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Assessment of Groundwater Potential Zone in Paschim Medinipur District, West Bengal – A Meso-scale study using GIS and Remote Sensing Approach

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Abstract

The investigation of groundwater in hard rock terrains is a complex task. To overcome this complexity, the integrated approach based on advanced applications of remote sensing and GIS lends itself to evaluate groundwater prospective zone based on multi-criteria evaluation approach (e.g. seasonal land use/land cover and vegetation, hydro-geology, geomorphology, soil, drainage density, monsoon and post monsoon water level and elevation). A probability weightage index overlay method was adopted that allows a linear combination of probability weights of each thematic map with the individual impact value using Bayesian statistics. These capability values are then multiplied with the respective probability weight of each thematic map. The result shows groundwater potentiality of Paschim Medinipur is stretched along the eastern part and in small pockets in northern and southern part. The hydrologic parameters-based groundwater potential zone map also indicated, 8.08% of the study area was classified as having very high potential, 11.99% high potential and 17.72% moderate potential. The groundwater abstractions structures feasible in each of the various potential zones have also been suggested. This study also provides a methodological approach for an evaluation of the water resources in hard rock terrain and enables an opening of the scope for further development and management practices.

Keywords: Remote Sensing, GIS, probability weightage index , Groundwater potentiality

1. Introduction

Groundwater is a dynamic and replenishable natural resource but in hard rock terrain availability of groundwater is of limited extent. Water resources development occupies a key place in India because of its role in stabilizing the Indian agro-economy. In India, more than 90% of the rural and nearly 30% of the urban populations depend on ground water for meeting their drinking and domestic requirements (Reddy et al. 1996). Dependence on groundwater has recently increased due to the introduction of high yielding varieties of crops and adoption of multi-cropping patterns, both of which require a timely, assured water supply and over exploitation of groundwater resources (Tiwari et al. 2009; Naik and Awasthi, 2003). Increasing population and agricultural activities are not only creating more demand for groundwater resources due to the inadequate availability of surface water resources, but are also polluting groundwater resources by releasing untreated wastes.

Groundwater, being a concealed natural resource, averse to direct observations and, hence, assessment of this resource plays a pivot role in determining locations of water supply and monitoring wells, and in controlling groundwater pollution (Roscoe Moss Co, 1990; Fetter, 2001). The most reliable and standard methods for determining locations and thickness of aquifers and other subsurface information though test drilling and stratigraphy analysis is very costly, time consuming and requires skilled man power (Todd, 1980; Roscoe Moss Co, 1990; Fetter, 2001). However, integrated studies using conventional surveys along with satellite image data, and geographical information system (GIS) tools, are useful not only to increase the accuracy results, but also to reduce the bias on any single theme. Previously, many researchers used the remote sensing and GIS technique to define the spatial distribution of groundwater potential zones on the basis of geomorphology and other associated parameters (Krishnamurty and Srinivas, 1996; Ravindran and Jeyaram, 1997; Sree Devi et al. 2001; Sankar, 2002; Jagadeeseara et al. 2004). Hence, a reliable procedure for the assessment of dynamic water resources potential is necessary to delineate the future groundwater potential areas.

The present study focused on the identification of groundwater abstractions structures feasible in each of the various potential zones in and around Paschim Medinipur district using RS and GIS.

2. Materials and Methods

2.1 Study area

Paschim Medinipur in West Bengal, India lies between 21°46′ N to 22° 57′N latitudes and 86°33′ E to 87°44′ E longitude (Figure 1), covered with an area of 9081.13 sq km. The district enjoys with tropical climate and the land surface of the district is characterized by hard rock uplands, lateritic covered area, and flat alluvial and deltaic plains. Extremely rugged topography is seen in the western part of the district and rolling topography is experienced consisting of lateritic covered area. These rolling plains gradually merge into flat alluvial and deltaic plains to the east and south east of the district. The soil is fairly fertile and a great group of the Taxonomic classification system as paleustalfs and haplaquents. Average temperature of the district varies widely across seasons, varying between maximum 43°C and minimum 7°C respectively with an annual average rainfall, 1428 mm.

2.2 Data used

Different types of data sets were used for preparation of ground water potential zone map of Paschim Medinipur block. (i) Landsat -5 Thematic Mapper (TM) sensor with better spatial resolution of 30m and seven spectral bands with 16 days revisit and 8-bit quantization were being used. The images were acquired nominally 9:30 am local time on a descending path. All the data scenes were acquired under clear atmospheric conditions during the dry and post-monsoon season; time weather is generally cloud free (during early April, 20010 and November, 2009). (ii) One of the most widely used digital elevation model (DEM) data sources is the elevation information provided by the shuttle radar topography mission (SRTM), but as with most other DEM sources, the SRTM data requires significant levels of pre-processing to ensure that there are no spurious artifacts in the data that would cause problems in later analysis such as pits, spikes and patches of no data. In the case of the SRTM data, these patches of no data are filled, preferably with auxiliary sources of DEM data, like-topographical maps. (iii) Three topographic map sheets (73J, 73N, and 73O) at a scale of 1:50000 cover the Paschim Medinipur district, West Bengal, India. Additionally, block map was also collected at the same scale. These maps were digitized from paper maps to produce the infrastructure map of the Paschim Medinipur (figure 1). The digitized map was also used to perform the geometric correction of the satellite images and to confirm ground truth information. The root mean square error (RMSE) of the image to map registration was 0.40 and 0.45 pixel, while was 0.10 and 0.14 pixel with image to image registration. (iv) One hundred and sixty nine wells were surveyed from the entire Paschim Medinipur district during monsoon and post-monsoon periods of 2009 to provide the information about the water level. Location of wells has been obtained with handheld Global positioning system (GPS) and plotted on map with its coordinates in ArcGIS (v9.2) environment. These points were used to examine the training sets, during delineation of ground water potential zone. The details of all the data were given in the table 1.

2.3 Satellite data and image processing operation

The satellite data sets were geometrically corrected in the datum WGS84 and projection UTM zone N45 using the second order of polynomial function and nearest neighbor resampling method, which was chosen in order to preserve the radiometry and spectral information in the imagery (Richards and Jia, 1999). All the images were mosaicking and subset to the boundary of the Paschim Medinipur district. Image processing was completed using ERDAS IMAGINE 9.2 (Leica Geosystems, 2008) software.

Land use/land cover maps were produced to identify the different classes of land from Landsat5 TM imagery. Different training sets were delineated for each land cover class and verified through a digital topographic map, ground truth points, and the visual interpretation of different images. Using the training sets, various spectral signatures for each class were developed and evaluated using separability analysis to estimate the expected error in the classification for various feature combinations (Landgrebe, 2003). Using a separability cell array, different spectral signatures in each class were merged together (Jensen, 2004). The maximum likelihood decision rule, the most common supervised classification method used with remotely sensed imagery data (Richards and Jia, 2006), was used as a parametric rule. The study area was classified into 12 land cover classes, indicated that river, sand, surface water body, settlement, moist land, dry fallow, dense forest, degraded forest, open forest, lateritic land, crop land, and agricultural fallow.

The NDVI is the most widely used index in the processing of satellite data (Myneni et al. 1995; Tucker, 1979). Rouse *et al.,* (1974) initially proposed the normalized difference vegetation index (NDVI) images were generated from the ratio of RED (Band3) and NIR (Band 4) bands of Landsat5 TM after calibration coefficients procured from corresponding header file. The images were applied for monitoring vegetation changes during dry and post-monsoon period in the study area. NDVI is a sensitive bio-physical parameter that correlates with photosynthetic activity of vegetation and provides an indication of the greenness of vegetation (sellers, 1985). The vegetation index is a very sensitive factor in studying the hydrological processes.

Accuracy of land use land cover classes were resolute empirically, by independently selecting one-hundred random samples of pixels from each resulting map, from each technique at each date and checking their labels against classes determined from reference data. The results were uttered in tabular form recognized as the "*error matrix*", previously presented by Congalton (1991). Two different measures can be derived from the values in an error matrix: user's and producer's accuracy (Campbell, 2002; Story and Congalton, 1986). The user's accuracy is the number of correctly identified sets in one class divided by the total number of sets recognized in that class. Inaccuracies insets are referred to as errors of commission. The producer's accuracy is calculated by dividing the number of correct pixels in one class by the total number of pixels derived from reference data and includes the error of omission. A Kappa coefficient is commonly used as a measure of map accuracy (Congalton & Green, 1999; Hudson & Ramm, 1987). Thomlinson *et al.,* (1999) set an overall accuracy target of 85% with no class less than 70% accuracy. The USGS proposed an accuracy level of 85% as the minimum requirement for land use/cover mapping with Landsat data (Anderson et al., 1976).

2.4 Digital elevation model (DEM)

SRTM obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of earth produced by Jet Propulsion Laboratory, California Institute of Technology, CA, USA (http://www.jpl.nasa.gov/). This mission generated the most complete high-resolution digital topographic database so far based on elevation data collected in February 2000. Geo-referenced SRTM (WRS2) elevation data from a 90m tiles (3arc second) digital elevation model of the study sites were collected from GLCF community (http://glcfapp.umiacs.umd.edu/data/srtm/description.shtml) and the data were overlaid throughout the model.

2.5 Database generation

In ArcView 9.3, attribute layers were prepared viz. those of drainage density, soil, geomorphology, hydro-geology, and created as separate layer, for road map, the topology has been built by data automation kit. The monsoon and post-monsoon water level data were recorded by well surveyed from 50 wells at different location within the entire district. For water level data, local polynomial interpolation was used based on the weightage value. The highest values point towards the higher potential for groundwater potentiality.

2.6 Groundwater potentiality analysis

To identify the ground water potential zone a weighted overlay analysis is used for computing the index value. The choice among a set of zones for future development of groundwater is based on multiple criteria such as drainage density, geomorphology, hydro-geology, present land use of dry and wet season, vegetation condition, and elevation. This process is most commonly known as Multi-Criteria Evaluation (MCE) (Voogd, 1983). A probability-weighted index overlay approach has been adopted that allows a linear combination of probability weights of each thematic map (W) with the individual impact value (IV) (Sarkar and Deota, 2000). Reclassified map was produced based on weight calculated. For ground water potential, these weights ranged from 1 to7 according to World Health Organization (WHO) guidelines. The rank of each parameter has been converted to a probability weight using Bayesian statistics. These scores are again reclassified to impact values using Bayesian statistics. For example, highest weight is given to the class that is most favourable, either to potential, and lowest weight is given to the class that is least favourable. All thematic maps related to ground water potential zones were integrated and classified depending on the added weight factors (capability to store and transmit water) determined in the analysis (Equation 1). These scores are again converted to impact values using Bayesian statistics. These capability values (CVi) are then multiplied with the respective probability weight of each thematic map to arrive at the final weight map (Equation 2). Mathematically, this can be defined as-

$$Gw = f\,(DD,\ Geom,\ HydroGeo,\ S,\ Lu_d,\ Lu_w\ \ NDVI_d,\ NDVI_w,\ Wl_m,\ Wl_{postm}) \qquad (1)$$

where,
Gw = Groundwater
DD = Drainage Density
Geom = Geomorphology
HydroGeo = Hydro-Geology
S = Soil
Lu_d = Landuse in drier month
Lu_w= Landuse in wet month
$NDVI_d$= NDVI in drier month
$NDVI_w$= NDVI in wet month
Wl_m= Water level in monsoon season
Wl_{postm}= Water level in post-monsoon season

Now groundwater potential map values can be expressed as

$$GWP = \Sigma\ Wi * CVi \qquad (2)$$

where, GWP = Groundwater Potential
Wi = Map weight
CVi = Capability value

The resultant final weight map indicates the potentiality of groundwater occurrence in Paschim Medinipur district. This map is then classified into four categories, namely very high, high, medium, moderately to low and low, very low to negligible.

3. Results and Discussion

3.1 Drainage density and its relation to groundwater potentiality

Drainage density is one of the important parameters to understand the ground water potential of a watershed. Generally, lower the drainage density higher the ground water potential and vice-versa. The drainage number (frequency) can express the drainage density property, and it has the strongest relationship with water recharge into sub-surface media. In this study, drainage network was extracted directly from topographic maps (1:50,000) and each class represents an interval of the number of drainage segments per 2x2 sq. km grid area. Additionally, a point layer was generated using local polynomial interpolation technique based on weightage value. The resulting drainage map has been ordered as<0.019 sq.km to >0.65 sq.km (Figure 2). Thus, the study area can be classified as moderate to fine drainage texture and low to moderate drainage density. The drainage of the study area mainly controlled by Kansai river on the south and Silai river on the north and intersected by numerous khals. Different drainage pattern such as, dendritic, sub-dendritic and radial are predominantly seen within the study area (Figure 2). Major streams flowing through narrow valleys deposited considerable amount of denudated material which can be delineated as valley fill shallow landform. Very high drainage density is found in the western and northern part, whereas, moderate to low drainage density is found in the southern and eastern part. The spatial arrangement of streams with structural control can act as conduit for ground water recharge and storage at places. Density also provides indications of the type of aquifers the magnitude of the recharge area and direction of ground water flow.

3.2 Geomorphology and its relation to groundwater potentiality

Geomorphologic maps help to identify various geomorphic units and groundwater occurrence in each unit (Bahuguna et al., 2003; Rao et al., 2004). Selected field checks were carried out in the field to verify different geomorphic unit (table 2). Geomorphology and associated features as identified through visual interpretation of satellite imagery (Figure 3). Studying the importance of geomorphology for groundwater in Paschim Medinipur region through remote sensing, flood plain are interpreted by its typical reddish tone found along the banks of the river courses. The flood plain area comprises mainly of sands and slits with minor inter clarified of clays and they act as good aquifers, covered with an area of 31.78% of the entire district. The ground water potential of flood plain is very high. The notable feature of this study is the demarcation of flood plain in the Kossi river system which resulted in the excellent ground water potential. A small portion of the study area is covered by pediment, whereas, deep buried and moderately deep buried pediements swathe 22.13% (2009.47sq.km) and 21.07 (1913.87Sq km.) Extensive laterization has taken place, mainly at the water divides. Due to rugged landforms, ground water is occurred mainly valley fill deposits, but sometimes valley fill contain relicts of laterite. The depth of the valley varies from a few to several meters. The alluvial portion may be subdivided into two divisions; first, there is a strip of purely deltaic country bordering Hooghly, intersected by numerous river and water-courses, which are subject to tidal influence. The latter are usually connected with one another, thereby rendering it an easy matter to travel by water; and the country generally partakes of the character of the neighboring district of Hooghly. This low-lying tract extends for about 32.18 km inland from the Rupnarayan and Hooghly. The alluvial deposit, which is then reached, seems to cover the final swells of the laterite formation.

3.3 Hydro-geology and its relation to groundwater potentiality

Hydro-geological maps depict important geological units, landforms and underlying geology so as to provide an understanding of the processes, materials/ lithology, structures, and geologic controls relating to groundwater occurrence as well as to groundwater prospects. Such maps depicting prospective zones for groundwater targeting are essential as a basis for planning and execution of groundwater exploration. Hydro-geologically, the study area has been classified as: younger alluvium, older alluvium, fluvio-deltaic sediment overlained by secondary laterite (double profile), fluvio-deltaic sediment overlained by primary laterite (in situ), Platform margine conglomerates and basement crystalline complex (metamorphites) (Table 3 & Figure 4). Their characteristics and groundwater prospects are given in Table 2. Nearly 49.49% of the study area is covered by younger alluvium, placed at western part of the study area. The fluvio-deltaic sediment overlained by secondary laterite within the region comprise a total area of 30.40%. Older alluvium covers nearly 5.33% of the study area in the northwestern and SSE portions. Groundwater occurs under unconfined conditions in shallow, moderately weathered zones of the older alluvium and in semi-confined conditions in joints, fissures, and fractures that extend beyond the weathered zones. As such, secondary porosity (the weathered zone and fluvio-deltic sediments) is the main source for groundwater occurrence, movement and transmission. In the study area, 5.07% is covered by basement crystalline complex, whereas, fluvio-deltaic sediment overlained by primary laterite roofed by 8.82%. In the northeastern part of the study area, platform margin conglomerates and basement crystalline complex were found, covered only 0.89% of the whole area.

3.4 Soil characteristics and its relation to groundwater potentiality

Information on soil also forms an important input in mapping groundwater potential zones, e.g. coarse textured soil are generally permeable while fine textured soils indicate less permeability. Highly permeable soil permit relatively rapid rate of infiltration wherein much of the rainwater can reach ground water table. Soil type in paschim Medinipur district can be divided into sixteen categories, represented as coarse loamy typic haplustalfs, coarse loamy typic ustifluvents, fine aeric ochraqualfs, fine loamy aeric ochraqualfs, fine loamy typic paleustalfs, fine loamy typic ustifluvents, fine loamy typic ustochreptas, fine loamy ulti paleustalfs, fine vertic haplaquaepts, fine vertic ochraqualfs, loamy lithic ustochrepts, loamy skeletal lithic ustochreprs, residential area, rocky outcrops, and very fine vertic haplaquepts (table 4 and figure 5). Soil ranking was indicated on the basis of its infiltration capability. The soil act as a natural filter to screen out many substances that mixes with water (Donahue *et al.,* 1983). In the eastern part of the district very fine vertic haplaquepts and sandy loam soil has a high specific yield (19-30%) and porosity value (32-38%), which indicates that recharge from precipitation should pass easily form the surface to the zone of saturation (Holt Jr., 1965). On the other hand, crystalline rocks of the north-west part of the district has low porosity and low permeability due to small grain sizes with large surface areas, which resulted in increased friction, because it contains very few openings, so water cannot pass through (Donahue *et al.,*1983). Hence, the amount of groundwater recharge, storage, and discharge as well as the extent of groundwater contamination all depend on the soil properties.

3.5 Topography and its relation to groundwater potentiality

Several researchers have used Digital Elevation Model (DEM) data for purposes such as delineating the drainage networks (Zhang *et al.,* 1990), deriving hydrogeomorphological units (Hodgson, 1999) and for landscape description and classification (Brabyn, 1996; Swati, 2002). A DEM has been derived from Shuttle Radar Topographic Mission (SRTM) data to delineate the altitudinal distribution of study area. The area has an undulating micro-relief with highs and lows. The maximum elevation is found to be 319 m above mean sea level (msl) (figure 6). Generally, the elevation declines from north-west to eastern and south eastern direction. The slope amounts have shown that elevation is low in south-eastern and eastern part. The ground water reservoir is in the form of a low relief, water table aquifer to nearly uniform gradient (Parizek *et al.,* 1967). The study area has been categorized into seven elevated area with 50 intervals, following- <50m, 50-100m, 100-150m, 150-200m, 200-250m, 250-300m, and >300m (Figure 6). Lower altitudinal areas were given the higher weightage, whereas, higher altitudinal areas were given the low weightage to mark out the ground water potentiality.

3.6 Land sue/land cover characteristics and its relation to groundwater potentiality

For the identification and interpretation of land use pattern of the area, image interpretation through remote sensing data (Landsat5 TM) of dry and wet months were adopted and the various land use classes delineated includes river, sand, lateritic land, dry fallow, moist fallow, mixed forest, dense forest, degraded forest, open forest, crop land, agricultural fallow, and settlement (Figure 7a and 7b). The various land use classes, areas and percent of total areas are given in table 5. To confirm the classification accuracy, accuracy assessment analysis was calculated. Table 5 identifies the error matrices for both the images developed from the supervised classification technique. In table 5 the overall classification accuracy and kappa statistic were 92.00% and 0.90 respectively in April, 2010. A similar circumstance was found in November, 2009 resulting in an overall classification accuracy and kappa statistics of 86.00% and 0.83 respectively. The land cover categories were ordered according to high advantage to water permeability (table 5). Different uses of terrain surfaces result a miscellany of surface water recharge processes. This factor involves a number of elements, but the major ones are: bare rocks, human settlements, sparse vegetation cover (Su, 2000). For example, bare rocks (lateritic land) they often give a chance to water to move through fissures and joints into deeper stratum, thus often considered as enhancing parameter. Human settlement and construction retards water infiltration through it and thus prevent water to reach ground water reservoirs. Accordingly for vegetation cover, the higher the vegetation cover, the higher the evapotranspiration rate and this imply less chance for percolation to the subsurface layers (Darwich *et al.,* 2003). In view of the groundwater potentiality, river/surface waterbody, mixed forest, sand, moist land, and crop land were given the higher weightage, whereas, agricultural fallow, open forest, dry fallow, lateritic land were given the lower weightage.

3.7 Vegetation condition and its relation to groundwater potentiality

The parameters derived from remotely sensed observations are being directly used in various studies relating NDVI (Normalized Difference Vegetation Index) and hydrological processes (Sellers, 1987; Gamon et al., 1995; Kondoh and Higuchi, 2001). NDVI is this property that is exploited as an indirect indicator of the availability of groundwater below the surface of the earth. Thus during the dry (i.e. April) and wet (i.e. November) spell of the study area a good quality vegetation in an area is often found to be associated with shallow ground water levels. Figure 8a and 8b is the pseudocolour representation of the same image in dry and wet spell of the study area. In this image the intensity values are classified by density, slicing the pixels values into seven classes' namely luxurious vegetation, healthy vegetation, areas with moderate dense, stressed vegetation, areas with less vegetation, areas with very less vegetation and areas with no vegetation. The maximum and minimum values of NDVI in drier month was +1.0 and -0.24 respectively, whereas in wet month it was +0.54 and -0.34, respectively. It can be observed that the areas close to the dry river channels have a good concentration of Luxurious and healthy vegetation as compared to rest of the area. This is primarily due to better groundwater supply and moisture replenishment from the alluvial deposits of the rivers. As one moves away from the stream the density of the luxurious / healthy vegetation rapidly decreases. Thus, apart from the vicinity of the riverbeds, the interior areas that show signs of luxurious/healthy vegetation are considered favorable targets for the next phase of a detailed groundwater survey. However as an essential practice the results obtained from an NDVI analysis are usually matched with other outputs of groundwater modeling themes before finally outlining the groundwater potential zones. With the advent of satellite remote sensing it has become possible to understand the green leaf concentration or chlorophyll status of vegetation for a large area of the earth surface with the help of a single digital image (Campbell, 1996; Gupta 1991). Though, the health of a plant depends on several environmental factors ¾ it is often found that, for a large area the vegetation health largely depends on; as to how much moisture is available to the root zone of the plants. NDVI was generated in the analysis was found to be correlated well with water availability due to the good water content in the soil covers and weathered zones. Field investigations showed that the NDVI was controlled by shallow groundwater levels around topographic low, which forms the pathways for surface runoff during monsoon form the good zones of groundwater. Thus, the vegetation index in this area is a response of the green vegetation condition to environmental factors including soil moisture and water availability. Higher NDVI values implied availability of sufficient shallow groundwater and surface to stimulate vegetation growth and to support local water needs.

3.8 Water level characteristics

Properly and correctly observation wells to measure the periodical changes in ground water level, are the most useful information which can be used to plan groundwater development programmes indicators. Quantum of recharge/discharge that had taken in the aquifer has been assessed from the monsoon and post monsoon water level fluctuation data (Figure 9a and 9b). The water table occurs in unconfined and semi confined conditions. Dynamic ground water potential of the study area was computed using local polynomial interpolation method. The spatial distribution of groundwater is not uniform, area has very shallow (1.5 m bgl) to very deep (9.2 m bgl) water table. Deep water table occurs adjacent to the foot hill. Higher well yields indicate relatively greater groundwater availability than areas with low well yields.

3.9 Groundwater potential zone delineation and assessment

By integration of all the maps (classified maps of land use/land cover in dry and wet month, NDVI map of dry and wet month, hydro-geology, geomorphology, soil, elevation, water table in monsoon and post monsoon, and drainage density), groundwater potential zones were delineated and classified as: very high potential, high potential, moderate potential, moderate to low potential, low potential, very low potential and low to negligible (table 6 and figure 10). Only 8.08% (734.32 km^2) of the study area was classified as having very high potential at few locations (eastern and small pockets of central regions), 11.99% (1089.907 km^2) was of high potential (southwest, east, northeast and central regions) and 17.72% (1611.247 km^2) was classified as having moderate potential (most of the central-east and the small patches of northern and southern zone). The moderate to low groundwater potential zone was occupied by 21.40% (1945.54 km^2) of the entire area, stretched in most of the central region. Furthermore, the poor zones were found in western and small pockets of north-central part of the district, covered with an area of 20.91% (1901.09 km^2). Additionally very low potential and low to negligible groundwater potential zone enclosed 5.88% (534.30 km^2) and 0.09% (8.33 km^2), respectively. Spatially, the very high potential and high potential area are distributed along less drainage density, lower elevation, older alluvium region and the flood plain deposits regions is affected by the secondary structure and having interconnected by pore spaces. Areas with moderate ground water prospects are attributed to contributions from the combinations of land use/land cover, NDVI, valley fill deposits, fluvio-deltic sediments overlained by secondary laterite by moderate well yields are present. The low to poor categories of ground water potential zones are spatially distributed mainly along the ridges, lithology is compact, low to very low well yields are present, and extremely far to the farthest distance from drainage as pockets spreads over the whole study area.

4. Conclusion

In Paschim Medinipur, groundwater is being extensively used to cater to the needs of the people. Groundwater withdrawal is increasing year after year due to very erratic rainfall and insufficient surface water bodies resulting, in the drying-up of dug and bore wells. Remotely sensed satellite image data from Landsat 5 provided information used to identify landscape characteristics, vegetation condition, and outline geomorphological and hydro-geological properties. Accordingly, SRTM data offer the elevation of the surface as well as to delineate the drainage characteristics. To understand the ground water regime, well inventory data also have been collected in the monsoon and post-monsoon periods. The integration and analysis through GIS of various thematic maps and image data proved useful for the demarcation of the zones of groundwater potential for suitable planning and management programmes. Yields performance of the tube wells in different land cover confirmed the correlation exists among respective land cover, vegetation vigor and groundwater potential. To help to overcome this situation, remedial measures have to be implemented by imposing restrictions on the construction of water harvesting structures for argumentation of groundwater resources and also through the implementation of proper best management practices for watershed throughout the region.

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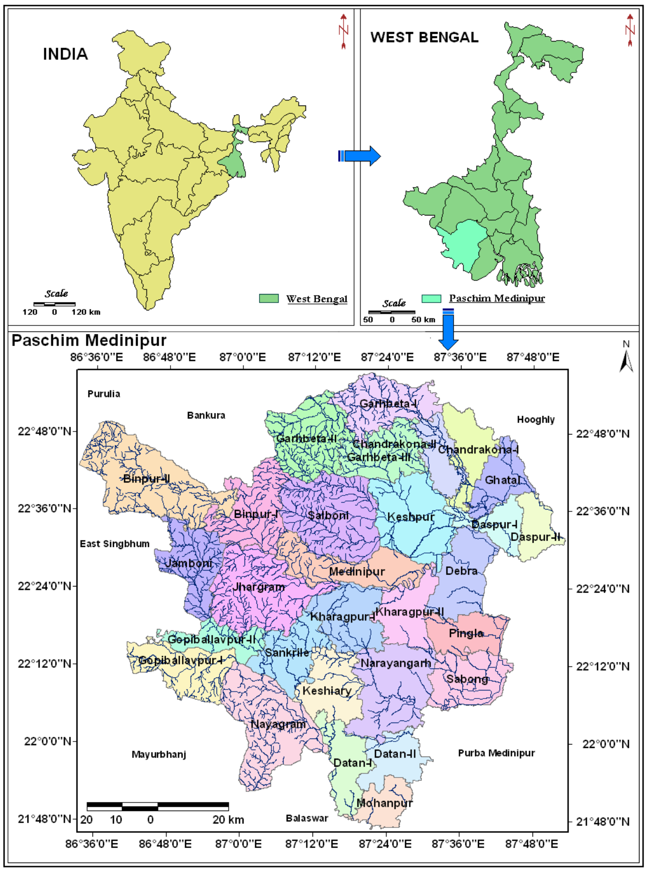

Figure 1. Location map of Paschim Medinipur district, West Bengal, India

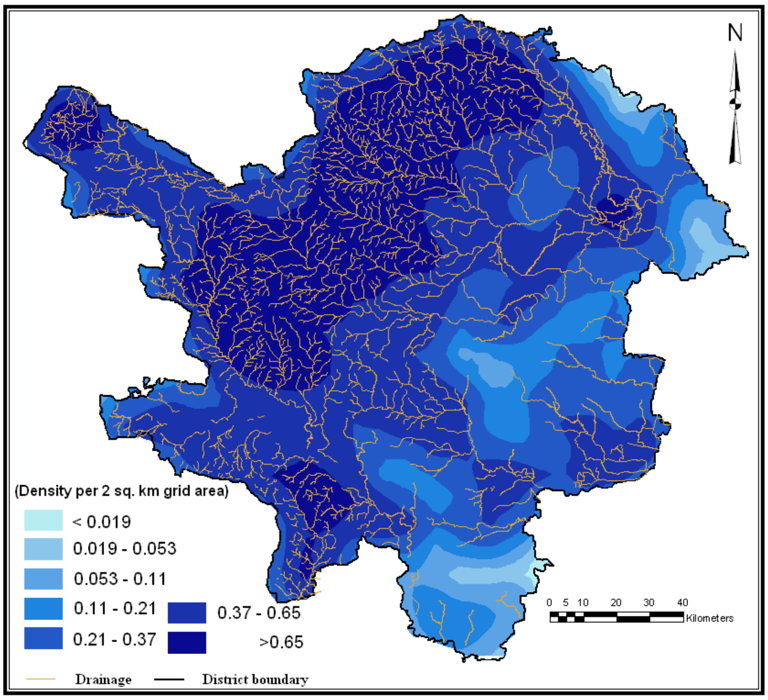

Figure 2. Drainage density per sq km grid area of Paschim Medinipur based on satellite imageries and topographical map

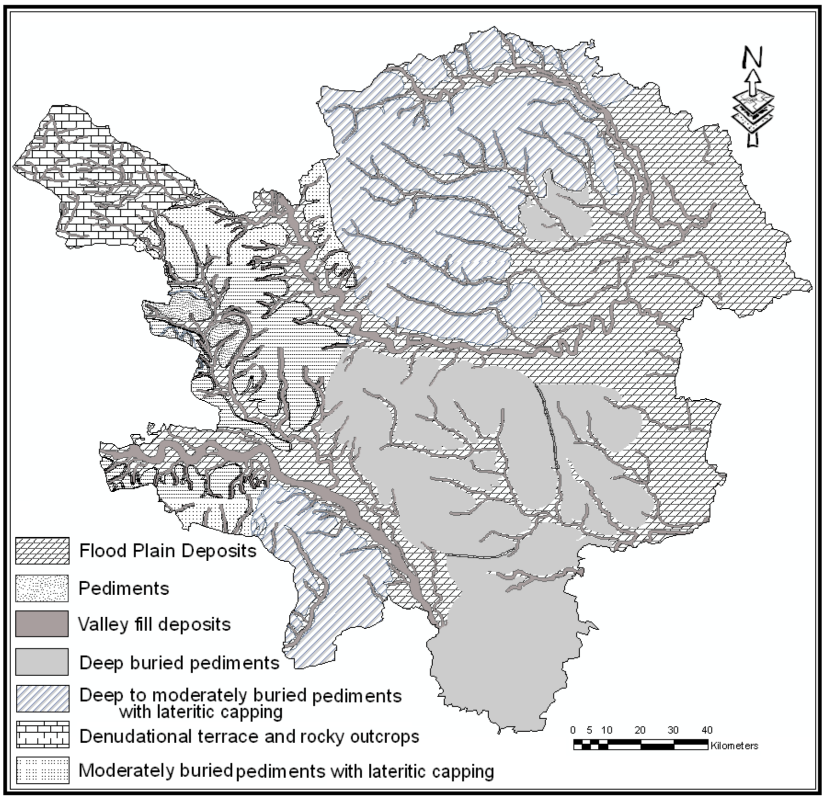

Figure 3. Geomorphological characteristics of the Paschim Medinipur base on morphological map of West Bengal

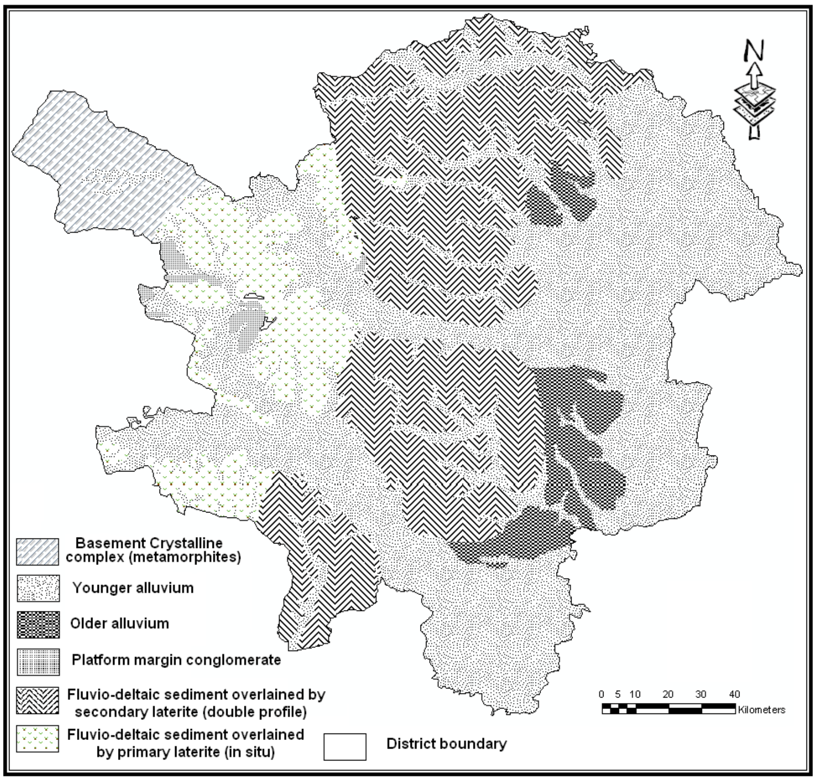

Figure 4. Hydro-geological characteristics of the Paschim Medinipur base on geological map of West Bengal

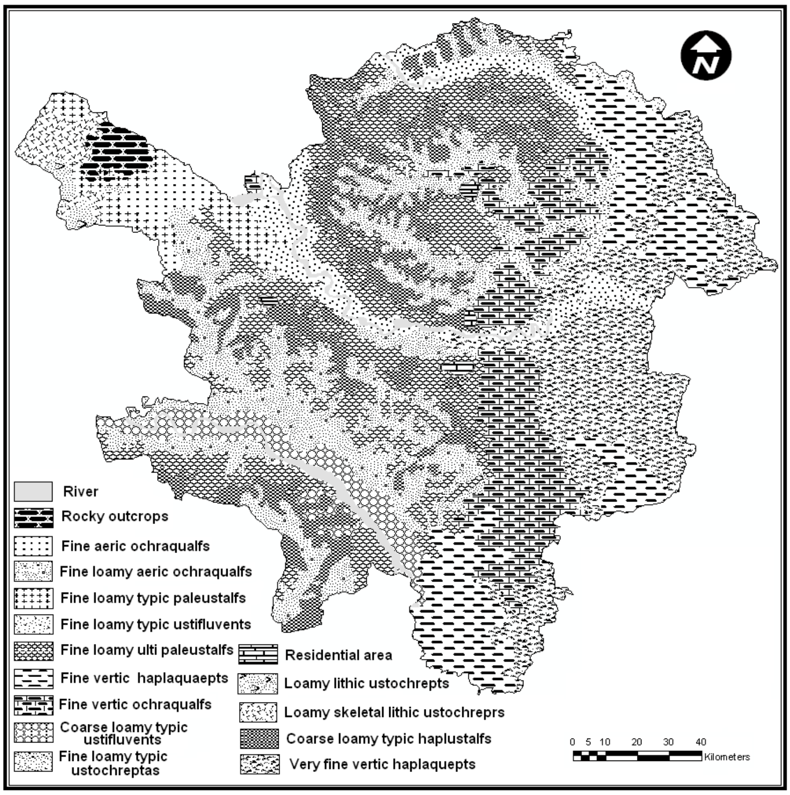

Figure 5. Spatial distribution of soil characteristics of Paschim Medinipur base on soil map of West Bengal

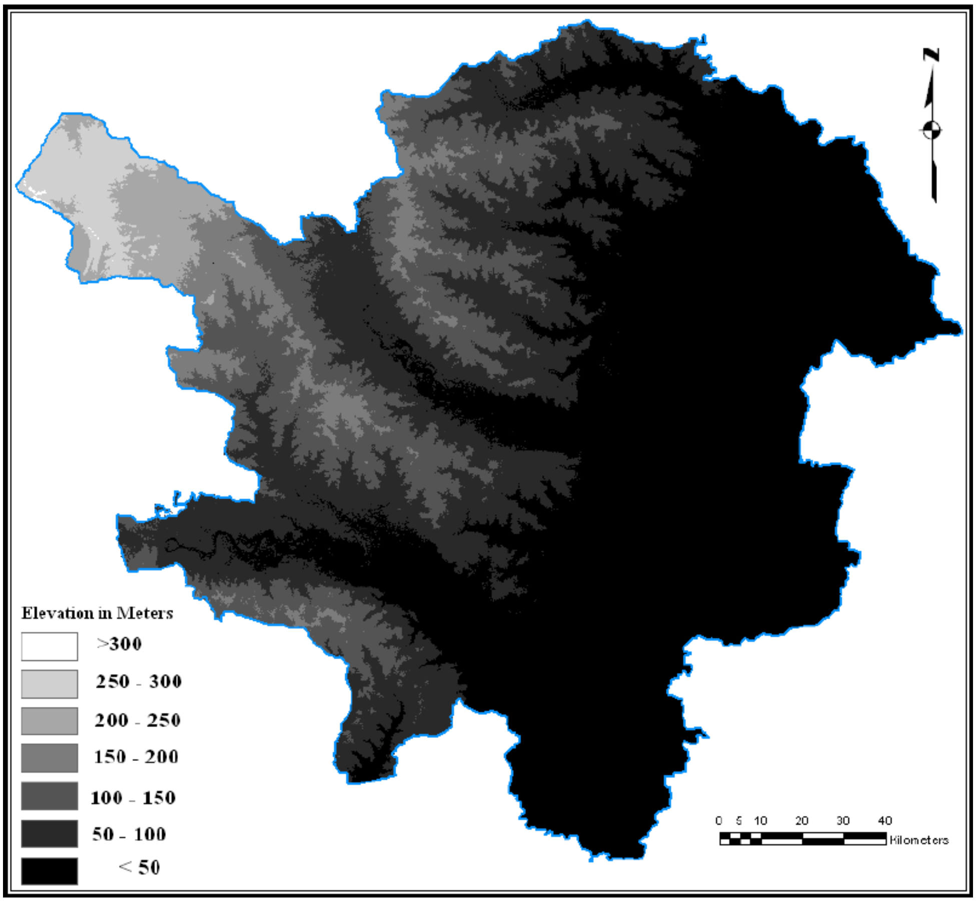

Figure 6. Digital Elevation Model of the area base on topographic map and SRTM dataset

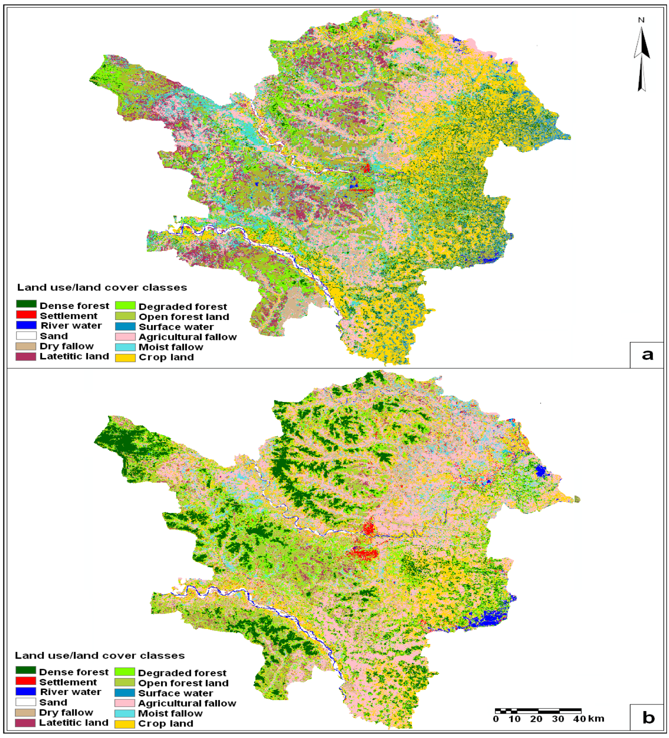

Figure 7. Land use/land cover characteristics in the monsoon (a) and post-monsoon (b) season of the area based on Landsat5 (TM) satellite imageries

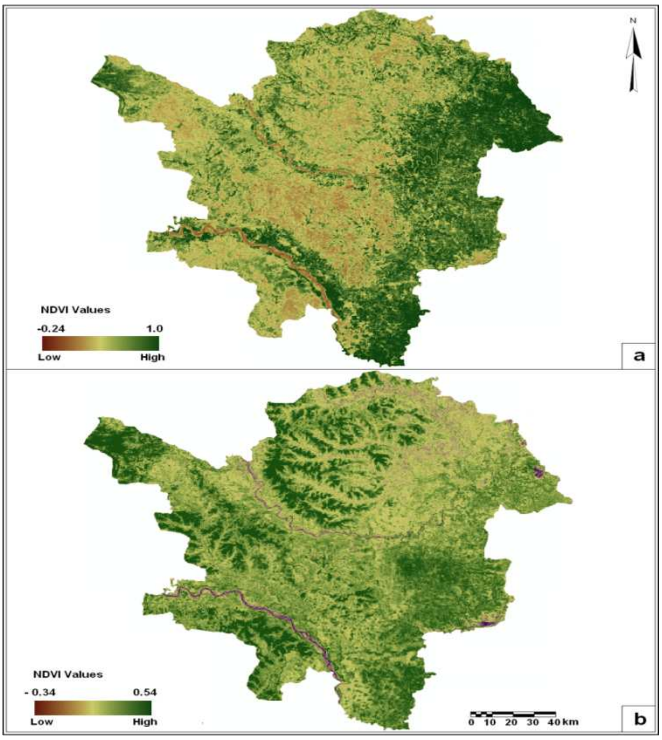

Figure 8: Vegetation (NDVI) status in the monsoon (a) and post-monsoon (b) season of the area based on Landsat5 (TM) satellite imageries

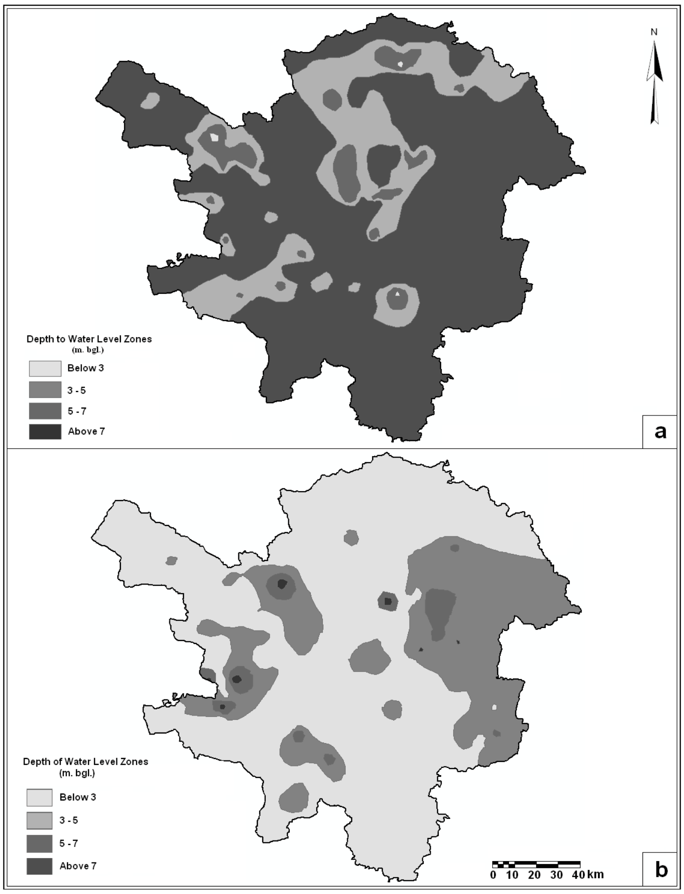

Figure 9: Ground water level of monsoon (a) and post-monsoon (b) season of the study area based on wells measurement data

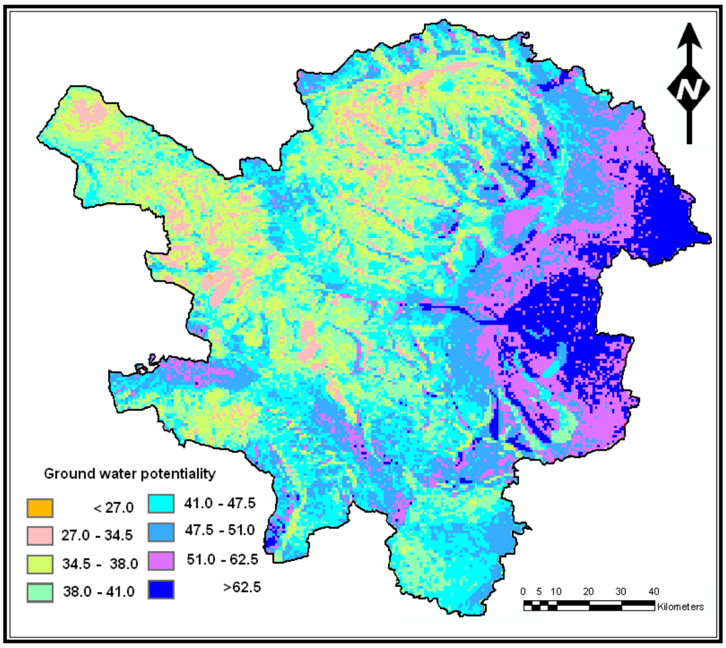

Figure 10: Ground water potential zone of Paschim Medinipur based on all the parameters

Table 1: Details characteristics of the data

Data type	Characteristics	Year of acquisition	Source
Satellite Data Landsat 5 TM	Path and row - 139/44 and 139/45	25/11/2009 and 18/04/2010	www.landcover.org
Shuttle Radar Topography Mission (SRTM) data	Resolution of 3-arc seconds	2000	http://www.jpl.nasa.gov/
Topographical maps	No. 73N/1 to 16, 73J/9 to 16, 73O/1, 73O/5 in Scale of 1:50000	1972	Survey of India, Kolkata, West Bengal, India
Block Map of Paschim Medinipur	Scale 1:50000	1982	Block Office, Paschim Medinipur, WB, India
Monsoon & post monsoon water level data	169 wells from different geographic location	2009	Ground Survey
Soil and Geo-morphological, hydro-geology data	Scale 1:50000	2002	Geological survey of India

Table 2: Geomorphologic units and their groundwater prospect in the area

Geomorphologic units	Area in sq. km	Percent of Cover	Groundwater prospect
Valley fill deposits (VFD)	991.5776	10.92	Good
Flood plain deposits (FPD)	2886.475	31.78	Very good to excellent
Deep buried pediments (DBP)	2009.474	22.13	Very poor
Deep to moderately buried pediment with lateritic capping (DMBPLC)	1913.871	21.07	Poor
Moderately buried pediment with lateritic capping (MBPLC)	834.8254	9.19	Moderate
Pediment (Ped)	95.52667	1.05	Poor to negligible
Denudational terraces and rocky outcrop (DTRO)	349.7218	3.85	Moderate to good

Table 3: Hydrogeological characteristics in Paschim Medinipur District, West Bengal, India

Hydrogeologic unit/sub unit	Acquifer age	General lithology	Acquifer deposition in mbgl	Aquifer character
Younger alluvium (YA)	Recent to late pleistocene	Finer to medium sand with vertical and lateral facies change to sandy clay or clay. Prismatic sand bodies consisted mainly of moderately to well sort rounded to well round quartz with significant flaky minerals, Grey to Greissh white in colour.	From top surface to down to a depth of 48.80m G.L. In general subsurface disposition is between 5-36m bgl. i.e. thickness variable from 30-35m.	Cumulative thickness of granular zones forming aquifers 10-20m. Ground water occurs with phreatic water surface and under semi confined condition. Under low pumping rate yield varies from 12-25m^3 /h which may be increased to 100m^3 /h for high capacity pumping. Transmissivity ranges from 2200-4000m^2/day
Older alluvium (OA)	Late pleistocene	Sands, medium to coarse with brownish tint , poorly sorted but texturally matured with ferruginous modules and Kankars Ghuttings (Calcaereous concretional aggregates) are present. Occasionally gravel sand	Granular zones encountered down to a depth of 400m. Phreatic aquifer is underlained by	Acquifers are both confined and unconfined. Summer ground water level varies from 1-18m bgl. (Elevated areas) and post-monsoon water level varies from 1-7 m bgl. Seasonal water level fluctuation has a wide range of 6-18m. Yeild

		bed is present. Repeated cyclothemes are represented by sand, silt and clay beds.	semiunconfined aquifer below 25 from G.L	capacity of L.D.T.W. varies from 30-50 m^3/hr and that fro H.D.T.W. 70-185 m^3/hr. Transmissivity ranges from 1200-4000m^2/day and storativity 4.5*10 – 5.0*10.
Fluvio-deltaic sediment overlained by secondary laterite (double profile) (FDSO$_{dp}$)	Middle to early pleistocene	Laterite: hard crust 1.5-16m thick molted clay 03.-7m thick lithomarge. Mio-pliocene sedimentaries: Sand-silt-shale alteration. Sand coarse to medium with thin fine sand stratum shale and silt bed. Coarse sand with vertical facles gradation to silt.	Disposition of water bearing prospective aquifers are within 250m bgl.	The depth of phreatic acquifer varies from 12-30 m bgl. Summer water level varies form 2-21m bgl. And post-monsoon water level varies from 1.5-9m. bgl. Range of G.W.L. fluctuation 6-19m Transmissivity ranging from 400-1000m^2/day.
Fluvio-deltaic sediment overlained by primary laterite (in situ), (FDSO$_{pl}$)	Pliocene	Lateritic hard crust; highly porous in places with honeycomb weathering structures underlained bylithomergic clay. Mio-pliocene sedimentaries with indication of more oxidation and presence of ferruginous clay of brownish colour and higher proportion of Kankars.	Lateritic profile: 0-25m bgl. With spring zones in places. Multiple aquifer (mainly 2/3 granular zones) are found down to a depth of 165m bgl. Consisting of Mio-pliocene sedimentaries.	Both semi confined and unconfined with yield capacity 80-100m^3/hr. Summer water level 6-21m bgl. Post-monsoon water level 1.5-9m bgl. Transmissivity – shallow (42-47m): 397.05-506.64 m^2/day; Intermediate (116-133m): 531.9-329.07 m^2/day; Deeper (141-146m): 569.81-267.07 m^2/day; Storativity-shallow (42-47m): 2.03*10-8.03*10; Intermediate (116-133m): 3.002*10-2.1*10; Deeper (141-146m): 5.33*10-7.21*10
Platform margin conglomerates (PMC)	Early Miocene	Pebbles, cobbles, and boulders in coarse sand matrix. Significant constituent lateritic gravel, cobbles and gneissic rocks.	Down to a depth of 30m bgl.	Hill slope discharge zone with springs and auto flows along Dulong river
Basement crystalline complex (metamorphites) (BCC)	Pre-cambrian	Ortho and paragneissic complex, schists, metabasics, epidiorites, phyllites, pegmatites, granites with colluvial material.	Fracture conduits extend down to a depth of 150m maximum from G.L. The thickness of the regolith cover varies from 5-20m from G.L.	Unconfined anisotrphic. Summer G.W.L. 2-11m bgl. Post-monsoon G.W.L. 0.5-5m bgl. Yeild capacity 2-5m^3/hr in dug well in areas of truncated junction of weathered profi;e with fracture conduits. It may raise upto 70m^3/hr. Transmissivity 14-843m/day

Table 4: Soil characteristics of the Paschim Medinipur district and their percent of area covered

Type	Area (in sq m)	Percent
Coarse loamy typic haplustalfs (CLTH)	1,008.53	11.11
Fine loamy ulti paleustalfs (FLUP)	1,506.94	16.59
Fine loamy aeric ochraqualfs (FLAO)	1,513.46	16.67
Fine vertic haplaquaepts (FVH)	940.03	10.35
Fine loamy typic ustifluvents (FLTUSTI)	469.03	5.16
River	1,521.52	16.75
Fine loamy typic paleustalfs (FLTP)	226.71	2.50
Loamy skeletal lithic ustochreprs (LSLU)	126.27	1.39
Very fine vertic haplaquepts (VFVH)	123.93	1.36
Rocky outcrops (RO)	90.27	0.99
Fine vertic ochraqualfs (FVO)	878.77	9.68
Loamy lithic ustochrepts (LLU)	51.13	0.56
Fine aeric ochraqualfs (FAO)	122.86	1.35
Fine loamy typic ustochreptas (FLTUSTO)	173.05	1.91
Residential area	35.44	0.39
Coarse loamy typic ustifluvents (CLTU)	293.15	3.23

Table 5: Identified features land use/ land cover from Landsat TM of Paschim Medinipur district, West Bengal

Land use Category	Area in Sq. km	Percent	Reference category	Classified category	Corrected number	Producers accuracy	Users accuracy
April, 2010							
Settlement	15.23	0.17	1	1	1	100.00%	100.00%
River	71.36	0.79	0	0	0	---	---
Dense Forest	496.77	5.47	7	7	7	100.00%	100.00%
Dry Fallow	363.00	4.00	2	2	2	100.00%	100.00%
Crop Land	1,963.26	21.62	24	26	23	95.83%	88.46%
Degraded Forest	610.53	6.72	7	6	6	87.50%	100.00%
Surface waterbody	271.65	2.99	1	1	1	100.00%	100.00%
Sand	76.46	0.84	1	1	1	100.00%	100.00%
Mixed Forest	106.68	1.17	0	0	0	---	---
Lateritic land	770.77	8.49	15	14	13	87.50%	93.33%
Open forest	1,353.03	14.90	11	12	10	90.91%	83.33%
Moist fallow	1,297.10	14.28	11	9	9	81.82%	100.00%
Agricultural Fallow	1,685.76	18.56	20	21	19	95.00%	90.48%
			100	**100**	**92**		
Overall Classification Accuracy = 92.00% *Overall Kappa Statistics = 0.9045*							
November, 2009							
Dense Forest	1097.49	12.08	13	13	12	92.31%	92.31%
Settlement	147.678	0.63	3	1	1	33.33%	100.00%
River	148.905	1.64	3	2	2	66.67%	100.00%
Sand	74.0904	0.82	0	0	0	---	---
Dry Fallow	424.201	4.67	4	5	3	75.00%	60.00%
Lateritic Land	173.689	1.91	3	3	3	100.00%	100.00%
Degraded Forest	1213.4	13.36	12	12	11	91.67%	91.67%
Open Forest Land	960.499	10.58	14	12	12	85.71%	100.00%
Surface Waterbody	2.35667	0.03	0	0	0	---	---
Agricultural Fallow	2618.13	28.83	28	33	25	89.29%	75.76%
Moist Fallow	518.69	6.71	6	5	4	66.67%	80.00%
Crop Land	1702.48	18.75	14	14	13	92.86%	92.86%
			100	**100**	**86**		
Overall Classification Accuracy = 86.00% *Overall Kappa Statistics = 0.8320*							

Table 6: The classification of influencing factors on groundwater potentiality

				Groundwater potentiality				
	Low					High		
Class (Factors/Weight)	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**Multiplier**
Drainage density (Sq. Km)	>0.65	0.37-0.64	0.21-0.37	0.11-0.21	0.053-0.11	0.019-0.053	<0.019	15
CV$_i$(Consistency ratio=0.02)	0.02	0.04	0.08	0.13	0.19	0.24	0.30	
Geomorphology	Ped	DBP	DMBPLC	MBPLC	DTRO	VFD	FPD	15
CV$_i$(Consistency ratio=0.02)	0.00	0.02	0.06	0.11	0.19	0.26	0.33	
Hydro-Geology	PMC	YA	BCC	-	FDSO$_{pl}$	FDSO$_{dp}$	OA	15
CV$_i$(Consistency ratio=0.07)	0.03	0.06	0.10	-	0.16	0.25	0.40	
Soil	RA/FLTUSTO/ FLTU/LSLU	RO/FLTP/LLU	FLUP	CLTH/FAO/FLAO	CLTU/FLTUSTI/ FVO	FVH	River/VFVH	10
CV$_i$(Consistency ratio=0.07)	0.00	0.01	0.06	0.13	0.20	0.27	0.33	
Elevation	>300	250-300	200-250	150-200	100-150	50-100	<50	5
CV$_i$ (Consistency ratio=0.02)	0.03	0.04	0.06	0.10	0.16	0.24	0.37	
Landuse in drier month	Lateritic land	Agricultural/dry fallow	Crop land	Open forest/moist fallow/sand	Degraded Forest	Dense/Mixed forest	River/surface waterbody	5
CV$_i$ (Consistency ratio=0.02)	0.03	0.04	0.07	0.10	0.15	0.24	0.37	
Landuse in wet month	Lateritic land	Agricultural/dry fallow	Crop land	Open forest/moist fallow/sand	Degraded Forest	Dense/Mixed forest	River/surface waterbody	5
CV$_i$(Consistency ratio=0.02)	0.03	0.04	0.07	0.10	0.15	0.24	0.37	
NDVI in drier month	<0.13	0.13-0.21	0.21-0.25	0.25-0.36	0.36-0.42	0.42-0.50	>0.50	5

CV$_i$(Consistency ratio=0.02)	0.03	0.04	0.06	0.10	0.16	0.24	0.37	
NDVI in wet month	<0.13	0.13-0.21	0.21-0.25	0.25-0.36	0.36-0.42	0.42-0.50	>0.50	5
CV$_i$(Consistency ratio=0.02)	0.03	0.04	0.06	0.10	0.16	0.24	0.37	
Water level in monsoon season (m. bgl)	-	-	<2	3	4	5	7	10
CV$_i$(Consistency ratio=0.05)	-	-	0.03	0.06	0.14	0.27	0.50	
Water level in post-monsoon season (m. bgl)	-	-	<2	3	-	5	7	10
CV$_i$(Consistency ratio=0.07)	-	-	0.04	0.12	-	0.26	0.58	