Use of IRS-1C data in groundwater studies

P. R. Reddy, K. Vinod Kumar and K. Seshadri

National Remote Sensing Agency, Balanagar, Hyderabad 500 037, India

Satellite data have been proved to be highly useful for groundwater studies and mapping. Using the coarser spatial resolution data available from first generation satellites namely, Landsat, SPOT, IRS-1A and 1B, prospective groundwater zone maps could be prepared up to 1 : 50,000 scale. With the availability of higher spatial resolution data from recently launched IRS-1C, up to 1 : 10,000 scale is possible. A quick appraisal of the data available from different sensors of IRS-1C has been carried out to bring out their potentialities and capabilities for groundwater studies. The IRS-1C data are useful not only in identification of the prospective groundwater zones, but also in locating them properly on the ground. The high resolution data of PAN coupled with multispectral LISS-III data also provide spatial information about the extent of groundwater utilization for irrigation in different areas, help in groundwater budgeting, delineation of over-exploited areas and identification of problem villages to facilitate systematic planning and development of groundwater.

GROUNDWATER is one of the most important natural resources. In India, more than 90% of rural and nearly 30% of urban population depend on groundwater for meeting their drinking and domestic requirements. In addition, it accounts for nearly 60% of the total irrigation potential in the country, irrigating about 32.5 million hectares as compared to 25.8 million hectares irrigated by all major and medium irrigation projects put together. Due to its longer residence time in the ground, low level of contamination, wide distribution and availability within the vicinity and reach of the consumer, groundwater development gets first priority for meeting the evergrowing demand of water and occupies an important place both in the hydrologic cycle as well as in the life cycle of mankind.

Groundwater distribution in the ground is not uniform and is subject to wide spatio-temporal variations depending on the underlying rock formations, their structural fabric and geometry, surface expression, etc. Hence, to understand the movement and occurrence of groundwater below the ground, the geology, geomorphology structural set up and recharging conditions have to be well understood[1].

Use of satellite data in groundwater studies

From the interpretation of satellite imagery in conjunction with sufficient ground truth information, it is possible to derive significant information on the geology, geomorphology, structural pattern and recharge conditions which ultimately define the groundwater regime. During the last two decades, considerable work has been done in the country using satellite data[2,3]. Under National Drinking Water Technology Mission sponsored by the Department of Rural Development, the Department of Space with the active co-operation of several other departments has prepared the district-wise hydrogeomorphological maps on 1 : 250,000 scale for all 447 districts in the country using IRS-1A data[4]. Subsequently, the Department of Space has also demonstrated the potential of satellite data in preparation of 1 : 50,000 scale maps for limited areas.

With three sensors, viz. WiFS, LISS-III and PAN, IRS-1C can be considered as a three-tier system offering data for:

a) regional level studies on 1 : 50,000 scale; b) systematic and semi-detailed studies on 1 : 30,000 to 1 : 50,000 scale; and c) more detailed studies using 3-D information wherever required on 1 : 10,000 to 1 : 15,000 scale.

In this article we highlight the advantages and capabilities of IRS-1C data in groundwater studies based on a quick study carried out in parts of Ranga Reddy district, AP.

Methodology

The data provided by WiFS, LISS-III and PAN sensors of IRS-1C have been analysed using EASI/PAGE image-processing software. Initially, WiFS data have been studied to understand the regional geological, geomorphological and structural set up of the area for deriving a holistic view of hydrological conditions in the entire basin. Then, LISS-III data have been interpreted to map the major faults, fractures/lineament, hydrological features, etc. of a selected area for identifying prospective groundwater zones *vis-à-vis* the status of groundwater development on 1 : 30,000 scale. To obtain further detailed information, two small windows have been selected and studied in greater detail on 1 : 15,000 scale using high spatial resolution PAN data in conjunction with multispectral LISS-III data. The multispectral nature of LISS-III data has provided enough hydrogeological information, but it could not be enlarged beyond 1 : 30,000 scale owing to its coarser spatial resolution. The PAN data due to its finer spatial resolution could be enlarged up to 1 : 10,000 scale, but because of its panchromatic nature, sufficient hydrogeological information could not be picked up. In view of this, hybrid FCCs have been generated by resampling and merging the LISS-III data with PAN data and used for more detailed studies of small areas.

Results and discussion

The quick study based on visual and digital analysis of IRS-1C data has shown the following advantages/ potentialities for groundwater studies:

Analysis of WiFS data

WiFS data have provided synoptic coverage of large areas in a single frame, enabling regional understanding of the hydrogeological set up of the entire basin. It has been found that these data will be useful in basin-wise studies for:

i) groundwater resource estimation
ii) understanding the inter-basinal flow of water across the basin divides and
iii) adopting holistic approach for basinwise rainfall-runoff estimations and water budgeting (surface and groundwater).

Analysis of LISS-III data

The LISS-III data are superior to previously available LISS-II data from IRS-1A and 1B in terms of higher spatial and spectral resolutions. Due to its higher spatial resolution of 23.5 m, it has been found to be quite useful in semi-detailed surveys and mapping on 1 : 30,000 to 1 : 50,000 scales both for groundwater resource estimation and identification of prospective zones. Due to increased spatial resolution, the hydrological features like faults, fractures, groundwater-irrigated areas, etc. appear sharper and defined in LISS-III data. Further, the multispectral data provide information on crop types (paddy and irrigated dry crops) which are highly useful in estimating the season-wise and year-wise groundwater usage in different areas which form a critical input in groundwater resource estimation, planning and budgeting.

Figure 1 shows the LISS-III FCC (432 = RGB) imagery (reduced scale) of parts of Ranga Reddy district, AP which has been studied on 1 : 30,000 scale. The area is occupied by granitic gneisses intruded by dolerite dykes and cut across by a number of faults and lineaments. The dolerite dykes act as barrier for movement of groundwater, whereas the lineaments/faults which cut across them act as conduits for groundwater movement. The weathered zones within the granite gneisses contain limited quantities of groundwater. The water bodies (tanks) which are seen on the imagery as black patches not only provide irrigation facility in the area but also contribute for recharge to groundwater. Thus, by providing appropriate hydrogeological information the LISS-III data facilitate proper identification and mapping of prospective groundwater zones on 1 : 15,000 to 1 : 30,000 scales. The LISS-III data by providing spatial distribution of irrigated crop land as bright red patches (Figure 1) are not only useful in calculating where and how much of groundwater is being tapped for irrigation but also in classifying the entire area into over-developed, under-developed, optimally developed and undeveloped zones, indicating the status of groundwater development. Further, it was found useful for identifying the problematic villages either due to unfavourable hydrogeological conditions or due to over exploitation in their vicinity.

Analysis of PAN data

Because of its higher spatial resolution, the PAN data have been found to withstand large-scale enlargements up to 1 : 10,000 scale without breaking the pixels. Thus, bestowed with higher spatial resolution and stereo capability, these data provide information similar to aerial photographs on that scale.

The main advantage of PAN data is the proper identification of prospective groundwater zones on the ground. Earlier, in the absence of such high resolution data, often aerial photographs were used to exactly locate on the ground the faults, fractures and other hydrogeological indicators interpreted from satellite imagery. Now, in case of well-defined faults/fractures, their exact location on the ground can be identified more clearly using PAN data. The large scale enlargements of PAN data on 1 : 10,000 to 1 : 15,000 scale are quite useful in more accurate demarcation of the zones on the ground with the help of field boundaries, roads, villages, individual trees, stream courses and other controls. By overlaying or comparing the cadastral maps with PAN imagery on 1 : 10,000 scale, it is also possible to identify the survey numbers of the fields through which the fractures and lineaments pass. Further, due to finer spatial resolution, the minor slips, offsets and dislocations in the linear ridges and intrusives like dolerite dykes could be identified more easily. Thus, the faults responsible for such displacements which also form the prospective groundwater zones can be mapped more accurately using PAN data.

Analysis of hybrid FCCs of LISS-III and PAN

Figures 2 and 3 show the hybrid FCCs corresponding to two small windows shown in Figure 1. These images clearly depict minor faults and lineaments indicated by slips/offsets and gaps and in the dyke ridges. These faults/lineaments act as conduits for movement of water below the ground and form the prospective groundwater zone. With the help of field boundaries, cart tracks, stream courses and other reference points which are clearly seen on PAN data, these zones can be more accurately demarcated on the ground. In addition, some minor fractures originating from these major faults/lineaments, and passing through water bodies (tanks) which also form potential sources for tapping drinking water to the nearby village could be delineated.

Further, IRS-1C data have also been found to provide important inputs, especially in the following fields of groundwater studies:

In groundwater resource estimation. PAN and LISS-III data provide more accurate and season-wise information on the following factors which form essential inputs in groundwater resource estimation.

i) Spatial distribution and areal extent covered by reservoirs, tanks, canals, streams and other water bodies whose seepage form an important input to groundwater recharge.
ii) Irrigated area statistics (season-wise) which are useful

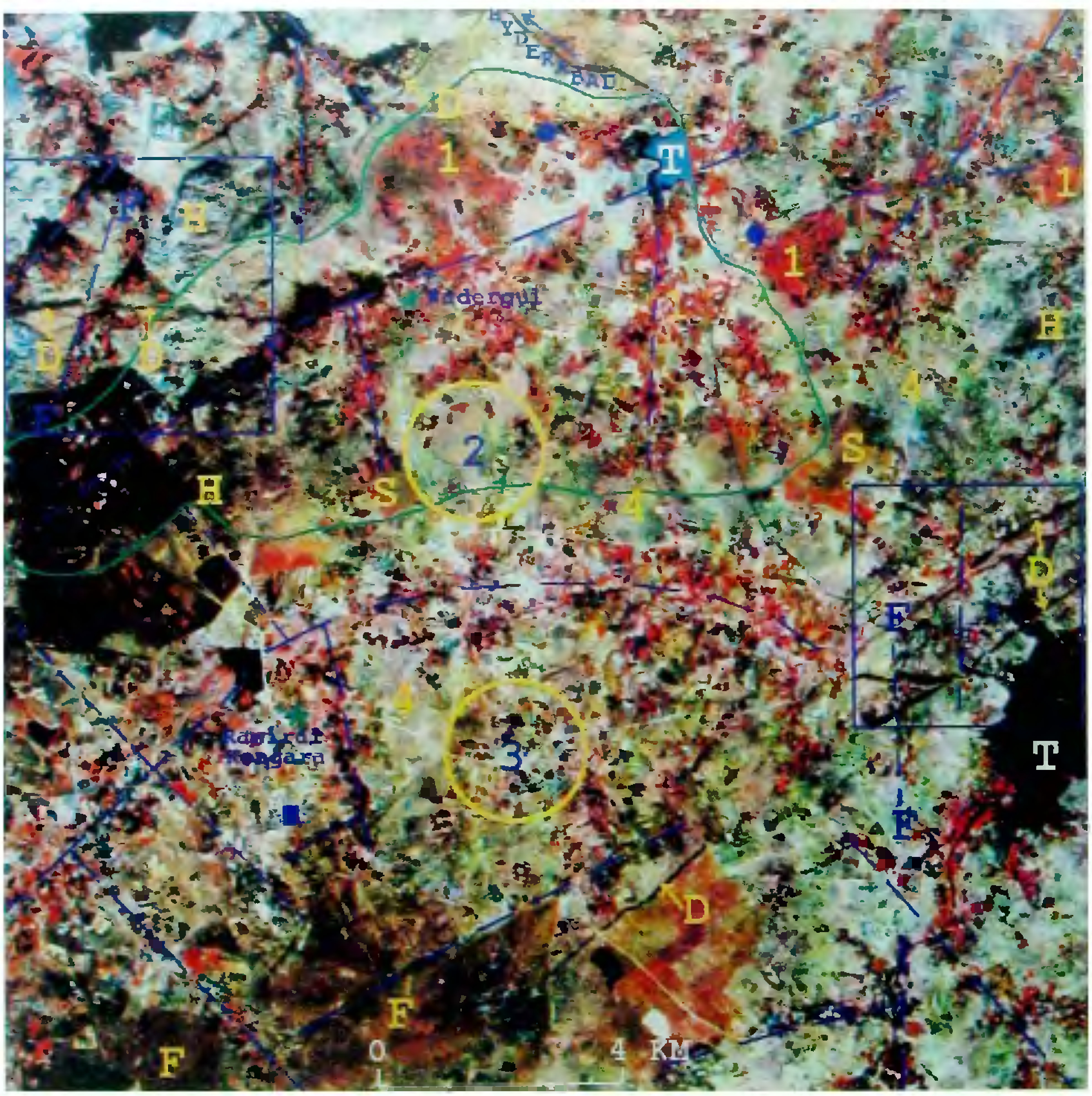

Figure 1. IRS-1C LISS-III FCC (432 = RGB) of part of Ranga Reddy district, AP showing various hydrogeological features. Two windows marked in blue colour represent the area taken up for detailed study using PAN data. H, Hills; D, Dyke; T, Tank; F, Forest land; S, Scrub land; F---F, Fault; ---, Fracture/lineament; *Nadargul, village name. Stage of groundwater development. 1, Overdeveloped; 2, Underdeveloped; 3, Optimally developed; 4, Undeveloped. Problematic villages. ●, Due to over-exploitation of groundwater; ■, Due to unfavourable hydrogeological condition.

in estimating deep percolation losses from the irrigated fields which also forms an essential input to recharge.

Areas of groundwater development and utilization. Satellite data have been proved to be highly useful in knowing where and how much of groundwater is really being utilized for irrigation purposes[5]. In the hard rock areas, arid and semi-arid regions where individual wells hardly irrigate 1–2 acres, mapping of such small patches and calculating the groundwater utilization in those areas were difficult tasks using the coarse resolution data. Now, the PAN data with 5.8 m spatial resolution, in synergism with LISS-III data have been found to be useful to identify and map such small irrigated patches based on which the status of groundwater development and utilization can be calculated (Figures 1 and 4).

Over-exploitation of groundwater. In many parts of the country where groundwater resource is limited, utilization of groundwater has reached a peak, resulting in drastic decrease in water levels and drying up of the existing wells. Besides wastage of investment by the farmers, this is also leading to serious socio-economic and environmental problems including severe shortage of drinking water in rural areas. The LISS-III and PAN data, by providing reliable information on the spatial distribution and extent of groundwater irrigation, have been found to be highly useful in identifying the zones/areas of over-exploitation (Figure 1) where appropriate remedial measures can be planned.

Systematic development and planning. The LISS-III and PAN data by providing information on the status of

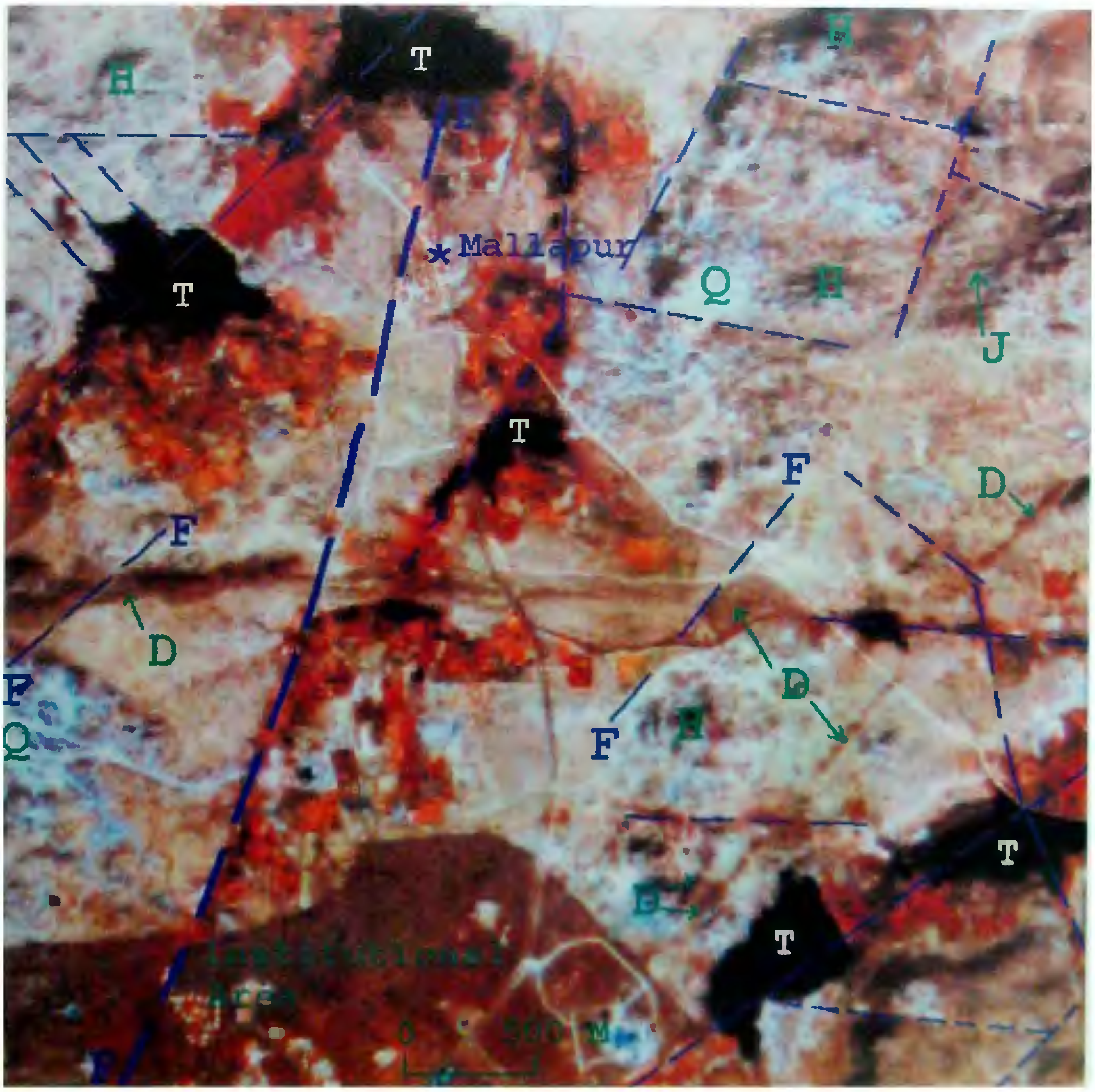

Figure 2. Hybrid FCC of LISS-III and PAN (BGR = band 2, 3 and PAN). H, Hills; D, Dyke; Q, Stone quarry; T, Tank (water body); F– – –F, Fault; – – –, Fracture/lineament.

groundwater development (through spatial distribution of groundwater-irrigated areas) help in identifying the under-developed and over-developed areas, besides locating prospective zones (Figures 1 and 4). Thus, it helps in planning appropriate remedial measures in the over-developed areas and systematic development in the under-developed areas.

Identification of problem villages. As discussed above, IRS-1C data help in identification of the areas where groundwater resource is scarce or not available. Based on this, the problematic villages having poor groundwater prospects can be identified. Similarly the problematic villages due to over exploitation in their vicinity can also be identified for adopting suitable remedial measures to solve the drinking water problems.

Conclusions

The IRS-1C data provide useful details required in groundwater studies. The high-resolution PAN data are useful in identifying more precise location of faults/fractures and other prospective groundwater zones on the ground with reference to field boundaries. The high resolution data are useful in providing spatial informations on the status of groundwater usage for irrigation. Further, the PAN data in synergism with the multispectral LISS-III data are useful in groundwater resource estima-

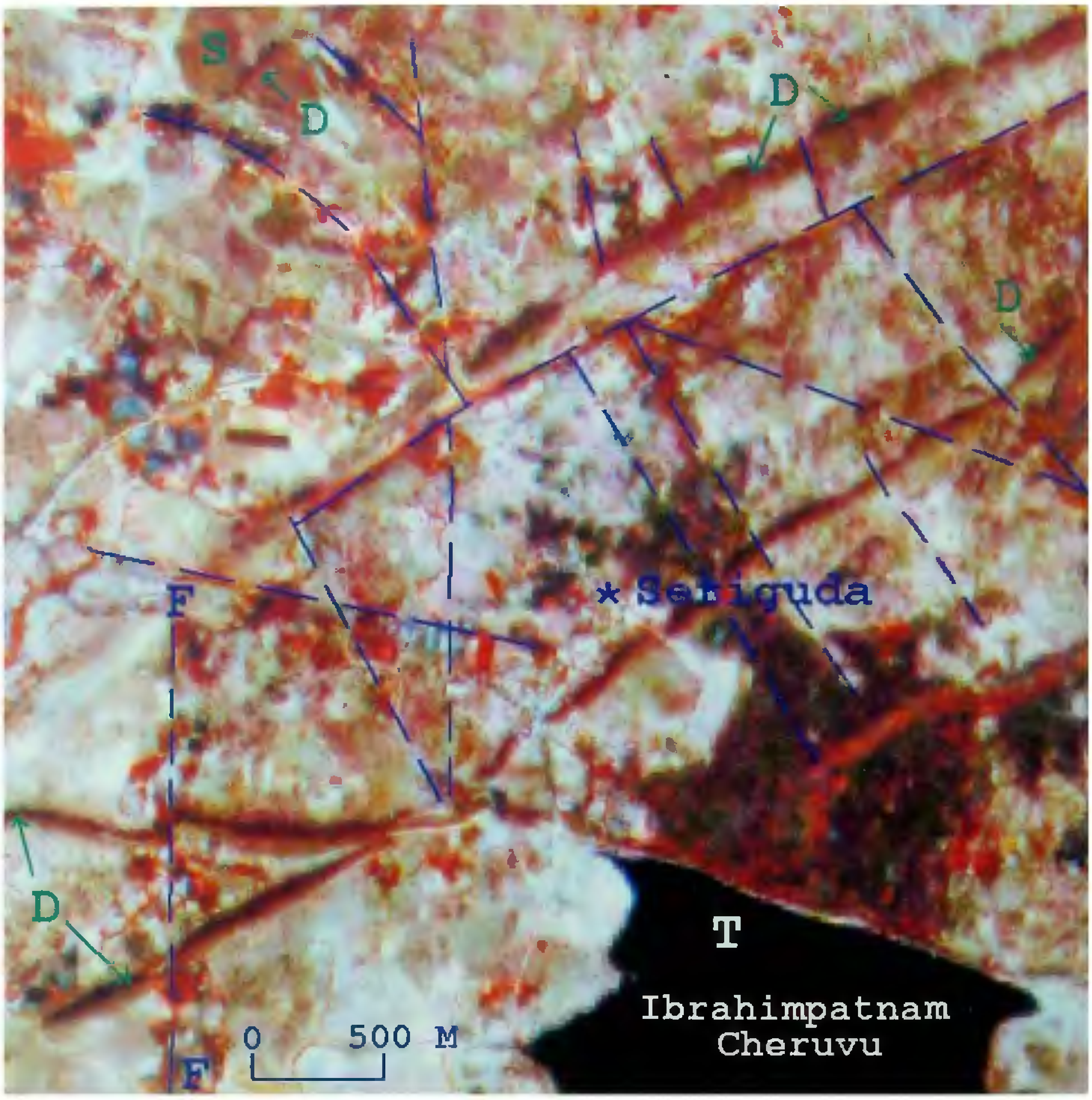

Figure 3. Hybrid FCC of LISS-III and PAN (BGR band 2, 3 and PAN). D, Dyke; T, Tank (water body); S, Scrub land; F– – –F, Fault; – – –, Fracture/lineament.

Figure 4. Hybrid FCC of LISS-III and PAN (Bands 2, 3 and PAN BGR) of a small watershed, which has been further subdivided into microwatersheds (W_1, W_2, W_3) on large-scale imagery 1 : 15,000 scale showing individual field boundaries clearly (printed on reduced scale). C, Irrigated crop land; S, Scrub land; P, Poultry farms.

tion/budgeting, mapping of over-exploited areas and identification of problem villages, etc. for systematic planning and development of groundwater to meet drinking and irrigational requirements in the rural areas.

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