Identifying Water Harvesting Sites In Watrak River Basin Using GIS Technologies And Considering Equity Measures

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Abstract:-

Geographical Information Services (GIS) has become an inalienable part of watershed development due to its versatility and also availability of spatial data worldwide. In India too, GIS has been widely used for watershed management. Watershed development in India has earlier been characterized by inequities in distribution of benefits and thus led to grudges among people suffering from negative externalities. Guidelines framed by National Watershed Development for Rainfed Areas have tried to mitigate the inequities creeping in watershed development projects. The use of GIS technologies in watershed development, too have facilitated implementation of these guidelines as well as other measures for equity in watershed planning, development and prioritization. One such attempt for equity in watershed development has been attempted in this research paper for the Watrak river basin, which is located in one of the relatively backward regions of Gujarat, India. These and other such measures can go a long way in increasing the effectiveness and reach of watershed development especially when vast areas await development and financial resources required for such development are scarce.

Keywords: GIS Technology, Watershed Management, Equity, Water Harvesting.

1. INTRODUCTION

GIS is a computer based information system that enables capture, modeling, manipulation, retrieval analysis and presentation of geographically referenced data [6]. As per another definition, GIS is a digital representation of landscape of a place structured to support analysis[Oak Ridge National Laboratory]. The ability to interlink and analyze spatial data is the distinguishing characteristic that sets GIS apart from the multitude of graphics and other mapping softwares[7].

Watershed can be construed as a basic and natural unit of development. It is an spatial area from where runoff from precipitation is collected and drained through a common outlet. Soil, water and vegetation, the three important interdependent natural resources can be easily and effectively managed at the watershed level. This has been increasingly understood by the scientific community and hence, watershed management has thus gained a greater prominence in recent times. Long term sustainability of agriculture and rural communities through local planning can be effectively achieved at watershed level. Watershed management has long been used for the development of agriculture, land and rural communities. Several policies and programmes have been framed and implemented for effective watershed development and management of resources there in[1].

However, inequities often arise and increase due to watershed programmes[22, 23,24,25,26]. This leads to dissatisfaction among negatively affected communities and also defeats the purpose of the programmes to a great extent. This inequities arise due to number of factors like differences of gender, caste, class, technology selection, spatial location [8, 10, 11].

Other shortcomings of watershed management programmes in india include[2]

- Lack of attention to watershed hydrological boundaries.
- Lack of consideration of connectivity of watersheds and instead treating them as one.
- Ignoring of environmental sustainability aspects, etc.

Another problem encountered in watershed management programmes pertain to unavailability of information required for integrated planning and management, especially quantities of surface water and ground water.

GIS technology has diverse application in watershed management right from assessing watershed conditions by simulating the impact of human activities on water quality and also of alternative management scenarios.[4,17,18,21] GIS technology has grown tremendously over the last two decades and has become even more inalienable to watershed management. Advancements in computer hardware, software, increasing availability of digital data, etc has supported the use of GIS further in watershed management. GIS application in watershed management has changed from operational support to prescriptive modeling and strategic decision making[4].

GIS based modeling of natural factors, other variables and processes can be effectively used in local planning to prioritize watersheds and water harvesting structure locations[2,16].Many of the shortcomings pertaining to inequities and other limitations of watershed management programmes as mentioned above can be addressed using the GIS technology and its recent advancements[19].

Further, many of the physical and socioeconomic guidelines for watershed prioritization suggested by National Watershed Development Project for Rainfed Areas (NWDPRA) can be implemented using GIS. The guidelines for watershed prioritization as per the order of their importance are as under[1, 2,15,20]

- Highly eroded areas with much land degradation.
- A watershed scarcity problem.
- Less than 750 mm rainfall per year.
- Net Cultivated area of no more that 20 % of the total area.
- An irrigated area not exceeding the state average or 30 % of the total land area.
- No areas of long duration or water intensive crop.

2. STUDY AREA

The research work was undertaken on Watrak river basin, a part of Sabarmati river basin in Gujarat, the western state of India. The Watrak river originates in Panchara hills, a part of Aravali hills, in Dungarpur district of Rajasthan and after travelling for a distance of 248 kms in south west direction meets the river Sabarmati on its left bank. It covers the remaining drainage area of the main river downstream of the confluence of Khari and upto its meeting with the Gulf of Khambhat. Watrak and its tributaries drain an area of 2606.7 km^2 till Ambaliyara. The mean annual surface water resource in the subbasin is 1955 x 10^6 m^3 [5].

WATRAK BASIN

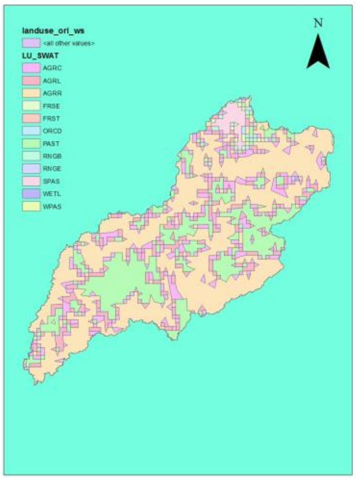
The elevation of the Watrak river basin varies from 47 m to 378 m, with mean elevation being 175 m. 94% of area of the basin was having terrain slope of 10% or less. Agriculture comprised of 73% of land use followed by 23 % of land use under pasture. Vertisols form the dominant soil group with a coverage of 56 % of basin area. Luvisols cover about 34 % of basin area [FAO UNESCO soil map of the world].

The basin has sizeable Scheduled Tribal Population, in certain parts, it being greater than 60 percent[12]. The basin has a sizeable Scheduled Caste Population too. Further, working population in the basin area is less than 50 percent of total population in overwhelming majority area of the basin[12]. Agriculture is the dominant economic activity in the region by far [5] and thus most of the population is rural. Further, a weak industrial base of the region also confirm the same. The above parameters clearly indicate the backwardness of the region and thus a fit case for watershed programme prioritization. Besides, average annual rainfall in the basin is about 827 mm [13], little above the priority criteria for watershed development for rainfall (should be < 750 mm). Political map of the region was obtained from DIVA-GIS website [14].

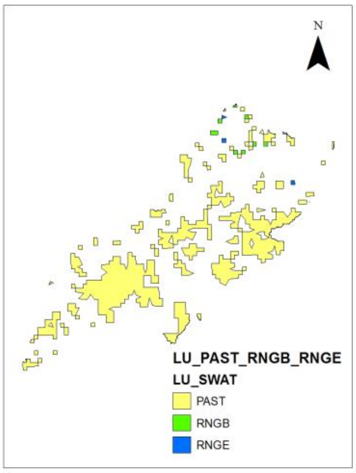
3. METHODOLOGY

As discussed above, the Watrak river basin is among the backward regions of Gujarat. Further, the agriculture is not irrigated as in other parts of Gujarat. Watershed development in this region requires priority in general. The research intends to identify locations for developing water harvesting sites in the basin considering some of the guidelines given by National Watershed Development Project for Rainfed Areas (NWDPRA) plus some other factors mentioned below so as to mitigate inequity and facilitate water resource availability and prevention of degradation of land resources. The additional factors considered for identifying the water harvesting locations are as under:-

- Selection of land under pasture or grasslands so that land under agriculture or forest is preserved for the intended use

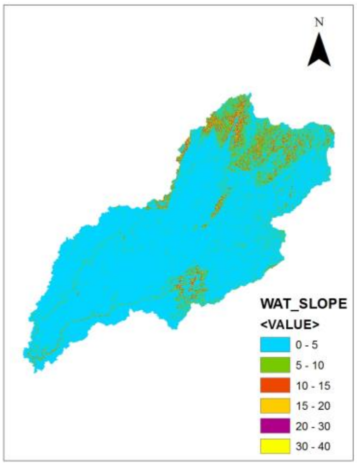


LAND USE MAP OF BASIN

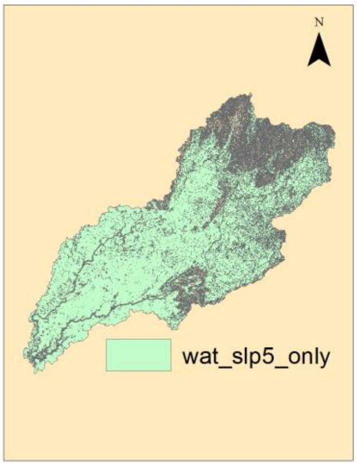


PASTURE LAND USE MAP

- Slope of the water harvesting site should be less than 5 percent, so that it is easy to develop the harvesting structure be it contour bunds, ponds or check dams.

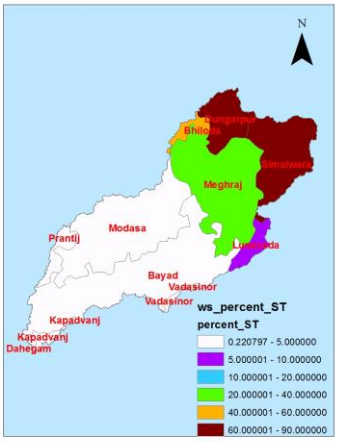


SLOPE MAP OF BASIN

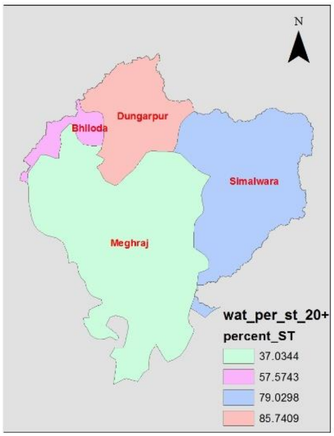


< 5 PERCENT SLOPE MAP

- Tribal population, which is more often most deprived part of the overall population constitutes more than 20 % of the population.

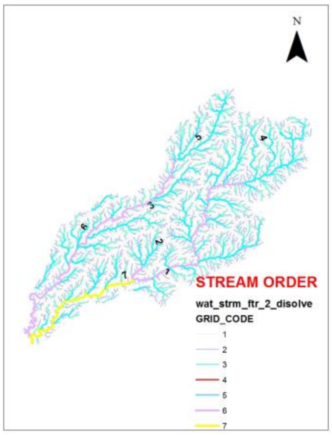


% TRIBAL POP. MAP

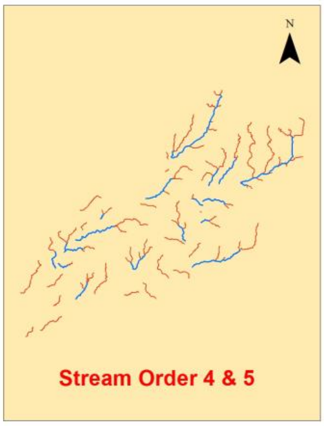


>20% TRIBAL POP. MAP

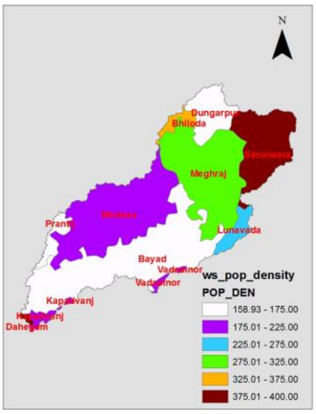
- Streams are of the order of 4 or 5 (out of 7 hierarchial levels from smaller to higher), so that reasonable quantities of water can be harvested.
- Density of population should be greater than 250 persons per km^2, so that benefits of water harvesting are passed to maximum population.



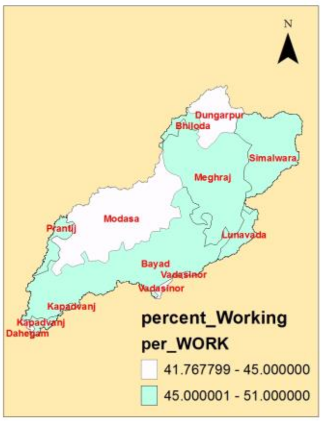
STREAM ORDER MAP



STREAM ORDER 4 & 5 ONLY



POP. DENSITY MAP



% WORKING POP. MAP

A. *Data Processing*

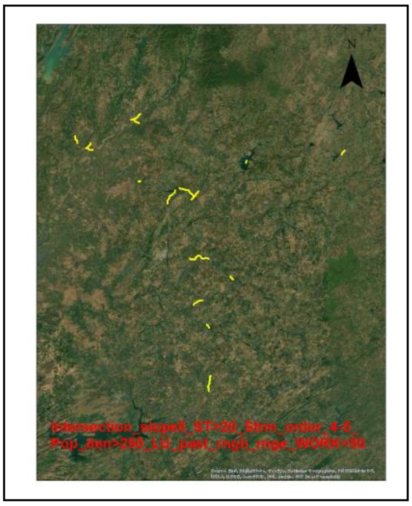
Raw data was available from the websites mentioned above. These data were clipped for the basin area and projected in UTM 43N projection and WGS1984 datum using various GIS functions. The census data available from the census website as mentioned above was in excel format. The population enumeration data like SC, ST population, Total Population, Working population etc was converted into format which could be processes in GIS. Further, data like population density at taluka level, percent ST, SC population was found out using GIS functionalities and represented in GIS processable data. This was integrated with the extracted political map of the basin obtained from India Political map available on DIVA GIS.

Following data maps (layers) in shapefile format were obtained using various GIS Functions and commands for use in obtaining best locations for water harvesting structures considering equity parameters discussed in this research paper and some from the NWDPRA guidelines.

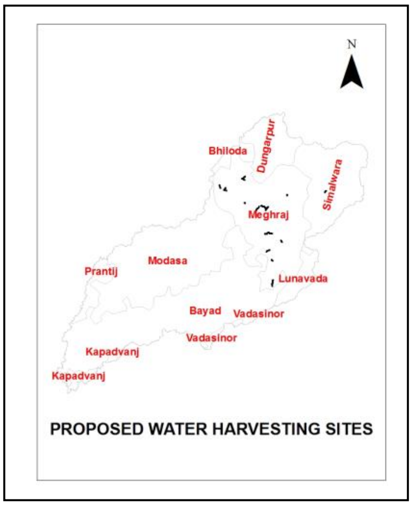
- Data maps for slope less than 5 percent.
- ST Population percentage wise for the basin tehsils.
- Stream orders all(1 to 7) and customized stream order 4 & 5
- Population density map representing taluka having population greater than 250 persons per square km
- Landuse map displaying only Pasture and grasslands landuse.

B. *Data Operations*

Finally, all these separate map layers were superimposed over each other and then the intersection of all the layers was obtained to get best locations for water harvesting sites considering the equity parameters considered in this research as well as some of those given by NWDPRA.



WATER HARVESTING SITES WITH TOPOGRAPHICAL MAP IN THE BACKGROUND

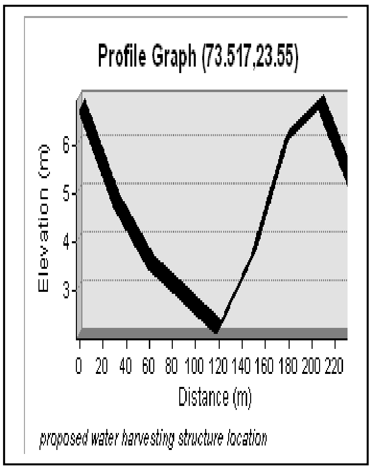


WATER HARVESTING SITES IN BLACK WITH POLITICAL MAP IN THE BACKGROUND

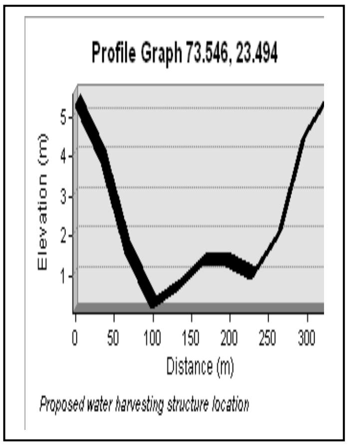
4. RESULTS AND DISCUSSIONS

The final output from the above Data Processing and Data Operations was in line shapefile format. These locations indicated best sites for constructing water harvesting structures like contour bunds, ponds and check dams as equity considerations were accounted in zeroing over these sites. As these sites were in line shape file and some of them spanning few 100 mts, these sites were further refined using profiling command in GIS.

With the help of profiling, best cross sections of the stream were identified to further increase the accuracy of the locations for more economical results in construction of water harvesting structures.

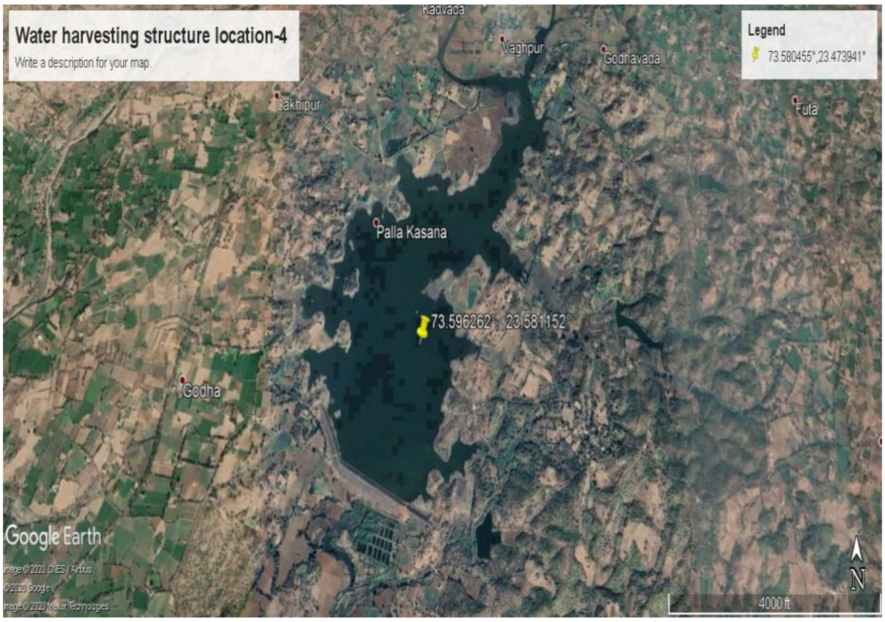


C/S Profile of Water Harvesting site as indicated by coordinates



C/S Profile of Water Harvesting site as indicated by coordinates

Finally, these sites were verified using Google Earth maps, so as to confirm that the landuse at the sites is non agricultural and they are not over the residential locations. The locations are shown by points in the figure, but are to be understood as area. The google earth locations confirmed that the results were in conformity with the input criteria, eventhough the landuse data used in processing and google earth maps used for verification were of different time lines.



GOOGLE EARTH PHOTOS OF TWO WATER HARVESTING SITES INDICATED BY ARROW

5. CONCLUSION

GIS technology goes a long way in helping in watershed development, especially considering importance of equity measures. Past experiences with implementation of watershed development projects clearly indicate such projects do bring development of the region, but the larger chunk of benefits have more often than not been ripped by the haves leading to increase in the inequities.

It has the potential of being an effective answer in prioritizing backward areas for watershed development considering the quantum of financial resources required in watershed development and corresponding scarce availability of the same. Further, it considerably reduces the efforts required in planning provided right data sources are available.

Lastly, though technology can play a very effective role, particularly in watershed development, findings from use of technology often needs to be confirmed by physical verification which may be again be helpful in further refining the findings for better outcomes.

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