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Rooftop Rainwater Harvesting for Domestic Water Demand and Supply Management and Designing of Optimum Rainwater Harvesting Structure in Imphal West District Manipur

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ABSTRACT

Rains are the main source of water and if rainwater is harvested, the scarcity of water can be eliminated. Manipur state was chosen for the study. The state lies at a latitude of 23°83'N – 25°68'N and a longitude of 93°03'E – 94°78'E and having a geographical area of 22,347 km². In Manipur many areas face serious threats to a safe and steady supply of water. To solve the problems of water supply and availability of quality water can be complex, but through rooftop rainwater harvesting, it can be one of the feasible solution to meet the domestic water demand. Rooftop rainwater harvesting is one of the methods of rainwater harvesting. It is a system of catching rainwater directly from where it falls. Runoff occurrence over the rooftop is collected for storage for future usage and this water is considered to be free from contamination. The total domestic water demand of Manipur was estimated at 84043520 m^3 and domestic supply potential only from rooftop rainwater harvesting was estimated at 28134022 m^3 which fulfil about 33.5% of total domestic water demand. The shortage which is about 66.5% can be through State Government's water supply scheme, from the private sector and also from other sources like pond, river, lake, spring water, *etc*. January month was found to be the most water stress month with about 1.3% of water could be fulfilled through rooftop rainwater harvesting to the total domestic water demand. Whereas from May to September months rather peak monsoon months, rooftop rainwater harvesting could fulfilled more than 50% of the total domestic water demand. The average annual increase in domestic water demand from 2001 to 2026 was predicted at 1.09% and total increased in domestic water demand was predicted at 27.16%. So, there will be huge domestic water demand in coming future years.

1. Introduction

Rainwater harvesting is a technique used for collecting, storing and using for domestic water supply, kitchen gardening, groundwater recharge, irrigation and other uses. The rainwater can be collected from various hard surfaces such as rooftops and other hard surfaces above ground surfaces. Rains are the main sources of water in Manipur and if rainwater is harvested, the scarcity of water in the state can beeliminated or minimize the water stress in the state during the dormant season. Rainwater harvesting can be one of the alternative technologies for domestic water supply in Manipur and it has been a traditional way of enhancing domestic water supply through the ages. Rainwater harvesting systems provide better options for storing of water for domestic uses, groundwater recharge, better water quality for irrigation and also for reduction of drainage problems during peak rainfall periods.

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Some of the advantages of rainwater harvesting (Singh, et al., 2014)

- = To reduce soil erosion and water conservation
- = To recharge groundwater
- = To rejuvenate groundwater decline and augment ground water table
- = To beneficiate water quality
- = To conserve surface water runoff during monsoon
- = Independent of water supply
- = Mitigation of drought as well as flood situation

Rooftop rainwater harvesting

Rooftop rainwater harvesting is one of the methods of rainwater harvesting. Rooftop rainwater harvesting is the technique through which rain water is captured from the rooftop. The main objective of rooftop rainwater harvesting is to make water available for future use and harvested rainwater is considered to be free from contamination. Water is channelled through gutter or drainpipe to the storage structure.

Advantages of rooftop rainwater harvesting (Singh, et al., 2014)

- = Harvesting of the water at the doorstep
- = It is less expensive
- = Freely available
- = Better quality water
- = Free from chemical treatment
- = Free from contamination
- = Excess water can be used for kitchen gardening and other uses
- = Excess water can be used for recharging groundwater

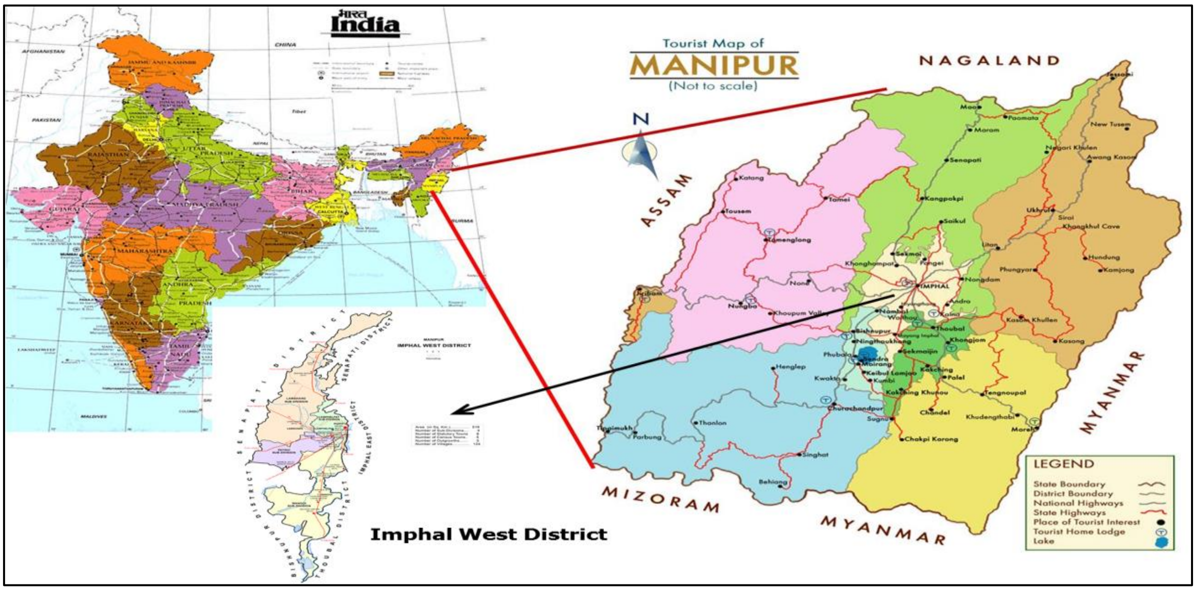
In Manipur many areas faces serious threats to a safe and steady supply of water particularly Imphal West district of Manipur due to the increase in urban population. Imphal West districts the only district in Manipur where urban population is more than rural population. There is less reliability on centralized water delivery systems controlled by state government under Public Health Engineering Department (PHED). People in the district spend huge money on purchasing of water during the water stress period in the state from the local water supply through water tankers. To solve the problems of water supply and availability of quality water can be complex, but through rooftop rainwater harvesting, it can be one the feasible solution to meet domestic water supply.

2. Materials and Methods

Study area

Imphal West district of Manipur was chosen for study. Imphal West is one valley districts of Manipur (Fig.1). The state capital of Manipur is Imphal and is located in Imphal West. Imphal West district is located between latitude of 25°8'8"N to 24°27'22" N and longitude of 93°57'44"E to 93°46'45" E and having area of about 519 km².

Figure 1. Study area location



Rainfall data

The monthly rainfall data of Manipur were downloaded from IMD website (http://www.indiawaterportal.org). Average monthly rainfalls were considered for estimation of rooftop runoff. Data from 2004 to 2010 were used to calculate mean monthly rainfall. Average annual rainfall has been estimated as 1216mm.

Water supply data

Domestic water supply data was calculated based on the water delivery at the household level and later converted into monthly water supply.

Only sources of water supply in Imphal West district is through Public Health Engineering Department (PHED), Government of Manipur.

Population and household data

Population data and household data were collected online from http://www.manipurstat.com/.Year-wise Imphal West population by residence and sex in Manipur as per Census, 2011 and population of Manipur, 2006 are given in Table 1. Imphal West district houses and use by their condition in Manipur are given in Table 2 and available data was of 2001. Household data were used for calculation of rooftop catchment area.

Table 1. Year-wise Imphal West district population by residence and sex in Manipur (Population of Manipur, 2006; Census, 2011)

Year	**Rural**			**Urban**			**Grand Total**
	Male	**Female**	**Total**	**Male**	**Female**	**Total**	
1961	62130	64415	126545	26385	25305	51690	178235
1971	82920	81704	164624	38884	37647	76531	241155
1981	74926	75152	150078	75670	75033	150703	300781
1991	83016	81919	164935	109425	106441	215866	380801
2001	99278	98421	197699	122503	124180	246683	444382
2011	96948	98165	195113	158106	164773	322879	517992

Table 2. Imphal West district census houses and use by their condition in Manipur, 2001 (http://www.manipurstat.com/)

Area	**Residence**			**Residence-cum-other use**			**Total**
	Good	**Liveable**	**Dilapidated**	**Good**	**Liveable**	**Dilapidated**	
Rural	20414	11947	1525	306	170	19	34381
Urban	28015	11711	1419	815	362	31	42353
Total	48429	23658	2944	1121	532	50	76734

Estimation of runoff

Estimation of rooftop runoff required rainfall of the given area, rooftop catchment area and runoff coefficient of the catchment area. By using these three factors rooftop runoff volume will be estimated. Runoff coefficient was referred from Handbook for Rainwater Harvesting for the Caribbean, (2009) and adjusted at the local conditions. Three different rooftops namely good, liveable and dilapidated were considered for the runoff estimation and runoff coefficient for each rooftop were considered as 0.8, 0.7 and 0.6 respectively (Table 3). Rooftop areas are varying from one household to another, so for estimation of runoff, the optimum rooftop size considered was $120m^2$ per household.

Table 3. Assumption considered for runoff coefficient for different rooftop

Residence	**Runoff coefficient**
Good	0.8
Liveable	0.7
Dilapidated	0.6
Residence-cum-other use	**Runoff coefficient**
Good	0.8
Liveable	0.7
Dilapidated	0.6

Estimation of population growth and future forecasting

Population growth was estimated using Census data from 1961 to 2011 (Population of Manipur, 2006; Census, 2011). Simple linear regression model was used for forecasting of future population (Table 4).

Table 4. Relationship between population and linear regression model

Population type	Linear regression equation	R^2
Urban-Male	y = 2694.90x + 18428	0.9834
Urban-Female	y = 2823.80x + 15476	0.9846
Rural-Male	y = 660.73x + 66024	0.7958
Rural-Female	y=644.77x + 66532	0.8295

Water demand estimation

Daily water demand was calculated using the population data and daily water requirement per person. According to the field survey report average water requirements per day per person have been found 94 litres person^{-1} day^{-1} (Table 4). Both urban as well as rural areas daily water requirements were found to be almost same.

Table 4. Daily water requirement of a person

Particulars	Water requirements (litres/person/day)
Cooking	8
Drinking	4
Washing	20
Toilet	12
Bathing	30
House Cleaning	5
Kitchen Gardening	15
Total	94

3. Results and Discussions

Monthly rainfall pattern

Monthly rainfall data from the year 2004 to 2010 collected from IMD website and were used for analysis of monthly rainfall pattern. July month has the highest monthly rainfall followed by June, May, April, August, September and October. Least monthly rainfall occurred in the month of January followed by December, November, February and March. Highest monthly rainfall deviation was found in April month followed by October, May and least monthly deviation was found in the month of January and followed by December, November. Rainfall mostly occurred during April to October and remaining months, January, February, March, November and December occurred less than 50mm.

Water demand supply assessment

Water demand was assessed based on population data on daily basis and later converted to monthly basis. Average monthly water demand was estimated as 1.471 MCM. Water supply through PHED could not fulfill the domestic water in all the months. Average monthly shortage of water supply was estimated at 0.956 MCM (Fig.3). Potential monthly rooftop rainwater harvesting was estimated using monthly rainfall data, residential data and residential condition of the household available in the Imphal West district (Fig. 4). During monsoon season there is high scope for harvesting of rooftop rainwater. Monthly amount of rooftop rainwater which can be harvested are shown in the Fig. 5. Maximum rooftop rainwater can be harvested in the month of July at about 1.385 MCM and followed by June, May, April and August.

Figure 2. Average monthly rainfall during 2004 – 2010 periods.

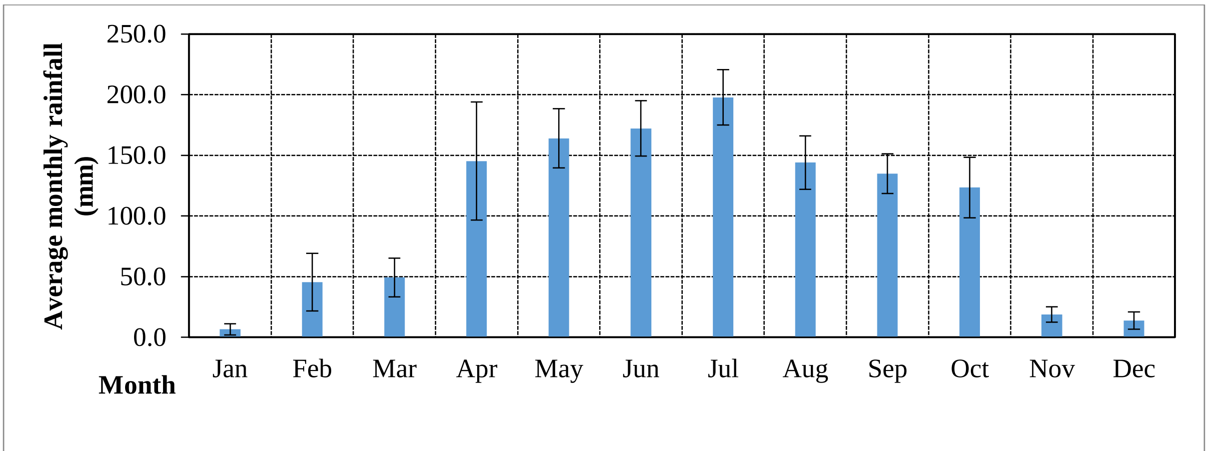
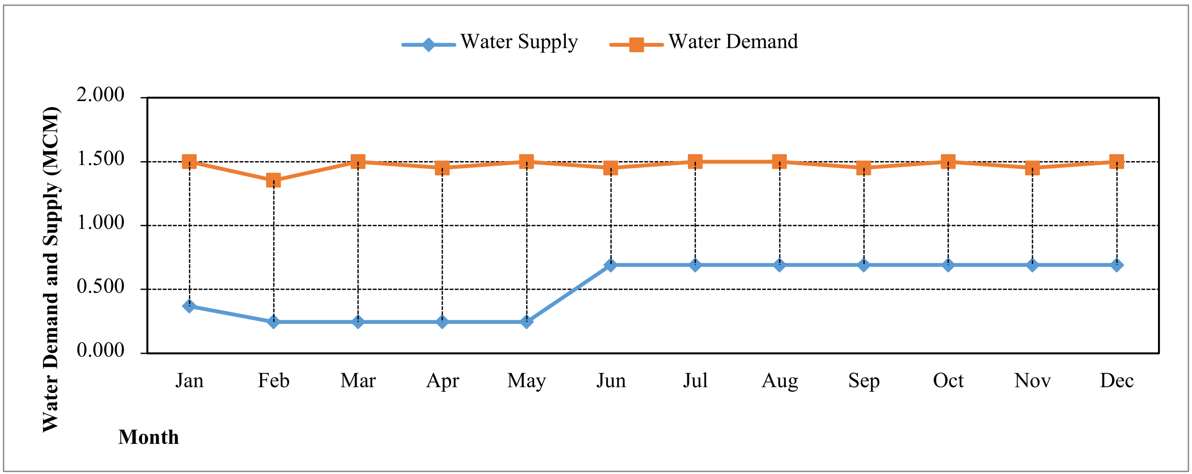


Figure 3. Monthly Water supply (PHED) and water demand



Though water supply from PHED may not satisfied the water demand in all months, if rooftop rainwater harvesting is also considered, water demand can be fulfilled for five months from June to October. When total water supply considering both PHED and rooftop rainwater, five months from June to October were estimated as excess water supply months (Fig. 6). This excess water can be stored for uses during the water stress months and monthly excess water available were estimated litres per person per month (Table 5). July month has the highest excess water available followed by June, August, September and October months. Excess per capita total amount of water of which can be saved was estimated 2827 litres person^{-1} year^{-1} and this amount of water is consider for optimum design of rainwater harvesting structure capacity (Table 5).

Figure 4. Potential monthly rooftop rainwater harvesting

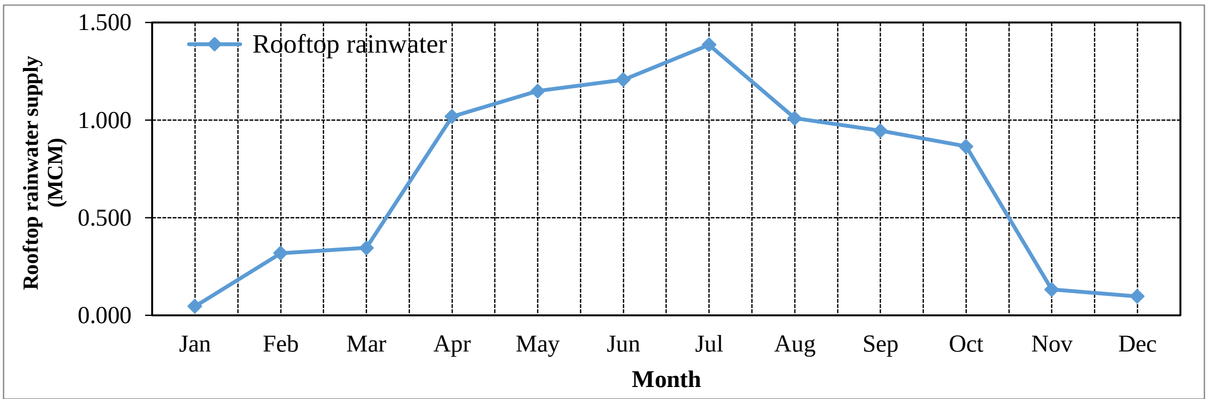
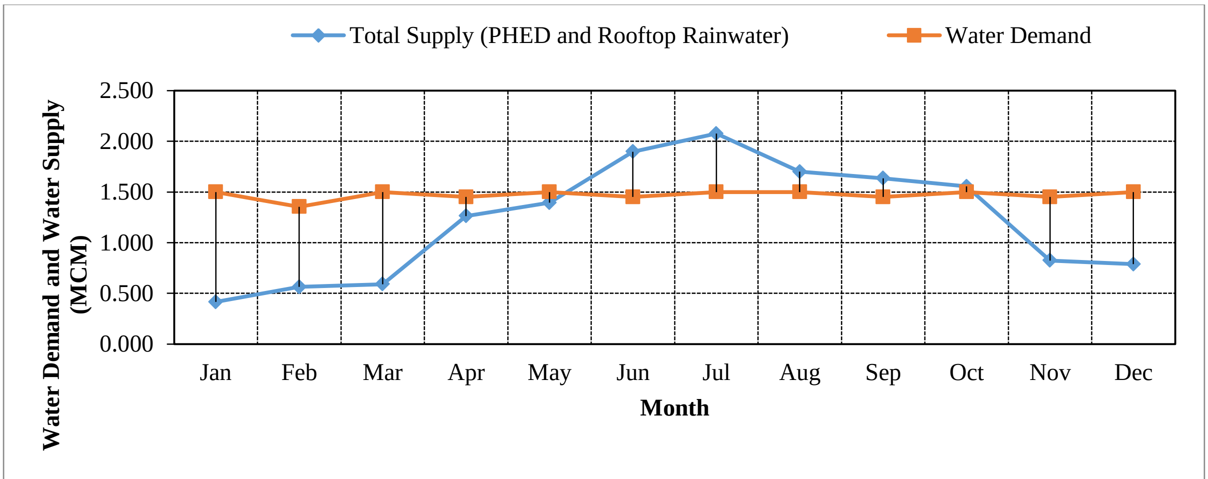


Figure 5. Total water supply (PHED and Rooftop Rainwater) and water demand



Future water demand forecasting

Simple linear regression model (Table 4) was used for forecasting of urban-male, urban-female, rural-male and rural-female population and later on combine all categories of the population to forecast future population of the district. Average population growth rate was calculated at 1.18%. Estimated population in the year 2021 and 2031 will be 548615 and 650978 respectively. Future water demand was calculated using population data. Future water demands were estimated at 19.99 MCM, 20.93 MCM, and 22.34 MCM for year 2021, 2015 and 2031 respectively. Details of future water demand are given in Fig. 7.

Figure 6. Monthly excess water supply

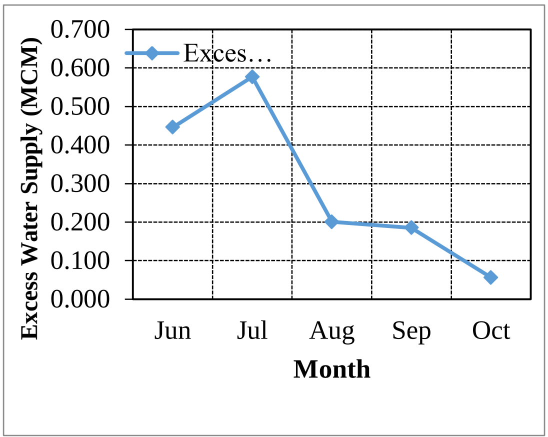


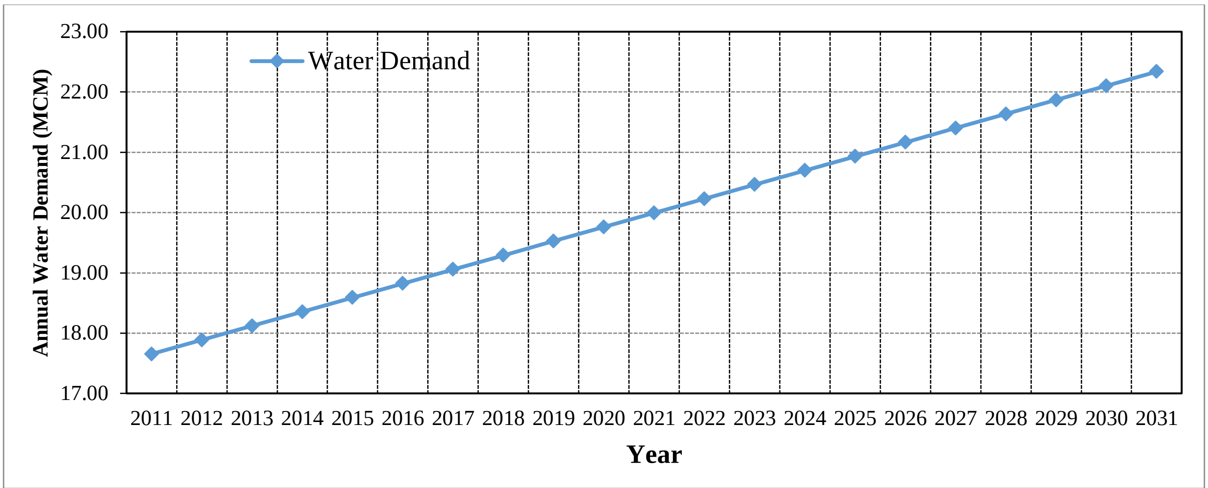
Table 5. Monthly excess water available per person per month

Month	Excess water (litres/person/month)
Jun	861
Jul	1113
Aug	387
Sep	357
Oct	109
Total	2827

4. Summary and Conclusion

The total domestic water demand of Imphal West was estimated at 17.652 MCM and water supply from state government's water supply scheme (PHED) was estimated at 6.185 MCM, which fulfil only about 35% of total water demand. If rooftop rainwater is considered another 52% of water shortage can fulfilled. The shortage which is about 17% can be through rainwater storage and through private enterprise. The average annual increase in domestic water demand was predicted at 1.33% and total increased in domestic water demand from 2011 to 2031 was predicted at 26.53%. So, there will be huge domestic water demand in coming future years.

Figure 7. Year-wise forecasting of water demanding Imphal West district, Manipur



Rooftop rainwater harvesting is yet to beexploited in Imphal district, Manipur. Imphal district is facing acute drinking water shortage as the government's water supply facilities fully depends on the rivers and which are generally remain dry during the dormant season. Rooftop rainwater can be one of the best options to stored quality water for use during the dormant months. During the water crisis period, there are many other private traders who supply the drinking at much higher price, which increases hardship to the common people. Groundwater resources are not yet exploited in Manipur, so groundwater can be one of the options for supplies of water during non-rainy months and same groundwater can be recharged during the monsoon months.

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