking readings of the major landmarks i.e., intersection points, pumping station, pipelines, Chak roads etc. with the help of GPS for updation of details for final output. Major land use classes which were identified on the false color composite (FCC) were also verified during the field visit.

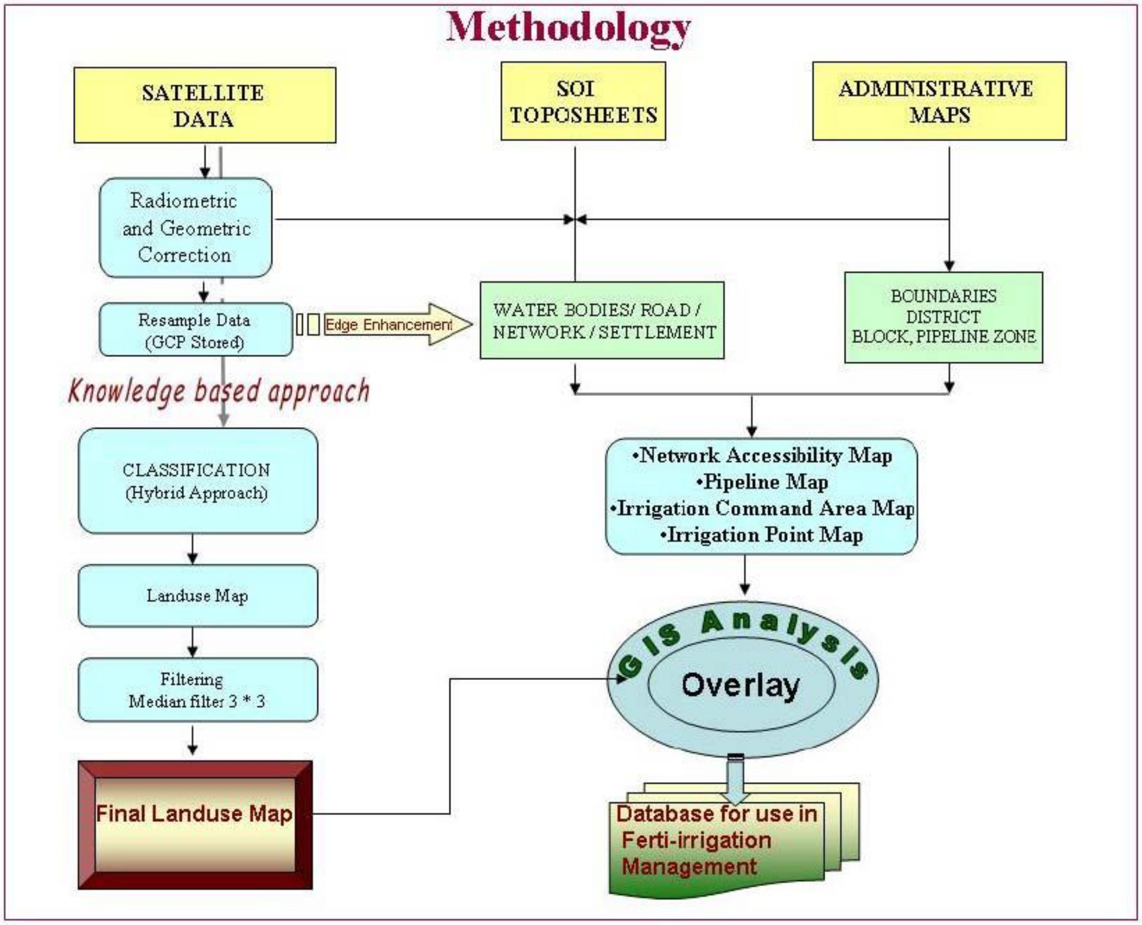


Fig.2. Flow chart for methodology

Post- field Interpretation

With the help of topomap, satellite data and ground truth existing major landuse, major roads (highway), minor roads (chak roads) were identified taking into consideration the elements of image interpretation and were overlaid on False Colour Composite (FCC) for further investigation and all the maps like Landuse map, Network Accessiility map, Pipeline map, Irrigation command area map and pipeline point map are finalized for further analysis.

Rank filter has been used for the finalisation of the landuse map. In Rank filter a window are ranked by intensity values, and the center pixel is replaced with a new value. The new value is calculated as a function of the ranked pixels. Only the original pixel values are used in the ranking when determining the new pixel value.

The output maps were prepared by using ARC GIS software in the GIS environment.

4. RESULT & DISCUSSION

Disposal of distillery effluent is a major problem. To solve this problem treated distillery effluent after dilution with water has been utilize for irrigation as provides its inherent nutrients to the plant. It has been observed that, it is beneficial in both way as it help to get rid of problems of disposal and it cut the cost of synthetic fertilizer.This treated spent wash has been applied as ferti-irrigation i.e. application of effluent through irrigation water after proper dilution during 2004-05, 2005-06 to Sugarcane crop as presown and postsown.

For effectively utilization of this treated distillery has to reach to the farmer land from the source point (after dilution). This can be managed by two ways.

1. Tanker irrigation (filling this treated distillery water in tanker and reaching to the field)
2. Way to put pipeline so treated distillery water can reach to field by pipe line.

For this second way there should be intensive mapping for laying pipeline. GIS has helped us in determining the way for pipeline. After preparation of pipeline map we could divided the field area in to four zones depending on the area and pipeline network.

With the help of GIS we have prepared a sustainable irrigation management plan for ferti-irrigation of sugarcane.

The preparation of resource map is a basic requirement for developing management plans. In this regard the accurate intermediate or large scale landcover information for many applications including understanding spatial pattern of landscape, landuse planning, policy development and irrigation planning are primary requirements of management planner.

4.1 Landuse Pattern

Based on the study conducted it was evident and validated that the study area is used for agricultural activities (Fig 3). Agriculture is the main occupation as well as the major source of income for occupants of the study area. The total area under crop land consisted of 3506.04 hectares (43.46%). The crop land mainly consisted of sugarcane, rice and other crops. 19.65 % of area found to be under sugarcane cultivation followed by other crops (consisted of cereals, vegetable etc) and rice, which was 12.24 % and 11.57 % respectively (Table 3).

4.2 Irrigation Command Area

The study area has a network of HDPE underground pipelines used for ferti-irrigation. The irrigation command area has been categorized into four zones; the same were validated during the field investigation. Four zones are namely,

ZA- Shahbazpur Zone,

ZB- Bagad and Chhoya River Zone,

ZC- Firozpur Zone and

ZD- Sultanther & Munammadpur Zone.

In these zones the total length of irrigation pipeline has been measured as 17.5 km. The zone ZC (Firozpur zone) out numbered all the other zones by having maximum length of 5.15 kms followed by ZD having 4.24 kms of pipeline. The other two Zones (ZB and ZC) have approximately 4.0 km of pipeline each. (Refer to table 4). Apart from pipeline irrigation tanker irrigation is also prevalent.

The total area under four Zones was calculated as 1877.71 hectares under agriculture, non-agriculture and degraded forest /Orchids (Table 4). The maximum area i.e. 347.19 hectare in ZA was covered by agriculture followed by non-agriculture which covered 91.38 hectares of area. The degraded forest and Orchards covered 37.59 hectares of total area only. Refer to Fig.6. the maximum area under agriculture i.e. 329.82 hectare was covered by ZB followed by 40.42 hectares of area under forest and Orchards. The non-agriculture area was only 16.17 hectares. Refer to Fig.6. In Firozpur (ZC) 372.92 hectare (85.35%) consisted of agriculture area. The area under non- agricultural and degraded forest/Orchards was 59.13 hectares (10.46%) and 34.13 hectares (4.18%) respectively. In Zone D 83.17% fall under agricultural area. Non-agricultural and degraded forest/Orchards were 73.34 hectares (13.46%) and 19.02 hectares (3.46%) respectively.

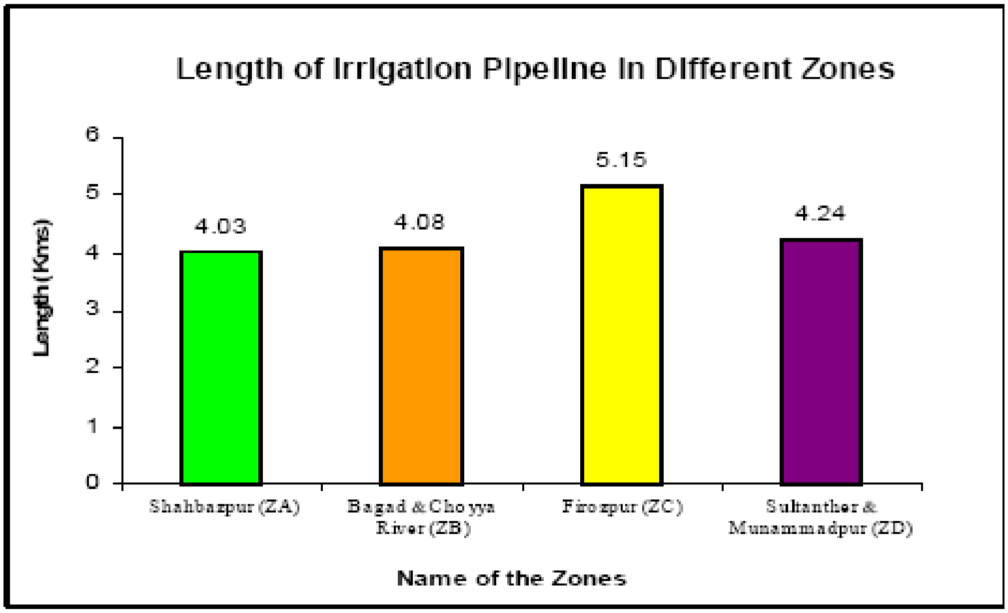


Fig.6. Status of pipelines in different Zones

4.3 Zone Wise plot mapping The irrigation command area has been categorized under four zones. A detailed analysis regarding landuse, pipeline irrigation, plot- wise information of each farmer in each zone has been done Fig.4.

4.4 Network Accessibility

For network accessibility, major and minor (chak) roads were delineated with the help of SOI topomaps. These roads were updated on the basis of high resolution image by applying edge enhancement technique. The input was generated in the GIS environment and network accessibility map was prepared for irrigation purpose (Fig.5).

5. CONCLUSION

Earth observation from satellite is unique process of gathering information. It has large advantage of providing homogeneous, repetitive, continuous and global coverage of the earth surface in a cost effective way but it has certain limitations too. The present study has evaluated landuse information for ferti-irrigation of a small area by using IRS P6– LISS-IV multispectral data with adequate ground truth. So in overall GIS has helped us in preparation of Irrigation management plan as well in implementation of treated distillery effluent in field (to get rid of the problem of disposal) for irrigation purpose. Although this study has solved the primary purpose of irrigation planning but it is advisable at the outset to have proper information on each aspect of area under investigation.

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Table 3.Landuse Classes

S. No.	Landuse classes	Area in Hectares	Area in %age
1	Sugarcane	1585.35	19.65
2	Rice	933.38	11.57
3	Other crops	987.31	12.24
4	Fallow land	2366.25	29.33
5	Tree groves Orchards	660.94	8.19
6	Degraded forest/scrub	82.47	1.02
7	Water body	10.15	0.13
8	River	21.2	0.26
9	Built-up land (Urban)	165.91	2.06
10	Settlement	207.68	2.57
11	Industrial waste treatment facility	36.28	0.45
12	Industrial area	206.51	2.56
13	Other	805.1	9.98
	Total	**8068.53**	**100**

Table 4. Length of irrigation pipeline

S. No.	Irrigation Command Zone	Villages under Command Area	Length of Irrigation Pipeline(in Km)
1	Shahbazpur **(ZA)**	Shahbazpur	4.03
2	Bagad and Chhoya River **(ZB)**	None	4.08
3	Firozpur **(ZC)**	Firozpur & Tgharia Khadar	5.15
4	Sultanther & Munammadpur **(ZD)**	Sultanther, Munammadpur & Fatehpur	4.24
	Total		**17.5**

Fig : 3 Land use Map of Study Area

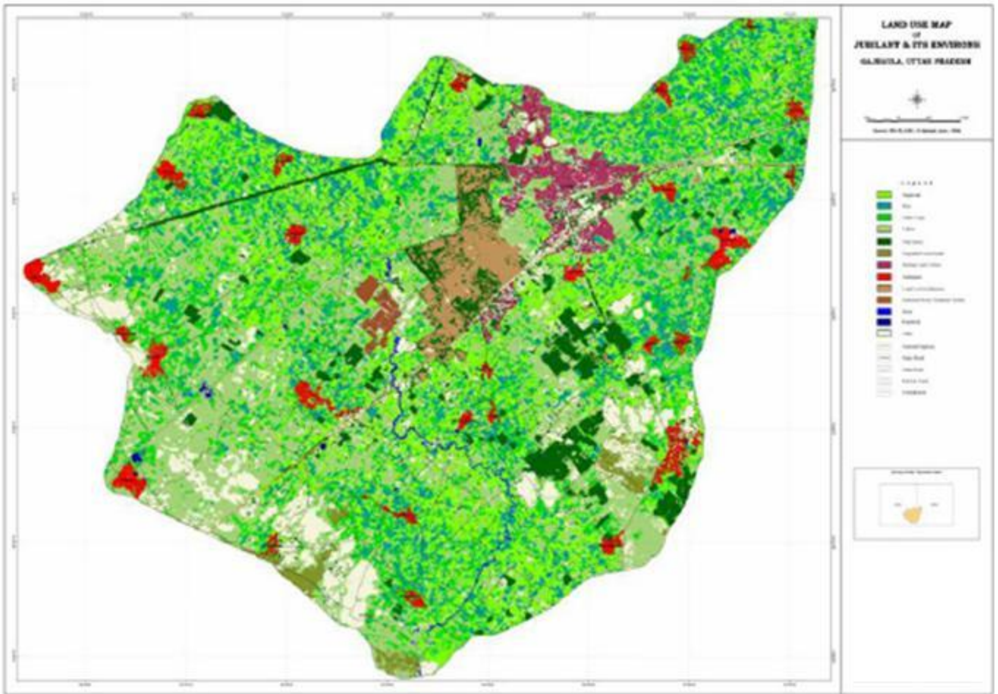
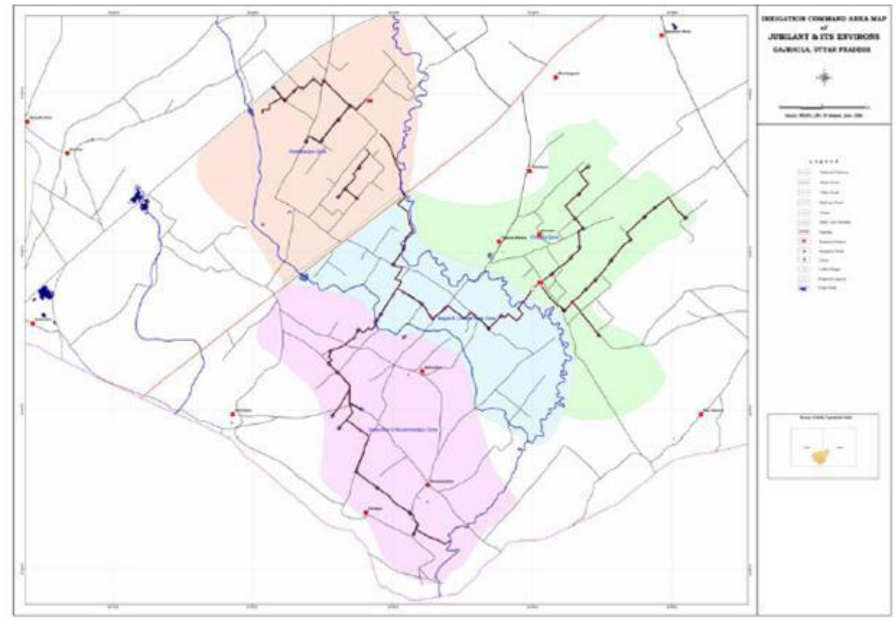


Fig : 4 Irrigation Command Area Map



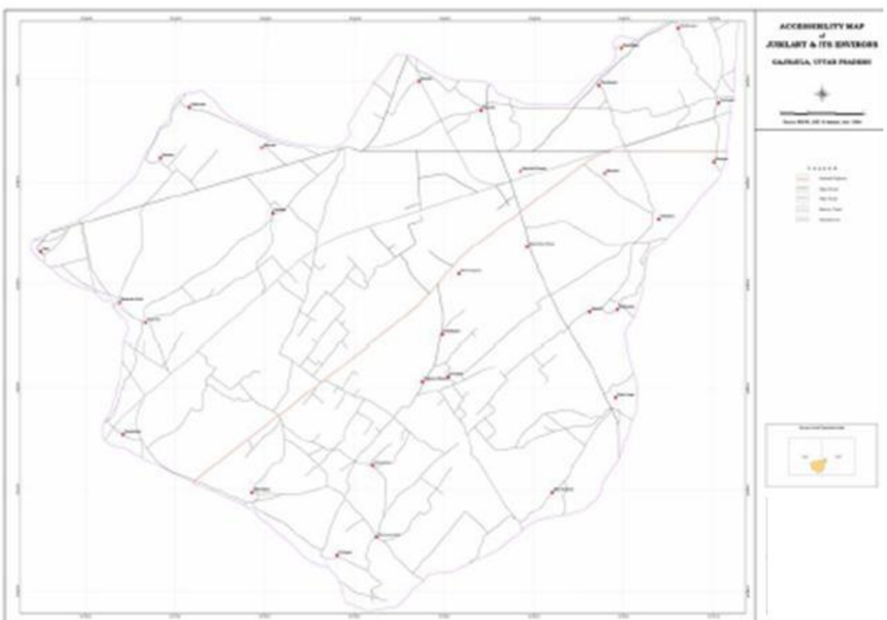


Fig : 5 Network Assessability Map

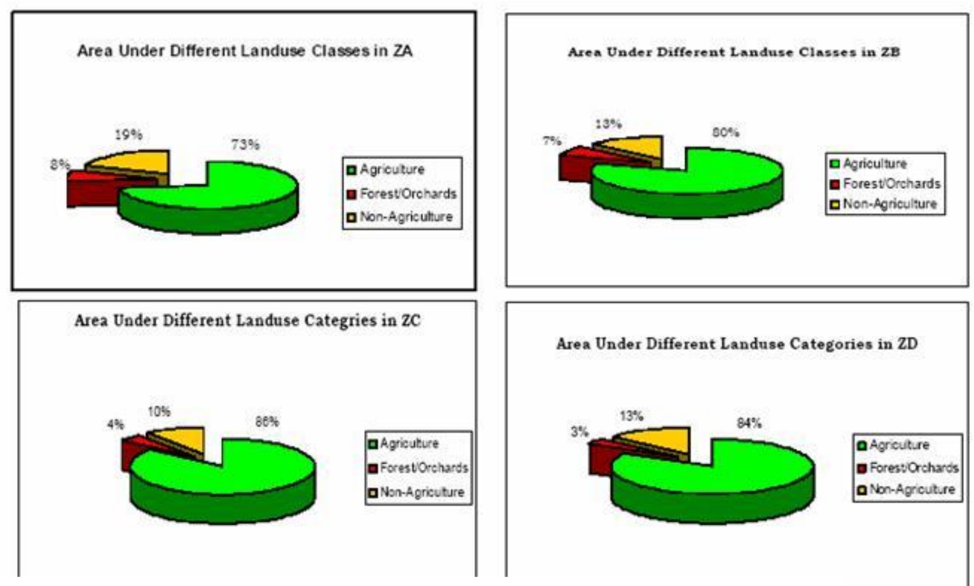


Fig : 6 Status of Agriculture and Non Agriculture in different zone