Identification of water storage site using GIS and Analytical Hierarchy Process - A Review

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.***Abstract***- The watershed is a geo-hydrological area on which precipitation occurs and drains towards common outlet and there is common harmony among the soil, water and land use. So it is more significant to take the watershed as a development unit and to adopt the sustainable development program at watershed level to conserve land and water resources. The need of present hour is to tap maximum water available in the river basin that can be utilized especially during the period of drought. Many years ago there is no satellite systems developed. But today's scenario is totally different with the help of satellite data many things are possible. One of the things are prediction, estimation, calculation and locations related to water resources. This is a literature review based on paper aims at studying various researches already done in the field of GIS and AHP for selection of water storage site.

Index Terms-**Geographic information system, ArcGIS, Analytical hierarchy process, Water storage structures**

I. INTRODUCTION

Water storage structures are the major component of water resource management. Dams check dams, farm ponds and nala-bunds are the major structures of water storage. It has been used for irrigation, hydropower generation, to conserve amount of water and to discharge water for various purpose. It can also serve as a protection during flood and drought situations. But it is very important to locate a structure in a suitable position to satisfy need and fulfill requirements. To develop a structure several properties to be examine of land and river also. The parameter that influence water storage site are Land use land cover, hydrological soil group, stream order, lineament that represents the uncertainties and it is very essential to consider in selection of site for water storage.

In the developing countries like India where financial resources are limited, it is not possible to implement the watershed development program over the whole watershed simultaneously. So it is necessary to identify those areas which are prone to flood hazards and soil erosion. Thus watershed prioritization involves the ranking of sub-watersheds or priority allocation procedure according to which the watershed development actions are implemented. Priority watershed is the most deteriorated and of manageable size. Various structures like check dams, farm ponds, percolation ponds and nala bunds help to control excessive surface runoff and subsequent soil erosion therefore act as flood controlling structures as well as soil and water conservation structures. They help in harvesting surface water by storing it on their upstream side and the ground water recharge can be enhanced by infiltration of stored water. Therefore, the provision of water harvesting structures is a key task while implementing watershed management program.

Here ArcGIS (Geographic Information System) approaches engage in this study. The ArcGIS is computer based software which can be used for digital elevation model, water delineation process, to identify different zones and many other uses. It is the GIS based software developed by ESRI to work with geographic information. The capability and the speed of the software make the representation of the watersheds with thousands of hydrological elements. Conventionally, these elements were identified by tracing the drainage boundaries of the topographical maps so it was time consuming and cumbersome process. This task can be performed quickly by using elevation data in geographic algorithms. Geospatial Hydrological modeling Extension can be used with ArcGIS software to create the basin models.

Analytical hierarchy process (AHP) is a process developed by Thomas Saaty in 1960. Thomas Saaty gives scale to decide various parameters comparing to each other and decide their importance. These scales were widely used in many fields for decision making such as in management, engineering, public private partnership, choice for machinery etc. Thus scale played very crucial role for choosing a particular alternative with respect to other.

II. Analytical Hierarchy Process

This process was very important to understand before applying it to achieve our aim. AHP has been applied in a wide variety of applications – multi objective decision making being just one. A look at the three primary functions of AHP, structuring Complexity, measurement, and synthesis helps in understanding why AHP is such a general methodology with such a wide variety of applications. Structuring complexity, measurement on a ratio scale and synthesis are the basic

functions or say steps to complete the process. Basically multi criteria decision model. Decomposition of problem into a hierarchical structure will be done through AHP process. It can handles number of criteria and sub criteria. AHP takes care of inconsistency in judgment. Provide method to improve such consistency. So in AHP process first we have to select number of alternatives for a particular result. Alternatives were arranged in form of matrix. Then normalization of matrix will be done by equalizing to value 1. Then find out the weighted values based on analysis. Then apply some mathematical equations for easy results. Find CI for particular matrix.

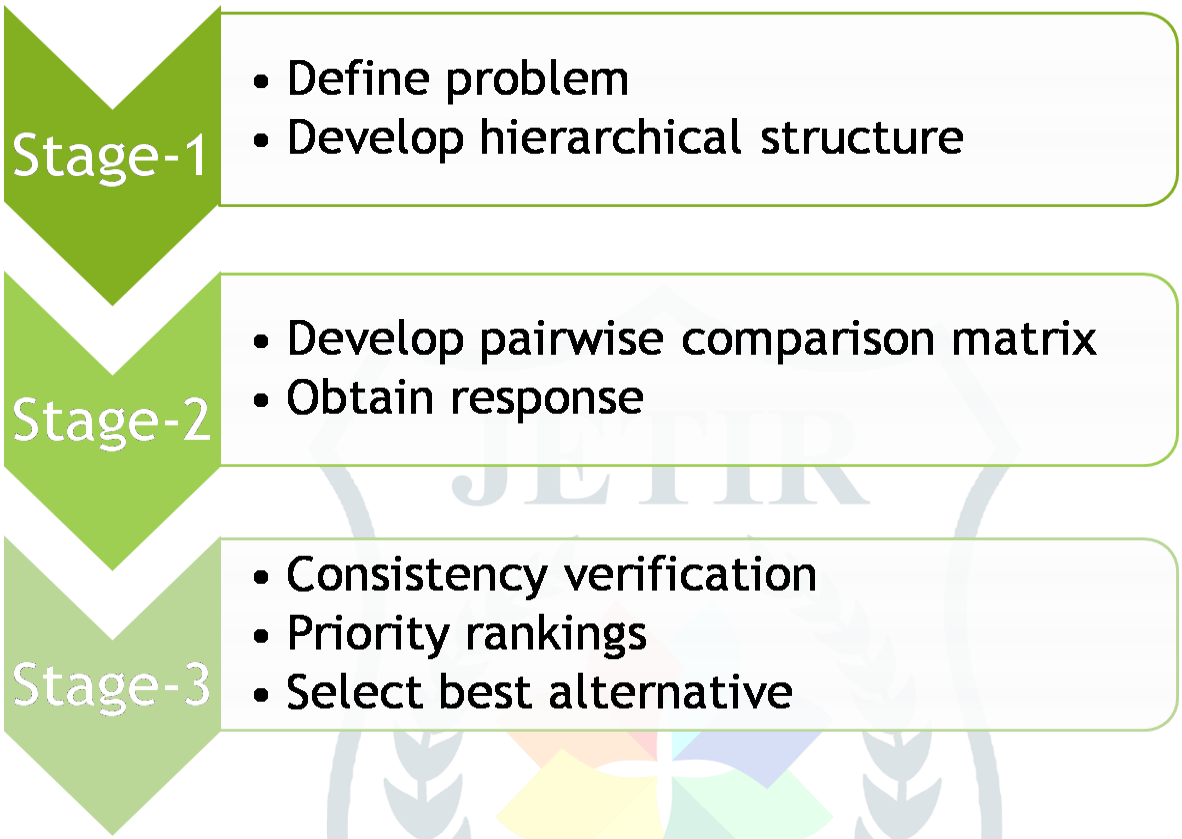

Fig. 1 Analytical Hierarchy Process

These are the steps to follow to obtain needed result. By applying AHP, best alternatives can be finding easily and accurately. It was very popular method but there are some advantages and disadvantages also. For better results take more alternates and obtain matrix as per condition. As per given size of matrix randomized index (RI) is available on Saaty scale which can be used to obtain for desire result.

C. I. = $\lambda_{max} - n / n - 1$ as per Saaty scale to find out Consistency Index. C.R. = C. I. / R. I. by this Consistency ratio can be obtained. After all the process CR will be checked it will be less than 10% then and then only it will be acceptable. This is the process of analytical hierarchy process.

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective.
3	Moderate Importance	Experience and judgment slightly favour one element over another.
5	Strong Importance	Experience and judgment strongly favour one element over another
7	Very strong Importance	One element is favoured very strongly over another, it dominance is demonstrated in practice
9	**Extreme importance**	**The evidence favouring one element over another is of the highest possible order of affirmation**

Fig. 2 Saaty Scale

III. LIETRATURE REVIEW

GIS and AHP have been used by different researchers for locating structures of water storage.

Ahmad and M.K.Verma (2017) presents to locate suitable site for water storage site at Upper Sheonath sub basin. Analytical hierarchy process is used as a decision making tool to determine the percentage importance of various parameters used in the determination of suitable area. To identify suitable location for water storage site using Multi criteria evaluation technique under the guidelines of integrated mission for sustainable development (IMSD 1995). For this various parameters like run-off, hydrological soil group, land use, settlement, lineament, stream order etc has been used. To achieve objective several spatial and non spatial data were used like DEM were prepared from ASTER GDEM, topographic sheets from SOI and soil data from state water centre. The conclusion given by authors is like for that particular area either check dam or regional reservoirs along the drainage lines can be built for possible water storage. AHP can be best utilized for decision-making in terms priority of parameter one over another. AHP easily update suitability levels and weighted score of decision criteria on which the potential sites of water storage are based.

W. M. Jabr & F.A. El- Awar (2005) the research was to be conducted for sitting water harvesting reservoirs in a 300km^2 area of Irsal –Lebanon by low and erratic precipitation to improve agriculture potential. Here three steps were applied first is ArcGIS second one was watershed modeling system and last was decision hierarchical structure using AHP. A water harvesting reservoir sitting methodology was developed as a approach for increasing the availability of water during summer months through supplement irrigation. The main issue was dry marginal lands of Lebanon where recent plantations of rain fed cherry and apricots orchards were suffered from low fruit yield and quality. This involved development and application of a three-step Hydro-Spatial Analytical Hierarchy Process (AHP). First Arc GIS was used to produce pertinent spatial coverage. These included base, topographic, land cover and soil maps. GIS techniques are very useful for site selection studies due to their excellent capabilities in storing, analyzing and displaying spatially distributed data according to user defined specifications. In the second step, Watershed Modelling System (WMS) was used to simulate the runoff in the watersheds. Finally, in the third step, a decision hierarchical structure using the AHP was developed and implemented to rank various potential reservoir sites according to their suitability expressed in terms of a Reservoir Suitability Index. Furthermore, the lack of historical data for weather and hydrology forced the use of a large time step for analysis and forced the use of approximation techniques. Nevertheless, this method still provided a valuable tool for site selection in remote areas. The application of the methodology shows that it works efficiently for sitting such reservoirs. Moreover, the methodology is highly flexible regarding the number, types, threshold values, and RIWs of decision criteria on which the reservoir sitting process is based. The use of the same clearly defined hierarchical structure of decision criteria to rank all candidate sites insures the general objectivity of the method.

J.P.Singh & Darshdeep Singh (2009) the research was carried out to locate rainwater harvesting sites at Sonkhad watershed, Punjab with help of remote sensing and GIS techniques. Soankhad watershed has drainage area of 92.97 sq. km. SOI topo sheets were digitized using ArcGIS 8.3 software. Due to the steep slope, study area faced extreme soil erosion due to higher surface runoff and there was a need to control surface runoff and soil erosion. With the help of IRS-1C satellite image, the land use map was prepared. The hydrological soil group map was prepared from soil map considering infiltration rates of soil texture. The slope map was prepared from DEM& buffer map prepared from land use map. Overlaying these all thematic maps in ArcGIS, the ideal sites for water harvesting identified according to IMSD criteria. The 14 sites for check dams and 6 sites for percolation tanks were suggested. Due to the steep slope and higher runoff velocity, suitable site for locating farm ponds and nala bunds were not found. The study shows that the integrated approach of remote sensing and GIS has utmost importance in watershed development. The suitable sites were not found for nala bunding and farm ponds due to steep slope, less soil thickness and high runoff velocity. Fourteen check dams and six percolation tanks were proposed for the construction as per Integrated Mission for Sustainable Development (IMSD) guidelines. The water balance study of the Soankhad watershed was also computed with monthly mean temperature and rainfall data using TM model. The average runoff for the wet season (July September) 1996 was computed to be about 1543.82 mm and the total runoff volume from the Soankhad watershed was estimated to be about 143.52 Mm^3.

D Ramakrishnan et al. (2009) the SCS-CN method and GIS techniques were used to locate rainwater harvesting sites for kali sub-watershed of Mahi river basin at Gujarat. Kali sub watershed has drainage area of about 200 sq. km. and located at Godhra district of Gujarat. It was necessary to manage water scarcity by providing water harvesting structures in the area of Kali watershed because of low average rainfall, high runoff and evaporation. The study shows the applicability of integrated approach of remote sensing and GIS in watershed development. The region has been experiencing soil degradation due to inadequate forest cover, denudation of forest, uncontrolled grazing and neglect of available pasture land. The climate is semi-arid and experiences three well defined seasons. Soil and land use map were prepared from IRS-LISS3 image & NBSSLUP maps, slope map was prepared from calibrated DEM of SRTM, and digitization was carried out from topo sheets and updated from SRTM. The runoff potential was found by using SCS-CN method. The runoff found from SCS-CN method is a function of runoff potential which is expressed in terms of runoff coefficient(ratio of runoff and rainfall) and classified into three classes like low(<20%), moderate(20-40%), high(>40%) The spatial information of runoff coefficient, drainage, lithology, slope and fracture were used for locating water harvesting sites considering IMSD criteria. This research concludes that by applying decision approach system result was fast, reliable and more accurate. GIS is a very powerful tool that gives better results and site suitability map which was far better than conventional approach.

Patel et al. (2015) GIS based decision support system was developed by the researchers for locating check dams at Hathmati watershed of Sabarmati basin in Sabarkantha district of Gujarat. Hathmati watershed has drainage area of 1085.66 km^2. With help of ArcGIS 9.1, Hathmati watershed was delineated in thirteen sub watersheds using S.O.I. topo sheets and SRTM data of 90 m spatial resolution. Morphometric analysis was carried out on sub watershed basis. Stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, circulatory ratio, elongation ratio, form factor, compactness ratio were considered for sub watershed prioritization. Various spatial datasets such as compound morphometric parameter, drainage density, soil map, slope map were considered for weighed overlay in GIS. Using AHP-MCE, the normalized weights for different layers were found out. Then weighted overlay was carried out in ArcGIS software and prioritized areas were identified. Based on prioritized areas, the ideal location for check dams were suggested according to IMSD (Integrated mission for sustainable development) criteria. The study revealed that the SRTM data along with GIS is very helpful in Sub watershed delineation and their prioritization. This study also shows the applicability of AHP-MCE (Analytical hierarchy process for multi-criteria evaluation) in watershed management.

Mishra et al (2010) The researchers carried out analysis and prioritization of sub-watersheds for watershed of Hati river. The watershed is located at Bhavanipatna area of Kalahandi district and covers an area of 1515.45 sq. km. The drainage network was digitized from SOI toposheets in GIS environment. Watershed was further delineated in twelve sub-watersheds. Morphometric parameters like bifurcation ratio, drainage density, stream frequency, circulatory ratio, elongation ratio, compactness constant and relief ratio were calculated. The prioritization of twelve sub-watersheds was carried out considering compound parameter values. The subwatershed having the lowest compound parameter value was assigned the highest priority. The study highlighted the use of GIS in morphometric analysis and prioritization of sub-watersheds. The study also shows the applicability of morphometric parameters integrated with land use map can help in decision making process for water resources management.

Abdel Rahman Al-Shabeeb (2016) the researcher aimed to select the optimum sites for water harvesting in the Azraq basin of Jordan through the use of GIS techniques. This area is characterized by flash floods which involves large quantities of runoff. In this they decided five parameters like rainfall, slope, soil clay contents, lineament density and drainage density. After selecting criteria the structural interview was undertaken with local experts. A questionnaire was prepared based on

scale of 1-9 for the experts to give the relative importance of each individual parameter. After survey primary data was to be collected like digital maps of rainfall, lineament, drainage, faults, soil clay contents, and slope based on ASTER DEM etc. After collection and digitization of data it was converted into matrix form in which several mathematics processes completed. All the generated thematic layers were integrated in ArcGIS in order to get map depicting the suitable areas for water harvesting of the area. Different thematic maps were prepared to identify prior location for water harvesting structure. AHP process was used very accurately because of expert's interview and their priority ranking. Study area classified into five classes in terms of suitability for the water storage structure. Here Boolean technique was used to eliminate sites which are not suitable for the water storage area within the study area. Result of Boolean technique was there were only two classes remain suitable and not suitable. After all the process final suitability map was prepared. Map shows area which was suitable or not suitable for that particular study area.

IV. CONCLUSION

- During the literature review it was observed that different researcher's uses different parameters for input such as rainfall, slope, lineament, drainage density, land use land cover, hydrological soil group etc.
- Most of the researcher used ArcGIS software and analytical hierarchy process (AHP) for decent and accurate result for locating various water storage structures.
- ArcGIS software can be use for digitization and other geo processes. It is very reliable software which is not very complicated and easy to use.
- Analytical hierarchy process can be widely used in the field of civil engineering also for better selection among various alternatives like in water management, solid waste management, irrigation etc.
- There are several other methods to choose best alternative between many but AHP can be applied successfully and provide superior results for selection of water storage site or any other selection.

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