**NATURAL RESOURCES SYSTEMS PROGRAMME**

***PROJECT REPORT*[1]**

## DFID Project Number

R7830 and R7839

## Report Title

Participatory GIS and its role in natural resource management at canal commands of Bihar.

Annex Bvii of the Final Technical Report of projects R7830 and R7839.

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## Date

2004

## NRSP Production System

High Potential

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[1] This document is an output from projects funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

CONTENT

# Summary

Participatory GIS is a spontaneous fusion of participatory forms of developmental planning with modern information technologies. Concerted effort was made for mapping natural resources through participatory approach in sixteen villages under the command of RP Channel V distributary and 22,000 plots were mapped through a combination of DGPS and LASER range finder technologies with the help of Pocket GIS software in Huskey and Pocket PC. Direct observations were recorded on the Palm IIIxe hand held computer. Data in the Palm were integrated with the maps in Arc View GIS to produce basic large-scale maps. Direct observations regarding date of sowing of crops, tillage practices, source of irrigation and methods of irrigation, location of outlets, outlet commands, tube wells and presence □association of different self-help groups in the villages were recorded against each plot by members of self help groups (SHG). Integrating maps with direct observations, different thematic maps were prepared. Farmers' responses regarding the maps were collected and they found the maps useful in many respects. Information extracted from the thematic maps revealed that there were total 55 outlets in the command covering 127□ha area. 325 wells are existing in the command area, out of which 257 are shallow tube wells, 24 are deep tube wells and 44 are open wells. Tube well water was used for nursery growing in 3□ ha.,for conjunctive use in 134 ha and for crisis management in 374 ha command area during *kharif,2003*. During *kharif* season of the year 2003, 1117 ha area was covered by paddy. It was observed that in 40.□% of the area, transplanting was done before 30th July during *kharif,2003* whereas it was late in 38.□% and very late in 20.8% of the area. Wheat is the major crop in *Rabi (winter)* that occupied 4□4% of the total area, lentil occupied 27.4%, wheat, oilseeds and pulses (mixed crop) occupied 12.□% of the area. Offline linkage between maps and water balance model of hydrologists was established to develop a Decision Support System (DSS) for generating water availability scenario under each outlet command in controlled and uncontrolled outlet situation for facilitating water management related interventions by outlet management group. Distribution of 150 self-help groups and their income generating activities were spatially and temporally monitored and compared through the map. Dialogues have been initiated with SHGs of farmers for promotion of agriculture-based activities by the groups in the villages and taking participatory resource management decisions as evidenced from personal discussion with representative of groups. Dialogues among project team members and Irrigation department stakeholders using DSS for problems and solution have been initiated for future uptake.

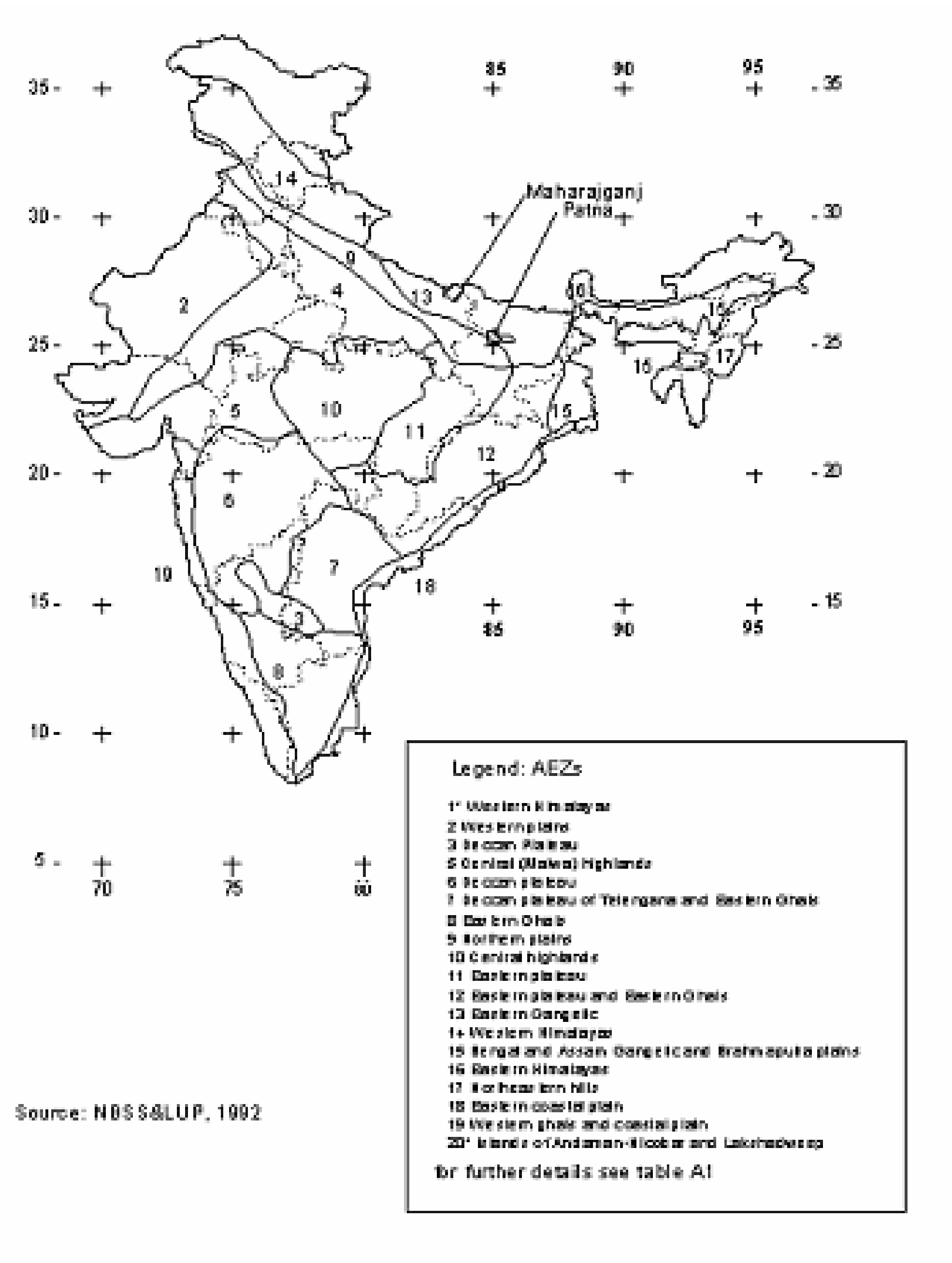
## 1.0 Introduction

RPC V distributary command area comes under high potential low productive irrigated ecosystem of eastern India. Though it is bestowed with most fertile soil and abundant water resources, yet agricultural productivity of the region is the lowest in the country due to poor management of natural resources. In a DFID□NRSP funded pro-poor livelihood improvement project, concerted efforts were made to enhance agricultural productivity through improved land and water management practices in RPCV distributary command. . Appraisal of natural resources of the distributary command area is very much imperative for giving suitable soil,, crop and water related interventions towards improvement of productivity. Geographical Information System (GIS) is a powerful modern dynamic and interactive tool for natural resource mapping and evaluation. Now-a days planners are busy in searching ways for merging community participation with GIS in different contexts like urban planning, environmental equity, and sustainable development in different corners of the world (Aitken and Michel 1995; Craig and Elwood 1998; Talen 2000; Sieber 2000). Through development, demonstration and modification of methodologies for linking of community participation with GIS by academicians and practitioners the concept of Participatory GIS emerges. An effort was made to use participatory GIS (PGIS) for natural resource mapping, monitoring and management at sixteen villages of RP Channel 5 distributary of Patna Main Canal (PMC) in Patna district of Bihar, which is narrated through this paper.

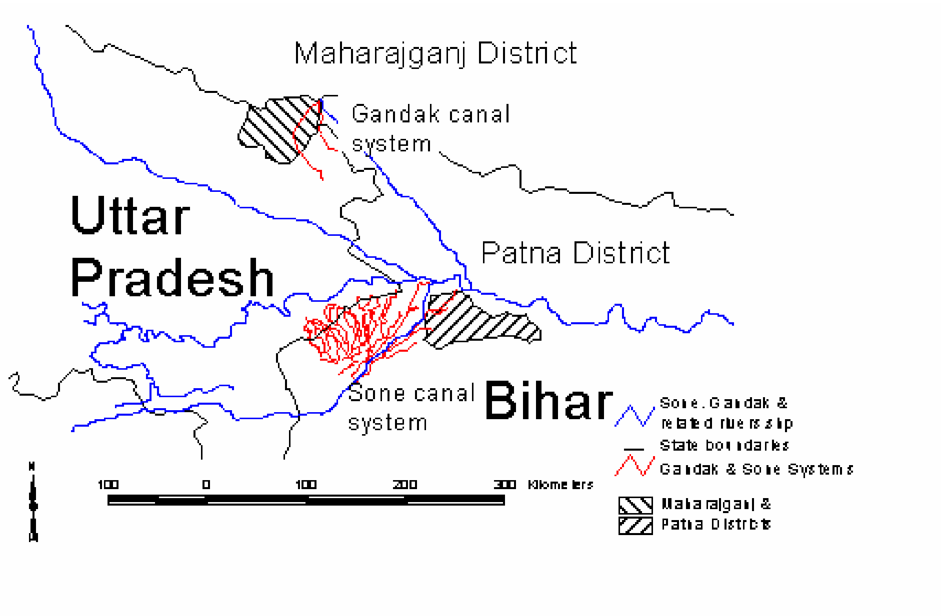
## 2.0 Materials and Methods

### 2.1 The Study Area

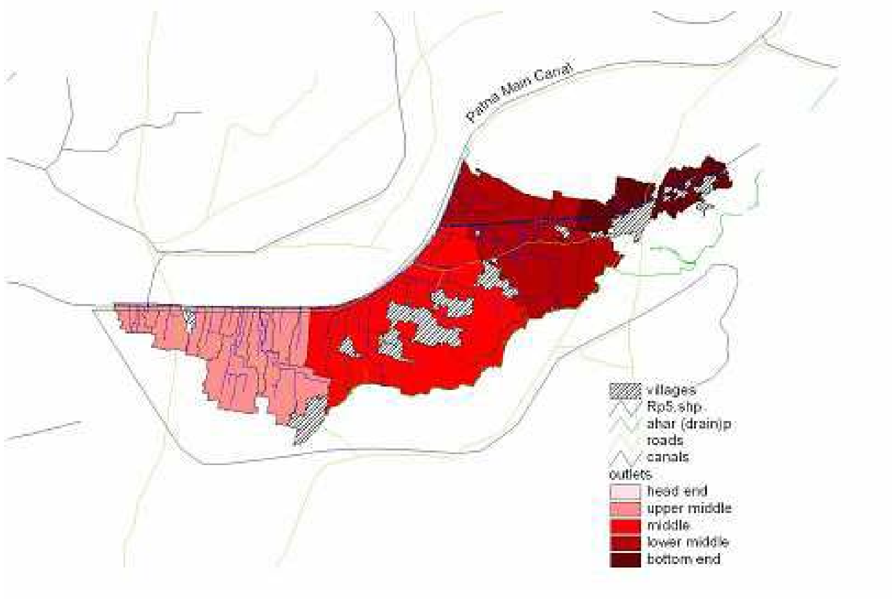
The study area comes under agro-ecological region 13 (Map 1). Fieldwork was conducted at different villages of RPCV command area (latitude $84^0$ 51' –$84^0$ 55' E and longitude $25^0$25'-$25^0$28'N) under Patna Main Canal System. RPCV distributary is □ km in length and carries a discharge of 1.42 Cumec. Another sub-distributary Tangrela takes off from 5.10 km of RP Channel 5 and is of 4.4 in length. Its design discharge is 0.□2 cumecs. The combined culturable command area of both is 1400 ha. Sixteen villages namely Amwa, Alipur, Bawan, Bedauli, Danara, Fatehpur, Gopalpur Gangachak, Harpura, Mohammadpur, Nishapura, Rampur, Sangrampur, Sikaria, Telpa, and Unchauri are selected for the study (Map 2 and 3).




# Map1. Agro-ecological Zones in India

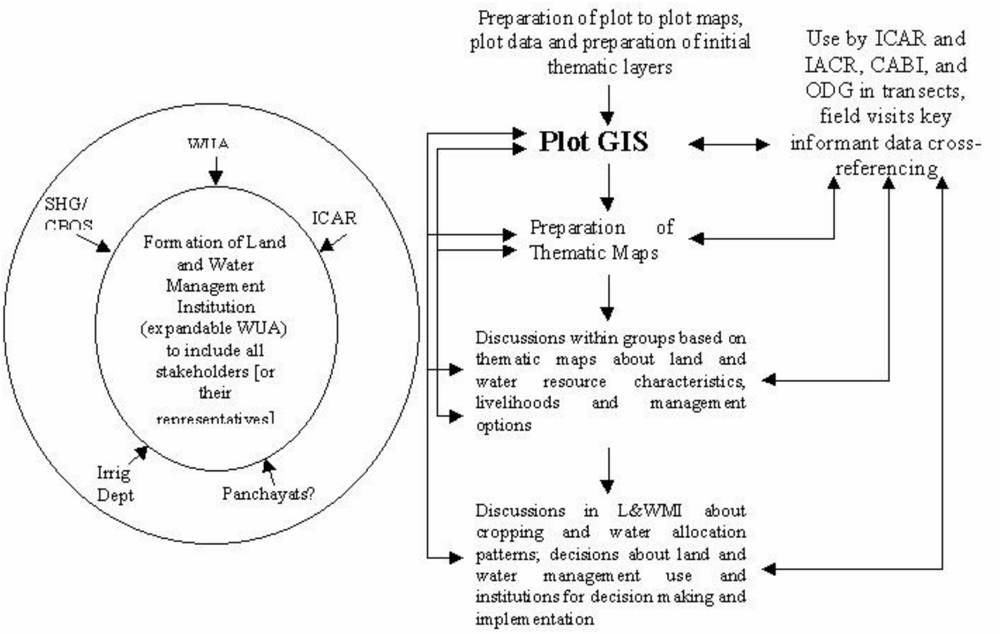



**Map.2 Patna and Maharajgunj Districts and Major Irrigation Schemes**




**Map3. RPC V Infrastructure**

## 2.2 Methodology




**L&WMI- Land & Water Management Institute**

### Fig.1 Interaction between GIS/direct observation data and other activities

Three main steps were involved: the first step was to produce geo-referenced database, the second was to use that to systematically and periodically enter data on variables through participatory approach which could be observed and the third step was to initiate dialogues between SHGs, farmers and scientists regarding the future soil, crop and water management strategies on the basis of thematic maps. The interaction envisaged between GIS direct observation data and other activities are shown in the Fig.1.

Existing revenue maps of the villages prepared during colonial period were collected from the Patna Cadastral survey offices. In the initial participatory sessions with the self-help groups, specific problems were discussed. Various issues starting from canal and water management, waterlogged areas, time of transplanting of crops, tillage options and agricultural laborers were the focus of the discussion. Villagers communicated well with the existing cadastral maps, but the condition of maps was very poor. After a number of discussions, it emerged that; agricultural production could be increased through improved management of land and water, appropriate technological interventions and improved communication between different stakeholders. The information requirements were a combination of basic spatial information and management information for managing land and water resources in best possible ways using qualitative and quantitative information. Data collection process was developed after finalization of information needs.

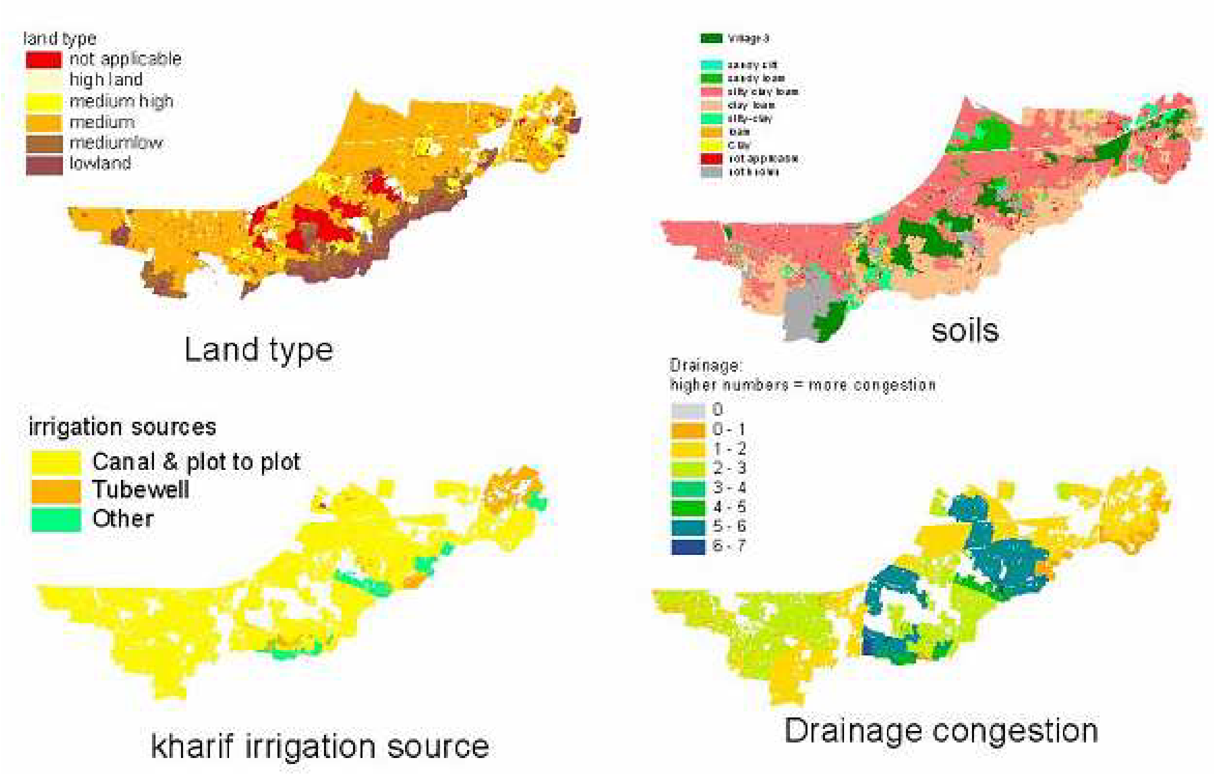
The boundaries of several villages were walked with the local key informants using a RACAL made Landstar DGPS georefernced maps. A number of prominent features (the Patna Canal Bank and the road from Akhtiarpur to Nabatpur) were traced using the GPS technique. These larger scale traces were used to reference the 1:50000 survey of India toposheet no. 72 C 15.They were also used to reference a LISS 3 image from the IRS 1D satellite taken in February 2000. Given confusion about village boundaries geo-referencing has been facilated by an up- to-date satellite image.

As the plot recorded in the village maps appeared to have poor correspondence with plots identifiable in the field; the plot to plot mapping was undertaken using Differential Global Positioning System (DGPS) and LASER range finder with built in compass coupled to Huskey fex21 Pocket PC (Compaq IPAQ) using pocket GIS software in WINDOWS CE environment. Each plot has been given a particular identification number. Direct observation data of the plot regarding land type; land use, soil type, crop, tillage, drainage and irrigation are recorded through a structured schedule formed using Satellite Form software on a Palm computer. Maps and direct observation data are integrated through ARC View GIS software through the common identification number. In that process 22000 plots in the entire area was mapped and cadastral maps with identification number of plots were constructed.

Community Building Organization (Self Help Group) volunteers were trained in using palm IIIxe for recording direct observation data in respect of each agricultural plot as per cadastral maps. Information regarding date of sowing transplanting of crops, tillage practices, source of irrigation and methods of irrigation, location of outlets, outlet commands, tube wells and presence association of different self-help groups in the villages were recorded by them. They charged Rs 0.5 per plot for recording data during temporal and spatial monitoring. They collected response from villagers regarding the maps. Thematic maps of the whole command area regarding different aspects have been produced on the basis of direct observation data and the raw inventory data were made available to use by water management groups, agronomists, social scientists, farmers and self help groups for taking management decision with suitable interventions. On the basis of temporal and spatial monitoring of plots in kharif season; date of transplanting of paddy in different outlet commands, area coverage under *kharif* crops mainly paddy in each command were estimated from attribute data of thematic maps. Tube well-irrigated area has been marked and the plots irrigated through tubewell during different periods of time have been identified and possibilities of conjunctive water use in different reaches of the canal are being explored. Outlets along the distributary and command areas under each outlet have been marked with the key informants. Using these Geo-referenced plot maps of villages, Participatory Rural Apprisal exercise (Geo-PRA) was conducted to integrate social and natural resource information in respect of each plot. The information were uploaded to the laptop and integrated in a GIS environment to develop thematic maps.

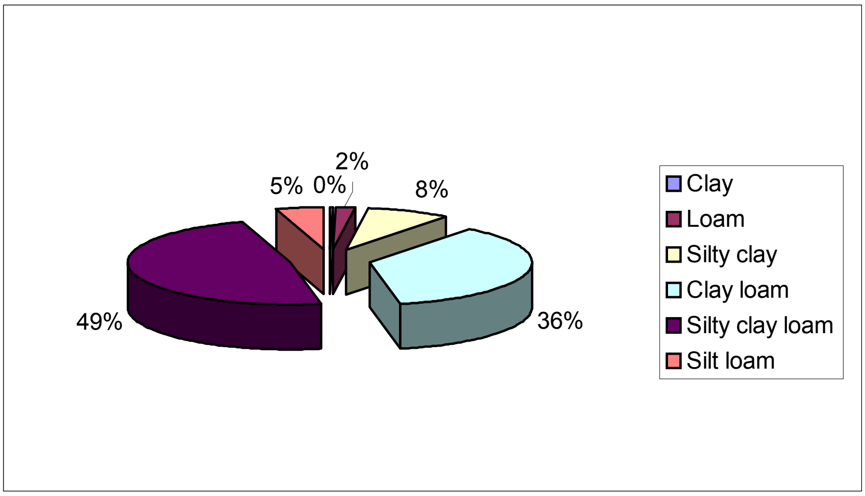
## 3.0 Results and Discussions

Cadstral maps with basic information of land type, soil, *kharif* irrigation source and drainage




congestion were prepared (Map 4.)

**Map 4. Land and Water Characteristics of RPC V command**




Information extracted from the thematic maps revealed that, the soil texture of the area is dominated by silty clay loam (49%) followed by clay loam (3□%) as per the (Map4 and Fig. 2) Heavy soils were

**Fig.2 Percent area under different soil textures**

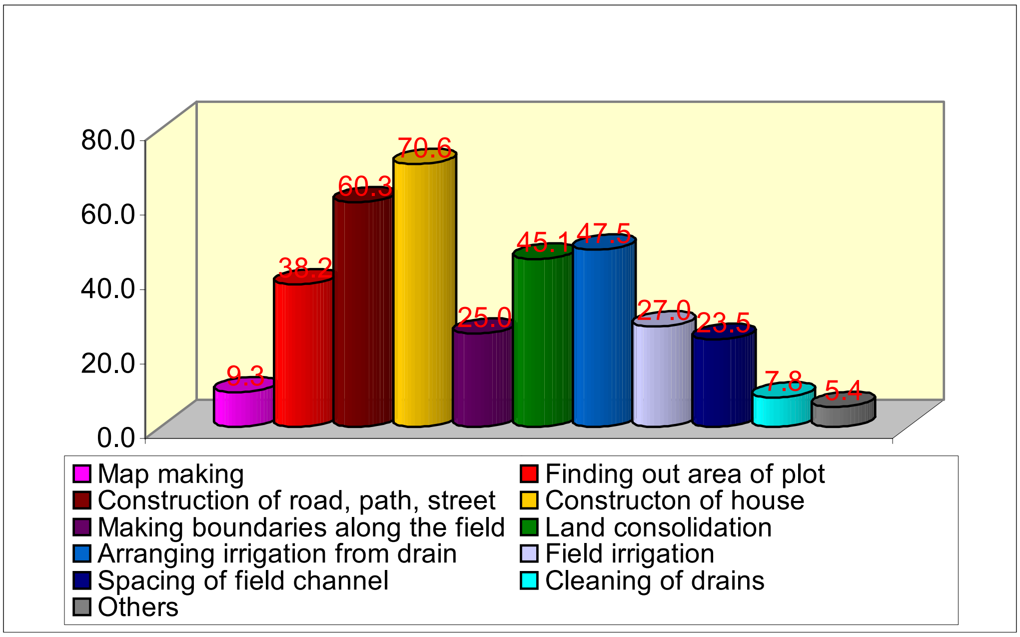
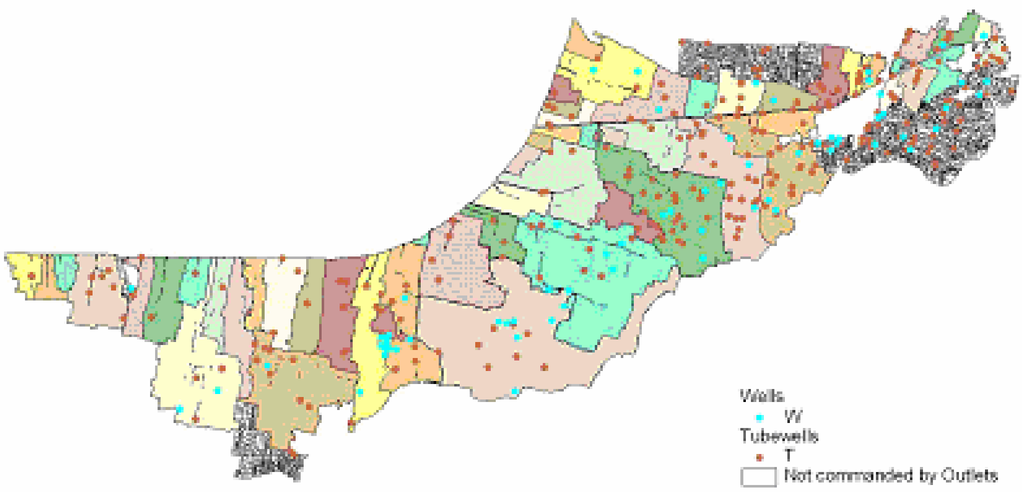



**Fig.3 Farmers' reaction (percent) regarding maps**

ers were excited with rapid survey techniques. They were capable to interpret the maps. Gradually, they learnt to use palm computer. Village volunteers themselves later recorded direct observation data using palm and cadastral maps during temporal monitoring of changes in natural resources in exchange of money. In these processes unemployed youths of villages acted as service providers and got employment opportunity.




**Map 5. Locations of canal outlets, tubewells and wells**

DGPS was much harder for community to use for scientific mapping. However, villagers quickly grasped ideas of DGPS- Laser range finder survey of the plots. Farmers' responses regarding the

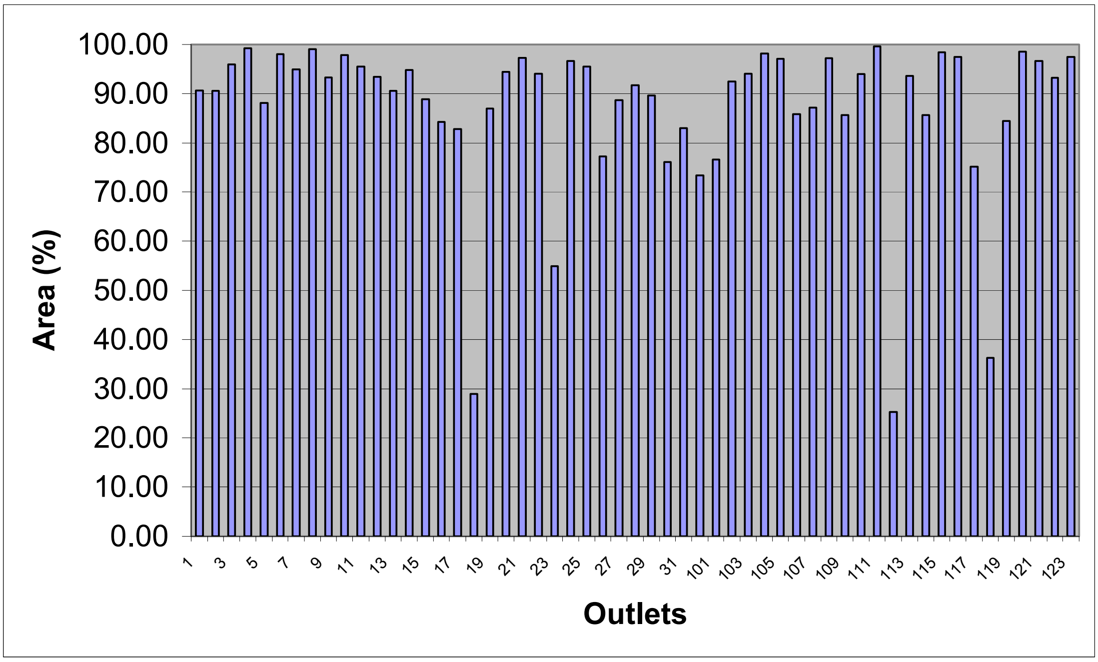
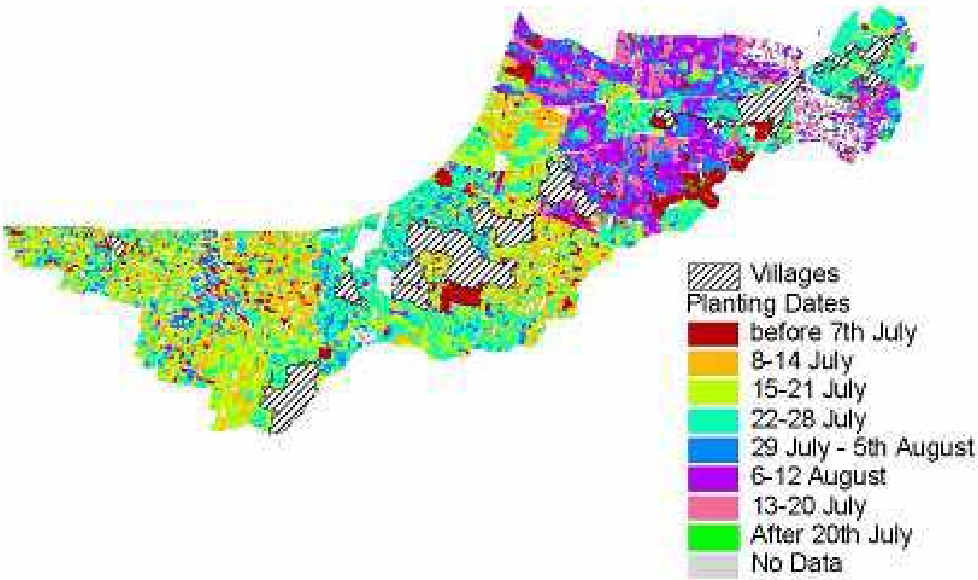



**Fig.4 Paddy area (%) under different outlets**




**Map 6. Planting Dates in Kharif 2003**

maps revealed that, the maps were very useful for solving land dispute problems, planning agricultural activities, and judging accessibility of their fields to irrigation (Fig.3).

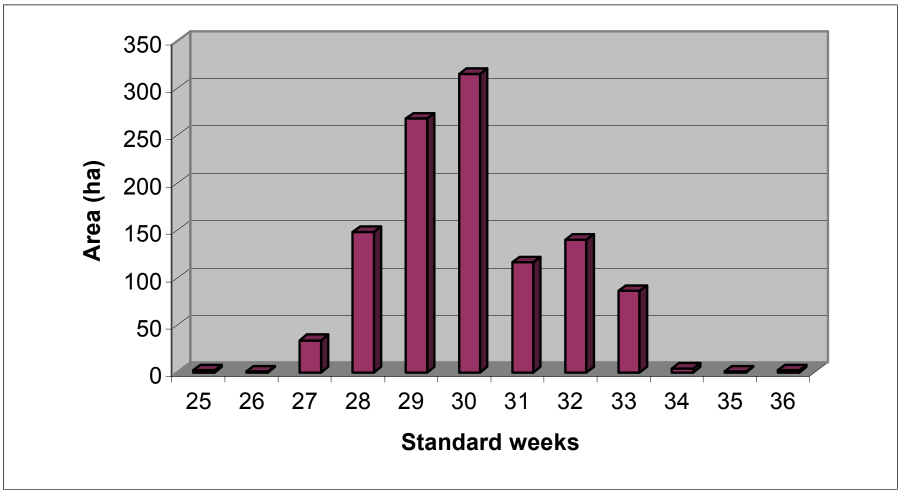



**Fig.5 Area (ha) transplanted by paddy in different weeks**

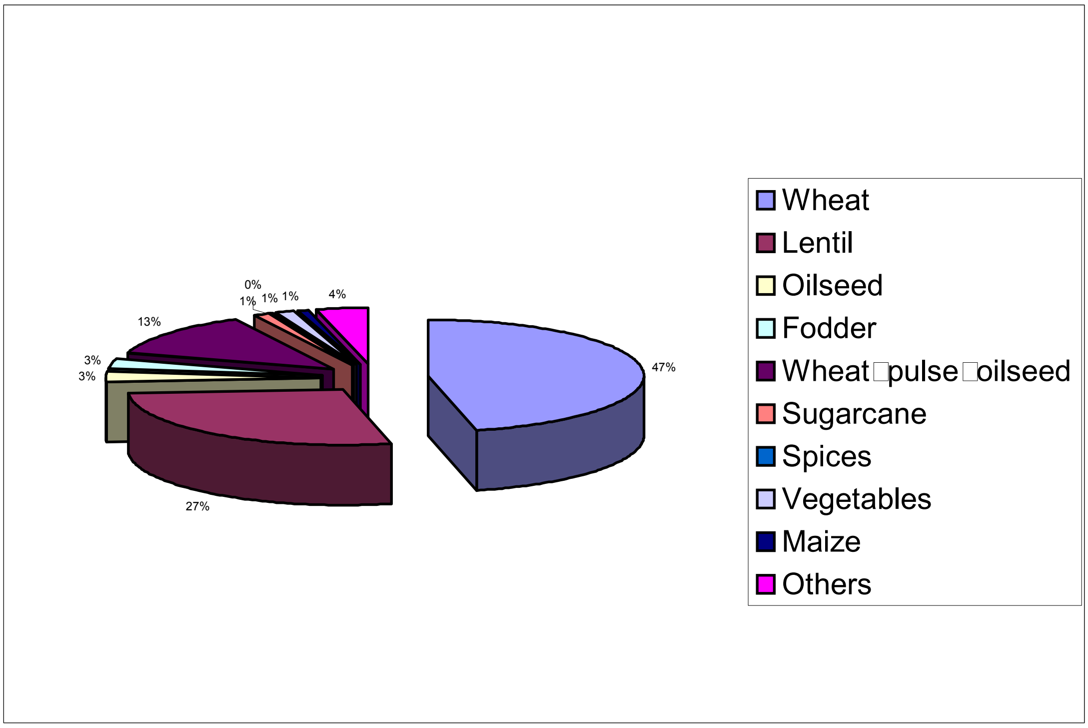
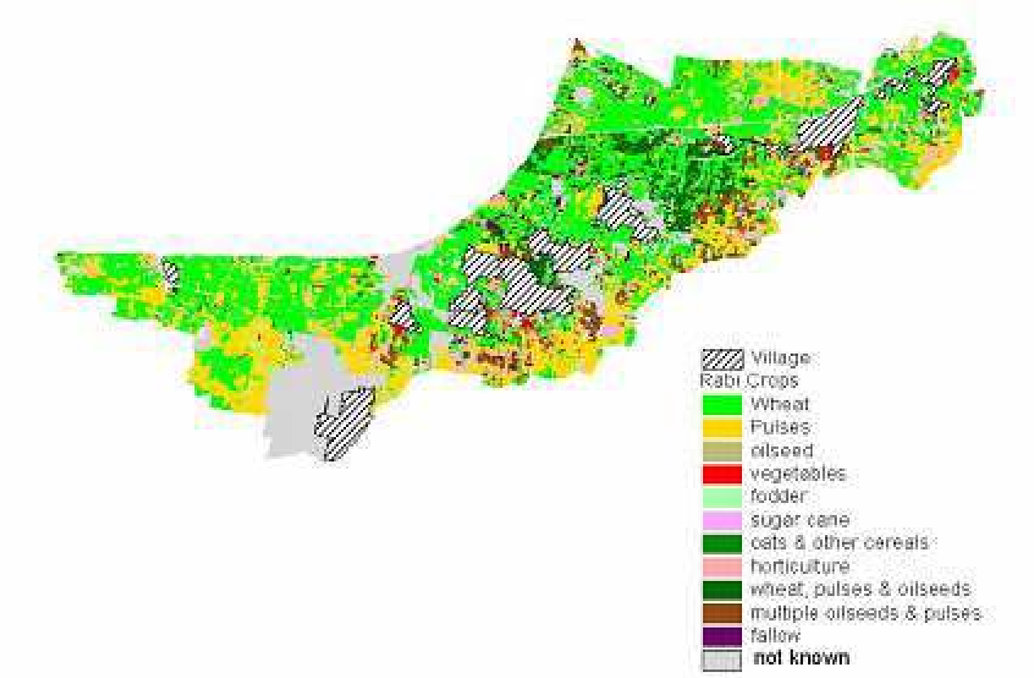



**Fig.6 Percent area covered by *rabi* crops**

Total number of outlets existed in the study area is 55 covering 127□ha command area (Map 5). The percentage of paddy coverage varied between 80-100% in most of the outlet command area, whereas, in few outlet commands the range varied from 30- 50% (Fig.4). During *kharif* season

1117 ha area was covered by paddy. Timely (before 30th July) transplanting was done in 40.□% of the area, whereas it was late in 38.□% and very late in 20.8% of the area (Map □ and Fig.5). Percentage of area covered by paddy under different outlets and date of transplanting of paddy were used as input of water balance model to generate different scenarios of water availability.




**Map7. Rabi crops in RPC V in 2003**

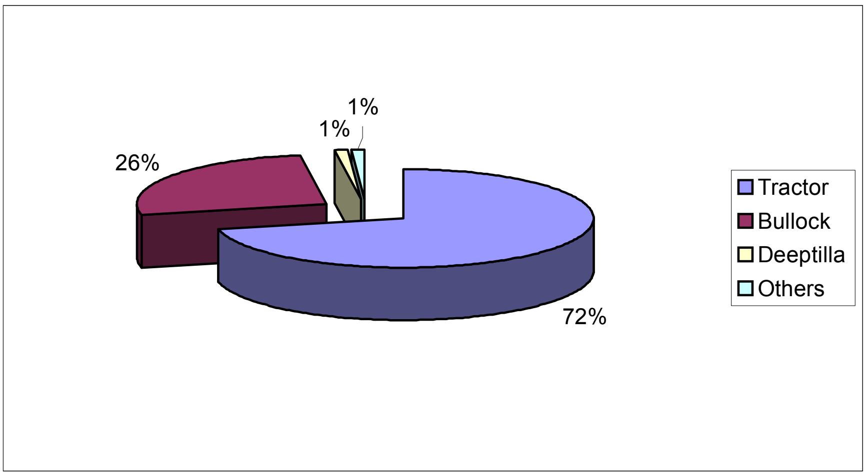



**Fig.7 Percent Area under different tillages in 2003**

Wheat is the major crop in *rabi* season occupying 4□4% of the total area is raised in proximity to the distributary during *rabi* season. Wheat, oilseeds and pulses (mixed crop) occupied 12.□% of the area. Farmers are taking more pulse crops in the heavy soils of low-lying areas near the drain and lentil occupied 27.4% of total cropped area (Fig. & Map 7).

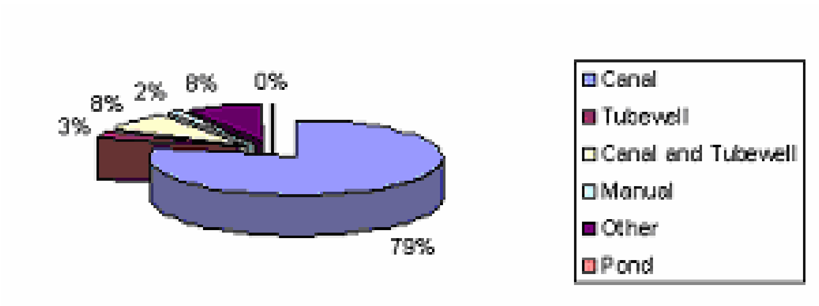



**Fig.8 Percent area covered by different sources of irrigation**

Conventional tillage through tractor is used in 72% of the area followed by bullocks (25%) in the command (Fig.7). Practice of deep tillage and zero tillage is also picking up steadily as per the need of farmers. In the RPCV command area, 79% area is irrigated through canal and 8% of area is covered under tube well irrigation. 8% of the area is covered by both canal and tubewell irrigation (Fig.8).

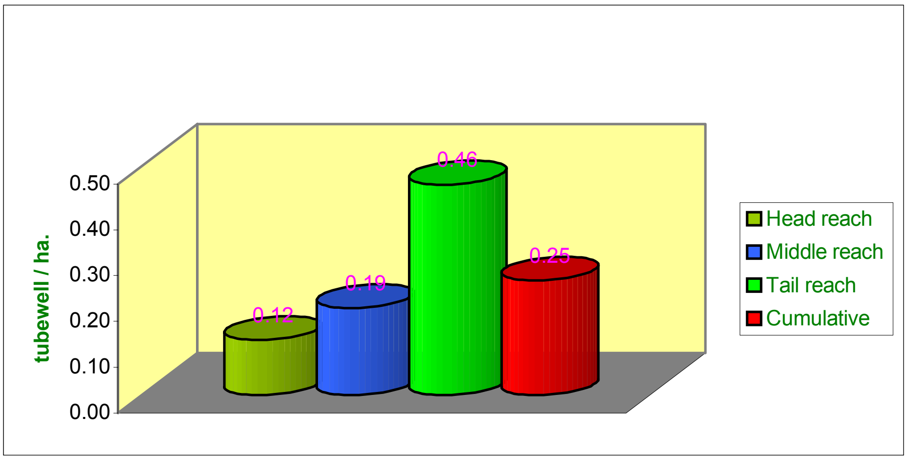



**Fig.9 Tubewell density (per ha.) in the canal command**

325 wells are existing at present in the command area, out of which 257 are shallow tube wells, 24 are deep tube wells and 44 are open wells (Map 5). Highest tube well density of 0.4 ha was observed in tail reach followed by middle and head reach (Fig.9). Overall tubewell density in the command is 0.25 ha.

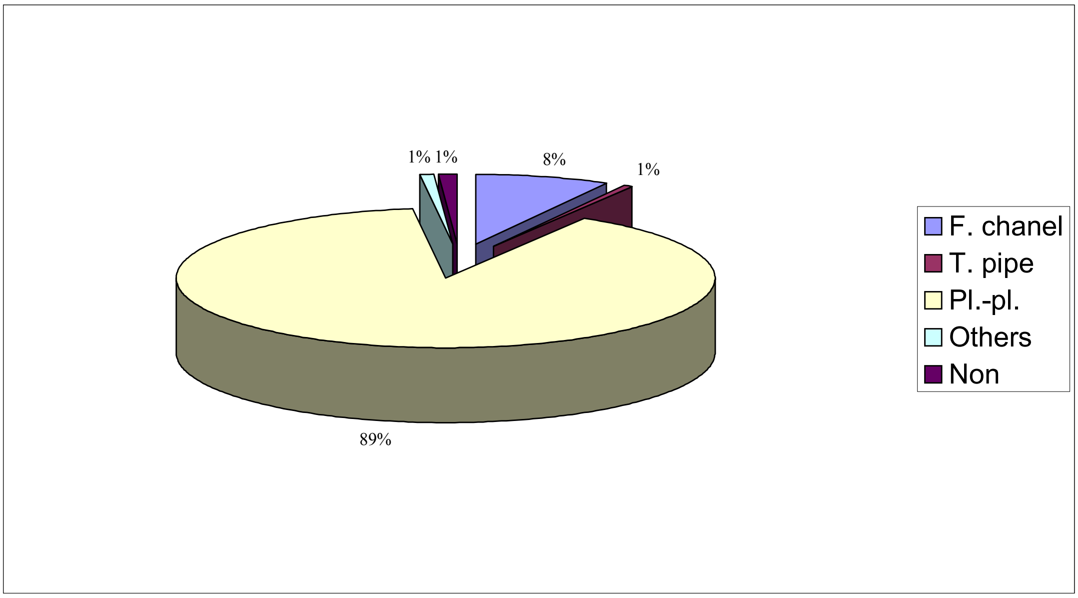
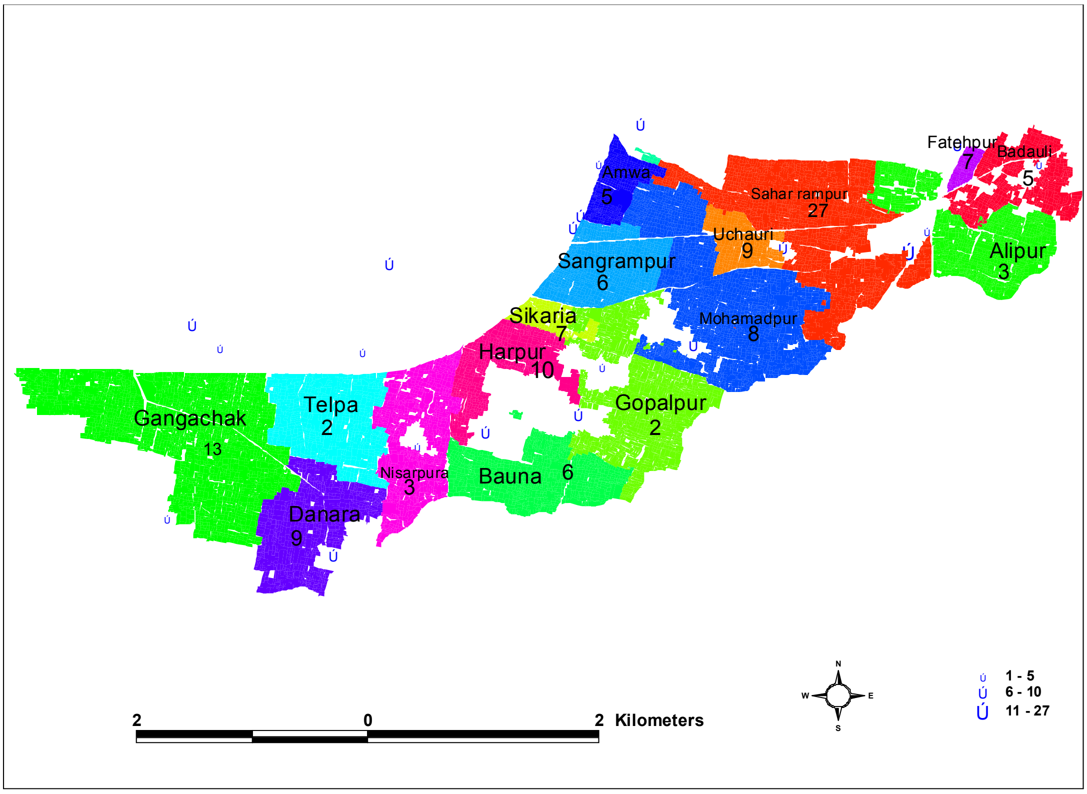



**Fig.10 Percent Area covered by different methods of irrigation (ha)**

Among different irrigation methods plot to plot irrigation has been noted to dominate with 89% of the area followed by 8% (Fig.10) through field channels causing loss of nutrients from top soil and poor yield of crops during *kharif* season

Self help groups developed by our project partner CMS are scattered in different villages. Most of the 150 self-help groups are confined in the head and middle reach of the command (Map 8).

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**Map 8. Distribution of self help groups in different villages**

## 3.1 Use of Maps

### *3.1.1 Cadastral Maps in Communication and Planning*

Cadastral maps were used for communication among different stakeholders for planning improved mangement related interventions.

**Photo 1.Farmer points to revenue maps to describe land characteristics**

**Photo2.Scientists discuss land and water management with farmer using rough mosaic of Revenue Maps**

**hoto 3.Community is using GIS maps in participatory mapping and livelihood planning**

## 3.1.2 Use of maps by SHGs

•Maps were shown and discussed within group members for crop planning on the basis of land type, access to irrigation to their plots , soil texture, crops and varietal performances

•Maps were used to substitute conventional rice varieties with high yielding hybrid rice towards improved productivity

•It would facilitate landless people to choose lands on lease basis after considering natural resources availability

•These thematic maps contain comprehensive information in respect of agricultural plots including boundary updates, therefore are better than revenue maps which contain area of the land only

•Maps can be used to easily depict, monitor and compare the self-help groups and their income generating activities

•The maps have good potential market among the group members for its multipurpose use

•The maps could be effectively used for better planning and utilisation of natural resources leading to improvements in livelihood of poor, landless, sharecroppers and women

(Source: Sunil Chowdhury, CPSL)

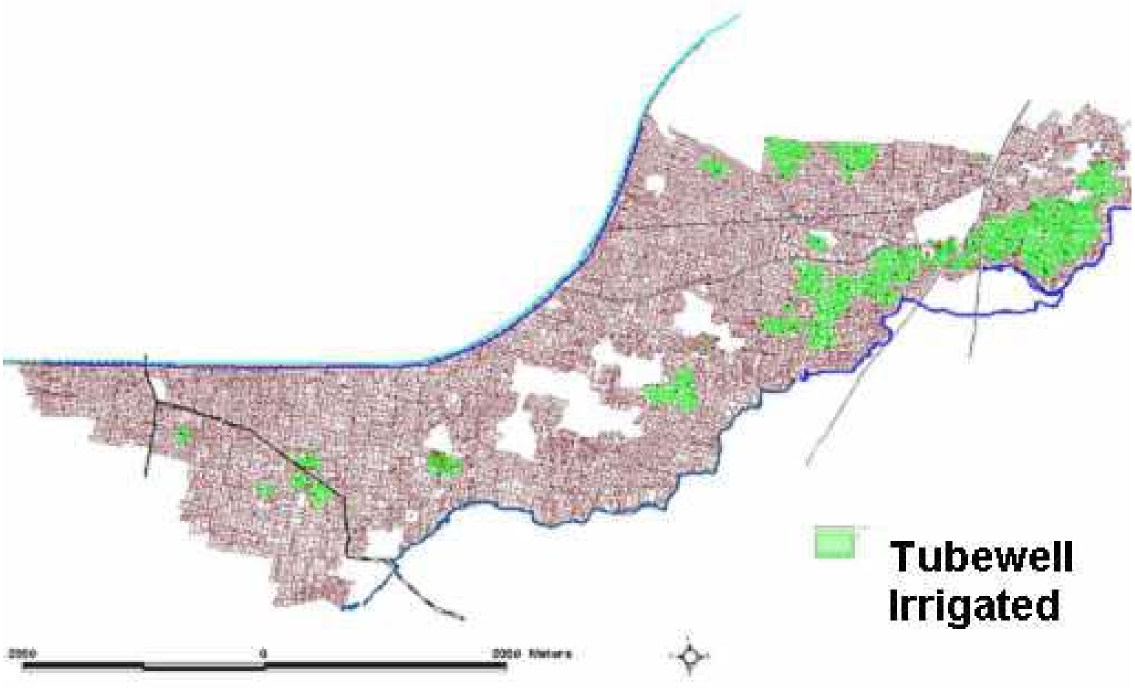
*This leads to innovation in localised efforts to manage waterlogging, cleaning of well, purchase / rent of tube wells to irrigate vegetables.*

### 3.1.3 Assess progress of technical innovations – early transplanting of kharif rice

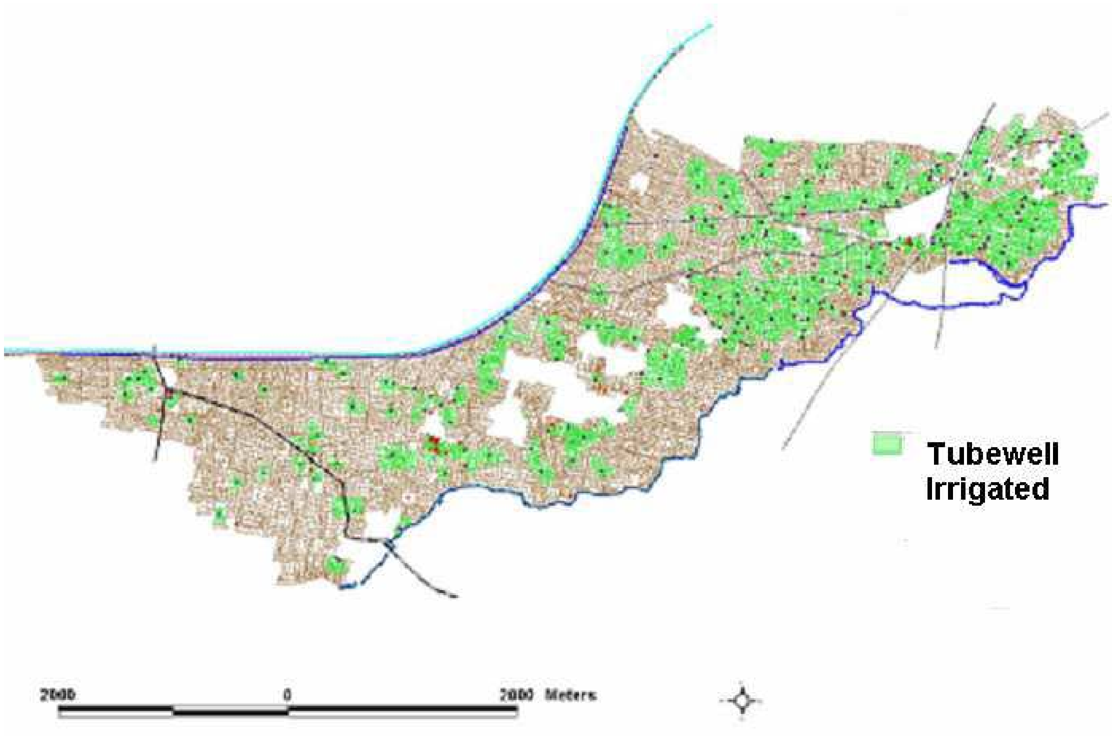
Land preparation for rice is done only after arrival of monsoon in the region. Delayed rice-planting leads to late harvest and late planting and low yields of wheat in *rabi* season as temperatures climb rapidly in February. Maps helped to monitor progress in adoption of early transplanting with Direct Observation data linked to GIS.

### 3.1.4 Use of maps for identification of tube well irrigated area for different purposes through direct observations

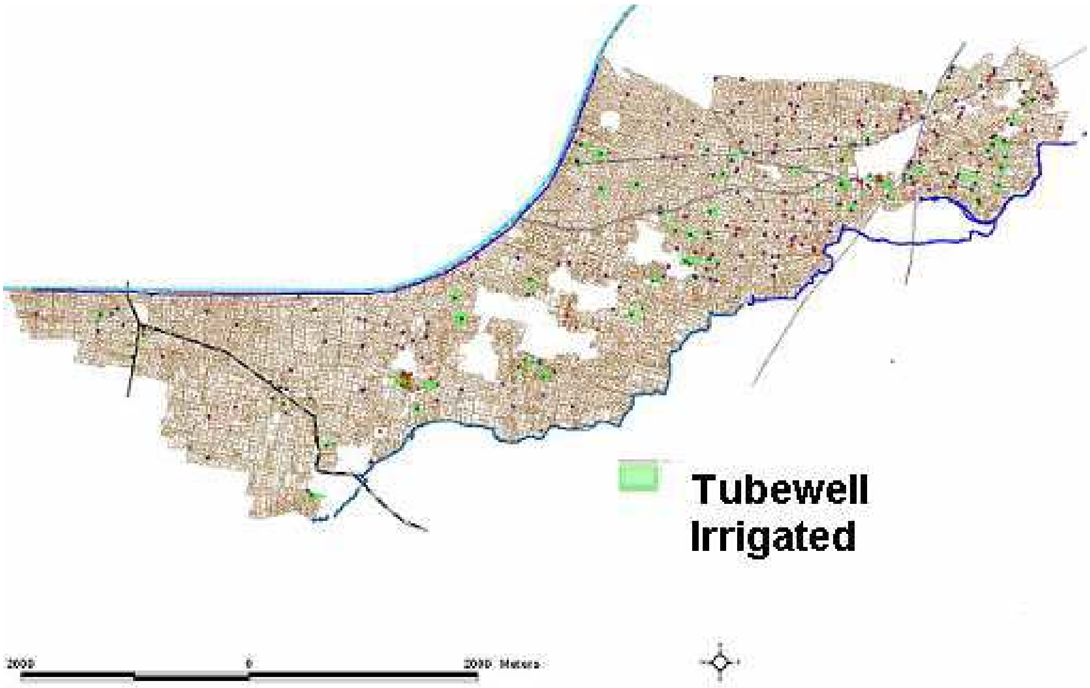
Tube well irrigated area for different purposes and different periods of time was identified through direct observation data using the cadastral maps as depicted in the following maps (Map 9-12).



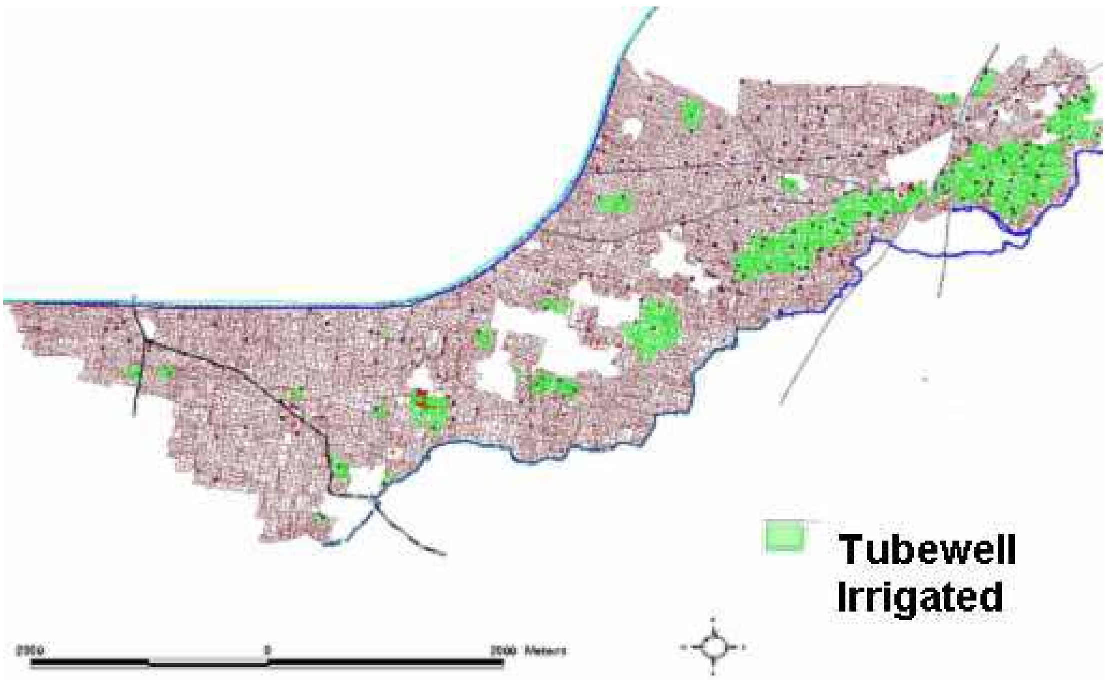

**Map 9. Tube well Irrigation during Kharif crop**




**Map 10. Tube well irrigation at critical periods of crop**




**Map 11. Tube well irrigation for nursery preparation**




**Map 12. Tube well irrigation during *rabi* crop**

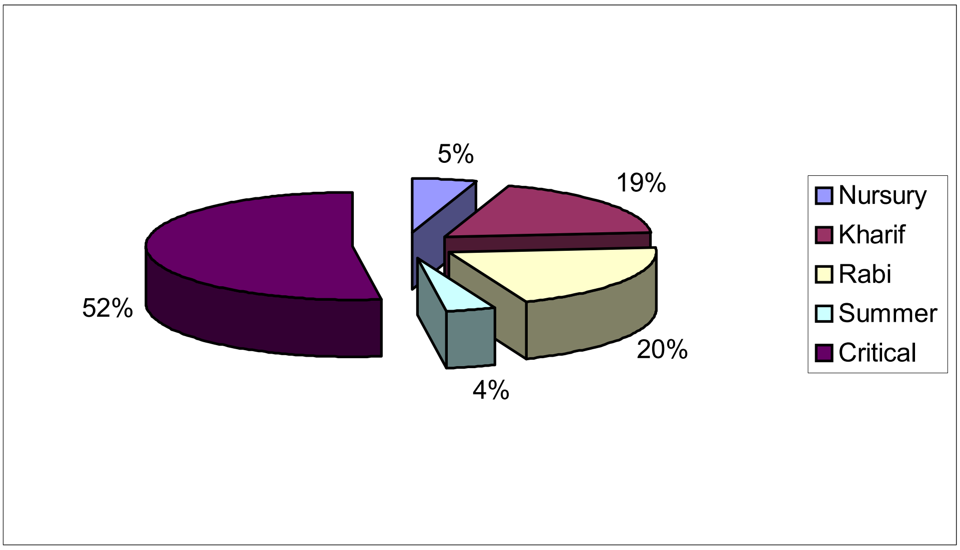



**Fig.11. Percent use of tube well irrigation for different purposes**

Tube well water was used for nursery growing in 3□ha.of plots. 134 ha of plots were irrigated by tube well water during kharif season in conjunction with canal water. Irrigation was provided to 374 ha command area from tube well during water crisis period (Fig.11)

### 3.1.5 Addressing Water-management issues

- Water mismanagement through formal and informal outlets has been identified through maps.
- Uncontrolled flow from outlets causes head reach-tail reach problem among community.
- Discussions with Water Users Association (WUA) with the maps for probable solution lead to the formation of Outlet Management Group (OMG).
- Head reach and tail reach problem was mitigated but could not be eliminated.

### 3.1.□Community Development

- Maps incorporated into the Dialectic approach for strengthening social and cultural capital.
- Poor and marginalized were empowered and entered into new relationships with scientists and other outside experts.
- WUA□OMG and SHGs recognise mutual benefits from planning water management and cropping patterns, including share cropped lands.

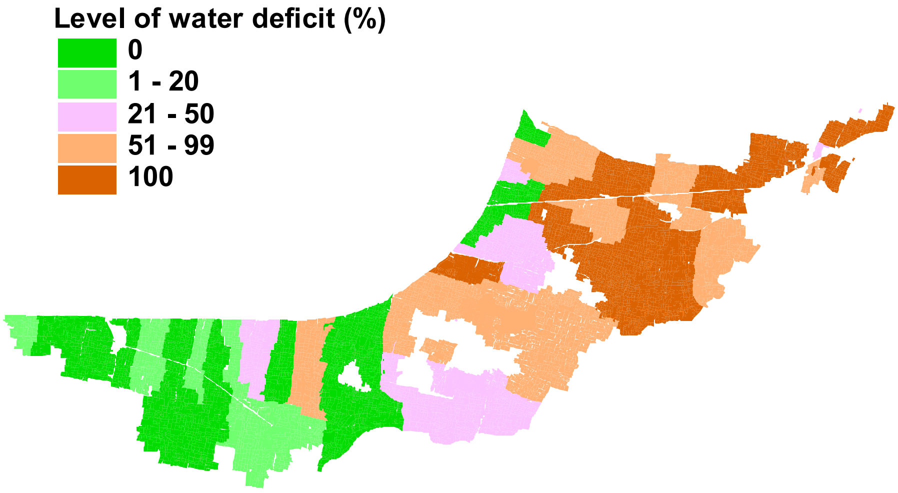
### 3.1.7 Estimation of water productivity

- Promoted interest in and dialogue on water and land management issues among stakeholders

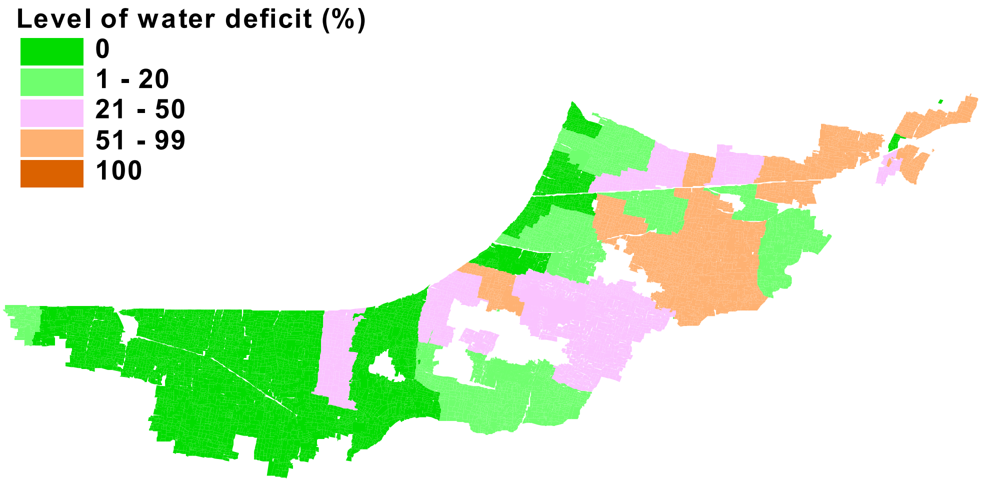
Thematic maps along with cadastral maps are now being used by water management scientists for estimating water productivity under different outlet commands of RPC V distributary in terms of plant biomass and food production.

## 3.1.8 Decision Support System (DSS) tools through linkage of PGIS maps and model

Offline linkage between maps and water balance model (Annexe B-vi) has been established to develop a Decision Support System (DSS) for facilitating water management related interventions by outlet management group in cases of different discharges from main canal during on and off periods of canal operation.




**Map 13(a). Water availability in uncontrolled outlet**




**Map 13 (b). Water availability in controlled outlet**

Thematic maps generated through linkages of water balance tool and GIS mapping estimated that, with the uncontrolled outlets, water loss through surplus flow is 32.19 % and water applied to field is only 35.38% (Map 13 a). It predicts that if all the outlets have controlled flow, 25.99% of water will be lost due to surplus flow and availability of water due to irrigation will rise to 43.52% (Map 13 b).

## 4.0 Conclusion

## 4.1 Evaluation of technology

### 4.1.1 Hardware and brainware

•Reliable hardware and software and adequate budget is necessary for the work

•DGPS is not necessary

•Laser Range Finder (LRF), PDA & Pocket GIS, Direct Observation (D.O) & Palm and Satellite Forms are a viable technology

•Regular backup on desktop and data archiving with reliable and properly used UPS is mandatory.

•Mapping requires proper aptitude, interest and training

4.1.2 Appropriate management of field survey work during different seasons are crucial

- It depends on land characteristics, competence, work organisation and weather
- Visual blockages (trees, sugar cane, buildings, standing crops, standing water, rocky outcrops) creats problem
- 1-500 plots per day @ 0.05ha per plot = 5-30ha per day can be covered as per the competence of the individual worker

## 4.1.3 Participation by community could aid both mapping and Direct Observation

- Community should be organised in advance for proper participation during GIS mapping
- SHG, WUA or Schools institutes should be trained and used for mapping for cost effective result.
- During the process of developing maps more meetings and discussions with the members of groups are required for growing awareness among the groups and making it user friendly.

## 4.2 Lessons Learnt

**GIS used in participatory processes but not driven by "participatory mapping"**

- Most important stakeholders found the GIS useful once it is in place
- But did not appear to recognise potential in advance

**GIS proved a valuable resource when partners encountered research and communication problems**

- GIS needed to be in place to respond to emerging issues and problems

**Implications for scaling up above the outlet**

- Costs and time to prepare GIS maps was heavier than anticipated. It should be cost effective and rapid, so that interventions should be planned and implemented in time

## 4.3 Scaling Up

- Linkage of GIS and water management model was demonstrated to State level canal managers and promoted dialogue about alternative water management strategies
- Dialogue among project team members and Irrigation department stakeholders to analyse problems and solution has been initiated for future uptake.
- It was presented to Federal Ministry of Water Resources which showed interest in GIS for improved Command Area Development
- Work was presented to various national level and international level symposiums held in India for future uptake
- Effort was made for scaling up to international agencies through oral presentation in front of water experts at Stockholm water symposium during World Water Week held at Stockholm, Sweden during 21st to 27th August,2005.

## 4.4 Policy implications

- Appropriate policy may be developed for construction of large scale maps for comprehensive survey and monitoring of natural resources through participatory GIS approach
- Guidelines of water release from main canal may be developed for different outlet commands on the basis of water availability scenario estimated from the linkage developed between maps and water balance model

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