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# Applications of Geographical Information System (GIS) in Assessment of Water Balance in Watersheds

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**Abstract -**The present study area is lying in the drought-prone zone of North Ahmednagar district, where the Bhandardara dam is main source of water for drinking, agriculture, and industries. Last 10 to 15 years mainly because of an extra share of water is taking by industries and urban centers, numbers of villages are facing water scarcity problem.GIS a powerful technique can be utilized to determine the water balance in watersheds. Therefore, in present study emphasis has been given to the scientific investigation of water balance within eight watersheds covering areas of three tehsils namely, Rahata, Shrirampur and Nevasa using GIS technique. The result indicates that total demand for water is 195.52 MCL, whereas water available is 1253.30 MCL consequently, 1057.77 MCL water is surplus in the entire study area. Though the 1057.77 MCL water is surplus in all eight sub-watersheds, water scarcity is increasing day by day. The result clearly shows that miss management of water in this area is the main cause of water scarcity hence, it needs to the hour that to focus on water management with storing the surplus water and its proper utilization. The modification of agricultural practices and changes in irrigation schemes are the most crucial steps should be taken to eliminate the miss management of water. With the help of GIS technique, it is possible to tackle the water scarcity problem in watersheds.

**Keywords:** Water Scarcity, Watershed, Water balance, GIS.

## I. Introduction

Water is a finite resource and it is becoming a scarce commodity in many parts of the world (Rouaida Trabelsi et al, 2007). In recent times, there has been rapid growth in population, industrialization and agricultural activities that have lead to a tremendous increase in demand for fresh water (N. Janardhana Raju, 2006). In another hand, the industries are discharging their effluents consisting of dissolved salts more than the permissible limits along with overuse of fertilizers on agricultural land coupled with more usage of irrigation water have resulted in causing salinity in groundwater. This has resulted in creating pressure on the freshwater resources leading to its over-exploitation. This has resulted in increasing the scarcity of surface water resources apart from the reduction in the groundwater resources. The trend of decreased water resources has affected the villages at the micro level thereby necessitating water balance evaluation based on supply and demand assessment choosing watersheds as hydrological planning unit.

Ahmednagar district is the largest district of Maharashtra, most part of the district is lying in rain shadow zone of Western Ghat. Hence, the rainfall is less (550 to 500 mm) and decreases from west to east. In the northern part of the district, Bhandardara dam is the main source of water for drinking, agriculture, and industries. But because of the extra share of water is taking by industries and urban centers, numbers of villages are facing water scarcity problem. The water balance analysis can give surplus and deficit scenario of water resources in respect of different watersheds of the area and can help in the formulation of strategies in the form of suggestion of alternatives, practice modification, process modification and changes in irrigation schemes.

## II. Study Area

The study area lies in Ahmednagar District of Maharashtra including Tahsil Rahata, Shrirampur, and Newasa. The entire area falls in Pravara River Basin between extents of 19 $^{0}$15’ to 19$^{0}$ 50’ N and 74 $^{0}$17’ to 75$^{0}$12’ E. The slope of the area is varying from 5 % to 9 % (up to 5 degrees) and the aspect of the area is generally directed towards North East direction. The area is generally plane with the elevation variation ranging from 695 meters to 465 meters. As per National Bureau of Soil Survey and Land Use Planning, Nagpur; the soil in the study area can be classified into three categories, silty, shallow and medium loamy black soils, deep clayey black soils. The climatologically, area is semi-arid and temperature varying from 9$^{0}$C to 43$^{0}$C whereas relative humidity for the area varies from 40 % to 80%. The annual rainfall varies from west to east between 540 mm to 500 mm.

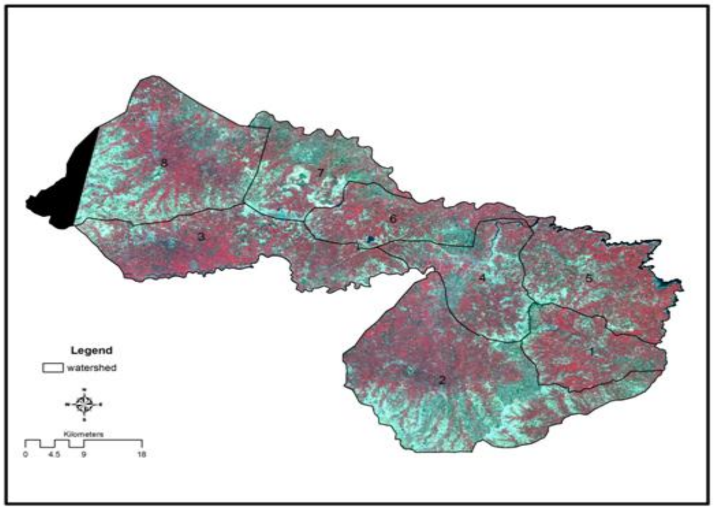


Fig. 1: The study area of eight automatically delineated sub-watersheds

## III. Materials and Methodology

- Watershed Delineation

In present study the S.O.I toposheet for the area were digitized to obtained contour of 20 meter interval and raster tools were used to generate DEM. The depression free Digital Elevation model was applied for automated eights sub watershed delineation using Arc GIS-9.3 software.

- Calculation of Surface Water Availability

The average rainfall of eight sub watersheds was calculated. The surface water availability was calculated after assuming that fifty percent of the precipitation water infiltrates to form ground water on the basis of average runoff to rainfall ratio in the area.

- Calculation of Demand of Water

The demand of water was assumed as 100 lpcd for humans and 25 lpcd for livestock. There are three types of industries in the area such as diary industry, sugar and distillery industries for which the per capita water requirement catered was 50 lpcd, 1 to 2 lpcd and 1000 lpcd respectively. The number of such rural industries existing in each watershed group along with their capacities was obtained from field visits to work out the quantum of water demand due to these industries in each watershed group. The watershed wise annual agricultural water requirements during kharif and rabi periods was taken from the study carried by Dr. S. P. Cholke (Cholke, 2013).

- Water Balance Analysis

Comparative assessment of water availability and water demand for each watershed group was carried out to arrive at the surplus or deficit water balance for all the eight watershed groups of the area necessary for conservation planning and to work out action plans.

## IV. Result and Discussion

The watershed (basin) wise runoff potential was calculated and represented by map (Fig.2). Sub watershed wise estimates of runoff potential and average annual runoff (in cm depth) are given in Table 1.

Table 1: Estimates of Runoff Potential and Average Annual Runoff

| Basin | Area(m) | Surface water(cm) | Runoff potential (Q/P) | Average Q |
|---|---|---|---|---|
| 1 | 205517954.4 | 566.26 | 0.988322 | 560.94 |
| 2 | 661804075.7 | 562.73 | 0.988819 | 557.41 |
| 3 | 393608922.0 | 485.46 | 0.986767 | 480.15 |
| 4 | 255309208.2 | 536.73 | 0.988555 | 531.41 |
| 5 | 312967127.1 | 501.53 | 0.987443 | 496.22 |
| 6 | 214682988.3 | 526.73 | 0.987854 | 521.42 |
| 7 | 240519638.7 | 526.00 | 0.988367 | 520.69 |
| 8 | 550372479.4 | 490.00 | 0.987366 | 484.69 |

(Source: Computed by Researcher)

 

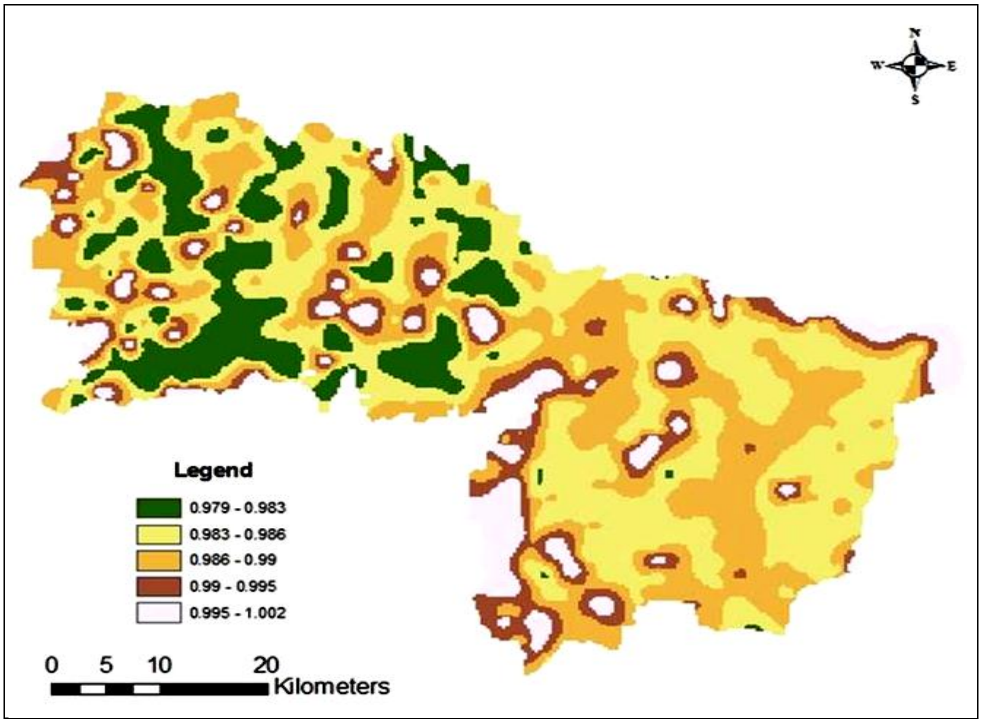


Fig. 2: Runoff potential raster map of Study Area

The availability of water from precipitation for each watershed group was obtained by taking into consideration both surface and subsurface runoff that is useful for meeting various water demand and is shown in Table 2.

Table 2: Water Availability within Sub watersheds

| Basin | Area (Sq. m) | Rainfall (Liters) | Runoff (QL) (Liters) | Subsurface Flow (Liters) | Subsurface Flow*0.5 (SS) in (Liters) | Water Available (QL+SS) (Liters) |
|---|---|---|---|---|---|---|
| 1 | 205517954.4 | 1.16377E+11 | 1.15284E+11 | 1092992857 | 546496428.7 | 1.1583E+11 |
| 2 | 661804075.7 | 3.72417E+11 | 3.68898E+11 | 3519434152 | 1759717076 | 3.70657E+11 |
| 3 | 393608922 | 1.91081E+11 | 1.88991E+11 | 2090220930 | 1045110465 | 1.90036E+11 |
| 4 | 255309208.2 | 1.37032E+11 | 1.35675E+11 | 1357132585 | 678566292.7 | 1.36354E+11 |
| 5 | 312967127.1 | 1.56962E+11 | 1.553E+11 | 1662530745 | 831265372.3 | 1.56131E+11 |
| 6 | 214682988.3 | 1.1308E+11 | 1.11939E+11 | 1140975622 | 570487811 | 1.12509E+11 |
| 7 | 240519638.7 | 1.26513E+11 | 1.25235E+11 | 1278272766 | 639136383.2 | 1.25874E+11 |
| 8 | 550372479.4 | 2.69683E+11 | 2.6676E+11 | 2922977797 | 1461488899 | 2.68221E+11 |
| Total Water Available 1.47561E+12 Liters | | | | | | |

(Source: Computed by Researcher)

The current watershed-based demand worked out to cater for the population and live stocks for each watershed group is based upon the assumption that every person consumes 100 litres per day of water to meet the various requirements and according the quantum of water to meet the population requirement for each watershed group was arrived by multiplying the daily consumption of each person with the total number of persons and number of days in an year (365 days). The same analogy was followed for livestock wherein the current water requirement of each livestock assumed as 25 liters was multiplied by the total population of live stocks for each watershed group and subsequently with the number of days in the year to arrive at the quantity of water demand for live stocks. The number of different industries and its capacity was obtained for each watershed group to compute the current annual industrial water demand. The watershed group wise annual agricultural water demand for both the crop periods was obtained using remote sensing data of 23.5m resolution.Table 3 gives the details regarding the watershed group wise annual water demand to cater for the requirements of the population, live stocks, industries and agriculture for the area.

Table 3: Watershed wise annual water demand

| Basin | By People (MCL) | By Animal (MCL) | By Sugar Industries (MCL) | By Distilleries (MCL) | Agriculture (Kharif & Rabi) (MCL) |
|---|---|---|---|---|---|
| 1 | 1.7848865 | 0.4370054 | 0.00144 | 0.001533 | 13.40908 |
| 2 | 4.695871 | 0.4370054 | 0.00144 | 0 | 32.24195 |
| 3 | 6.2440185 | 0.636998 | 0.003636 | 0.0049275 | 31.47764 |
| 4 | 2.889194 | 0.4370054 | 0 | 0 | 11.83453 |
| 5 | 2.4165555 | 0.4370419 | 0 | 0 | 21.63038 |
| 6 | 2.318115 | 0.434496 | 0.0018 | 0.002044 | 14.95708 |
| 7 | 1.9976815 | 0.4320049 | 0 | 0 | 9.506385 |
| 8 | 4.3603995 | 0.841982 | 0.009 | 0.003942 | 29.63547 |

(Source: Computed by Researcher)

The Table 4 gives the details about the supply and demand of water resources for the eight watershed groups in the area covering the three tehsils. The water balance for each watershed has been worked out to indicate the surplus or deficit in the water resources potential for the respective watersheds. This can enable planning for water resources through a well laid water management schemes.

Table 4: Water Balance for eight watersheds in the study area

| Basin | Annual Water Available (MCL) | Annual Demand of Domestic & Livestock (MCL) | Annual Demand of Agriculture (MCL) | Total Annual Demand (MCL) | Water Balance |
|---|---|---|---|---|---|
| 1 | 98.4 | 2.224865 | 13.40908 | 15.6339449 | 82.7660551 (+) |
| 2 | 314.8 | 5.134316 | 32.24195 | 37.3762664 | 277.423734 (+) |
| 3 | 161.4 | 6.88958 | 31.47764 | 38.36722 | 123.03278 (+) |
| 4 | 115.8 | 3.326199 | 11.83453 | 15.1607294 | 100.639271 (+) |
| 5 | 132.6 | 2.853597 | 21.63038 | 24.4839774 | 108.116023 (+) |
| 6 | 95.6 | 2.756455 | 14.95708 | 17.713535 | 77.886465 (+) |
| 7 | 106.9 | 2.429686 | 9.506385 | 11.9360714 | 94.9639286 (+) |
| 8 | 227.8 | 5.215324 | 29.63547 | 34.8507935 | 192.949207(+) |
| **Total** | **1253.30** | **30.83** | **164.49** | **195.52** | **1057.77** |

(Source: Computed by Researcher)

## V. Conclusion

Last two decades mostly because of extra utilization of water by industries and urban sectors in drought-prone areas of north Ahmednagar district, especially Rahata, Shrirampur and Newasa tehsils, the numbers of villages are facing water scarcity problem. To investigate this water scarcity problem scientifically, Remote Sensing and GIS techniques are applied. GIS technique is more reliable technique shows the result that demand for water is 195.52 MCL yearly, whereas in other hand water availability is 1253.30 MCL annually, hence there is 1057.77 MCL surplus water. However the 1057.77 MCL water is surplus, people are facing water scarcity. The result mainly points out that, miss management of water is the major cause of scarcity, thus it needs to the hour that to make proper management water. The surplus water can be stored with different rainwater harvesting methods and utilized properly. The modification of agricultural practices and changes in irrigation schemes are the most crucial steps should be taken to tackle the miss management of water in the entire study area. With the help of GIS better water management is possible to solve scarcity problem, it can also help in the formulation of strategies for sustainable development of watersheds.

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Dr. Sunil Cholke is working as an Associate Professor in Geography at Rayat Shikshan Sanstha's R. B. N. B. College, Shrirampur, Maharashtra. He is having 27 years of experience in teaching and awarded Ph.D. by Savitribai Phule Pune University. His areas of interest are Remote Sensing, GIS, Rainwater Harvesting. He has published and presented over 19 research papers in international and national journals of repute.

 