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An Analytical Investigation to Select a Suitable Site for Reservoir to Meet the Challenges of Water Scarcity in Rural Areas of Tripura

Saumyadeep Bhowmik, Bishnu Kant Shukla*, Murari Kumar

School of Civil Engineering
Lovely Professional University, Punjab, India
*Corresponding author: bishnukantshukla@gmail.com

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Abstract

The provision of safe drinking water supply and sanitation facilities is a basic necessity of life and a crucial input in achieving the goal of health for all. Tripura is rich in natural resources but due to lack of storage of runoff and also due to the increasing level of urbanization, the retention capacity of the watersheds in these areas is receding day by day. As the pattern of climate is also changing, a drought like situation seems to be most probable in such areas. In this regard, the technological advancements of Artificial Neural Network (ANN) were implemented to achieve selected objectives of reservoir site identification. This study is focused to store rural water in a reservoir like structure at a suitable site to facilitate supply to rural and urban area during dry season. The rank of each parameter was also obtained using fuzzy logic decision making and Analytical Hierarchy Process. Using these weights reservoir site Identification was developed by AHP and Fuzzy logic and predicted for Gomati River. At the end, a reservoir was designed at the suitable location having pre defined storage capacity to cater the needs of the local population.

Keywords- Water Scarcity, Reservoir Site, ANN, Fuzzy Logic, AHP.

1. Introduction

Scarcity of water in hilly parts of Tripura, covers almost two-third of total geography of the state Average rainfall of Tripura did not vary much over the decades but due to rise of river bed, water storing capacity of all 10 perennial rivers shrink down substantially, which caused flash flood. Despite having 2200 mm rainfall annually over 10,491 sq km area every year hill people are suffering from water crisis and water borne diseases are claimed 113 lives in past four years. The latest statistics shows, as many as 330 habitations of Tripura are still uncovered for purified potable water sources. The experience says, the tribal women demands either to supply them sweet water at the top otherwise, they will continue to consume the stream or unhealthy water from open mud well. Drinking of contaminated water from streams due to drying up of regular water sources have led to diseases resulting in casualties every year. The record says, Tripura receives plenty of monsoon rainfall but a maximum amount is flown down to Bangladesh due to storage capacity.

Many researchers have worked on the problem of rural water resources planning in recent past (Byrne et al., 1998; Anderson et al., 1999; Anderson, 2000; Biswas et al., 2001; Ellis, 2002; Howells et al., 2005; Wang et al., 2008). A model of water development planning was

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developed (Shonsey and Gierke, 2013) by taking both technical and social aspect into consideration. Wind energy was suggested to be an efficient tool to address the water scarcity problem of around half the population of rural sub-Sahara Africa (Harries, 2002; Chen and Ravallion, 2008). Another study on river pollution and water quality was carried out in recent past over a vast area of China and effect of water pollution on GDP of the country was studied in detail (Wang et al., 2008). A major study was carried out in northern area of Germany in two monitoring campaigns from 1972 to 1974 and from 1996 to 1998 to investigate the development of the water quality in a rural catchment. The study was further documented and a model was suggested for development of water quality and protection of water bodies as a result of the change of environmental legislation (Deunert et al., 2007). Detailed explorations amongst the links between water infrastructure, water policies, processes and protections, along with mechanisms for women's leadership and decision-making for contributing to rural well-being were done recently and based on the same an exhaustive model were suggested (Ghosh, 2002; Kevany and Huisingh, 2013). An investigation on urban-rural development model (Zhang et al., 2015) concluded that the urban-rural development included the development of water resources which is one of the key pillars in driving regenerative development that includes economic, social, and environmental balance. Recently another model was build which was aimed at to solve water scarcity problem in rural area of Bangladesh (Biswas, 2011). It was concluded that 70% population of the country can be given access to safe drinking water employing renewable energy (Johnson et al., 2008).

2. Methodology

Current study is aimed at selection of most suitable site for reservoir planning to address water scarcity problem of rural part of hilly eastern Tripura. Fuzzy logic and AHP techniques were applied to develop a working model based on which best location is selected for reservoir site.

2.1 Study Area

The study area for the project work was Amarpur sub-division (Figure 1) of Tripura state of north-eastern India. It is located in Gomati district. Amarpur is located at 23.53°N 91.64°E It has an average elevation of 24 metres (78 feet) above sea level.

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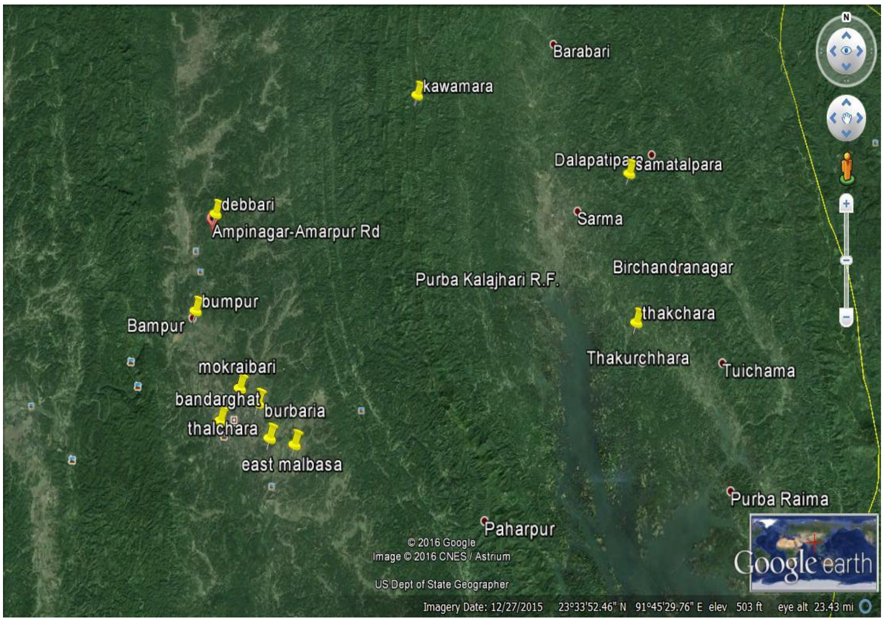

Figure 1. Locations of study area

2.2 Selected Locations for Reservoir Site Selection

In a total ten locations were selected for possible reservoir site. The locations were a) Thakchara (L1) b) Samatalpara (L2) c) Kawamara (L3) d) East Malbasa (L4) e) Thalchara (L5) f) Burburia (L6) g) Debbari (L7) h) Bampur (L8) i) Bandarghat (L9) j) Mokraibari (L10). Rank was given to each site based on several parameters as shown in Table 1.

Table 1. Reservoir site selection survey rank

Parameter	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Availability of a dam site	8	5	8	4	9	8	7	8	7	8
Water tight hilly area	5	5	7	4	8	7	5	5	5	9
Water tight river basin	5	5	6	5	7	6	8	7	7	9
Less demages of land and property	6	4	4	6	8	7	7	9	9	8
Less sediment content in water	7	7	6	5	5	3	9	9	8	7
Low cost of the land	4	2	5	4	5	8	8	8	7	9
Evaporation loss	3	5	3	6	8	8	5	8	9	9
No objectionable minarels in the reservoir site	2	3	2	2	2	3	3	3	2	3
Quality of water stored in the area	8	8	8	7	7	6	9	8	6	7
Less material carrying cost	9	8	6	5	9	4	4	2	1	6
Availability of workers	9	9	9	7	9	4	8	2	1	7
Transportation facility at the construction site	9	9	9	6	9	3	5	2	2	5
Workability and durability of the reservoir	9	9	9	8	9	8	7	7	7	7
Possibility of connection of the reservoir with off taking canal	5	7	5	3	5	4	6	6	6	4
Vegetation condition at the reservoir site	10	10	9	9	9	8	8	8	9	9
Suitability of the foundation of dam	3	4	3	3	6	5	5	7	6	9
Distance from Gomati river	1 km	200 m	500 m	2 km	4 km	4 km	10 m	10 m	2 km	1 km

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2.3 Ratings as per Fuzzy Logic

Each selected site was given a Fuzzy logic rating and ranked as shown in Table 2.

Table 2. Fuzzy logic rating and ranks

Ratings	Ranks
1.Excessively Extreme High Importance (EEHI)	9/10
2.Extreme High Importance (EHI)	8
3.Very High Importance (VHI)	7
4.High Importance (HI)	6
5.Neither High Nor Low Importance (NHNLI)	5
6.Low Importance (LI)	4
7.Very Low Importance (VLI)	3
8.Extreme Low Importance (ELI)	2
9.Excessively Extreme Low Importance (EELI)	1

To construct a reservoir inflow, total demand and monthly rainfall data was collected. Inflow has assumed based on the different months of the year. As per the data, total demand has calculated by using total population of the Amarpur sub-division. Assuming water required per person per day is 120 liters. Monthly rainfall data has collected form irrigation department. By using this total required storage can be calculated.

Table 3. Location details of canal path

Latitude	Longitude	Elevation (ft)
23°31'38.83" N	91°39'35.84" E	130
23°31'47.51" N	91°39'35.53" E	127
23°32'08.64" N	91°39'26.21" E	127
23°31'54.46" N	91°39'19.42" E	125
23°31'52.73" N	91°39'09.47" E	123
23°31'51.57" N	91°38'41.17" E	115
23°32'16.22" N	91°38'32.92" E	109
23°32'29.61" N	91°38'33.60" E	107
23°32'44.54" N	91°38'25.06" E	107
23°32'54.83" N	91°38'34.23" E	106
23°32'59.01" N	91°38'20.98" E	124
23°33'16.41" N	91°38'07.68" E	113
23°33'21.05" N	91°37'54.40" E	112
23°33'04.09" N	91°37'30.85" E	112
23°33'17.71" N	91°37'23.73" E	110
23°33'23.49" N	91°37'20.29" E	130
23°33'29.28" N	91°37'14.75" E	125
23°32'46.75" N	91°36'17.90" E	410
23°32'15.34" N	91°35'50.36" E	309
23°31'58.30" N	91°34'49.23" E	172
23°31'56.84" N	91°34'09.01" E	138
23°31'51.44" N	91°33'11.02" E	108
23°32'07.72" N	91°32'04.37" E	94
23°32'35.49" N	91°31'53.64" E	85

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2.4 Selection of Suitable Path for Canal Design

One suitable canal path was to be selected from Mokraibari to Udaipur. A detailed study was carried about all suitable paths. Based on the study, one path was selected. The criteria of prime importance were total cost of construction, minimum distance, minimum disturbance to natural habitation, least pollution to water and minimum distance from Gomtai River. The location details of the path best satisfying these criteria are shown in Table 3.

3. Results and Discussion

In the case of Fuzzy logic decision making, the parameter scores were given as per the expert survey score and extensive analysis was done by every possible combination of parameters to obtain final result as in Table 4.

Table 4. Fuzzy logic final result

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	Avg
L1	.00312	.00604	.00922	.0105	.0094	.0071	.0099	.0045	.0115	.0074	.0105	.0094	.0082
L2	.00282	.00604	.00922	.0107	.0077	.0078	.0105	.0067	.0115	.0074	.0105	.0097	.0084
L3	.00309	.00622	.00941	.0107	.0098	.0071	.0099	.0073	.0115	.0074	.0102	.0094	.0085
L4	.00276	.00561	.00922	.0105	.0094	.0079	.0099	.0076	.0107	.0071	.0102	.0094	.0084
L5	.00312	.00628	.00979	.0097	.0098	.0083	.0099	.0045	.0115	.0074	.0102	.0103	.0084
L6	.00309	.00622	.00941	.0102	.0103	.0083	.0105	.0078	.0099	.0065	.0096	.0100	.0085
L7	.00291	.00604	.00999	.0102	.0103	.0078	.0105	.0078	.0108	.0070	.0096	.0100	.0086
L8	.00309	.00604	.00979	.0077	.0103	.0083	.0105	.0067	.0078	.0054	.0096	.0105	.0080
L9	.00291	.00604	.00979	.0077	.0099	.0085	.0099	.0078	.0031	.0054	.0102	.0103	.0076
L10	.00309	.00640	.01008	.0097	.0104	.0085	.0105	.0073	.0107	.0070	.0102	.0106	.0087

Further analysis of the different locations was done based on several combinations of the parameters listed in Table 1 using AHP technique and final results were obtained as presented in Table 5.

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Table 5. AHP final results

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	Avg
L1	.035	.011	.003	.004	.002	.003	.002	.005	.006	.014	.005	.002	.008
L2	.017	.011	.003	.009	.002	.003	.004	.005	.006	.014	.005	.002	.007
L3	.035	.015	.004	.009	.003	.003	.002	.007	.006	.014	.003	.002	.009
L4	.014	.009	.003	.004	.002	.004	.002	.008	.002	.007	.003	.002	.005
L5	.070	.022	.005	.002	.003	.007	.002	.005	.006	.014	.003	.003	.012
L6	.035	.015	.004	.003	.006	.007	.004	.011	.002	.003	.002	.002	.008
L7	.023	.011	.008	.003	.006	.003	.004	.011	.003	.005	.002	.002	.007
L8	.035	.011	.005	.002	.006	.007	.004	.016	.001	.003	.002	.005	.008
L9	.023	.011	.005	.002	.004	.014	.002	.033	.001	.003	.003	.003	.009
L10	.035	.045	.015	.002	.011	.014	.004	.007	.002	.005	.003	.010	.013

3.1 Comparison between Fuzzy Logic and AHP Results

By using Fuzzy logic method our selected location was L10 (Mokraibari). Also by using AHP method also best location was L10 (Mokraibari). So, in the both cases the outcome result was same. So the final selected location is L10 (Mokraibari) as shown in Figure 2.

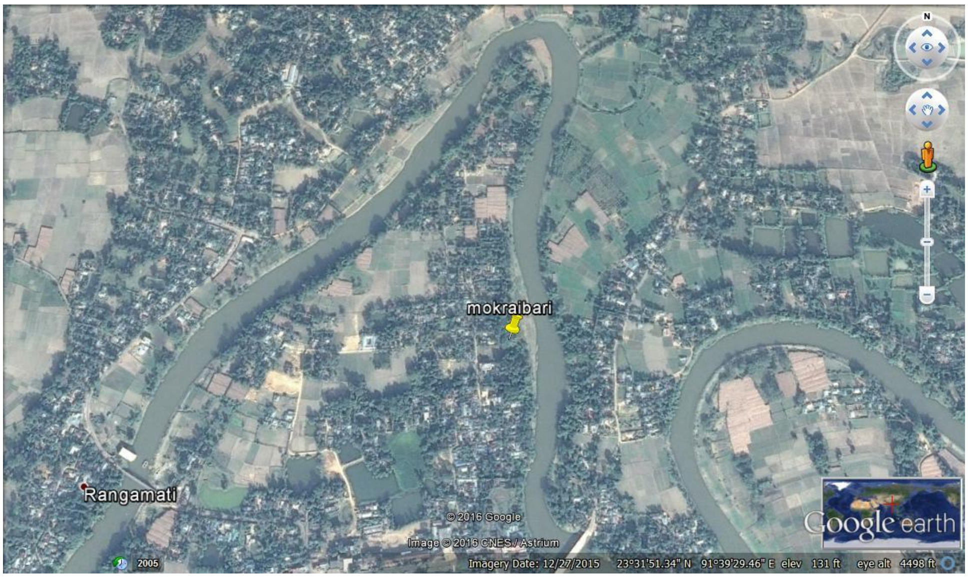

Figure 2. Selected reservoir location

3.2 Reservoir Design

The reservoir area was taken equal to four square kilometers, also for conversion of rainfall to flow to reservoir, a runoff co-efficient of about 0.9 was assumed. Monthly rainfall data was collected from irrigation department for last few years (Table 6). Inflow data was assumed as per the different months of the year.

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Assuming total population to be 1,00,000 and water demand of 135 lts/capita/day, water requirement is calculated as below:

Total daily uses of water = 1,00,000×135 = 1,35,00,000 lts. = 13,500 m^3
So, total monthly use of water = 13500×30 = 405000 m^3

Table 6. Reservoir design data

Month	Mean Flow (cm)	Total Demand (cm)	Monthly Rainfall (cm)
January	1000	7500	110.48
February	1500	7500	112.30
March	2000	7500	144.64
April	3500	7500	200.28
May	4500	7500	267.52
June	6500	7500	550.10
July	7000	7500	650.66
August	7500	7500	700.40
September	5500	7500	211.62
October	3000	7500	169.86
November	1500	7500	75.12
December	1200	7500	64.82

Analysis of the reservoir design flow data was carried out based on data obtained in (Table 6) to obtain total inflow, inflow demand, cumulative excess demand and cumulative excess flow. The results were presented in Table 7 as given below:

Table 7. Reservoir design data analysis

Month	Inflow(cm)	Rainfall(cm)	Total Demand (cm)	Total inflow (cm)	Inflow - Demand	Cum. Excess demand	Cum. Excess flow
Jan	1000	110.48	7500	1099.43	-6400.57	-6400.57	-
Feb	1500	112.30	7500	1601.07	-5898.93	-12299.5	-
Mar	2000	144.64	7500	2130.18	-5369.82	-17669.3	-
Apr	3500	200.28	7500	3680.25	-3819.75	-21489.1	-
May	4500	267.52	7500	4740.76	-2759.24	-24248.3	-
Jun	6500	550.10	7500	6995.09	-504.91	-24753.2	-
Jul	7000	650.66	7500	7585.59	85.59	-	85.59
Aug	7500	700.40	7500	8130.36	630.36	-	715.95
Sep	5500	211.62	7500	5690.45	-1809.55	-26562.7	-
Oct	3000	169.86	7500	3152.87	-4347.13	-30909.9	-
Nov	1500	75.12	7500	1567.60	-5932.40	-36842.3	-
Dec	1200	64.82	7500	1258.33	-6241.67	-43083.9	-

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Since, total inflow = inflow + 0.6×rainfall
So, the required storage for the reservoir is = 43083.9 cm
So, the required storage is $(4\times10^6)\times(430.83)$ cu.m = 1,723.32 Mm

4. Conclusion

Based on the current study, following conclusions are drawn:

- Total of ten locations were surveyed and several parameters affecting the site selection were determined and ranked. Each site was given a rating based on these parameters.
- The different sites were examined based on these parameters by using Fuzzy logic and a detailed rank was given to each site according to the pre-determined parameters. Several combinations of the parameters were studied for each site and finally L10 was concluded to be the best site for reservoir construction.
- The locations were further examined by using AHP decision making technique and all possible combinations of factors affecting site selection of a reservoir were investigated and finally L10 was concluded to be best possible site based on best possible combinations of the parameters.
- Since both Fuzzy logic and AHP yielded same result, L10 was suggested as final site for reservoir construction.
- Based on the Fuzzy and AHP, a reservoir was designed at a suitable location to cater the necessary water demand of the area under study.
- A suitable canal path was selected so as to cause minimum disturbance to local population, paddy fields of the region, health hazards, least distance from Gomati River and minimum cost of construction (Table 3).
- The problems pertaining to Iron, salinity and multiple causes have to be tackled through local solutions based on surface water harvesting /in-situ dilution / recharge techniques and there are element of sustainability inbuilt into the project report along with a provision for a monitoring well/system for observing variations in quantity and quality as a result of dilution due to rainwater harvesting.

References

Anderson, T., Doig, A., Rees, D., & Khennas, S. (1999). Rural energy services: a handbook for sustainable energy development. Intermediate Technology Publications Ltd (ITP).

Anderson, D. (2000). Energy and economic prosperity. UNDP, World Energy Assessment. Energy and the Challenge of Sustainability. New York: UNDP/UNDESA/WEC, 394-413.

Biswas, W. K., Bryce, P., & Diesendorf, M. (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. Environmental Science and Policy, 4(6), 333-344.

Biswas, W. K. (2011). Application of renewable energy to provide safe water from deep tubewells in rural Bangladesh. Energy for Sustainable Development, 15(1), 55-60.

Byrne, J., Shen, B., & Wallace, W. (1998). The economics of sustainable energy for rural development: a study of renewable energy in rural China. Energy Policy, 26(1), 45-54.

Chen, S., & Ravallion, M. (2008). The developing world is poorer than we thought, but no less successful in the fight against poverty. World Bank Policy Research Working Paper Series.

Deunert, F., Lennartz, B., & Tiemeyer, B. (2007). Legislative effects on the development of surface water quality in rural areas in Northern Germany. Journal of Cleaner Production, 15(16), 1507-1513.

Ellis, F. (2002). Rural livelihoods and diversity in developing countries. Oxford, UK: Oxford University Press.

Ghosh, N. (2002). Infrastructure, cost and labour income in agriculture. Indian Journal of Agricultural Economics, 57(2), 153.

Harries, M. (2002). Disseminating wind pumps in rural Kenya-meeting rural water needs using locally manufactured wind pumps. Energy Policy, 30(11-12), 1087-1094.

Howells, M. I., Alfstad, T., Victor, D. G., Goldstein, G., & Remme, U. (2005). A model of household energy services in a low-income rural African village. Energy Policy, 33(14), 1833-1851.

Johnson, D. M., Hokanson, D. R., Zhang, Q., Czupinski K. D., & Tang, J. (2008). Feasibility of water purification technology in rural areas of developing countries. Journal of Environmental Management, 88(3), 416-427.

Kevany, K., & Huisingh, D. (2013). A review of progress in empowerment of women in rural water management decision-making processes. Journal of Cleaner Production, 60, 53-64.

Shonsey, C., & Gierke, J. (2013). Quantifying available water supply in rural Mali based on data collected by and from women. Journal of Cleaner Production, 60, 43-52.

Wang, M., Webber, M., Finlayson, B., & Barnett, J. (2008). Rural industries and water pollution in China. Journal of Environmental Management, 86(4), 648-659.

Zhang, X., Wu, Y., Skitmore, M., & Jiang, S. (2015). Sustainable infrastructure projects in balancing urban–rural development: Towards the goal of efficiency and equity. Journal of Cleaner Production, 107, 445-454.