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A Spatial Model for Water Resource Management in Karamana River Basin Using Geoinfromatics

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Abstract: - The increase in the population growth, demands fresh water for development process of the mankind. This has created enormous pressure on the water resources all around the globe. New scientific methods and technologies introduce new farming techniques in the field of agriculture resulting increase in irrigated land hence creating more demand of water In terms of human necessities, Watersheds are fundamental units in water resources management as they are limited in area, convenient and usually well-defined topographic units. They are available in a nested hierarchy of sizes on the basin of stream ordering. They also are open system (in terms of inputs of precipitation and solar re-radiation), and hence as drainage basin, they can be used as a fundamental unit for effective study. An integrated watershed plan is drawn upon the basis of first drawing up its inventory (including analysis of its natural resources like drainage, soil, topography, ground water, land use etc. And the present trend such as degradation, deforestation, soil erosion, floods etc.) A pre requisite however, for the application of such plan includes availability of timely accurate and detailed information on the watershed resources. The advent of modern geo-information systems, such as satellite remote sensing provides a high degree of accuracy making water shed studies more meaningful.

Keywords: Watershed Development, Water Resource Management, Spatial models, Rainfall-Runoff models, Geographic Information System, Remote Sensing, Digital Elevation Models, System Dynamic Model.

I. INTRODUCTION

This study mainly attempts to the spatial representation of the environmental variables, related to the comprehensive water resources management, in a watershed, which is having regional importance. This study has been conducted based on the currently advanced and sophisticated technology such as Geographic Information System (GIS), Remote Sensing. This attempt is mainly focused in the study area at Karamana watershed in the Thiruvanathapuram district of Kerala state. The major objective of this humble attempt is to develop a comprehensive model, which is spatially dynamic, capable of delineating the areas, which are experiencing anomalies in water resource management strategies with emphasizing the need for constant attention in formulating sustainable resource management strategies with respect to time. In this attempt various variables which are having direct and indirect impact on this system and also play a vital role in the management process and building a Scenario for optimal water resources management. There are about 3000 watersheds in the state, the management of which through land use patterns, conversation practices adapted to the topography and soil conditions can determine the extend of run off retention and infiltration. Here is an urgent need for local community based micro watershed management couple with broader integrated river basin support and control management. An overall and integrated approach in water resource management in the State is yet to emerge. On a rough estimate, the source wise dependence by rural households for domestic water supply dependent on traditional ground water systems is 80%, 10-15% use piped water supply systems, and 5% use traditional -surface and other Systems.

II. STUDY AREA

The state of Kerala is a narrow stretch of land having a geographic area of 38,863 Sq.Km. located on the south western side of Peninsular India, bordering Lakshadweep sea on the western side and Tamil Nadu and Karnataka states in the eastern side. It lies between North latitudes 8^0 18' and 12^0 48’ and East Longitude between 74^0 02' and 77^0 22'. It has a long coastal line stretching to 590 Km. The state is having an average width of 70 Km with a maximum of 125 Km. Karamana River basin is the most important drinking water sources of Thiruvanathapuram City which is the capital of Kerala, the land considered with the distinct form of water resources. Apart from that the specialty of this river basin is that this is flowing through remote under developed areas, developing areas and almost developed areas of the district. Hence the influence of socio economic factors on the physiography of the basin is quite obvious to differentiate. The conventional water resource management is having highly vulnerability to high rate of anomalies and lacuna in quantifying and qualifying dependent and independent variables, Moreover to that the basin is being located in a high rainfall area characterized by undulating terrain. The average rainfall is in the order of 170 cms. As the state wise pattern of distribution of rainfall is also quite different from the rest of the regions in the country, with rains concentrated in a short period of around 60 days of the year. There is a lot of controversy around the argument that Kerala State has excess water and that inter–state basin transfer of water is possible. This State has no authentic record to make an objective case, for or against views raised, often, by other States. Much of the information available are a form that is not easily amenable to use.

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III. MATERIALS AND METHODS

Spatial Modeling for Watershed Management System

The complex inter-relationship in a watershed and its living population must be explored with greater precision. The major factors plays vital role in the river basin analysis. Systems and subsystems for the comprehensive water resources management strategies are represented like this. There is a 7-step plan by which preparing a GIS hydrology model can be broken down into component parts. The first five of these steps deal with defining the framework of the model in space, and time, and in preparing the environmental description, which may include representation of the land surface terrain, soils and land cover, subsurface hydrogeology, and hydrologic data such as precipitation, stream flow and constituent concentrations. The second five steps deal with simulating the water balance of spatial units, the flow of water and transport of constituents between units, the effect of water utilization structures such as dams and pumping systems, and finally, with the presentation of the study results.

1. Structural Design: Objectives and scope of study; spatial and time domain; process models needed, variables to be computed.
2. Terrain Analysis: Deriving a watershed and stream network layout from digital elevation data and mapped streams.
3. Land Morphology: Describing soils, land cover, land use, cities, and roads.
4. Subsurface Analysis: Hydro geologic description of aquifers
5. Hydrologic Variables: Locating point gages, attaching time series and their average values, interpolating point climatic data onto grids.
6. Soil Water Analysis: Partitioning precipitation into evaporation, groundwater recharge and surface runoff; partitioning of chemicals applied to the land surface.
7. Water Utilization & Impacts: Locating reservoirs, water withdrawals and discharges in rivers, and aquifer pumping. Their effects on water flow and constituent transport.

Based on this, a comprehensive action plan can be represented as a system model which can be spatially represented using GIS. This attempt is actually aimed to build a scenario based on certain assumptions which are derived based on the through analysis of the interrelationship between the dependent and independent variable and their trend in the positive and negative direction. The hydrological models which can be represented like this can be interpreted based on the system level so that the basic information about the conventional dynamics is obvious in its spatial manipulations. The methodology used in this attempt is the combination of system Dynamic Modeling and Spatial analysis based on Geographic Information systems with the help of Remote Sensing techniques.

Overlay analysis of Maps

The combination of several spatial datasets (points, lines or polygons) creates a new output vector dataset, visually similar to stacking several maps of the same region. These overlays are similar to mathematical Venn diagram overlays. A union overlay combines the geographic features and attribute tables of both inputs into a single new output. An intersect overlay defines the area where both inputs overlap and retains a set of attribute fields for each. A symmetric difference overlay defines an output area that includes the total area of both inputs except for the overlapping area. Data extraction is a GIS process similar to vector overlay, though it can be used in either vector or raster data analysis. Rather than combining the properties and features of both datasets, data extraction involves using a "clip" or "mask" to extract the features of one data set that fall within the spatial extent of another dataset. In raster data analysis, the overlay of datasets is accomplished through a process known as "local operation on multiple rasters" or "map algebra," through a function that combines the values of each raster's matrix. This function may weigh some inputs more than others through use of an "index model" that reflects the influence of various factors upon a geographic phenomenon.

IV. RESULTS

From the geographic analysis of the thematic maps which were generated from the Topographical sheets, field observations and laboratory analyses the following major observations were found to be unveiling in respect of the watershed region of Karamana river basin.

- The principal drinking water source exploited and operated by the Kerala Water Authority and other related agencies of Thiruvananthapuram city is the Karamana River (based on the number of drinking water abstractions points identified from field study using Global Positioning System.)
- Population related to commercial establishments, business enterprises, production and distribution of sophisticated materials based on Information Technology and other related industries were found to be comparatively high than any other river basin of the district (Analysis based of the Census reports of 1991 and 2001 along with the field survey conducted as random sampling.)
- Geological variables showed very meager variations according to the time scale. most of the areas of the watershed were found to be covered by strata of garnet biotitic siliminite gneiss with or without graphite (As per the observation made with reference to the Geological Map)
- Rainfall distribution throughout the watershed region was showing no linear variations according to seasonal time factor, Sometimes the distribution were found to be exhibiting chaotic nature with predictions. (Analysis of the Rainfall date collected

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from the Indian Meteorological Department Thiruvananthapuram for 10 years from 1999 to 2007)

- Population density in respect of the Karamana watershed was found to be showing significant growth and rate of urbanization with respect to time was also seemed to be having its own acceleration as per the developmental plans under taken by the Government. Reference may please be made with the Population Density Map (Map) prepared based of the Census reports of 1991 and 2001along with the field observations made
- Regarding the Ground Water Potential, almost 60% of the watershed areas were found to be coming under the category of potential as low to poor and around 40% of the areas were found under the classification of good to very good. The major parts of the Thiruvananthapuram Corporation were found to be lying under the classification of fairly good. Panchayaths such as Venganoor, Vizhinjam, Srekaryam, Kudappanakkunuu, Kazhakootam and Pothencode were also found to be in the same category. in these panchayaths the amount of ground water which can be exploited by human beings were up to an appreciable level so that Groundwater table which is the level in the geological formations below which all voids or cracks were found to be saturated. It represented the upper surface of the groundwater and top of the saturated zone for an unconfined aquifer. It was the level at which the hydraulic pressure is equal to the atmospheric pressure. The water level found in unsaturated wells is often the same level as the water table. The depth of ground water table plays an important role in determining the contamination risk of ground water. The pre-monsoon water level during April 2005 shows shallow water level in the range of 0.1 to 2.0 m in coastal tract of Thiruvananthapuram district. Areas in Perumkadavila, Thiruvananthapuram, blocks of Thiruvananthapuram district were showing a wide variation in the depth to water level mostly in the range of 2-20 m bgl. Water level in the range of 5.0-25.0 m bgl is seen in Nemom block of Thiruvananthapuram district. Depths to post monsoon water level during the months of August and November 2005 show range of 10-22 m bgl and 10-25.15 m bgl respectively in certain pockets of areas in Thiruvananthapuram district where thick laterite overburden was seen. The lower ground water potentials could be seen in panchayaths such as Karakulam, Aruvikkara, Vilappil Major part of Vilavoorkkal, Anad Poovachal , AryanadKuttichal Vithura Tholicode and most part of the Nedumangad Muncipality and Nanniyode.
- Based on the land use land cover map analyzed using the advanced techniques in Remote Sensing and Digital Image Processing it was observed that most part of the area were found to be covered by mixed crops. Another two major categorizations, those were observed using the digital image processing of Remote sensing imageries, were the built up land and the forest area. Rubber and tea plantations were also visible in these regions. An elaborated studies had been conducted for discovering the changes occurred from the earlier analysis conducted by the Survey of India in 1971 and the present physical status. This was done for distinguishing between the Land Use land cover map delineated with the help of remote sensing imageries interpretation disclosed that most of the forest areas were already transformed to built-up land and the natural; vegetation were changed mono crops planted by encroaching the forest areas and other mixed vegetation areas. Human encroachment was found to be quite obvious in the land use pattern analysis and certain new species of mono crop plantations were also found to be innovating in these regions.
- Based on the soil profile and structure analyzed it was estimated that the major areas of the watershed were coming under the categorization of Nedumangad - Kuttichal series and Kallar- Palode series. The coastal areas were found to be covered by Kazhakuttom - Poovar series and the middle parts of the watershed were seemed to be constituted with Trivandrum- Vizhinjam series where as the upper parts of the watershed were found to be covered by Kottoor and Ponmudi series.
- In consideration with the soil erosion dynamics of the terrain of the Karamana watershed, it was visible from the spatial analysis that nearly 70% of the areas were covered by erosion in moderate level. The coastal part of the watershed was found to be in the category of very low erosion and even seemed to be almost nil where as the catchments areas were found to be very much vulnerable to high degree of soil erosion so that the topsoil depletion can be visible with respect to the rainfall run off . which also predicted the possibility of occurrences of landslides in the highland areas.

V. DISCUSSION

The impacts of the variables were studied with the help of the spatial and no spatial modeling techniques. The three factors on which the base concentration has to be bestowed are the water demand, water availability and water supply along with the conventional utilization pattern. Almost all policy variables and natural variable have already been sorted out for finding out the inter relationship between these variable and their trend toward the change of time factor. Both natural and anthropogenic imposed variations were studied in the wok and it was well established that these variable are the major cause fo the dynamic changes of the watershed. Hence the following suggestion for implicating policies based for

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the development of comprehensive watershed management system.

(1) Considering the water demand of the entire watershed, a complete assessment should be conducted with reference to the population distribution and their conventional water use pattern.

(2) Extensive study should be conducted for calculating he efficiency of the conventional water supply system operated by KWA and other related agencies so that number of connections with respect to the population index has to be sorted out.

(2) More effective measures should be taken for improvising the water supply system so that the pressure in the pipes have to be monitored for eliminating the leakage and breakage which cause excess loss of drinking water mainly from the Peppara and Aruvikkara reservoir.

(4) Conventional land use pattern has to be modified so that worthless planting of trees whose water intake was compared to be more should be avoided. The plantation of mono crop vegetation and the trees which are only used for shadows should be of less water consumption

(5) It was observed that the evapo-transpiration as one of the major reason for the lack of water availability hence more trees should be planted with the measure of low evapo- transpiration there by the amount of available water can be saved from depletion..

(6) In consideration of the land capability. More assessments have to be done for the identification of schemes in accordance with the appropriate land use so that those which are suitable for those particular regions only can be established. This will keep the water availability with respect to the land capability. The land capability classification should be under gone for more thorough analysis so that the existing land reclamation activities are also monitored in the perspective of water availability.

(7) Constriction of more dug wells and tube wells generate a drastic reduction in the water table. In this study it was demarcated that those paces are having good ground water potential. In these areas more consent can be provide for the establishment of dug well and tube well. But in those areas where the ground water potential was low proper guidelines have to be imposed for the establishment of these exercises.

(9) Irrigation potential was also studied as one of the most important factor in the watershed management process. In the Karamana river basin the impacts of irrigation potential was well analyzed so that the areas where more places are subjected for the irrigation process should demarcated in the concept that these areas the water sue potential has to be regulated for other activities so that more thrust should be give for the irrigation process. The other activities other that irrigation for which the water use was more should be regulated by providing proper measures.

(10) Water consumption rate was one of the important parameter that has to be analyzed in respect of the population growth and change in the conventional water use pattern. More public water supply system and with more efficiency have to be introduced for meting the water supply with the existing and future water demand. The policy makers have to concentrate on anticipatory management studies with respect to the increase in the population in the future years and the modern technology enhancement with the augmentation of more projects in the existing water supply scheme.

(12) Water impoundment was considered as one of the major factor in the conventional water resources management. The merits and the demerits of the water impoundment have to be studied with the possibilities of check dams as well as the small barrages so that the demerits of the water impoundment such as the siltation process, deposition of sediments having traces of pesticides and the possibilities of eutrophication and also one the most important demerit of the water impoundment that is the reservoir induced seismicity can be regulated. More studies have to be concentrated on these areas.

(13) The sand mining activities are having strong negative impacts over the morphology of the river discharge volume and the net water availability of the place. Hence those areas with the water availability was in risk and more water demand was required, sand mining activities should be regulated and un authorized sand mining should be banned with proper legal measures.

V. CONCLUSION

Form the spatial data and the non spatial data analysis showed that the existing water resources management was having lot of irregularities. The non spatial analysis done with the help of system dynamics and Modeling techniques portrayed a clear schematic diagram for the representation and analysis of the related and indirect intervening variables which play vital role in the water resource management of Karamana river Basin. The inter relationship between the system variables and policy variables were analyzed with a conclusion that policy variables have to be regulated according to the changes frequently experiencing in the dynamic related variables of the system. The management decisions should be taken in accordance with the situations so as to regulate the pace of theses variables with respect to the changes a happening in the others. From spatial analysis made with the help of hydrologic modeling using the geographic information system and remote sensing techniques, logical map overlaying were done for finding out vulnerable areas of water scarcity. Possibilities of severe

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drought can also be predicted in these areas as they are having high water demand with low water availability. These factors were geographically represented in the map in a cartitian frame. The location of those palaces which can be vulnerable for the drought and subsequent water scarcity were demarcated Panchayath wise which gives a clear picture on which the hot spot areas were the measures have to be taken for protecting the water scarcity and drought. The water quality analysis done in the basin showed a clear insight over the utilization index of the water resources of Karamana river basin. From this also potential areas of water quality problems were identified and evaluated the proper measures that has to be taken for the implementation of water quality management practices along with the pollution abatement process in respect of the Karamana river basin. Several policy decision can be taken for regulating the enhance of negative parameters and so that tone could observe the related changes that may be affected on the system

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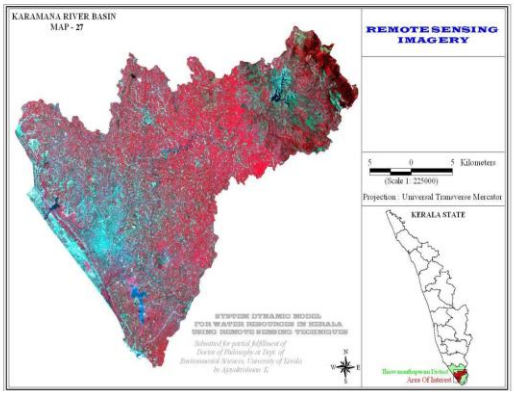
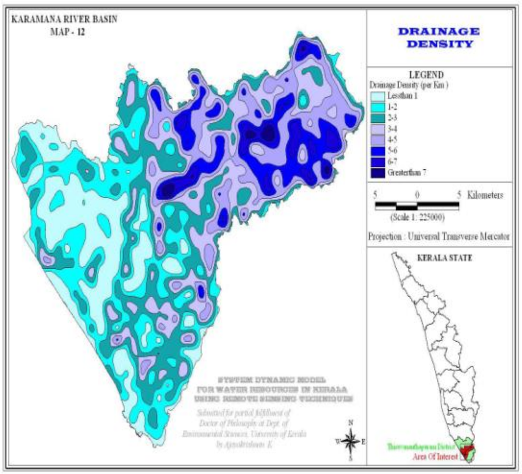
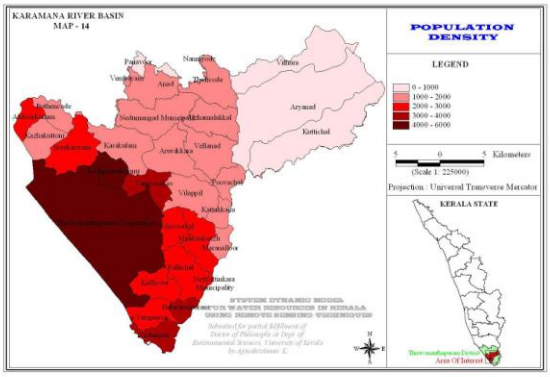
Map1- Remote Sensing Imagery of Karamana Watershed



Map2- Drainage Density of Karamana Basin



Map 3- Population Density of Karamana Basin



Map 4- Comprehensive status of Water Demand in the Karamana Basin

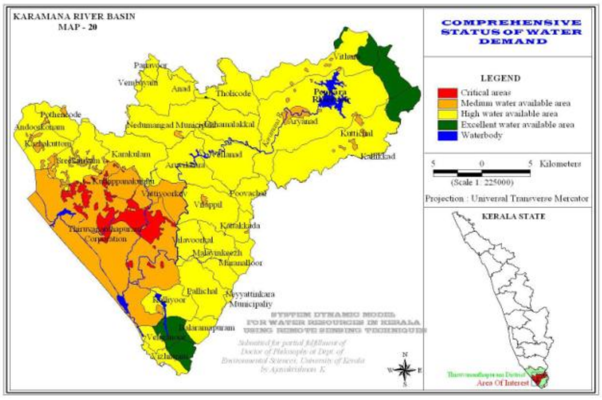


Table Showing location of Intake Points

Locations of Intake Points	Latitude	Longitude
Aruvikkara- 1	8^0 34.428 N	77^0 01.241 E
Aruvikkara- 2	8^0 34.508 N	77^0 01.131 E
Aruvikkara- 3	8^0 34.412 N	77^0 01.315 E
Kalathara	8^0 34.721 N	77^0 01.484 E
Vellanad	8^0 34.509 N	77^0 02.670 E
Aryanad	8^0 34.726 N	77^0 05.166 E
Kuttichal (Kokkottela)	8^0 34.683 N	77^0 05.125 E
Uzhamalakkal	8^0 35.545 N	77^0 03.189 E
Kundamankadavu	8^0 30.584 N	77^0 00.194 E
Adimadakku kayam	8^0 29.285 N	77^0 00.178 E
Mangattukadavu	8^0 29.917 N	77^0 00.281 E
Malamukal	8^0 32.751 N	77^0 00.675 E
Kummi	8^0 34.047 N	77^0 00.410 E