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Application of Remote Sensing and GIS Techniques for Estimation of Seasonal Groundwater Abstraction at Arani-Koratalaiyar River Basin, Tamil Nadu, Chennai

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Abstract: *Remotely sensed spatial data can be used for estimating the approximate quantity of groundwater abstraction. Groundwater modelling requires large amount of spatial data such as landuse, ground slope, geology etc., for estimating hydraulic conductivity and storativity. Groundwater abstraction rate can be estimated by the hourly consumption of electricity, horsepower of pump and by crop water requirement for irrigation. However as the electricity is supplied free of cost in several states in India and the data regarding the number of wells and the capacity of pumps are not known, it is not possible to estimate groundwater abstraction. Crop water requirement for different seasons can be easily calculated by using satellite remote sensing data. The objective of the present study is to estimate seasonal groundwater pumping in Arani-Koratalaiyar river basin by using remote sensing and geographical information system (GIS) techniques. Groundwater wells located in the Arani and Koratalaiyar river basin provides 10% of water supply to the Chennai city. LISS III (23 m spatial resolution) satellite imagery data for 2 different seasons (kharif and rabi season) were made use for estimation of pumping rate. Landuse map for these 2 seasons were prepared by supervised image classification technique in ArcGIS10.1. The characteristics of satellite imagery data such as tone and texture patterns were used for the level 3 classification of crop patterns. Several field visits were carried out to verify the level three classification made using the remote sensing data. Water requirement for different crop types was obtained from the report of Tamil Nadu Department of Agriculture was used for calculating pumping rate. Groundwater abstraction is estimated based on crop types and amount of water required for the whole crop period. Groundwater requirement for the built-up areas were calculated from the population of the particular area with per capita demand. The results show that approximate groundwater pumping in Arani-Koratalaiyar basin ranging from 500 MCM to 1000 MCM per year*

Keywords: *Remote sensing, Groundwater pumping, GIS, Landuse, A-K basin*

1. Introduction:

In most of the agricultural production areas, groundwater remains the ultimate source of freshwater when surface water sources are under depletion [7]. Advanced remote sensing technique and Geographical Information System (GIS) are useful for various groundwater applications such as identification of groundwater potential zone and artificial recharge zone, groundwater recharge and groundwater abstraction etc., Basin scale groundwater discharge is estimated by a simple method of Remote sensing data from satellite and GIS [8]. Groundwater abstraction is one of the application can be easily and cost effectively estimated from geospatial techniques. A number of direct and indirect methods have been used to estimate the amount of groundwater abstraction. Direct method of measuring the pumping rate through a flow meter mounted in bore wells is expensive and also mearly impossible in countries like India[11]. Indirect methods involves data regarding the electricity consumed, power of pump used and the crop water requirements to estimate groundwater abstraction. [1] assessed crop water demand by mapping monthly crop coefficient. [4] studied about the need for proper interfacing between irrigation, agriculture and consumption of electricity to develop a credible strategy for optimum utilization of electrical energy and groundwater resources. The electrical energy requirements have been calculated based on the area of land irrigated and also based on the crop pattern. [6] investigated the impact of landuse pattern on groundwater recharge and abstraction in a area highly pumping groundwater for irrigation. [5] analyzed the irrigation water requirement of wheat crop for rabi season using Landsat ETM+ image by applying Artificial Neural Network (ANN) classification technique. [2] presents a method of quantifying groundwater abstractions for irrigation based on the analysis of multi temporal and multispectral satellite

images. The irrigated crop area is directly proportional to the bore well yield [11]. High quantity of groundwater has been pumping for agricultural and municipal water supply from Arani - Koratalaiyar (A-K) river basin in Tamil Nadu, India. It is necessary to study about the groundwater abstraction for sustainable management of aquifer in this area. The objective of this study is to estimate seasonal groundwater abstraction in A-K river basin by using geospatial techniques. Calculating the groundwater abstraction rate from the consumption of electricity is impractical in A-K basin because of the free distribution of electricity for irrigation by the government. Further, it is a difficult task to estimate the exact operating hours of the pumps. Hence, crop water requirement used as best possible method to calculate groundwater abstraction which is cost effective and time saving

2. Study area:

The present study was carried out an area of 1455 km^2 in a part of A-K river basin which is located around 40 km north of Chennai metropolitan city (Figure 1). Arani and Koratalaiyar are the two non-perennial rivers and flow for about three months in a year during rainy season. Eastern boundary is surrounded by Bay of Bengal and south western side is bounded by Palar river. Topographically the elevation varies from 0.64 m in eastern side (Chennai mean sea level, Tide table, 1997) to 130 m msl in south west side as observed in survey of India toposheet. This area experiences arid to semi-arid climate with hot climate during the summer (April-June) having a temperature ranging from 34.7° C to 37.5°C and in winter (November - January) the temperature varies between 20.4°C and 22.7°C. The normal annual rainfall in this area is varies from 950 mm to 1150 mm falling mostly during the northeast monsoon (October- December). Rice, pulses, groundnut, sesame and vegetables are the crop cultivating in this area [10].

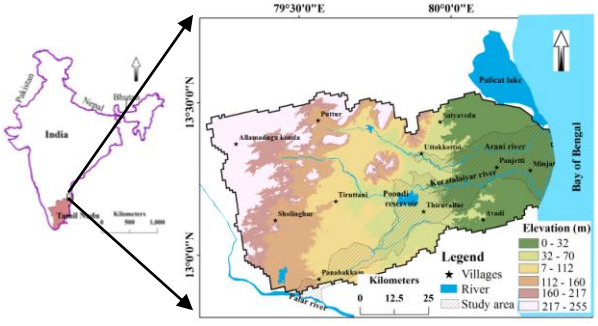

Figure 1. Location of study area in Arani-Koratalaiyar river basin, Tamil Nadu, India

3. Materials and method

The geological map (scale-1: 2, 50,000) was acquired from Geological Survey of India (GSI, 2005). Satellite data of Indian Remote Sensing System Linear Imaging Self-scanning Sensor III (IRS LISS III) multi-spectral image with spatial resolution of 23.5 m for May 2009 (Kharif season) was obtained from National Remote Sensing Centre (NRSC), India and for November 2009 (Rabi season) was downloaded from Bhuvan website. For the purpose of the delineating the study area, LISS III imagery was used to improve the geological map obtained from GSI. The geological map prepared were verified and updated (Figure 2) through fieldwork carried out along different traverses across the area. Subsurface geological formations were studied with the help of bore hole logs obtained from Chennai Metro Water Supply and Sewerage Board (CMWSSB). Arc GIS 9.3 software was used for the preparation of landuse and geology maps. The data for water requirement for crops and aquaculture was taken from [12].

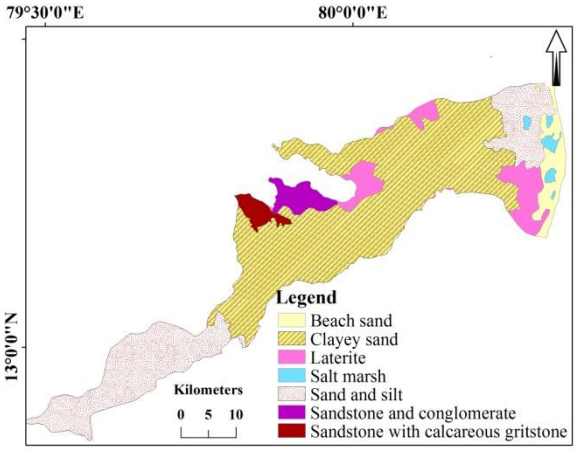

Figure 2. Geology map of the study area

Advanced techniques of remote sensing and Geographical Information System are used to prepare land use maps for two different seasons and geology map. The study area is demarcated based on the paleo channels comprising of alluvial aquifer which is one of the aquifer using for Chennai metropolitan water supply. Rabi and Kharif season landuse map was prepared because the water requirement of crops varies depending on the season. LISS III imagery was improved by using image processing techniques. Landuse was mapped by using supervised image classification technique like maximum likelihood in ArcGIS 9.3. The characteristics of satellite imagery data such as tone and texture patterns were used for the level three classifications of crop patterns [9]. Intensive field survey was carried out in monsoon and pre-monsoon seasons; these ground truth verification were incorporated into classified landuse map and level three landuse map was updated. Groundwater abstraction is calculated by multiplying the water requirements of each crop with its corresponding area. Domestic

abstraction is calculated based on the per capita demand. Groundwater pumping for the salt pan activities was estimated from number of bore wells and horse power of pumps depends on the data collected through field investigation and from salt pan authority officers.

4. Results and Discussion:

4.1. Classification of landuse:

Landuse map was classified into paddy, sugarcane, vegetable, plantation, current fallow, permanent fallow, wetlands, water bodies, educational institutions, industrial, residential, waste land, and forest (Figure 3 & 4).Further, the landuse map is simplified and grouped into cropland, domestic and industrial land, aquaculture, salt pan and non abstraction area for the purpose of calculating groundwater pumping rate for each categories. Seasonal irrigation requirement of paddy, sugarcane and vegetables were determined by considering the pumping hours for corresponding season because water requirement for crop varies in different season. Total area covered by paddy during kharif (November 2009) and rabi (May 2009) was estimated around 457.8 $km^2$and 547 km^2 respectively.

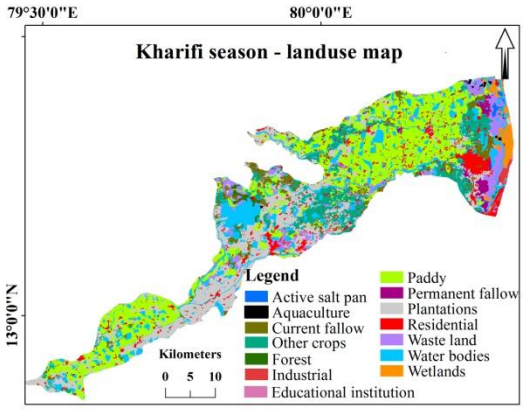

Figure 3 Landuse map for kharif season - May 2009

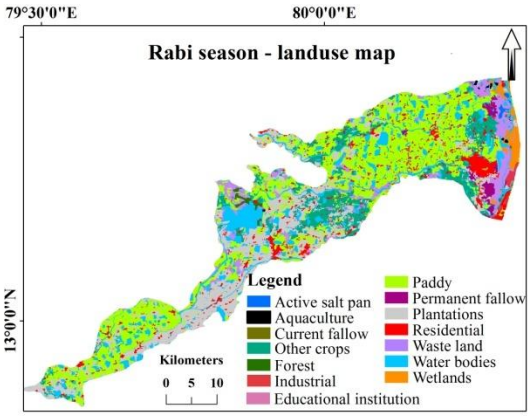

Figure 4. Landuse map for rabi season - November 2009

4.2. Estimation of irrigation requirement:

Groundwater requirement for each seasons were calculated from type of crop pattern. The average water requirement for the various crops is estimated in different seasons because pumping varies between the two seasons. The different types of crop such as rice, sugarcane, vegetables, sesame, flowers and groundnut have been cultivated in kharif season (May to October). Groundwater pumping rate in kharif season was calculated from crop water requirement obtained from [12]. Around 315 $m^3$of groundwater was extracted during kharif season. For irrigation, very high rate of groundwater pumping rate is estimated for the month of May and June and this was also observed during field visits. Groundwater pumping rate for rabi season (November to March) is also estimated from crop water requirement. Rice and sugarcane are the major crops grown during this season. Water requirement for irrigation is estimated about 184.3 m^3 in the rabi season.

4.3. Estimation of groundwater abstraction for other purposes:

Groundwater pumping rate for various purposes such as domestic, salt pan and aquaculture were estimated based on the per capita demand, number of pumps with horse power used and water replacing days respectively. For domestic abstractions, per capita demand required for town Panchayat was taken from Tamil Nadu Water Supply Board; the per capita demand of groundwater of this area is 0.07 m3/day. About 3.79 m3/a of groundwater is extracted for domestic purpose. Details regarding the horse power of the pumps used and the number of bore wells in the salt pan areas were collected through field investigation and from salt pan authority offices. Groundwater extraction for salt pan (0.04 m3/a) and aquaculture activities (0.00003 m3/a) is negligible compared to that for irrigation and domestic purposes.

The groundwater extraction for the municipal supply is not considered for the abstraction calculation, rather recharge from rain, infiltration in river beds and irrigation returns are considered. [13] reported that the average annual groundwater recharge of the A-K river basin is 450 MCM and the average pumping for irrigation from this basin during 1980 - 1984 is 350 Mm^3/a. [3] reported that an average of nearly 27 Mm^3/a of groundwater was pumped for domestic and industrial from the well fields. It has to be considered that the land use based method doesn't take into account a distinction between surface and groundwater extraction. Total groundwater abstraction estimated for irrigation and municipal supply for this area ranging from 581 to 1000 MCM/a.

5. Conclusion:

Geospatial techniques were used to calculate the area of cultivation of different crops to determine groundwater abstraction in a part of A-K basin. The groundwater abstraction is estimated as $315m^3$ and 184 m^3 during kharif and rabi season respectively. Total groundwater abstraction for irrigation, domestic, salt pan and aquaculture activities is around 580 Mm^3 per year in this area. Calculated abstraction will be useful for various groundwater studies such as groundwater modelling, groundwater budget calculation, aquifer sustainability etc.,

6. Acknowledgements:

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