Decision Support System for Water Resource Management in Mid-Elevation Watershed of Central Himalaya (India)

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Abstract: *Central Himalaya is facing a crucial water supply problem for drinking and other household purposes. The increasing utilization of water and lack of its natural storage cause a decline in the availability of water, particularly in the rainfed areas. Water resource management is predominant approach to develop new strategies for sustaining water supply. Water demand also is increasing day by day due to population growth, rapid urbanization and climate change. The condition is more critical in non-glacial river basins of Central Himalaya. Water availability at watershed and sub-watershed level is declining and water scarcity is experienced particularly in summer months. Under these conditions, it is necessary to make appropriate decisions to allocate supply for all sectors (urban & rural population, livestock and agriculture). In the present study conducted in Upper Kosi watershed of Central Himalaya, a Decision Support System (DSS) is introduced as interactive tool that understands the problem and explores various courses about water demand and supply management to help decision makers. Urban & rural water demand forecasting under different socio-economic scenarios, water allocation and optimization of allocations are the main prospects in proposed DSS. Data is analyzed for each month of forthcoming years (2012 to 2030). Two summer months (April and May) of summer season are explored as more critical under current water availability condition. DSS is tested and found suitable for water allocation in this situation and for optimization in June and July month. The study suggests that water supply cannot meet demand of any sector without storage of surplus water from Jan to March of the same year. Even with storage of surplus water, 100 % water demand of all sectors can be fully met till 2016. However, the urban demand can be met with this stored water.*

Keywords: *Water Demand, Water Allocation, Optimization, DSS, Water Resource Management*

1. Introduction:

More than one billion people today lack access to drinking water [1]. Many experts, governments, and international organizations are predicting that water availability will be one of the major challenges facing human society in the 21st century and that a lack of water will be one of the key factors limiting development [2]. It has been estimated that by 2025, population growth will increase the proportion of water used by humans to 70 percent [3]. The availability of water per capita itself has come down from about 5,177 cubic meter per head in 1951 to 1,820 cubic meter per head in 2001 and it is expected to further go down to 1,140 by 2050 AD [4]. According to assessment made by the Ministry of Water Resources, the total water requirement of the country for various sectors was estimated to grow from 694 km^3 in 2010 to 973 km^3 in 2050 [5].

Central Himalaya is a rich source of drinking water for Urban and Rural population, Livestock and of irrigation in Agriculture and of other uses in different industries. There are so many natural springs & streams, which are important for water supply. Presently, the Central Himalaya is facing the problem of water scarcity due to rapid growth of population along with improved standards of living & urbanization which have led to increased demand, competition and conflicts among different water use sectors. Water scarcity is the concept of relationship between water demand and its availability.

In Central Himalaya region, rainfall oriented rivers and other natural sources are important sources for drinking water and other uses. Rain-fed agriculture is common in the region. Due to improper management and scarcity of water, two major problems are confronted in rain-fed areas viz; soil erosion & siltation of water bodies downstream due to intense rainfall and surface runoff in monsoon seasons and severe drought due to acute water scarcity in summer seasons. Now-a-days rural areas of the region are leading to urbanization and urban areas are leading to metropolitan. In such a case water demand is increasing rapidly while available water is decreasing day by day.

Predicting future urban growth is the problem of single objective and multi-criteria decision analysis. The volume of public water use depends on the size of an urban population [6]. It is basic necessity to fulfill urban demand then other sectors. For water demand forecasting and water supply management, it is necessary to develop an efficient tool for supporting decision-making in water management. Decision Support System (DSS) is interactive program and modeling systems to aid decision-making activities, to understand the problem, to explore new approaches for further actions [7]. The DSS provides discussion platform to supply managers and users to reach some meaningful decisions on management. DSS develops decision-making skills and increases efficiency of decision makers to take decisions. The DSS is able to integrate research efforts in scientific disciplines, translate the results to the management level, increase the understanding of the relations between users of a water system and the system itself, provide a common and user-friendly framework for the analysis and comparison of management decisions, and facilitate the comparison of many different management options and measures [8]. DSS evaluates the various scenarios in achieving the desired objectives and mathematical models; analyze the behavior of the system giving basic support to the decisions on the preferable options [9]. A decision network was developed for sustainable urban water management [10], in which surface water, ground water, soil characteristics and population aspects were considered to develop sustainable techniques for urban water management. Andreu [11] have discussed the generic decision support system that was originally designed for the planning stage of decision-making associated with complex river basins. The purpose of the DSS models is to quantify the holistic response of the water resources system to alternative scenarios of basin development, hydrology, water use levels, and management policies [12]. Reitsma [13] has made an attempt to formulate the needs and opportunities relating to decision support system technology for environmental management in general and water resources management in particular. A decision support system (DSS) was developed to enable the evaluation of the current situation and of the eventual impacts of new water management options within river basin [14]. In this present study, a simple decision support system is developed which will help the decision makers or supply managers to identify water scarcity problem in forthcoming years and to explore concepts of different water management strategies for Upper Kosi Watershed of Central Himalaya Region.

2. Study Area:

In this study we have chosen rainfed Upper Kosi Watershed of Almora District. The watershed has its spatial extension between 29^0 30' and 29^0 55' N Latitudes and 79^0 30' and $79^0$45' E Longitudes covering 480.15 km^2 geographical land surface (Fig 1). It is major river of Ramganga (West) system. Its source point is Pinath and it joins to its main tributary Suyal near Kwarab. The watershed is the most centrally located basin in the Kumaun Himalaya and falls within the district Almora and dose not cross the district boundary. It has an average altitude ranging between 1500 and 2700 m. from mean sea level. It drains about 1475 km^2 area between its source at Pinath, NW of Kausani in district Almora and Ramnagar in district Nainital. About 30% of total agricultural land of Almora district depends on the watershed. According to Census 2011, Almora has population of 621,927.

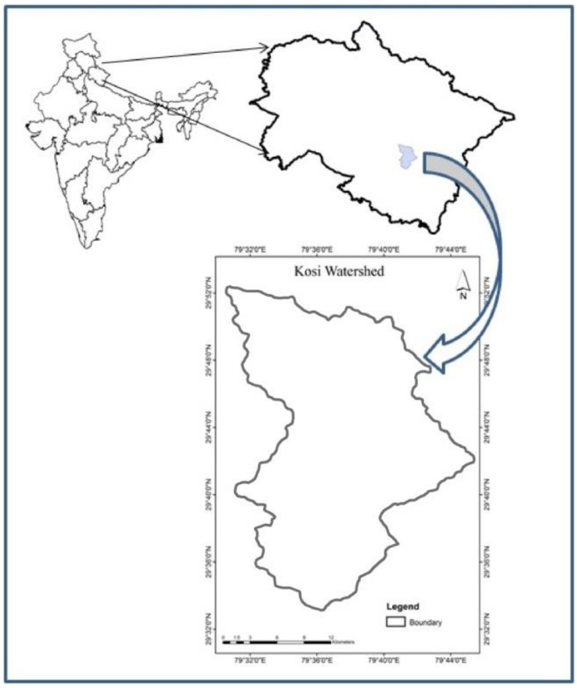


Figure 1. Study Area

3. Methodology:

DSS consists of urban & rural population forecasting, urban & rural water demand forecasting and available water for the current year 2012 and for the next 18 years (Fig 2 & 3). Implementing all these information into a support system, it may provide better options for water management and optimization model. All the required informations were collected from on-site measurement, survey, socio-economic studies, census data and stakeholders meeting.

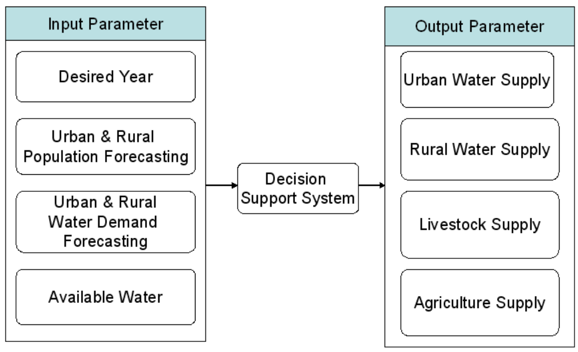


Figure 2. Decision support system parameters

3.1. Step 1:

From the previous study we have taken medium growth rate (20.7% per decade) for urban and constant growth rate (4.09% per decade) for rural population forecasting because it provide a realistic approach for further analysis.

3.2. Step 2:

Water demand forecasting is prediction of water requirement and sustainable use of water [15] in all sectors (Urban, Rural, Livestock and Agriculture) for forthcoming years. Water demand is calculated by standard limit of consumption rate viz; 40lpcd (liter per capita per day) low consumption rate, 51lpcd medium consumption rate and 155lpcd high consumption rate. For urban water demand we have chosen high consumption rate of 155lpcd for whole month because of urbanization while low consumption rate of 40lpcd is used for rural water demand in winter season and 50lpcd in summer season due to more consumption. Livestock and Agricultural water demand is calculated through Net Economic Return [16] method which is also used for water allocation and optimization. For the purpose of this study Agricultural and Livestock demand is assumed as constant. Now a day rural areas tend to urbanize, so 3 scenarios for rural water demand is described i.e., low growth rate 0.56%, medium growth rate 1.17% and high growth rate 1.78% for water demand prediction in forthcoming years.

3.3. Step 3:

Availability of water for the study area is rain water, natural springs and river. Available water of the month was calculated using daily rainfall data and water flow data of the river of year 2010 and assumed the same for further years.

3.4. Step 4:

Decision support system is a computer based program which helps decision makers to identify problems and solve them [17]. To develop the program we used Visual Basic 6.0 programming language platform. Different mathematical calculations were used in the program. The program is multi-form program in which only one time entry of your input viz; year from 2012 to 2030 (Fig 4). An additional entry of available water is permitted in the program. Available water is taken as optional, it may be constant for forthcoming years or it may increase or decrease as per the field measurements, so the decision maker can enter the new value. In the third step, result and condition is displayed for each month and in the fourth step results for optimization is displayed. For improving water supply in scarce months, it is assumed that surplus water of three previous months could be stored and carried forward to the next 3 months. Thus, there are four conditions for water allocation and optimization viz; condition A – normal available water, condition B – surplus water carried forward form March month, condition C – surplus water carried forward from March & February month and condition D – surplus water carried forward from march, February & January month.

Implementing above methodology the program is developed. To generate results it is necessary to enter any desired year from 2012 to 2030 in blinking cursor box. In the DSS, the population of the year 2001 is taken as primary data for forecasting and "Years" is input entity, entered only once and then the program generates result.

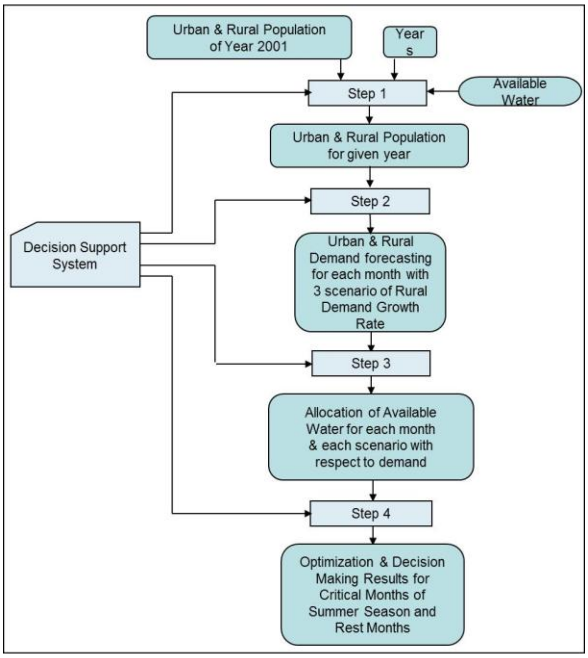
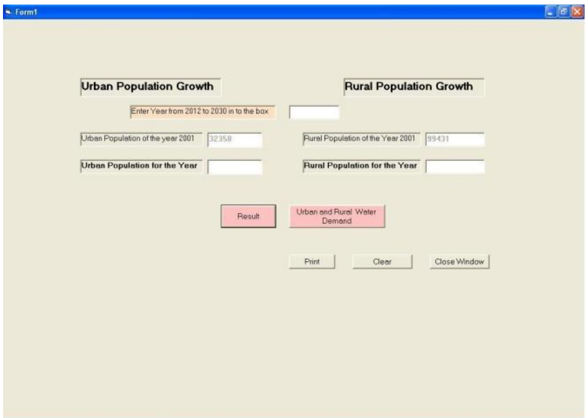
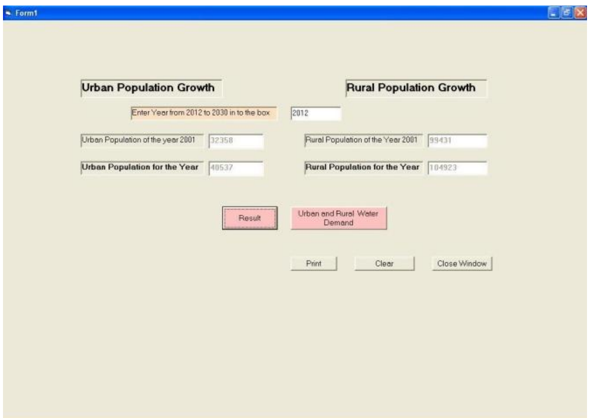


Figure 3. Flowchart for Decision Support System





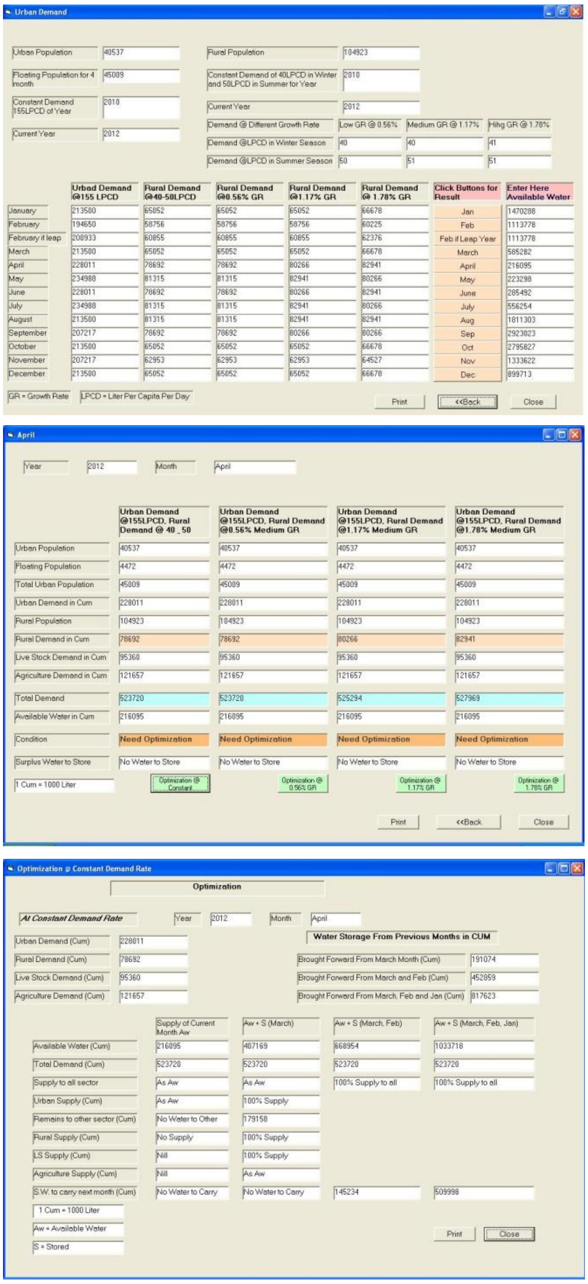


Figure 4. Decision Support System window

4. Water Demand Forecasting:

The developed DSS is tested on a case study of the upper Kosi watershed for forthcoming 18 years (from 2012 to 2030). It is capable of forecasting domestic (urban and rural) water demand in changing scenarios. It describes urban and rural water demand forecasting month wise in accordance with the desired year. It also provides rural water demand rate as per lpcd (liter per capita per day) in different scenarios, while urban water demand is taken as constant. For example, in all the months of the year 2012 urban water demand varies from 194650cum to 234988cum, whereas, the rural water demand rate increased from 58756cum to 81315cum in constant water demand rate, 58756cum to 82941cum in 1.17% growth rate and 60225cum to 82941cum in 1.78% growth rate. In year 2030, urban water demand varies from 273117cum to 331448cum while rural water demand varies from 64160cum to 88794cum in constant water demand, 70576cum to 97673cum in 0.56% growth rate, 80201cum to 111880cum in 1.17% growth rate and 89825cum to 126087cum in 1.78% growth rate.

5. Available water:

The DSS facilitate option to change value of available water on increasing or decreasing water availability. For this study it is assumed that available water supply is constant for each month of all the years.

6. Water Allocation:

For allocation of available water DSS is fitted in the case study of Kosi watershed. DSS is able to allocate available water month wise of upcoming years (from 2012 to 2030) in accordance with increasing domestic demand and changing scenario. In DSS, it is found that domestic water demand, livestock and agriculture water demand is fulfilled as 100% for the given months January to March and August to November till the year 2030 in different scenario. For example in Jan 2012, total water demand is 1105524cum (cubic meter) and available water is 1470288cum. DSS indicates surplus water which can be stored for augmenting water supply in coming scarce months. In Jan 2030, total water demand increases to 1198381cum which can be fully met by 1470288cum available water. There is some surplus water (271907cum) in constant demand scenario.

7. Allocation with Optimization:

DSS is able to indicate water scarce months and to optimize available water in those months for all the years in different scenarios. 3 months (April, May and June) are found more critical for water supply through DSS. It also provides increased available water in 3 different storage conditions. These values are fitted for allocation of available water in different scenarios. DSS indicates for use of optimization when all demands are not fulfilled. In constant supply rate all available water is allocated for urban demand. If surplus stored water is carried forward to this month, the volume of available water increases to change water allocation. For example, April month of the year 2030 in normal supply rate, all available water is allocated to urban in conditions A and B, to urban, rural and livestock in condition C and to all sector as 100% in condition D. In May, available water is allocated to urban in conditions A, B, & C and to urban as 100% and remaining to rural under condition D. Water allocation changes in all the three scenarios as per demand growth rate. For example, in medium growth rate of 1.17% in April 2030 available water is allocated only to urban in conditions A and B, to urban and rural as 100% in condition C and to all sectors as 100% in condition

D. In May 2030, available water is allocated to urban in condition A, B, C and D on water availability. DSS is able to use optimization in different scenarios. In June, available water is optimized to provide 100% supply to urban, 74.8% supply to rural and 25.2% supply to livestock. In July, available water is optimized for 100% supply to urban, 20.17% supply to rural, 25.79% supply to livestock and 54.03% to agriculture. In December, available water is optimized as 100% supply to urban, 9.05% supply to livestock and 82.45% to agriculture.

For better understanding the optimization of water, only two scenarios are taken and different storage condition in described below (Table 1).

Table 1:

Scenario 1- constant supply rate of 155lpcd for Urban and 40 – 50lpcd for Rural and Scenario 2- 155lpcd for Urban and 1.17% growth rate of 40 – 50lpcd for Rural			
Condition A: without storage	Condition B: stored water (M)	Condition C: stored water (M & F)	Condition D: stored water (M, F & J)
5	5	5	5
4	4	4	4
3	3	3	3
2	2	2	2
1	1	1	1

(5. If all sector fulfilled as 100%, 4. If domestic (Urban & Rural) demand and Livestock is fulfilled as 100%, 3. If domestic (Urban & Rural) demand is fulfilled as 100%, 2. If only urban demand is fulfilled as 100%, 1. No any sector is fulfilled as 100%, M for March Month, F for February month, J for January month)

Comparisons of two scenarios in April, May and June month is described in Fig 5, 6 and 7, shows a decreasing trend. As years are passing, level of supply condition is going down. However in June, with 3 months storage condition domestic supply can be met 100% till the year 2016.

8. Conclusion:

A model driven Decision Support System (DSS) is developed for water system infrastructure planning & water supply management in different water demand scenarios including water storage conditions that will enable the decision makers to consider future growth factors in determining the optimal utilization of current and likely future water system infrastructure. The importance of the DSS is to guide and to inform the decision maker rather than make the decision on own behalf. The usefulness of the DSS is demonstrated by the fact that is currently used by the Kosi watershed as a standard tool not only to develop their basin hydrological plans but also to manage the resources efficiently. The Kosi watershed has been used as case study in the development and validation of the DSS. The DSS is recognised as a valuable tool in water demand side and water supply side. The new element of this DSS is the ability to analyze water system at the most basic level such that the decision maker can perform real-world concrete analysis of the water system infrastructure requirements to meet future growth demand.

The DSS is capable of forecasting domestic (Urban and Rural) water demand in changing scenarios for forthcoming year (from 2012 to 2030). In normal urban water demand rate of 155lpcd, urban water demand will be increased from 194650cum to 234988cum and Rural water demand rate of 40-50lpcd, Rural water demand increased from 58756cum to 81315cum. If highest growth rate of 1.78 is applied in rural water demand, it will be increased from 89825cum to 126087cum. DSS is an effective tool to allocate and optimize available water to meet domestic water demand in different changing scenarios. Two months (April and May) are found more critical for water supply. Water Supply can't meet demand of any sector without storage of surplus water from January to March of the same year. Even with storage of surplus water, 100% water demand of all sectors can be fully met till 2016. However, the urban demand can be met with this stored water.

9. Acknowledgements:

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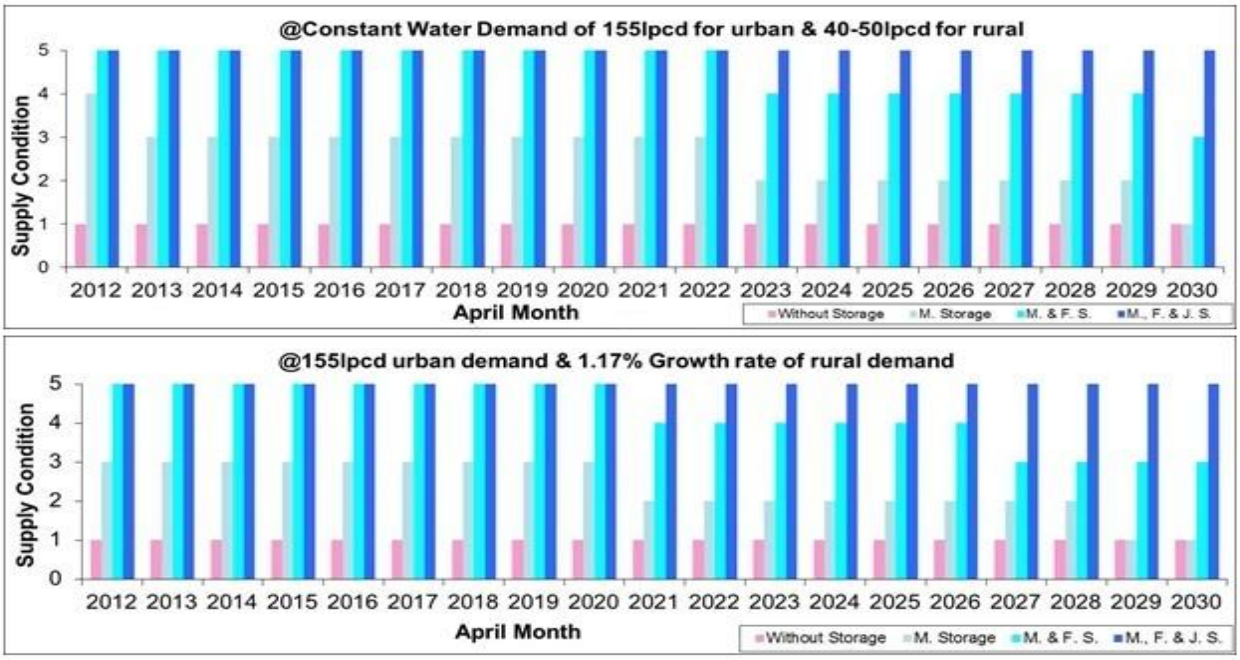

Figure 5. Comparison of water optimization in different water storage condition at constant supply rate and medium growth rate in April month

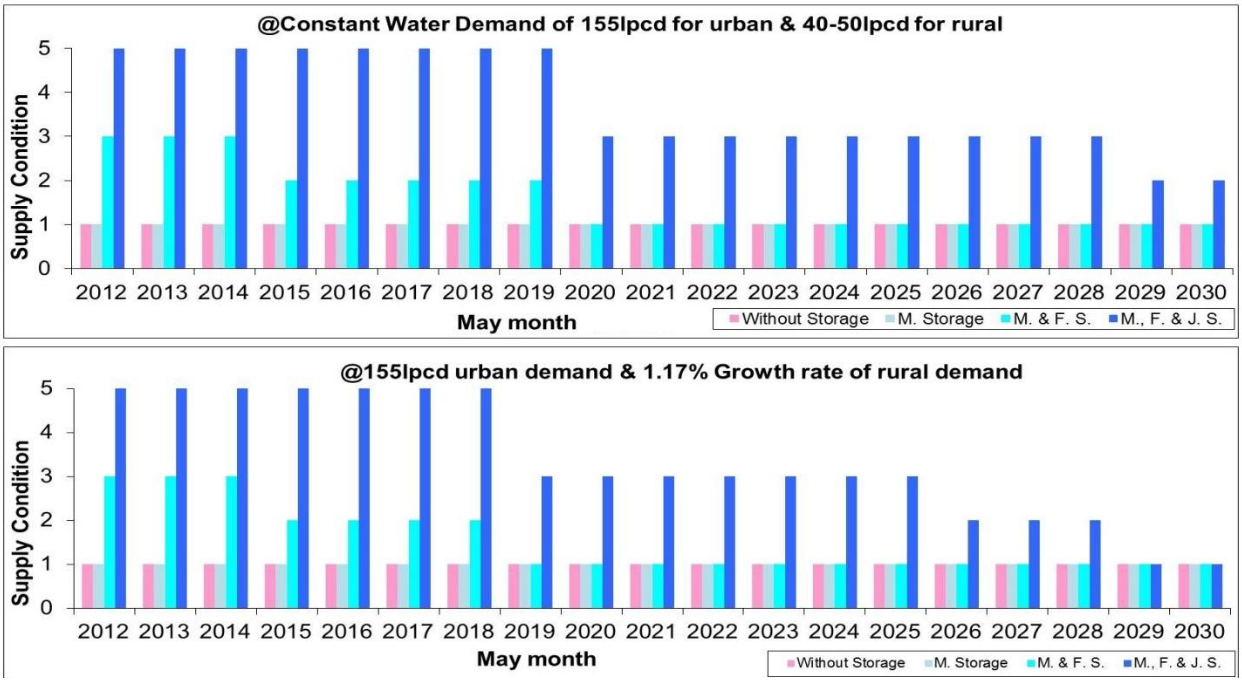

Figure 6. Comparison of water optimization in different water storage condition at constant supply rate and medium growth rate in May month

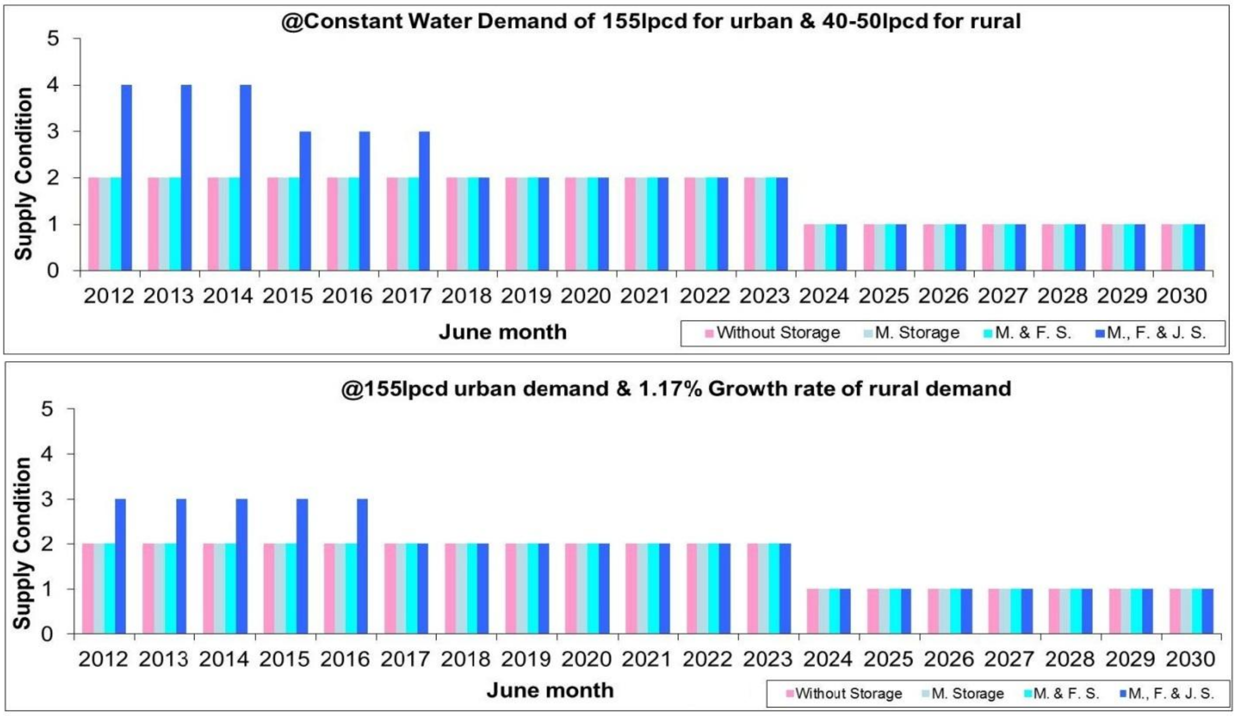

Figure 7. Comparison of water optimization in different water storage condition at constant supply rate and medium growth rate in June month