Available online at www.sciencedirect.com

ScienceDirect

Materials Today: Proceedings XX (2016) XXX–XXX

materialstoday: PROCEEDINGS

www.materialstoday.com/proceedings

PMME 2016

Water Security Assessment in Semi-arid Region using Geospatial Techniques

Abhijit M. Zende[a], Rahul A. Patil[b], Vidya M. Patil[c]

[a] *Dr. Daulatrao Aher college of Engineering, Karad, Satara, Maharashtra,415124, India*
[bc] *Annasaheb Dange college of Engineering and Technology, Ashta, Sangli, Maharashtra, 416301, India*

Abstract

Water assessment needs due to a variation of precipitation, water demand for various sectors, water storage structures etc. usually for a season or more, affecting virtually all climate regimes. The precipitation deficiency results in water shortage for some activities, group or environmental sector, causing economic losses and significant damage to human lives. Furthermore, water demand for growing human population, industrial development and agriculture has increased significantly in developing countries threatening the outcome of major environmental, social and economic problems. For water security, it is essential to assess the major sources of water demand and supply on a scientific based. GIS as a tool helps to assess on macro-level (basin) to micro-level (village) water assessment for water security. Out of 347 villages 116 villages (2,06,935 people) do not have any water source. Their drinking water requirement of 120.03 m^3/yr is not secured.

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

Keywords: *Water assessment, water demand and supply, micro-level, macro-level, water security*

1. Introduction

India is facing a serious water resource problem and as trends suggest, it is expected to become 'water stressed' by 2025 and 'water scarce' by 2050. Water security implies affordable access to clean water for agricultural, industrial and household usage and is thus an important part of human security. Water along with food and energy forms a critical part of the 'new security agenda' and redefines the understanding of security as a basis for policy-response and long-term planning. Water security for India implies effective responses to changing water conditions in terms of quality, quantity and uneven distribution. Unheeded it can affect relationships at the inter-state level and equally contribute to tensions at the intra-provincial level. Water resource management is experiencing large-scale changes in water withdrawals and availability (IPCC, 2001). Basic water requirement at local, regional & basin scale is critical for allocation of water. Drought, water scarcity has lowered the role of agriculture threatening rural farmers

2214-7853
Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

(Nageswara Rao et al., 2009). Variations in rainfall, use and availability of water are important to conserve village ecosystems. Water demand for growing population, industries and agriculture has increased significantly. Vulnerability in dry land agriculture is distinguished due to arbitrary irregular rainfall. Continuous exploitation of natural water resources, climate variability, water scarcity and drought are causing forced changes in villages. Rainfall, cultivated area, crops grown, rising demands needs rigorous study planning & development in rural area. Detailed analysis of rainfall and water requirements at root level viz. villages is crucial for better agricultural and water resource management (Abhijit Zende et. al, 2014). GIS is a very powerful tool for study and analysis of water resources, locating its features, extent of its coverage, its monitoring; and generating models for optimizing resource utilization.
Objective: To develop a methodology for assessment of demand and availability of water to determine water security using GIS of micro (village) level.

2. Materials and Methods

2.1 Data Collection

Topographic sheets was used in demarcating 1) drainage and storage (reservoir & tanks and ponds) systems in a river basin; and thematic map about the irrigation in delineating canal alignments. Census information corresponding 1981, 1991 and 2001 were used in demarcating the village boundaries and village level information such as – population, irrigated areas and sources of irrigation. Arc GIS 9.3 was used in integrating the spatial information into a geo-coded data set by digitizing the thematic maps. The individual polygons (villages) created were attached with attribute data base containing population, irrigation are and sources of irrigation. A comprehensive assessment of water accounting for Yerala River, tributary of Krishna River basin, India (**Fig. 1**) has been carried out in facilitating integrated river basin management.

2.2 Study Area

Yerala River is one among the tributaries in the Upper Krishna River basin. The entire basin is covered between 16^0 55’ to 17^0 28’ N and 74^0 20’ to 74^0 40’ E. The total length of the River is 125 km and basin area is 3035 sq km. It starts from Manjarewadi located at 914 m above MSL and joins Krishna River at (Brahmnal) 551m above MSL. The Yerala river basin is located in Satara and Sangli districts of western Maharashtra, India. It is located in the semi-arid region. 52% rainfall occurs during June to September, 30% during September to December and 18% after December. Most of the areas of this basin receive rainfall less than 700 mm from south west monsoon. The highest annual of rainfall 1038.4 mm was recorded during 2006 at Kadegaon and the lowest 167.3 mm during 2003 at Tasgaon. The maximum temperature of 42^0 C was recorded during May 1996 at Ambawade and the minimum of 7.5^0 C in January 1995 at Ambawade. The main livelihood opportunities existing in the basin for rural communities are agriculture, livestock rearing and allied activities. This region has three cropping seasons, viz, June-October (kharif), November -February (rabbi), March-May (Hot weather). The most important crop in the basin is Sorghum in kharif, gram during rabbi season and Sugarcane in yearly. Other most commonly cultivated crops consist of sugarcane, pearl millet, maize, groundnut, sunflower, pigeon pea and vegetables. Levels of the groundwater in aquifer have been falling over the years because of exploitation of groundwater for irrigation; this is further aggravated with lack of groundwater recharge due to scanty rainfall. Most bore wells run dry soon after to a bad monsoon year moreover only those boreholes near drainage tanks and river streams rarely yield water.

2.3 Methodology

2.3.1 Geo-spatial data base generation

Water resources information from the irrigation department (reservoir and canal alignment) and village level (area and information from the Census of India corresponding 1981, 1991 and 2001 was used. ARC GIS 9.3 was used in integrating point (position), linear (Line) and polygon (area) to a common co-ordinate system (latitude and longitude). Canal alignment was digitized from the map and also interpreted from the satellite image.

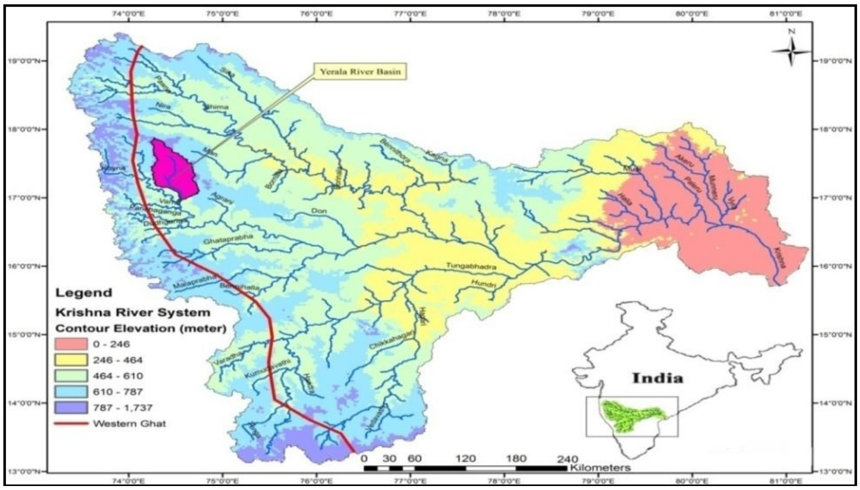


Figure 1 Location map of study area includes of upper Krishna basin

Areal extent of the Revenue Village maps (1st level administrative unit) was digitized using ARCGIS 9.3 interface. Individual villages were assigned map id number and the attribute information (Census 1981, 1991, 2001) such as – area, population, irrigated and non-irrigated area, source of irrigation – canal, river, ground water, forest area etc. were attached. Some of the villages were administratively redistributed (either transferred or bifurcated and created a new village) among the tehsils (2nd level administrative unit) during 1981-2001. Furthermore, the water demand estimated for human consumption, livestock and crops cultivation of each village in the above sections was entered as attribute data of the village map. Consecutively, thematic maps showing the spatial variability of water demand for domestic, livestock and cultivation were prepared. Thematic map showing the total water use of a village was also prepared. The factors that influence the water supply and demand are – 1) spatial variation and growth of the population, urbanization and income; 2) growth in crop area and intensity; 3) groundwater use (as supplementary or single source of supply; 4) contribution to production from rain-fed agriculture, and 5) future growth in domestic, livestock, industrial and environmental water demand.

2.3.2 Village Water Requirement Estimation

The total quantity of water required for each village was quantified. The amount of water required for a village is the sum of different water uses like domestic water requirements, livestock water consumption, agriculture and industrial sectors (Dileepkumar et al., 2007). The detailed methodology used in estimating the water requirements were discussed in the following sections.

A. Domestic water requirement (daily) ($Q_{Dom\ dai}$) is used for drinking, cooking and personal hygiene of population living in urban (Q_{pUr}) or rural (Q_{pRu}). The area having population of 10000 and above are classified as Urban and below as Rural. The civil developments (water supply and sanitation) in India rely on this factor. The basic human water requirements are **-** about 5 L/person/day for drinking**,** 20 L/person/day for basic sanitation; 15 L/person/day for bathing, and 10 L/person/day for food preparation (Gleick 1996). The recommended water per person in urban areas is 135 liters per day and in rural areas (population less than 10000) 45 liters/day as suggested by Drinking water supply agency, Government of Maharashtra, for the Revenue villages. The quantity of water required for each village per day and per annum was estimated as follows.

$$Q_{Domdai} = Q_{pRu} \text{ X } 45 + Q_{pUr} \text{ X } 135 \quad (1)$$

B. Livestock Water Requirement - *Livestock* is an integral part of rural life in India. Water requirement for livestock (Q_{Ani}) refers to the quantity of water required for drinking and animal hygiene conditions (animal and place washing). Hence, it is essential to have an estimation of water required for provision of water for livestock rearing. Water requirement for livestock refers to the quantity of water required for drinking and water in feed to support livestock production (Blummel et al., 2009). The water required for livestock rearing depends on the number of animals and consumptive use per head (Amarasinghe et al., 2004). The total livestock water required for a village was assumed as the sum of water required for domestic animals like cattle, buffaloes, sheep, Goat, Swine, and Poultry. The present practice is to make an additional provision of 5 liters per capita per day in supply rate to human population while planning rural water supply schemes. Daily Water requirement considered in this study is 85, 85, 10, 10 and 15 L/animal and 40 L/100 birds, for cattle, Buffaloes, sheep, Goats, Swine (L/day) and Poultry (Frasier and Hyers 1983).

$$Q_{Ani} = N_C * 85 + N_B * 85 + N_S * 10 + N_G * 10 + N_{SW} * 15 + N_{BI} * (40/100) \quad (2)$$

Where, N_C - No. of Cattles, N_B - No. of Buffaloes, N_S - No. of Sheeps, N_G - No. of Goats, N_{SW} - No. of Swines, N_{BI} - No. of birds

C. Agricultural water requirement of a village was estimated as crop water requirement (Cr_{WD}) for the cropped area (Cr_a in acres) deciphered from satellite images and ground validation. The crops cultivated during Kharif season ((Q_K) (June to October)), Rabi season ((Q_R) (November to February)) and hot summer ((March to May) (Q_S)) were used in the estimation. The agricultural water use estimation was carried out for paddy, sorghum, maize, wheat, finger millet (ragi), castor, cotton, and vegetables. The quantity of irrigation water requirements (Q_{Cr} in (M^3) is the product of crop area (Cr_a) and crop water demand (Cr_{WD}) per/ acre during the growing season (Kharif or Rabi) are shown in **Table 1**.

$$Q_{Cr}\ (M^3) = Cr_a \ X\ Cr_{WD}\ X\ 4046.9 \quad (3)$$

Table 1 Consumptive use of water for various crops

Crops	Irrigation (mm)	Crops	Irrigation (mm)
Paddy (Q_K)	1200 mm	Wheat (Q_R)	450 mm
Sorghum (Q_K) + (Q_R)	500 mm	Maize (Q_K) + (Q_K)	625 mm
Pearl millet (Bajra)	500 mm	Sugarcane (Q_K) + (Q_R)	2200 mm
Cotton (Q_K)	1100 mm	Sunflower (Q_K) + (Q_R)	210 mm
Groundnut(Q_K), Tomato, Onion, Chillies, Castor, Cabbage, Citrus, Pineapple, Sesame, Finger millet (ragi), Red Gram , Green Gram and Horse Gram (Q_R)			500 mm

(Source: Michael, 1978)

D. Total Water Requirement estimation of a village - The total water use of a village was estimated as the sum of domestic water use, livestock water use and agricultural water requirement that was estimated in above sections. Further, this water use information was used to create a GIS database for mapping the spatial variation of water use for domestic use, livestock and agriculture use during kharif, rabbi, hot weather and annual.

$$Q_{RuWR}\ (\text{Monthly}) = [(Q_{Domdai}) + (Q_{Anidai})) \ X\ 30 + \text{Cultivation (Crop Area X } Cr_{WD} \text{ X 4046.9)}] \quad (4)$$

$$Q_{urWR}\ (\text{monthly}) = [\text{Daily Drinking water (Human +Livestock)} + \text{Cultivation } (Q_{CrWD}) + \text{Industrial need } (Q_{Indus})] \ X\ 30 \quad (5)$$

E. Village Water availability - The total water available to a village is the product of amount of rainfall and surface area (Dileepkumar et al., 2007). The constraints in this approach are: uniform rainfall across the village area and every drop of rainfall could be collected and used.

The total amount of water received in a year by the village (m^3) = Area of the village in Sq m * Annual Rainfall (mm) * 0.001 m/mm (6)

The water thus received gets distributed as surface runoff, evapo-transpiration and ground water recharge. For estimating the water availability of a village it is essential to account the water that gets evaporated and rainfall-runoff that accounts for surface water and groundwater.

3. Results and Discussion

3.1 Water Demand Estimation

Estimations of total water use for domestic, livestock and agriculture were calculated as discussed in the methodology. The irregular wet and dry spell distribution of rainfall during the monsoon months affect the rain dependent kharif crops. The rain in June is of great importance for the kharif crop cultivation (tilling and sowing), and rains in October for Rabbi Crops. The domestic water requirement for urban and rural area per year is 291.67 m^3 and 361.98 m^3 as per census 2001 and the total domestic water requirement of Yerala basin is 653.65 m^3. The water requirement for livestock is 0.389 TMC (2001) and 0.409 TMC (2011). About 290 villages are having irrigated land less than 10% of their village area, 40 villages within 10% to 20%, 9 villages within 20% to 30%, and 8 villages within 30% to 60%**.** The crop water requirement for kharif, rabbi and hot weather season is 15.43, 5.67, 1.87 (2001) and 18.92, 6.59, 2.12 (2011), all in TMC. Sugarcane is the only crop taken yearly and its water requirement 3.65 TMC (2001) and 3.99 TMC (2011). Crop water requirement for various crop areas deciphered for year 2001 & 2011 are given in **Table 2.**

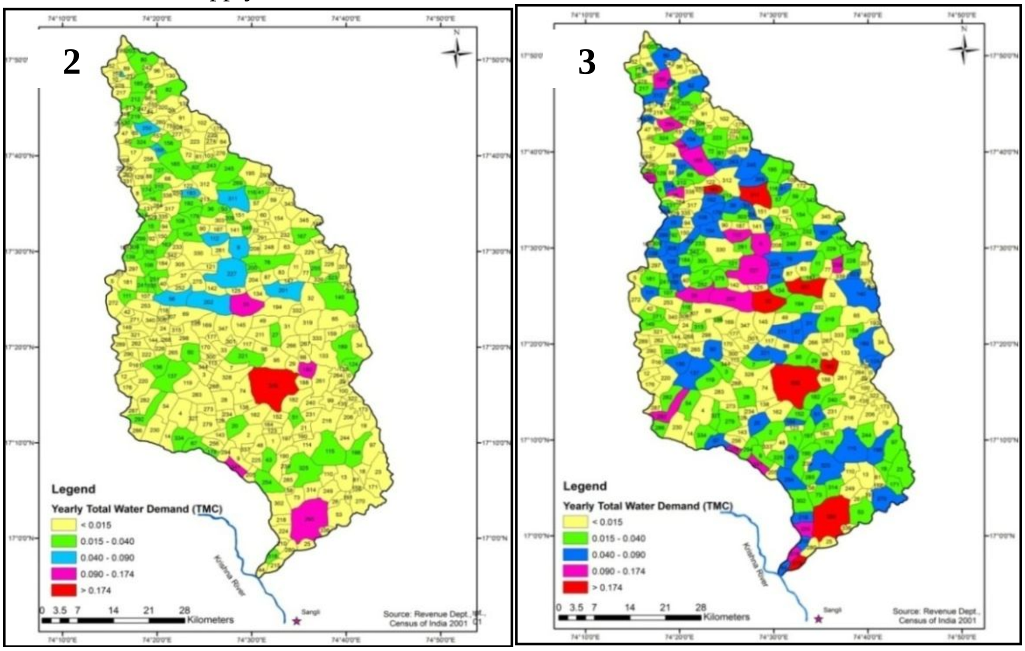
Table 2 Crop water requirement for various crops grown in 2001 and 2011

Sr. No.	Season	Crop	2001			2011		
			Area (Ha)	Water Requirement (TMC)		Area (Ha)	Water Requirement (TMC)	
1	Kh	S_o	42367.64	7.47	15.43	41144.36	7.26	18.92
2		G_r	8473.52	1.49		10286.09	1.81	
3		P_M	8473.52	1.49		15429.13	2.72	
4		S_y	8473.52	1.79		15429.13	3.27	
5		M_a	4236.76	0.93		5143.04	1.13	
6		V_e	8473.52	1.49		10286.09	1.81	
7		G_m	4236.76	0.75		5143.04	0.91	
8	Rb	S_o	13181.04	2.33	5.67	15158.45	2.67	6.59
9		W_h	8238.15	1.31		5684.42	0.9	
10		G_m	6590.52	1.16		9474.03	1.67	
11		V_e	4942.89	0.87		7579.22	1.34	
12	Hw	M_a	4707.52	1.04	1.87	4872.36	1.07	2.12
12		G_r	2824.51	0.5		3248.24	0.57	
13		V_e	1883.01	0.33		2706.87	0.48	
14	Yr	S_u	4707.51	3.65	3.65	5143.04	3.99	3.99
Total					26.62			31.62

(Kh – Kharif, Rb – Rabbi, Hw – Hot Weather, Yr – Yearly, S_o – Sorghum, G_r – Groundnut, P_m – Pearl Millet, S_y – Soyabean, M_a – Maize, V_e – Vegetables, G_m- Gram, W_h – Wheat, S_u – Sugarcane)

Total estimated water demand of the *entire basin* is about 27.71 TMC and 32.79 TMC for the land use and land cover and population conditions of 2001 and 2011 respectively. The total water demand for 2001 and 2011 are 0.706 TMC and 0.764 for domestic, 0.389 TMC and 0.409 TMC for livestock, and 26.62 TMC and 31.62 TMC for agriculture (for all villages). It is found that inadequacy in water availability either due to rainfall or product pricing are majority of the reasons. According to 2001 agricultural land is 94150.3 hec, and 344 villages are totally dependent on groundwater for the irrigation. Out of 344 villages 124 villages groundwater demand for irrigation is less than 0.025 TMC, 77 villages (0.026-0.050), 25 villages (0.051- 0.090), 14 villages (0.091-0.175) and only 4 villages more than 0.175 TMC. For the surface water demand for irrigation 65 villages are dependent. Out of 65 villages, 46 villages requires less than 0.015 TMC, 14 villages (0.015-0.039), 4 villages (0.039-0.135) and only 1 village is more than 0.135 TMC (**Fig. 2**). Out of 347 villages, 264 villages and water demand of 161 villages are less than 0.015 TMC in year 2001 and 2011. The water demand was more than 0.174 TMC for one village in 2001 and 8 villages in 2011 (**Fig. 3**). It is observed that a cultivated land in kharif is 90% and 45%; Rabbi is 35% and 19% and

10% of sugarcane is grown in 2001 and 2011 respectively. Around 30% of land is left uncultivated due to inadequate rainfall or water supply.



(**Fig. 2** for 2001 & **Fig. 3** for 2011)Yearly Domestic, livestock, agriculture water demand

3.2 Water availability

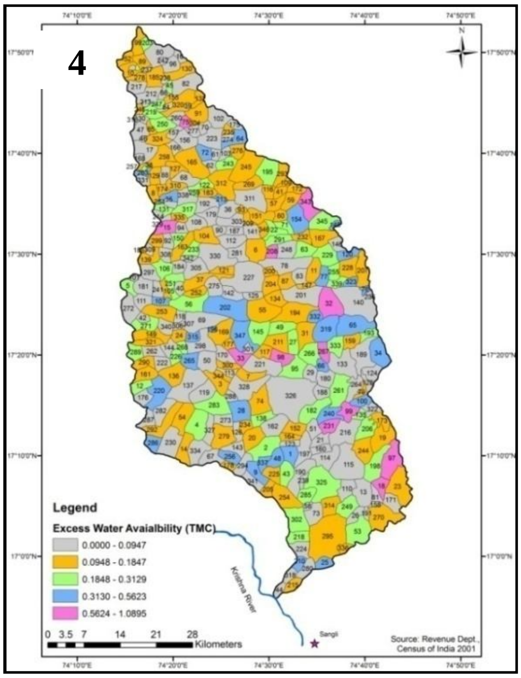
The existing storage systems could be used for water supply to the nearby villages. The village administration could manage the distribution and monitoring of the sources effectively. It is found that 60, 66 and 105 villages have the water source in their proximity (700m-optimal water fetching distance) from TLIS, reservoir and tanks. However, 116 villages do not have any water source in their proximity whose total population of 2,06,935 needs 120.03 m^3/yr for drinking water.

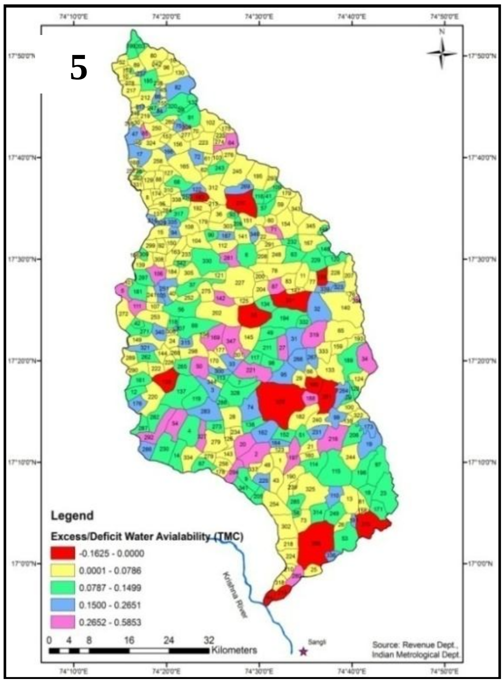
3.3 Water security Mapping

Water Security indicates the status of water requirements with reference to the available resources without any stress or scarcity. A village could be self sustained; if they could harvest the rainwater and store and use it for their needs. An attempt has been made in determining the water deficit/excess of individual villages in the light of present demand and rainfall pattern. The availability of water is calculated based on the area over which the rain falls. A village that is covered under a Thiessen polygon receives the same amount of rainfall considered in the run-off estimation. The demand requirements were calculated for individual villages as discussed earlier. If the difference between the availability and demand is a negative, then it is considered as deficit village and if it is positive (more water availability than demand), then it is considered as water secured village. **Fig. 4** and **Fig. 5** illustrate the spatial distribution of excess or deficit villages for 2001 and 2011. The ground water support is not considered, due to their poor recharge/exorbitant rate of extraction characteristics of this region. In 2001, the water availability was sufficient to meet the requirements. However, the water availability was deficient in 2011 for 13 villages that are marked as deficit villages.

4. Conclusions

About 80% villages are totally depends upon groundwater for their daily need. Due to unavailability of water supply 290 villages have less than 10% irrigated land and 45 villages do not having agriculture practices. It is found that 60, 66 and 105 villages have the water source in their proximity (700m) from TLIS, reservoir and tanks. Hence, their water security is assured. However, 2,06,935 people living in 116 villages do not have any water source. Their drinking water requirement of 120.03 m^3/yr is not secured.





(**Fig. 4** for 2001 & **Fig. 5** for 2011) Water demand – supply balance at villages

Acknowledgement

The authors wish to thank sincerely the anonymous reviewers whose comments greatly improved the quality of the paper.

References

1. Abhijit M. Zende, R. Nagarajan, and K. R. Atal, (2014). Village level water demand and supply from Natural Resources in Semi-arid region western Maharashtra, India, in Proceeding of International Symposium on Integrated Water Resources Management (IWRM 2014), pp. 1130-1136.
2. Amarasinghe U.A., Sharma B. R., Aloysius N., Scott C., Smakhtin V., and Fraiture C de., (2004), Spatial variation in water supply and demand across river basins of India, Research Report 83. Colombo, Sri Lanka: International Water Management Institute.
3. Blummel M., Anandan S., and Prasad C.S., (2009), Potential and Limitations of Byproduct Based Feeding Systems to Mitigate Green House Gases for Improved Livestock Productivity, 13th Biennial Conference of ANSI, Dec 17 -19, NIANP, Bangalore. Vol.1. pp 68-74.
4. Dileepkumar G., Nagarajan R., Kesava Rao A.V.R., and Balaji V., (2007), Village Knowledge Centers and the Use of GIS-derived Products, Second International Conference on ICT in Development, jointly organized by IEEE and ACM, Bangalore, India. 14-15 Dec 2007. http://research.microsoft.com/workshops/ictd2007/ICTD2007_Proceedings_CD.pdf.
5. Frasier G.W., and Myers L.E., (1983), Handbook of water harvesting, Agriculture Handbook - 600. Washington DC, USA: US Dept. of Agriculture, Agriculture Research Service.
6. Gleick P.H., (1996), Basic Water Requirements for Human Activities: Meeting Basic Needs, Water International, 21 (1996) pp.83-92.
7. Intergovernmental Panel on Climate Change (IPCC), (2001), Climate Change 2001-Impacts, Adaptation, and Vulnerability, Cambridge University Press, Cambridge.
8. Michael A. M., (1978), Irrigation: Theory and Practice, Vikas Publishing, New Delhi. India.
9. Nageswara Rao G. D., Anand Babu P., and Bantilan M.C.S., (2009), Dynamics and Development Pathways in the Semi-Arid Tropics: Dokur Village Profile, Research Bulletin no. 23. Patancheru, AP-India: Int. Crops Research Institute for the Semi-Arid Tropics, pp. 80.