Archives of Photogrammetry, Cartography and Remote Sensing, vol. 31, pp. 75-83
ISSN 2083-2214, eISSN 2391-9477
DOI: http://doi.org/10.2478/apcrs-2019-0006

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RESEARCH ARTICLE

APPLICATION OF GEOSPATIAL TECHNIQUES FOR GRAVITY-BASED DRINKING WATER SUPPLY MANAGEMENT

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KEY WORDS: drinking water, geospatial technology, gravity-based water supply, water management

ABSTRACT: There is growing interest in the research community to apply the various techniques pertaining to geospatial technology, with the advance part of Remote Sensing (RS) and Geographical Information System (GIS). This technology has been proven to be very essential in this identification and resolving the problem of water resource and allied water supply management. Considering the capabilities of geospatial techniques, the tools and techniques of similar disciplines used for gravity-based drinking water supply management in the hilly area where the human habitat is settled at foothill places. An attempt has been made in this paper to avail the use of tools and techniques of geospatial techniques for gravity-based water supply management at the village level. The Karule village is the part of central Maharashtra in India chosen for implementation of present bid. It was observed that, three-dimensional remote sensing data derived from space-borne satellite could be useful for gravity-based drinking water supply management with the help of other spatial and non-spatial database. Satellite-derived data and its incorporation with GIS and ground inventory data would be advantageous for delineation of such gravity-based water supply management in the similar area of the world.

1. INTRODUCTION

Water is the most significant resource in the environment as a whole, since no life is possible without water (Khan, 2012). It has unique importance among other natural resources, like fuels, forests, minerals, livestock, etc. because any region can survive in the absence of any other resources, except this one (Garg, 2013). The water is unevenly distributed on the Earth's surface, the ocean that covers roughly 71% and freshwater is accounted around 2.5% of the total water on the Earth. Therefore, the Earth appears blue from space, and is often referred to as the blue planet. In Asia, it has around 35% out of freshwater resources; however, it is inhabited by 60% of the world's population. Conversely, in the Amazon River basin, it is around 13% of water reserves with a population of only 0.5% (Boddu *et al*., 2011).

Rural economy of each country plays an essential role in the development (Canez-Cota and Pineda-Pablos., 2019). Most of the rural economy depends on agricultural activity in developing countries (Jasmine Neupane and Wenxuan Guo., 2019). As like the urban area development, the infrastructural development of the village depends on water supply availability. The drinking water supply management of the village is one of the most important aspects of the rural development. In the India, most of villages located in the hilly area or the foothill zones. The existed topography of same villages can be utilized for water supply management. Thus, proper identification of spatial and non-spatial structure of the villages and the surrounding area is a prerequisite fragment before any water supply management (Kunlun Ding, 2019). The advanced geospatial technology is widely used by several researchers for the water resource management in the various regions of the world (Singh *et al*., 2010; Dhanasekarapandian *et al*., 2016; Deshmukh and Aher, 2016). GIS is an emerging technology paradigm, which is potential to develop spatial database (Rao *et al*., 2012).

Considering the capabilities of GIS and remote sensing (Lillesand, 2009) rural drinking water supply issues, an attempt has been made in this paper to identify the real water supply situation and highlight recent drinking water supply problem of the study region. Similarly, to identify the spatial and non-spatial information of villages for precise drinking water supply management using the geospatial techniques (Abebe Tadesse, Techane Bosona, Girma Gebresenbet, 2013). The area selected for drinking water supply management is located in the rain shadow region of central Maharashtra, which is the part of Sangamner tahsil. The average rainfall is the less in this region (average rainfall 416.6 mm). The Government has declared this region as the drought region of Central Maharashtra. Therefore, Talegaon Dhige and 16th Village Water Supply Scheme implemented through Maharashtra Jivan Pradhikaran (MJP) to solve the drinking water supply issue in the surrounding villages. These villages located in undulating topography which can be utilized for gravity-base drinking water supply management in this study area. In view of this, the advent remote sensing and GIS techniques can support for the solution of the drinking water supply problem in the study region.

2. STUDY AREA

The present study area is under the rain shadow zone of central Maharashtra, where all the villages are famine-stricken villages. Inadequate water is a major cause of human misery in these villages (Ganesh S. Ragade et al, 2018). Villages are situated in the hilly area, where natural availability of slope. Thus, considering this background Karule village (Fig. 1) is selected for drinking water supply management modelling using geospatial technology. The drinking and agriculture water supply system of Karule village is dependent on the rainfall sources. The average rainfall of Karule village is 416.6 mm. The scarcity of water occurs from February to June. More than 447 families are residing in the village. The total population of the village is 1770 (Census, 2011). The government has estimated that every person needs minimum 55 liters' water per day, thus, the village needs minimum 97350 liters of water/day. Thus, for controlling the drinking water problem in the Talegaon Dhige and the surrounding region MJP has created the various types of projects since 2003. They have prepared the scheme for 17 villages for drinking water supply, which includes Karule also. Different problems in the scheme have resulted in incomplete plans in the study village. Most of household in Karule village are still not connected with this water supply scheme because of the uncompleted water supply scheme, unequal distribution of water to all households, electricity problem, poor quality of services, uncompleted MJP plan, and weak economic position of villagers.

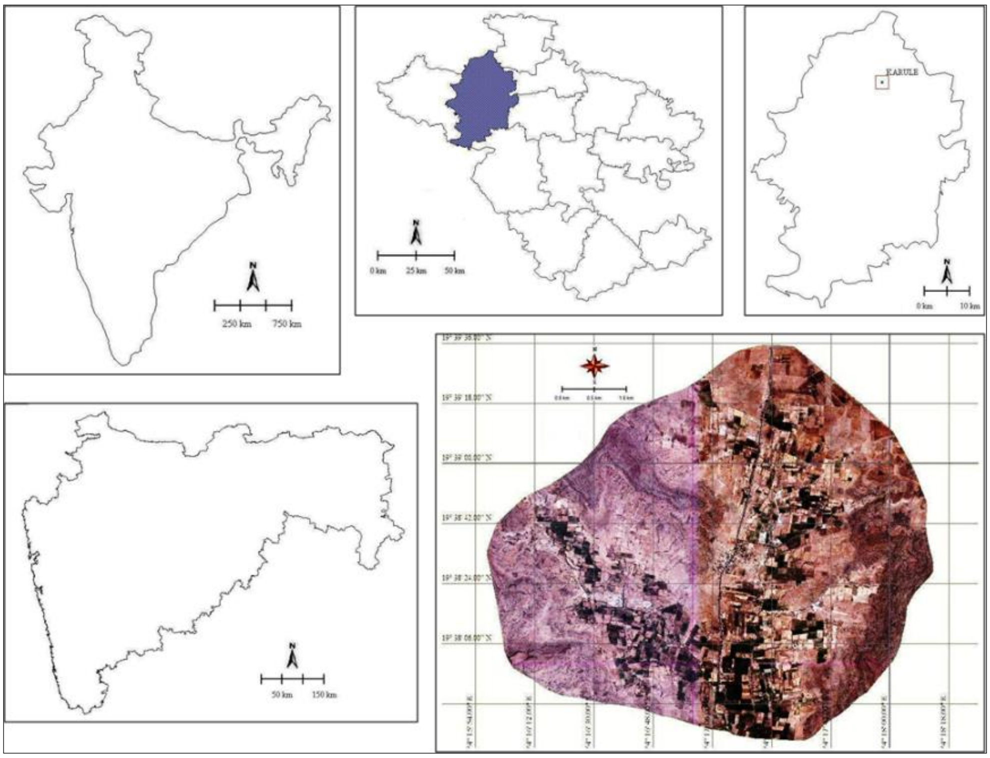

Fig. 1. Location map of the study area

3. RESEARCH METHODOLOGY

GIS and RS techniques with ground inventory method for drinking water supply management. Spatial and nonspatial database were collected to understand the existing situation of drinking water supply at village level. Primary database, like as Toposheet 47/I /6, Google Image 2011, Theodolite Surveying data, Grampanchayat and revenue department data etc. collected. Secondary data like Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) data has been used for topographical modelling. ASTER GDEM purports to be the highest resolution, 30 m (1 arc second) spacing as compared to CartoDEM and SRTM DEM (Guth, 2010, Aher *et. al*, 2017). A DEM refers to a quantitative model of the Earth's surface in digital form (Burrough and McDonnell, 1998) which consists of either (1) a two dimensional array of numbers that represents the spatial distribution of elevations on a regular grid; (2) a set of x, y, and z coordinates for an irregular network of points; or (3) contour strings stored in the form of x, y coordinate pairs along each contour line of specified elevation (Walker and Willgoose, 1999). Use of satellite-derived DEMs has a remarkable benefit over traditional methods (Machell *et al*., 2010) above large and inaccessible areas can nowadays be easily produced (near) real-time and within a relatively short time and at remarkable cheaper costs (Jiang *et al*., 2014). Obtained primary and secondary data were processed in various GIS software to create gravity-based drinking water supply model (Miller *et al*., 2019), in the Karule village. Obtained materials and methods of gravity-based drinking water supply modelling are presented in the Fig. 2.

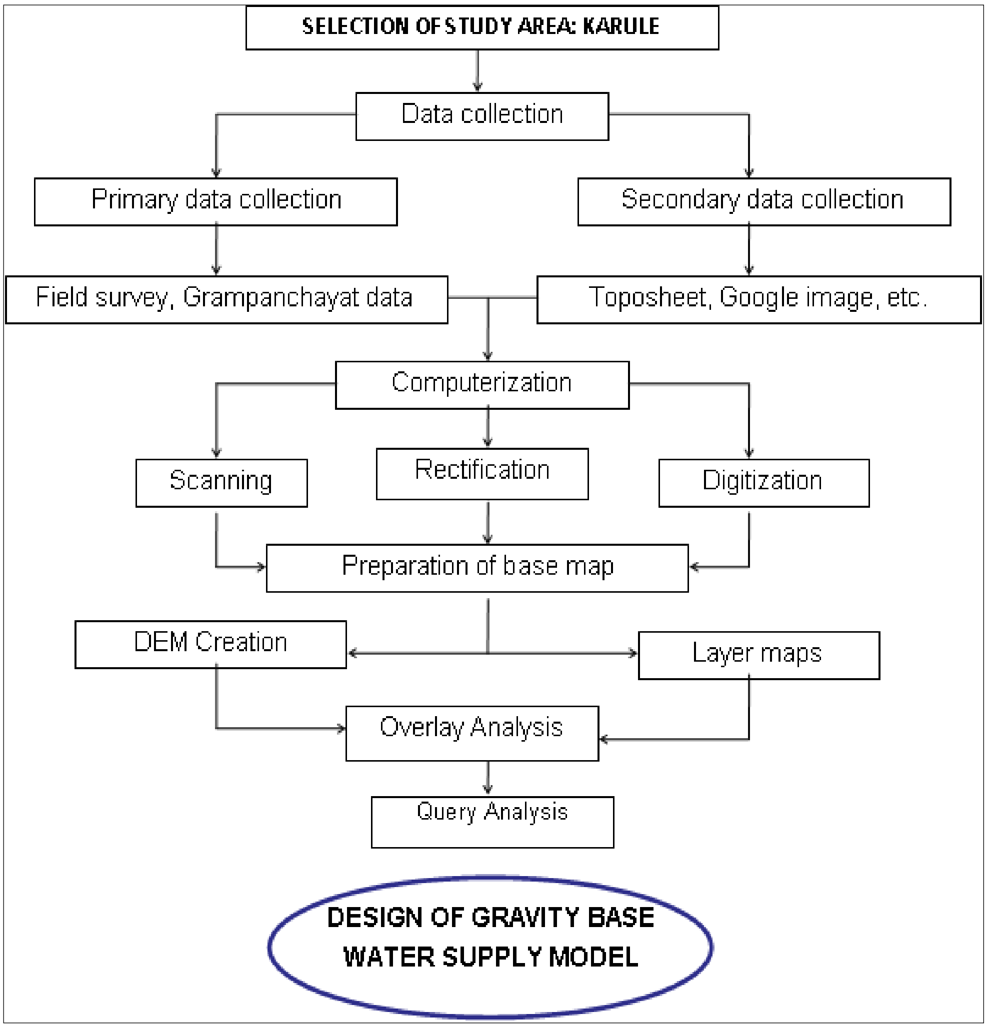

Fig. 2. Used materials and methodology

4. RESULTS AND DISCUSSIONS

Using the ground inventory, RS and GIS database along with gravity base designed the gravity based water supply management model (Sapna Raghav et al, 2019). First the DEM is created for calculating the actual slope of Karule village. Then the settlement, tank, pipeline, etc. are digitized for showing the water supply model (John Magrath, 2006). Designing of gravity base water supply to each family made on the basis of demand and supply management (Walski, Thomas, al., 2001). To supply the drinking water to each house on the basis of gravitational force, plan estimated for supply the water without using the electricity (Fig: 3).

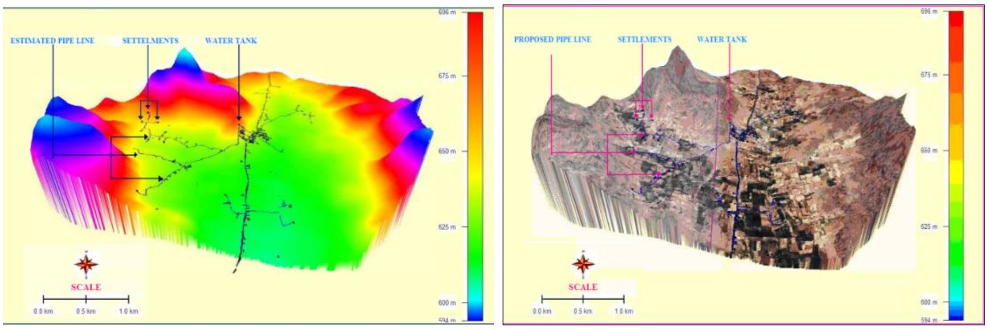

Fig. 3. Proposed water supply pipeline of Karule village on ASTER GDEM data

4.1 Use of Newton's gravitational law for water supply

The mechanisms of Newton's law of universal gravitation; a point mass m1 attracts another point mass m2 by a force F2 which is proportional to the product of the two masses and inversely proportional to the square of the distance (r) between them. Regardless of the masses or distance, the magnitudes of F1 and F2 will always be equal. Newton's law of universal gravitation is an empirical physical law describing the gravitational attraction between bodies with mass (Wikipedia, 2011). This law used in gravity-based water supply based (Samantha Lee, 2018) on derived topographical information about present village.

4.2 Laws statements

There is always a force of attraction between any two particles (matter). This force of attraction is called gravitational force which is directly proportional to the product of their masses (m_1, m_2) and inversely proportional to the square of the distance between them (r^2). (Newton, 1729). Applying this law of gravitational force (Yue Xua, Xiao-yu, 2012), for the study region, observed that there is always a force of attraction between two particles of matter (Tank water and settlement due to gravity). In this case, water from the tank can flow toward settlement (target). The velocity of water is higher from higher level to lower level due to slope created by in the study area. (Nur Lely *et al*, 2019) The water moves from higher level (hills) to the lower level (settlements) due to gravity. Thus, can be used the large cross section pipes (Epari Ritesh Patro, et al., 2018), for the water supply toward the settlement, which is located far from the tank. The reason of using large cross-sectional area pipes is the liquid water can flow fast as well as freely through this pipe according to the principal of fluidity.

4.3 Application of Newton's law for drinking water supply model

A basic science of gravity stating that, every point mass attracts every other point mass by a force. Intersecting both points (Tank water and settlements). The force is proportional to the product of the two masses and inversely proportional to the square of the distance between the point masses. Thus, the water from the higher elevated tank will easily pass toward each settlement (Fig. 4).

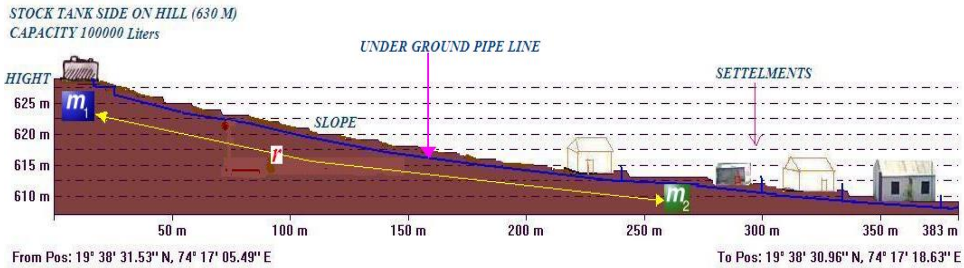

Fig. 4. Gravity base Water supply model

$$F_1 = F_2 = G\,\frac{m_1 x\, m_2}{r^2} \tag{1}$$

where,

- F is the magnitude of the gravitational force between the two point masses (tank and settlement),
- G is the gravitational constant 6.673 × 10−11 N m^2 kg^{-2}.
- m_1 is the mass of the first point mass (tank).
- m_2 is the mass of the second point mass (settlement).
- r is the distance between the two point masses. (tank and settlement).

We can apply this formula for calculations of water supply force here. For e.g. suppose
m1 = 5000 litters/hr (from tank)
m2 = 300 litters/hr (to household)
r^2 = 1 km (distance between tank and household)

which provides using formula (1) 1.5 mln N/m^2

5. CONCLUSION AND DISCUSSIONS

According to overall surveying of region, database, calculation, can be concluded here, the physiographic structure is useful for drinking water supply management in the present area. Water supply can be completed without using electricity to each household. The law of gravity can be implemented to derive the proposed role model for water supply management. This role model can be applied to Karule and surrounding parts of Sangamner tehsil, which has undulating structure. After the overall study of the area, we could finalize the probable solution for the uncompleted water supply. The identified solution is based on the scientific methods and approaches of geospatial technology. The current tank location is causing the fewer water supplies to household as compare to the new proposed tank. According to DEM result, identified the new tank location. After the construction of new tank on the 634 M. height, 2.22 sq. km additional area will be come under the water supply. The 300000 liters water capacity of the tank was useful for 3-day water supply without electricity up to the year 2012. In the year 2012, water requirement nearby 83 655.0 liters for per day and 50 965.0 liters water requirement of 3 days. Further population growth will cause more demand of drinking water. According to flow of fluidity law, we should use the less cross-sectional pipe for central part and maximum cross sectional pipe for surrounding area. The capacity of the new water tank should be up to 300000 liters for the increasing population. This role model can apply to any region which has such type of topography (Fig. 5). The nearest slope is useful for providing the drinking water supply using the gravitational force concept. The physiographical structure of Karule village will be useful for water supply, and it will responsible for saving electricity cost. If the present tank height is increased or alternative tank is constructed on suggested location, the water supply is possible to each household.

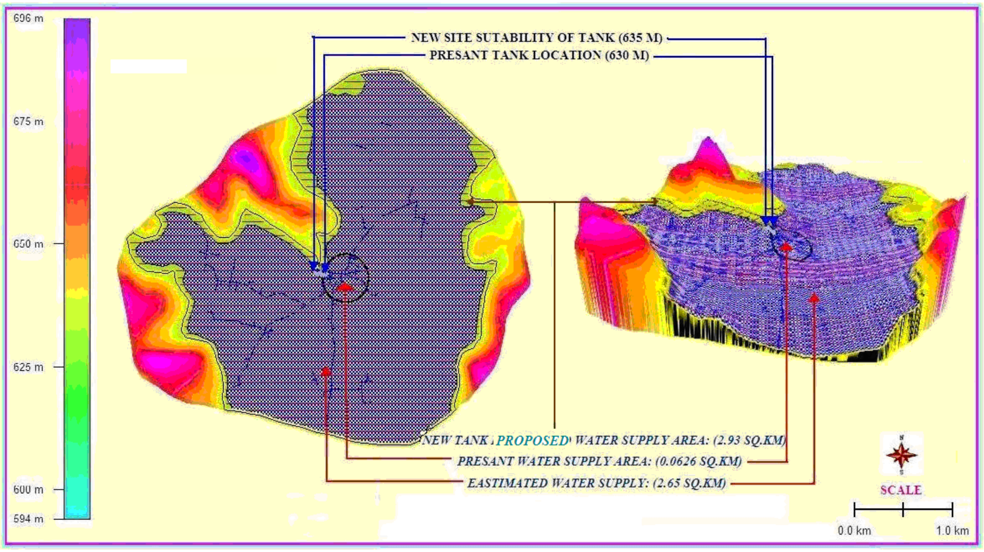

Fig. 5. Ideal Drinking water supply Management model for Karule Village

ACKNOWLEDGEMENT

The author would like to acknowledge the Agasti Arts, Commerce and Dadasaheb Rupwate Science College, Akole, Maharashtra, India for providing necessary research facilities.

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Submitted 22.08.2019
Accepted 6.09.2019