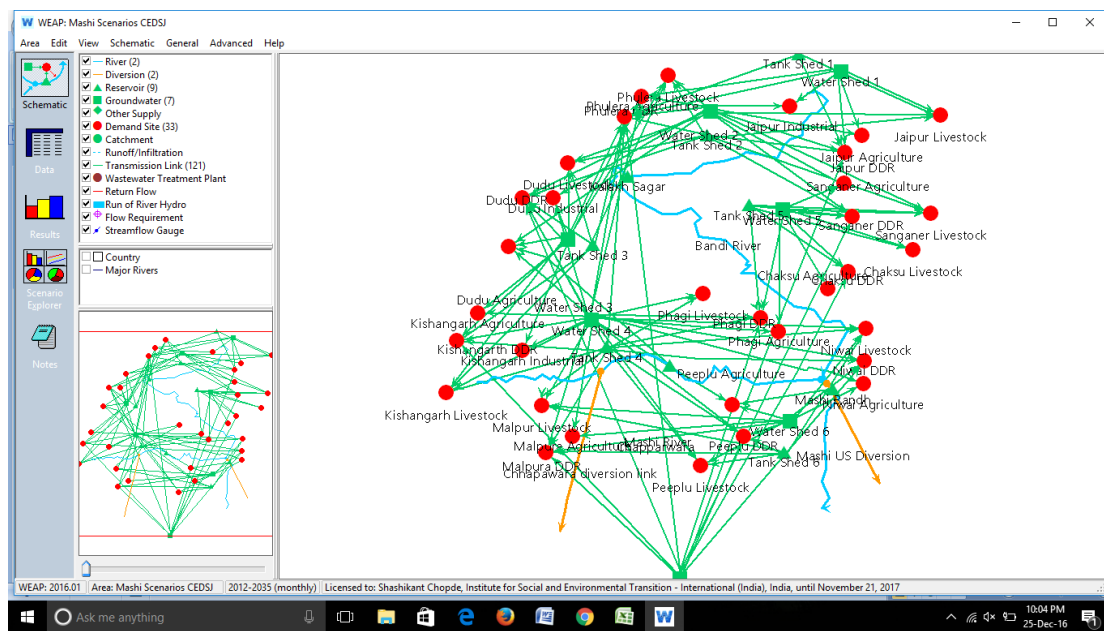


WATER BALANCE MODELING FOR MASHI BASIN, RAJASTHAN



Supported by
INDIA WATER PARTNERSHIP



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Water Balance Modeling for Mashi Basin, Rajasthan

Executive Summary

Returns to public investments in water infrastructure are viable only if followed by water management improvements, governance reforms, and institutional innovations rather than just public investment. The recent paradigm shift in water governance in India has led to enactment of River basin authority and review of water laws and formulation of comprehensive water law. But even this paradigm shift will fail in sustainable management of water resources unless we shift the focus from supply augmentation to water demand management with an integrated approach.

The study is aimed at providing the needed foundation for promoting an effective governance system in Mashi River basin in Rajasthan, India where there will be a balance among politicians, people and government, cooperating within the given legal framework in the larger interest of the society on long term basis. The larger objective is to create a framework (institutional and administrative) within which people with different interests can peacefully discuss/debate and agree to co-operate and coordinate their actions to sustainably manage the natural resources of the River basin.

There are numerous problems of water resources management in a river basin such as, availability, distribution, equity in access, quality, competition in usage, water pollution, encroachment on water bodies and catchment areas, ownership and right issues. Mashi basin having all the above problems has been selected to attempt a new model of water resource management. This study using WEAP draws on baseline study covering the geology, geohydrology, surface and groundwater availability and use pattern, watersheds and land use pattern and socio-economic features in the Mashi Basin.. The baseline and water balance studies are planned to be used for capacity building of stakeholders in the Basin with the overarching objective of forming a River Basin Parliament-- a new model of water governance.

Mashi is a water scarce basin with mere 71.8 MCM of water resources at 90 percent dependability. Groundwater is the major source for domestic water requirement in the Mashi basin with 20 percent of the domestic water demand in rural and peri-urban areas. Groundwater development in most tehsils/ blocks falls in the over-exploited category as per the Central Ground Water Board. There are two major irrigation dams namely, Chaparwara, and Kalakh Sagar, and two medium irrigation dams Mashi and Hingonia in the Basin. The major and medium irrigation dams are used solely for irrigation. Rest of the irrigation requirement is sourced from groundwater. In addition, 106 minor water tanks/dams are other sources used for meeting domestic and livestock water needs of the basin. These tanks/dams intercept most of the yield of the basin and recharge the groundwater.

The Water Evaluation and Planning Model

WEAP, the Water Evaluation and Planning, model developed by Stockholm Environment Institute (SEI, USA) is used to simulate: water supplies through groundwater, dams and tanks, and imports from Bisalpur dams; and, water demand driven by increasing population and urbanization, agriculture and industrial developments in the basin. The basin's water resources are modeled for 2012-35 in business-as-usual or reference base case and climate change scenarios.

For modeling the reference base case from which all the scenarios of climate, demand and supplies were developed, and the base account for the year 2012 was developed. The business-as-usual or reference base case was developed for 2013-35 using the projected and planned growth rates and trends of population, urbanization, and agriculture and water resources development. The model was run for monthly time step starting from June of every year, which is the first month of monsoon. WEAP allows flexibility to assign different supply side and demand side priorities. Scenarios for various water conservation schemes were created based on principles mentioned in the State Water Policy of 2010 assuming a certain rate of adoption and effectiveness for each of the policies, and that certain policies would be implemented simultaneously.

Results: The water demand and supply system setup in WEAP for Mashi basin includes domestic, agriculture and industrial demands. Various water demand nodes have been configured to account for increasing urbanization, changes in cropping patterns in Kharif and Rabi that depend on water-year-types and industrial demand that continues unaffected by water-year-types. In addition, supplies are accounted for through nodes for surface water storages that include the irrigation schemes as well as different clusters of numerous minor water tanks, and the groundwater resources. The model includes competition across various demand nodes from diverse supply nodes. It also models varying demand and supply levels across diverse water management scenarios.

Given the uncertainty in climate change projections, two extreme climate change scenarios, CGCM3 A1B_Wet and ECHAM5 A1B_Dry, are considered to assess their impacts on overall water resources of the Mashi basin. While in the dry scenario relative increase in groundwater storages is observed in comparison to Reference Base Case or business-as-usual scenario without climate change, the WEAP model shows decline in groundwater storages relative to the Reference Base Case in the wet scenario. This decline in the wet scenario is accompanied by overall higher agriculture production in the basin with the consequences that production of Mustard and "Other Crops" (vegetables) could increase substantially while maintaining the current level of production of Wheat and Barley. Despite assuming moderate and linear increase of coverage of drip and sprinkler to 50 and 60 percent, respectively, as in Demand Side Management (DSM) scheme, the groundwater decline continue but at lower rates. More such iterations will be needed by use of WEAP and consensus arrived on level of imports, artificial recharge, scale of irrigation and domestic water efficient technologies for sustainable water management in the basin. Interestingly, between the Supply Augmentation (SA) scheme (that assumes substantial water

imports from Bisalpur for meeting the domestic needs and artificial recharge) and DSM scheme, the model provides strong evidences of manifold advantages and much higher effectiveness of the DSM scheme.

In light of above the study suggest the following actions:

1. The results of WEAP modeling be shared and used to catalyse informed multi-stakeholder dialogue for water resources management in Mashi basin. The dialogues will be an avenue to ratify/ change and negotiate the assumptions used in the WEAP model to arrive at informed decisions pertaining to inter-sectoral allocation and intra-sectoral use efficiencies for managing water resources in a sustainable and equitable way. The stakeholders that we feel important to include are:
 - a. Community groups from various gram Panchayat's, apex level federated community groups at Tehsil levels;
 - b. MLAs and MPs from constituencies that include Mashi Basin; Chairman of District Panchayats;
 - c. Agriculture Department, Jaipur Municipal Corporation, Jaipur Development Authority, PHED, Department of Water Resources, Rajasthan State Industrial Development and Investment Corporation and Department of Environment.
2. Lay foundations and take concerted efforts for value-chain work in Mustard and "Other Crops" (vegetables). For this, the community groups engaged in the process can be used. This will ensure that increased production during wet and very wet years transforms into increased incomes for farmers.
3. Given the uncertainty of climate change projections a Steering Committee for Mashi Basin be setup that guides and monitors overall implementation of the action plan vis-à-vis how climate change unfolds/ manifests. We believe the assumptions in WEAP will need to be revisited on periodic basis (at least once in two years) to decide on allocations and use efficiencies across sectors.

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- (iii) Sh. Ladulal Sharma and Sh. N. P. Singh, Senior Research Associates, the main persons responsible for collecting primary and secondary information/data and feeding in the WEAP model and other inputs at all stages of the study.

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Dr. M. S. Rathore
Director, CEDSJ

Water Balance Modeling for Mashi Basin, Rajasthan

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Water Balance Modeling for Mashi Basin, Rajasthan

1. Introduction

Rapid economic development and societal change are putting increasing pressure on water ecosystems and other natural resources. There is worldwide demand for changes that leads to more effective, more efficient and more sustainable water resource management. Efforts are being made to rethink water planning and management. Water management today poses multi-dimensional challenges, with complex geographical, ecological, social, political and economic factors. Also water stress and water scarcity are challenges with far-reaching economic and social implications. Growth in population, increased economic activity and improved standard of living lead to increased competition for and conflicts over limited fresh water resources. The deep appreciation to the complex issues surrounding water resource development has led to new approaches that seek to meet the ecological, social, political and economic challenges posed by the prevalent practices.

Water management has moved from the sectoral approach to an integrated approach. All water management techniques have complex and multidimensional implications, related to the existing geographical, ecological, socio-political and economic situations. However, these techniques need to be modified, updated and adapted in response to changes in existing order.

Eradication of hunger and achieving Food self sufficiency were the prime goals of government immediately after Independence. This demanded large investments in creation of water infrastructures by huge investments in building dams and canal systems across the country. But over time very little emphasis was given on management improvements, governance reforms, and institutional innovations rather than just public investment in water infrastructure. This is why returns to public investments in water infrastructure in India have been poor and water projects and water sector as a whole have suffered. The recent paradigm shift in water governance in India has led to enactment of River basin authority and review of water laws and formulation of comprehensive water law. But even this paradigm shift will fail in sustainable management of water resources in the country unless we change our perspective on rivers.

The way we look at our Rivers in the past is as water resources to be exploited, completely ignoring the numerous ecosystem services provided by living river systems, as also the intrinsic value of rivers for our people and other forms of life. The entire focus has been on augmenting supplies, with little attention being paid on demand side management of water. Further, rivers are being used as dumping ground for liquid and solid waste. In the reoccupation with extraction and development, there has generally been an absence of considerations of sustainability, endangering the future of both groundwater and river flows. Therefore, river basin management with changed perspective should be the priority issue of discourse among policy makers, water departments at National

and State level, NGOs and public at large. The objective should be rejuvenation of rivers to effectively achieve the goals of *nirmal dhaara*, *aviral dhaara*, *swachh kinaara* (unpolluted flow, continuous flow, clean river banks).

Achieving good water governance cannot be undertaken hastily using blueprints from outside any given county or region. Good governance needs to be developed to suit local conditions. Incremental improvement and flexibility are key (Batchelor, C.)¹. Rogers and Hall (2003)² argues that there is no single model of effective water governance; indeed to be effective governance systems must fit the social, economic and cultural particularities of each country. Nevertheless, there are some basic principles or attributes that are considered essential for effective/good governance, such as, in Approach: Open and Transparent, Inclusive and Communicative, Coherent and Integrative, and Equitable and Ethical, while in Performance and Operation: Accountable, Efficient, Responsive, predictable, participative and Sustainable.

Governance can take many different forms depending on the economic, cultural and traditional political norms of a country and the behavior of the legislature and legislators. We want to have a governance system in Mashhi River basin in Rajasthan, India where there will be a balance among politicians, people and government, cooperating within the given legal framework in the larger interest of the society on long term basis aiming at sustainable development and management of natural resources in the Mashhi River Basin. This will require the politicians to move away from the mentality of severing the constituency to ensure reelection and look for long term development of the people by sustaining the health of natural resources. Our objective is to create a framework (institutional and administrative) within which people with different interests can peacefully discuss/debate and agree to co-operate and coordinate their actions to sustainably manage the natural resources of the River basin.

There are numerous problems of water resources management in a river basin such as, availability, distribution, equity in access, quality, competition in usage, water pollution, encroachment on water bodies and catchment areas, ownership and right issues, etc. Mashhi basin having all the above problems is selected to attempt a new model of water resource management. Also the Rajasthan State Government has enacted a River Basin Act without much understanding the implication of it in terms of governance of water. The proposed River Basin Parliament may help in understanding and addressing the future water governance and management needs of the State.

As a first step in developing River Basin Water Resource Management Model we conducted a baseline study in the Mashhi Basin covering the geology, geohydrology, surface and groundwater availability and use pattern, watersheds

¹ Batchelor, C., Water Governance Literature Assessment Report, IIED,

² Rogers, P. and Hall, AW. (2003), Effective Water Governance, TEC Background Papers No.2, Global Water Partnership Technical Committee (2003).

and land use pattern, socio-economic features, etc. Second, the present study “water balance study” of the basin. These two studies will then be used for capacity building of stakeholders in the Basin and formation of a River Basin Parliament a new model of water governance.

2. The Mashi Basin Context

Banas River originating in Khamnor hills of the Aravalli range flows for its entire length in the water-scarce state of Rajasthan and is a major tributary of Chambal River. Mashi is a sub-basin of the Banas basin. The Mashi sub-basin extends over parts of Ajmer, Jaipur and Tonk districts covering partly/ fully the 12 tehsils (revenue sub-districts). Table 1 shows tehsil wise area falling in the Mashi sub-basin.

Table 1: Geographical spread of Mashi basin across districts/ tehsils

District	Total geographical area (sq.km)	Tehsil	Total geographical area (sq.km)	Area in Mashi basin (sq.km)
Jaipur	11054.94	Amber	891.22	278.05
Jaipur		Chaksu	811.77	217.09
Jaipur		Chomu	683.61	132.94
Jaipur		Dudu	1338.56	1245.4
Jaipur		Jaipur	527.16	489.25
Jaipur		Phagi	1111.4	1111.4
Jaipur		Sambhar	1470.48	403.95
Jaipur		Sanganer	701.75	318.91
	11054.94		7535.95	4196.9
Tonk	7179.6	Malpura	1483.88	672.97
Tonk		Niwai	1030.49	233.37
Tonk		Peeplu	783.21	571.44
	7179.6		3297.58	1477.78
Ajmer	8423.45	Kishangarh	1728.94	810.59
	8423.45		1728.94	810.59
Total	26657.99	Mashi	12562.47	6485.32

Source: District Handbook 2006, Directorate of Economic and Statistics, GOR, Rajasthan

As per Census 2011 few tehsils in the basin display varying levels of urbanization while others are still fully rural. The tehsils in the increasing order of urbanization are Sambhar, Sanganer, Amber, Kishangarh and Jaipur, with Jaipur tehsil housing major part peri-urban population around the famous tourist destination of Jaipur city. Therefore the Jaipur tehsil has as high as 94.4 percent of the total population as urban.

Mashi is a water scarce basin with mere 71.8 MCM of water resources at 90 percent dependability. Groundwater development in most tehsils/ blocks falls in the over-exploited category as per the Central Ground Water Board. With low and erratic rains even the surface water sources are not that reliable.

Groundwater is the major source for domestic water requirement in the Mashi basin with 20 percent of the domestic water demand in rural and peri-urban

areas of Jaipur city currently being met by import of water from the Bisalpur dam. This apart, there are two major irrigation dams namely, Chaparwara, and Kalakh Sagar, and two medium irrigation dams Mashi and Hingonia in the Basin. The major and medium irrigation dams are used solely for irrigation supplies. Rest of the irrigation requirement is sourced from groundwater. In addition, 106 minor water tanks/dams are other sources used for meeting domestic and livestock water needs of the basin. These tanks/dams intercept most of the yield of the basin and recharge the groundwater.

Agriculture is the primary source of livelihood in the basin. Crops are grown in Kharif (monsoon) and Rabi (winter) seasons. Bajra, Jowar, Groundnut, Maize and Pulses are the major Kharif crops. In addition, crops grown in Rabi include Wheat, Barley, Gram, Mustard and vegetables. Groundwater supports critical irrigation when needed for Kharif crops while it is a major source of irrigation for Rabi crops.

Three industrial Nodes considered in WEAP Model are namely Jaipur, Kishangarh and Dudu fall in the basin. The details are as follows;

Industrial Node in WEAP	Number of Industrial area	Number of industries	Water consuming industry	Type of industry
<i>Jaipur</i>	5	2427	74	Bakery & Confectionery, Machinery manufacturing , Stone cutting unit ,Mineral water and cold drink, Paper and product, cold storage & ice factory, Plastic and plastic product, Chemicals , Drugs and medicine , Dying & Printing , Livestock concentrate
<i>Dudu</i>	1	37	7	Paper and product , cold storage & ice factory , Bakery& Confectionery, Cement brick manufacturing , Livestock concentrate
<i>Kishangarh</i>	3	305	55	Paper and product , cold storage & ice factory , Bakery& Confectionery, Cement brick Manufacturing , Livestock concentrate

The growing population with increasing urbanization in future will pose great challenge to the basin's precarious water resources. There are initial signs of water conflicts emerging across various users across domestic, agriculture and industrial sectors. Given this context it is important to assess current and future

water demand and supplies to promote appropriate water management options in a timely manner.

3. The Water Evaluation and Planning Model

WEAP, the Water Evaluation and Planning, model has been developed by Stockholm Environment Institute (SEI, USA). It is a user-friendly tool that takes an integrated approach to water resources planning. It provides a framework for assessing water resources and planning that is being used to understand current water resource conditions and explore a range of demand and supply management options that balance the need between environment and development. At the same time, WEAP has ability to model scenarios of socio-economic developments and climate change, and understand their implications on water resources demands and supplies. One of its strong features is transparency in data that has been used to promote multi-stakeholder negotiations. It has been successfully used worldwide. Even Government of Rajasthan has used WEAP for meso-scale modeling of water resources of the state.

Specifically in the context of the study, WEAP is used to simulate: water supplies through groundwater, dams and tanks, and imports from Bisalpur dams; and, water demand driven by increasing population and urbanization, agriculture and industrial developments in the basin. The basin's water resources are modeled for 2012-35 in business-as-usual or reference base case and climate change scenarios. Given the limitations of the time and budget, the results of climate downscaling conducted in 2011 under the earlier study by CEDSJ in partnership with ISET-International for the Banas basin are used. The scenario development is further described below.

4. Setting up WEAP for Mashi Basin

For modeling the reference base case from which all the scenarios of climate, demand and supplies were developed, the base account for the year 2012 was developed using the data and parameters of that year with following considerations:

- The level of demographic, agriculture and industrial development;
- The water use efficiencies in above sectors; and,
- The level of supplies, such as stream flows and storage characteristics of local groundwater and surface water storages including 106 tanks and four dams (Mashi, Kalakh Sagar, Hingonia and Chaparwara).

The business-as-usual or reference base case was developed for 2013-35 using the projected and planned growth rates and trends of population, urbanization, and agriculture and water resources development. The model was run for monthly time step starting from June of every year, which is the first month of monsoon.

Further, inflows to Mashi, Kalakh Sagar and Chaparwara dams are generated by using simple stream flow-rainfall regression model developed for Banas river basin as part of the earlier study by CEDSJ and ISET-I. The earlier study computed the percent deviations of the historical, annual averaged time series of the two stream flow datasets (TAHAL WAPCOS and CWC) for categorizing years according to five types: Very Dry (Very Dry (<66% of long-term average), Dry (67% to 89%), Normal (90% to 110%), Wet (111% to 133%) and Very Wet (>133% of the long-term average). The sequences of the reference base case stream flows and climate change conditioned stream flows were computed by applying the percent deviations to observed inflows in the base year (2012) of the major and medium irrigation schemes. However, data of inflows at head of streams/ dam was available only for Chaparwara. In addition, for flows at Mashi dam site we had the overall yield of the basin at various dependability levels. The actual inflows to the three dams are modeled by reducing significant part of the stream flow/ yield by applying diversion nodes upstream of the two dams, Chaparwara and Mashi. The diversions are accounted to take care of interceptions by many minor water tanks in the catchment. For inflows to Kalakh Sagar we allowed WEAP to use the modeled flows. In addition, for minor water tanks the inflows are considered to vary by the water-year-type.

The core approach was to consider all demand sites (agriculture, domestic and industrial) drawing water from diverse sources such as groundwater, surface water reservoirs/ tanks and imports from Bisalpur dam. The water allocation priorities across domestic, agriculture and industrial uses was set in descending order as per the national water policy. This approach enabled to model:

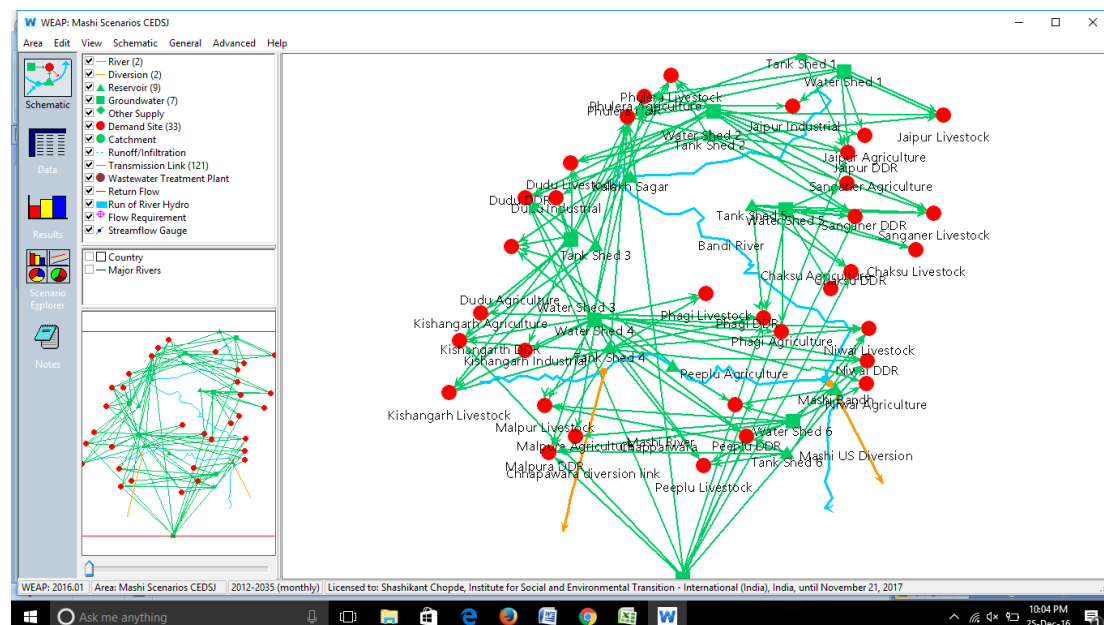
- Changes in rural and peri-urban water demand in the basin;
- Changes in levels of dependence of agriculture demand on surface and groundwater sources;
- Assess level of competition for the resource as socio-economic transition occurs and climate change manifestations trigger changes in basin flows; and,
- Assess impact of increased demand to population growth, urbanization and agriculture development on specifically, the already over-exploited groundwater resources.

5. Data for WEAP model

The water demand and supply system is modeled under all the scenarios for 2012-2035. The start-up year, 2012, was selected to initialize the models due to availability of data on population, cropped areas under various crops by seasons, industrial demand and supplies, both groundwater and surface water, for this year. The WEAP schematic for the Mashi basin is shown in

Figure 1.

Figure 1: WEAP schematic for Mashi basin



5.1. Demand sites

As mentioned in the foregoing, there are multiple demands on various water supply sources in the Mashi basin. There is vast diversity in level of socio-economic development across various tehsils that has implication for water use in the basin that needs to be accounted for. Further, diversity of extent of irrigation for each crop type by season needs to be considered. Due to this, any modeling attempt to assess fragility of supplies from various sources must include all known uses in the contiguous geographical area of the basin. The following sites were accounted for in the model:

Domestic demand sites:

- The sites for this demand need to account for population in various geographical areas of the basin; both, human and livestock population. We assigned a demand site for each tehsil falling in the basin with the exception that Amber and Chomu tehsils were not considered as very insignificant proportion of their areas occupied the basin. Also, since the basin boundaries seldom follow the administrative boundaries such as the tehsil boundaries at which the Census data of population is available, we computed the population for each tehsil falling in the basin by apportioning the population of tehsil level Census population based on percentage of geographical area of the tehsil falling in the basin. Hence, demand sites were setup for: Jaipur DDR; Sangner DDR; Kishangarh DDR; Chaksu DDR; Niwai DDR; Phagi DDR; Phulera DDR; Peeplu DDR; Dudu DDR; and, Malpura DDR.

Agriculture Demand: For modeling agriculture water demand same number of water demand sites; and,

Three industrial demand sites representing Jaipur, Dudu and Kishangarh.

Linking Demand and Supplies: All the demand sites were linked to supply nodes (data sources and setup described below) through transmission links. Data on present and future capacities of transmission links from various sources (groundwater and surface water) and transmission losses were accounted for in the model.

The inflows to the three dams are modeled after considering interceptions by numerous tanks in their catchments. Therefore, to be on conservative side we accounted for minimum inflows into tanks by assuming from experience that the tanks fill up at least once during normal, wet and very wet years while there is no inflow in dry and very dry years.

5.2. Data for demand drivers

Population for each Demand node: Population data for each of the ten domestic sites/ tehsils was computed by apportioning the total tehsil population as recorded by Census 2011 in the ratio of their geographical areas falling in the basin. Further, the population was split into rural and urban in each domestic site as per the share mentioned in Census 2011.

The livestock population was taken from Livestock Census of 2007. Similar to human population the livestock population for each domestic site/ tehsil was computed by apportioning the total tehsil population as recorded by the Livestock Census 2007 in the ratio of their geographical areas falling in the basin.

Growth rate of human and livestock population: was computed based on observed decadal growth rates over last five Censuses and seven Livestock Censuses (please see for example the growth rate used for Phagi in Figure 2 and Figure 3).

Figure 2: Projected growth rate of human and livestock population for Phagi

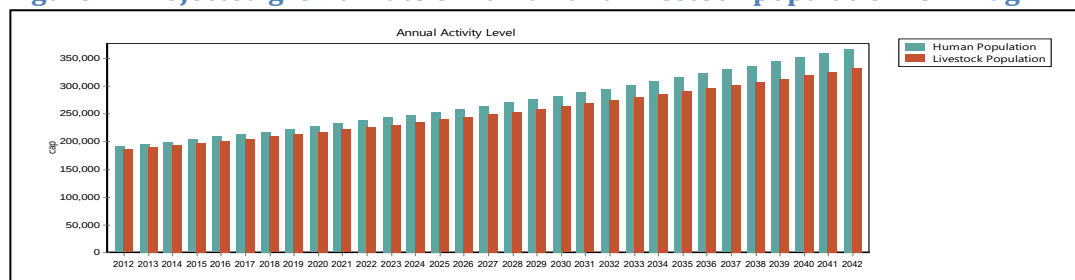
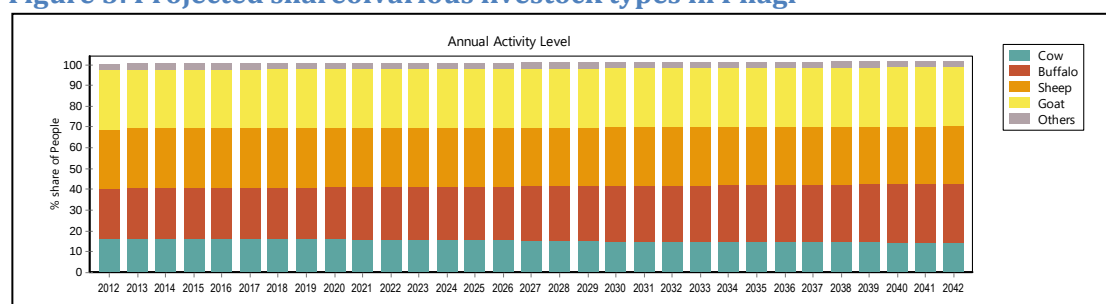
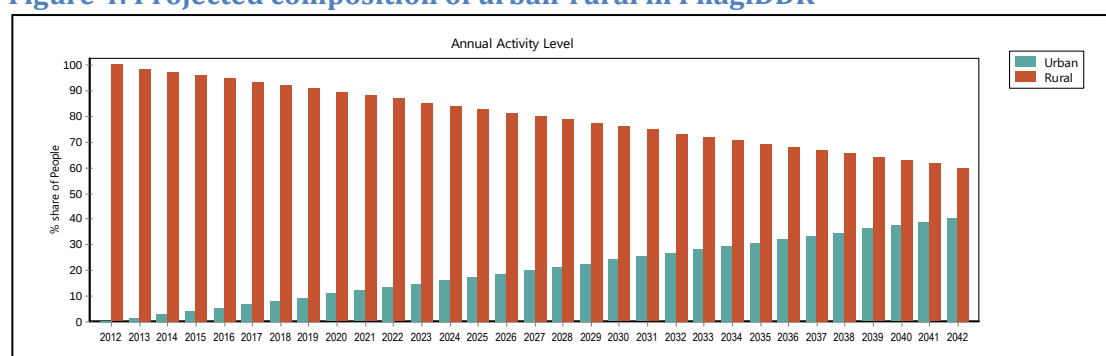


Figure 3: Projected share of various livestock types in Phagi



As mentioned in the foregoing, there is varying degree of urbanization across the tehsils in the Mashi basin. The growth rate for highly urbanized tehsils such as Jaipur, Sanganer and Kishangarh the composition of rural and urban population as per Census 2011 was maintained to be at the same level for the entire projection period. At the same time, the remaining tehsils that had no urban population are projected to be urbanized at a linear growth rate reaching to 40 percent by 2035 as per general rate of urbanization expected in India. Figure 4 shows, for example, growth rate for Phagi domestic demand node.

Figure 4: Projected composition of urban-rural in PhagiDDR



Cropped area and level of irrigation for each agriculture node: The number of agriculture demand nodes were same as the domestic demand nodes. The area under various crops by season and irrigated/ un-irrigated category for each tehsil was taken from District Handbook 2006. The cropped area for each agriculture demand node was assigned in the proportion of area of that tehsil falling in the basin. At core, we assumed a constant Gross Cropped Area (GCA) in each tehsil while computing the ratios of cropped areas across Kharif and Rabi to the GCA from the handbook 2006. These ratios were fed into the model for the base year 2012. In addition, ratios of cropped area under major crops to corresponding cropped area under seasons (Kharif/ Rabi) are computed that was also fed into the model for the base year 2012.

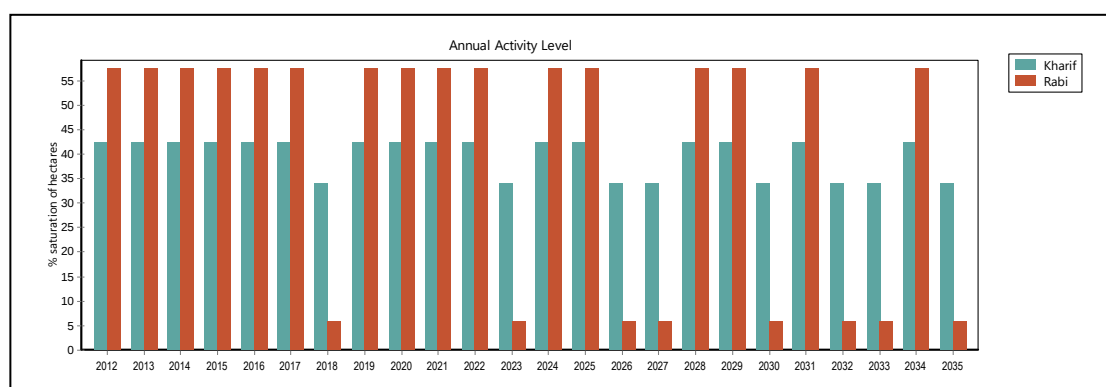
It is noteworthy that 2012 was a normal rainfall year as per our classification mentioned above.

For the projection period (2012-35) these ratios by seasons (Kharif/ Rabi) are varied depending upon the water-year-type:

- The ratio of Kharif cropped area to GCA is assumed to decrease by 20 and 50 percent in dry and very dry years while remaining the same as base year (2012) for wet and very wet years; and,
- The ratio of Rabi cropped area to GCA is assumed to reduce drastically by 90 percent in dry and very dry years while increasing by 30 and 50 percent in wet and very years relative to the ratio of base year 2012.

An example of variation of cropped area ratios of Kharif and Rabi to GCA are as shown for Phagi agriculture demand node in Figure 5.

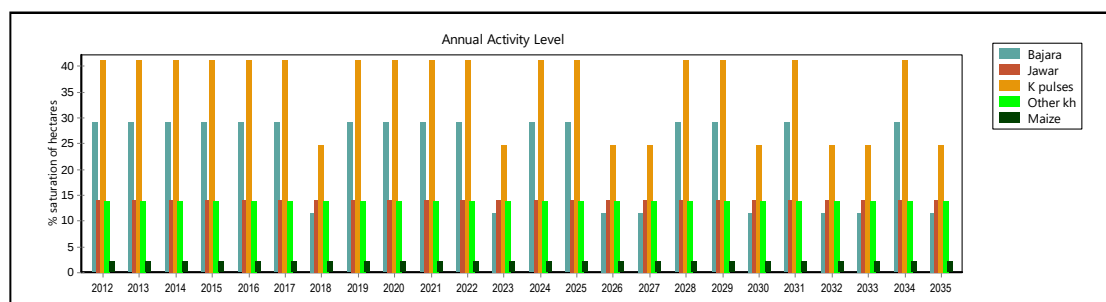
Figure 5: Ratio of Kharif/ Rabi cropped area to GCA in Phagi Agriculture demand



Further, even the ratios of individual cropped areas in each season (Kharif/ Rabi) are varied over the projection period (2012-35) based on the water-year-type:

- There are five major crop types in Kharif—Bajra, Jowar, Kharif Pulses, Maize and “Other Kharif” crops. It is assumed that ratio of cropped areas under Jowar, Maize and other Kharif crops will remain constant irrespective of the water-year-type. However, the ratio of cropped areas under Bajra and Kharif pulses will vary by water-year-type. The ratio of cropped area under Bajra and Kharif pulses will reduce by 60 percent and 40 percent, respectively, in dry and very dry years while remaining the same as the base year (2012) in wet and very wet years (see Figure 6).

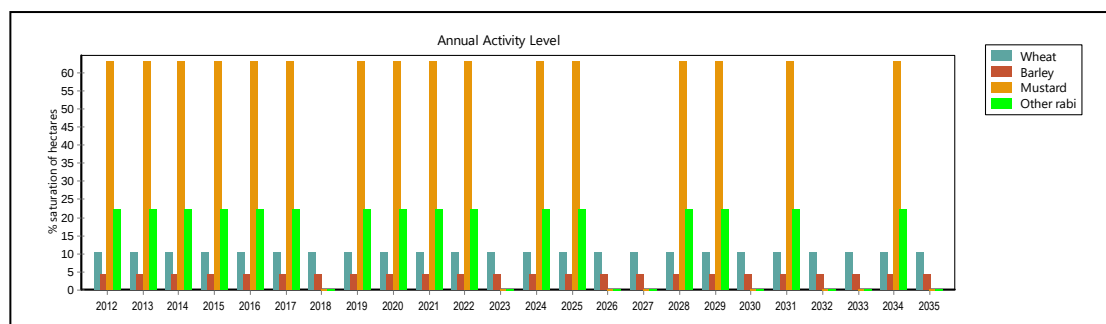
Figure 6: Ratio of area under various crops to total Kharif area for Phagi agriculture demand node



- Wheat, Barley, Mustard and “Other Rabi” (primarily Gram & vegetables) are major crops grown in Rabi. In Rabi it is assumed that cropped area

ratios will not change with water-year-type for Wheat and Barley while it will vary for other crops. The cropped area ratio under Mustard and “Other Rabi” crops will be **nil** percent for very dry and dry years, and 30 and 50 percent more as compared to the base year (2012) in wet and very wet years (see Figure 7).

Figure 7: Ratio of area under various crops to total Rabi area for Phagi Agriculture demand



Annual water use rates: The Government of Rajasthan norms for water supply for urban and rural areas are 120 lpcd and 40 lpcd, respectively. Further, higher norms are used at 145 lpcd are used for peri-urban areas around Jaipur city.

The per-day water requirement by various livestock types such as cow, buffalo, sheep, goat and all others are considered based on our own field survey.

The crop water requirements for various crops are taken as per FAO standard tables. It is assumed that the critical irrigation support needed for Kharif crops during dry years will be 80 percent of the standard crop water requirement while no irrigation will be needed in normal, wet and very wet years.

Water Supply losses: The losses in the conventional irrigation systems are assumed to be 40 percent.

Priority: WEAP allows flexibility to assign different supply side and demand side priorities. As per State Water Policy the domestic, irrigation and industrial demand sectors are assigned priorities 1, 2 and 3, respectively for supply. In addition, the model is setup for sourcing water from various sources at varying priorities: Supply Priority for Bisalpur imports, groundwater and tanks are assigned as 1, 2 and 3, respectively.

5.3. Hydrology data

The source of data for stream flows and water year sequences is described in detail earlier. In addition, diversion nodes that reduce the stream flows were applied to calibrate the model with the observed data on volume of inflows available for Mashri and Chaparwara dams in different water-year-types (very

dry, dry, normal, wet and very wet). The diversion nodes essentially account for interception of yield by numerous minor water tanks in the basin.

5.4. Data for Supply nodes

Surface water sources: Three surface water reservoirs, namely Mashi, Chaparwara and Kalakh Sagar are considered in the model. However past records show that Kalakh Sagar has remained empty even in normal rainfall years, so for practical purposes we confine to just Mashi and Chaparwara reservoirs. In addition, 106 minor water tanks are also accounted. The Mashi basin is subdivided into six watersheds and surface water resources are computed for each watershed by considering all the reservoirs and minor water tanks falling in that watershed. The data on storage capacities, initial storage, storage-elevation curve, net evaporation for each reservoir and minor water tanks grouped by watersheds is taken from; water resources rajasthan.gov.in/SPWRR/SPWRR.htm. Therefore, in WEAP we model the three reservoirs as above and six “Tank sheds” as surface water supply nodes.

Groundwater: Groundwater resource data for each block/ tehsil is taken from Dynamic Ground Water Resources of India, CGWB, GOI, (As on 31st March 2011). The data on annual replenishable groundwater resource and annual groundwater draft is aggregated at the level of each of the six watersheds by: considering all tehsils falling in each watershed; and, apportioning tehsil-level corresponding figures based on area of tehsil falling in that watershed. Hence, in WEAP we provide for six groundwater nodes—“Water Sheds” 1 to 6.

Storage Capacity: In the model, we considered the maximum theoretical capacity of groundwater at the level of each of the watershed as its storage capacity.

Natural Recharge: As more than 80 percent of annual precipitation takes place in the months of July-October, we divided annual aquifer recharge across four months, August-November in the proportion of 10, 35, 35 and 20 percent, respectively. Also, one-month lag was considered to account for time between rainfall and aquifer infiltration. In addition, natural recharge is considered differently across the five water-year-types, namely very dry, dry, normal, wet and very wet at 10, 20, 100, 110 and 120 percent, respectively of the average annual replenishable figures provided in Dynamic Ground Water Resources of India, CGWB, GOI, (As on 31st March 2011).

6. Developing future scenarios

As mentioned in the foregoing, all the scenarios including the reference base case were run for the period 2013-35. Scenarios for various water conservation schemes were created based on principles mentioned in the State Water Policy of 2010 assuming a certain rate of adoption and effectiveness for each of the policies, and that certain policies would be implemented simultaneously.

Firstly, the *Reference Base Case* scenario was developed. It assumes that no demand side or supply side conservation measures are taken and no climate change occurs. Primarily, it is a business-as-usual scenario without consideration of climate change impacts. Population, crop pattern and associated cropped areas, and consequent water demand continues to grow/ vary at current patterns and trends; conventional irrigation methods such as flooding with 40 percent losses are continued to be practiced in future; the import of Bisalpur waters for domestic uses continue at current level of 20 percent of demand; and, natural recharge is assumed to happen at varying levels by water-year-types as mentioned earlier.

Reference Base Case+ Climate Change: We investigated the impact of climate change on water supplies and change in demand in domestic, agriculture and industrial sectors in Mashi basin. Given the limitation of resources and time we used the monthly-stream flow-coefficients and water-year sequences under two extreme climate change scenarios (ECHAM5 A1B_Dry and CGCM3 A1B_Wet) that were developed as part of the earlier study for Banas river basin of which Mashi is a sub basin³. In each of these scenarios no water conservation measures are implemented to understand how climate change will impact the demand and supplies in business-as-usual scenario (also referred to as Reference Base Case scenario).

Subsequently, water conservation schemes were developed. Following schemes were considered based on emphasis of various policies of Government of Rajasthan including the State Water Policy 2010, State Environment Policy, 2010, and Rajasthan Environment Mission and Climate Change Agenda for Rajasthan (2010). These policies highlight the need for Integrated Water Resources Management, and consider diminishing flows in surface water bodies and groundwater depletion due to climate change calling for adopting strategies on demand side management and conservation of traditional water bodies:

a) Demand Side Management (DSM) scheme: As per emphasis of the policies we assumed adoption of water efficient technologies in both domestic and agriculture sectors.

In the domestic sector we focused only on the largest domestic water demand site—the Jaipur DDR. Here we assumed the proportion of population adopting water efficient technologies would increase in the following manner: 2016, 0%; 2020, 10%; 2035, 40%). And the savings from these technologies per capita per day would be 30 percent.

Irrigation water efficient technologies are assumed to be increasingly adopted in Rabi crops: Sprinkler in Wheat, Barley and Mustard; and, drip for “Other Crops” that significantly includes vegetables. Further, the coverage of sprinkler in each of the crop is assumed to increase as per linear interpolation from: *nil*%, 2016;

³For details please see the report “The Uncomfortable Nexus: Water Urbanisation and Climate Change, Jaipur, India (2011)” prepared by Institute for Social and Environmental Transition-International (ISET-I) and Centre for Environment and Development Studies, Jaipur (CEDSJ, Jaipur) available at <http://i-s-e-t.org/projects/climate-social.html>.

10%, 2020; 60%, 2035. The corresponding figures for drip are: *nil* %, 2016; 10%, 2020; 50%, 2035. Furthermore, the water savings from sprinkler and drip are considered as 70 and 90 percent of the conventional flood irrigation practices, respectively.

b) Supply Augmentation (SA) scheme: The supplies are augmented through increased imports to meet domestic water needs of the basin from Bisalpur and artificial recharge of groundwater.

Currently Bisalpur supplies account for 20 percent of the domestic demand to rural and peri-urban areas around Jaipur city. Given the demand from public to increase the allocation, the allocation is assumed to increase linearly to 50 percent by 2020 and continue at that level till 2035.

The artificial recharge of groundwater is introduced in six “Tank Sheds”/ surface water supply nodes that represent six different clusters of the 106 minor water tanks. The performance of recharge is assumed to linearly increase *nil* percent in 2016 to 10 percent of their storage volumes in 2035. The recharge at that rate of performance is assumed to occur only in normal, wet and very wet years with no recharge in dry and very dry years.

c) Combined DSM and SA scheme: The scheme considers the combination of above demand management and supply augmentation schemes.

We then evaluated each of the water conservation schemes against the reference base case and two climate change scenarios.

7. Results

The water demand and supply system setup in WEAP for Mashhi basin includes domestic, agriculture and industrial demands. Various water demand nodes have been configured to account for increasing urbanization, changes in cropping patterns in Kharif and Rabi that depend on water-year-types and industrial demand that continues unaffected by water-year-types. In addition, supplies are accounted for through nodes for surface water storages that include the irrigation schemes as well as different clusters of numerous minor water tanks, and the groundwater resources. The models include competition across various demand nodes from diverse supply nodes. The model presents varying demand and supply levels across diverse water management and two extreme (dry and wet) climate change scenarios namely, ECHAM5 A1B_Dry and CGCM3 A1B-Wet, as shown in Table 2.

Table 2: Scenarios run in WEAP for Mashi basin

Sr. No	Water Management Scenario/ Reference Base Case Scenario	Climate Change Scenario
1	Reference Base Case Scenario	No Climate Change
2	Reference Base Case Scenario	CGCM3 A1B_Wet
3	Reference Base Case Scenario	ECHAM5 A1B_Dry
4	Supply Augmentation (SA) Scenario	No Climate Change
5	SA Scenario	CGCM3 A1B_Wet
6	SA Scenario	ECHAM5 A1B_Dry
7	Demand Side Management (DSM) Scenario	No Climate Change
8	DSM Scenario	CGCM3 A1B_Wet
9	DSM Scenario	ECHAM5 A1B_Dry
10	Combined SA and DSM Scenario	No Climate Change
11	Combined SA and DSM Scenario	CGCM3 A1B_Wet
12	Combined SA and DSM Scenario	ECHAM5 A1B_Dry

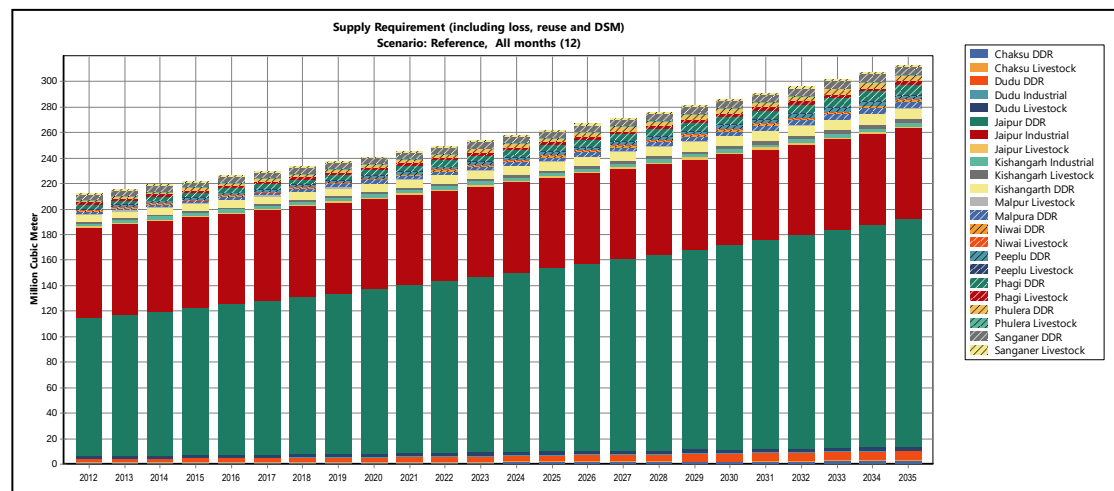
First, the results of Reference Base Case or business-as-usual scenario without climate change are presented on magnitudes and scales of demands across domestic, industrial and agriculture sectors, and consequent impact on groundwater and surface water supplies. Next, the demands and supplies in business-as-usual case under the two extreme climate change scenarios. Finally, we draw conclusions from the three water management scenario with and without climate change.

7.1. Reference Base Case

Domestic and Industrial Water Demand

In this section we present the scale of domestic and industrial water demand in the Mashi basin. Unlike other basins in the country this demand has much larger share of the total water demand in the basin. The domestic water demand for human population is significant in Mashi basin and is going to grow significantly due to increasing level of urbanisation. This will impact the groundwater supplies considering that there is a limit to water imports to Mashi basin from Bisalpur dam. In the Reference Base Case result the current water imports at 20 percent of the domestic demand is assumed to continue in future. The water demand for livestock is primarily sourced from minor surface water tanks while industrial demand is met solely from groundwater. As seen in Figure 8 the water supply requirement for domestic viz. human and livestock uses and industrial uses will increase from approximately 210 MCM to 310 MCM during 2012-35.

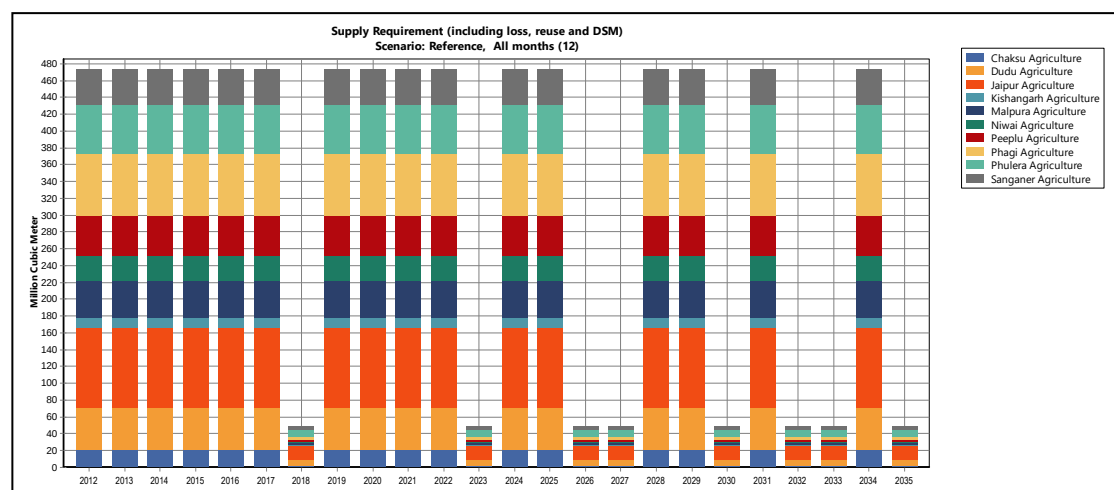
Figure 8: Water supply requirement for domestic and industrial uses in Reference Base Case



Agriculture Water Demand

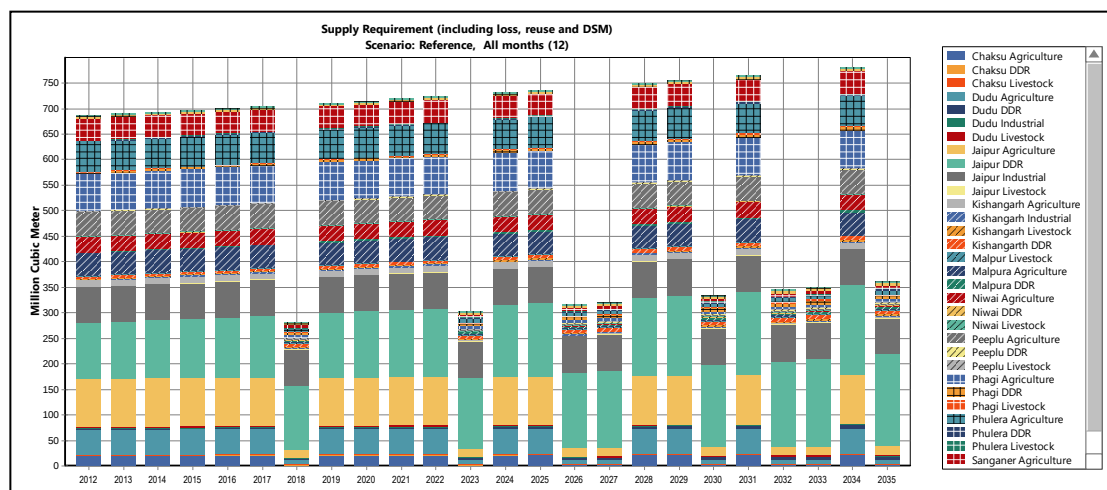
As mentioned in the foregoing, agriculture is practiced majorly in Kharif (monsoon) and Rabi seasons. While water is used for providing critical irrigation support during dry spells in Kharif, the Rabi crop is fully dependent on irrigation water that is sourced either from surface water reservoirs or groundwater as available. Generally surface water is a preferred source of irrigation to groundwater as the later incurs pumping cost. Irrigation is provided through conventional flood irrigation that results in water losses to the tune of 40 percent. Figure 9 shows that the agriculture water supply requirement is of the order of 470 MCM. However it reduces drastically to around 10 percent (~40 MCM) during dry years when farmers drastically reduce the cropped areas of especially Bajra and Pulses during Kharif, and Mustard and “Other Crops” that includes vegetables in Rabi season. However our experience says that farmers maintain the area under principle crops viz. Bajra, Jowar and “Other Kharif” in Kharif and Wheat and Barley irrespective of whether it is good or bad rainfall year. It is just the opposite farmers do in wet and very years. They increase the area under above crops by almost 30-50 percent. At core they extend the cropped area into current fallow lands in wet and very wet years.

Figure 9: Agriculture water supply requirement in Reference Base Case



The total annual water supply requirement during normal water-year-type, as evident from Figure 10, will increase from approximately 670 MCM to 775 MCM with the requirement dipping to mere 40 percent of it in dry years. As the Reference Base Case is created by repeating the historical water-year-types there are no wet or very wet years till 2035.

Figure 10: Total water supply requirement in Reference Base Case



Now we present how the surface and groundwater supplies change by meeting the above requirements in the Reference Base Case.

Figure 11 shows very low level of storages in both Mashi and Chaparwara dams. Mashi and Chaparwara dams have storage capacities of approximately 48 and 34 MCM, respectively. The figure shows that they never got filled to full capacity. In addition, Mashi remained filled maximum to its 75 percent capacity (~34 MCM) for only 5 percent of the time during the modeling period (2012-35). Similar low figures of Chaparwara are filling to maximum 30 percent (14 MCM) capacity for just 5% of time.

The status of groundwater resources is even more precarious. Groundwater is the next preferred source after surface water for the obvious reasons mentioned above. Given the grim scenario of filling of reservoirs groundwater becomes the next and only major reliable source. For modeling groundwater resources we divided the basin's entire groundwater resources into six groundwater nodes named as Water Sheds and computed annual recharge and draft at level of Water Sheds as mentioned in the foregoing. We kept the number of groundwater nodes or Water Sheds equal to number of drainage sub-basins in the basin. As seen in Figure 12 Water Shed 2 and 6 show highest and least groundwater decline, respectively. While Water Shed 2 caters to large domestic, agriculture and industrial water demand in peri-urban areas around Jaipur city, the groundwater quality is bad and at very shallow depths in Water Shed 6 that covers significant parts of Tonk district falling in the basin.

Figure 11: Water Storages in Reservoirs by Percent Time Exceeded in Reference Base Case

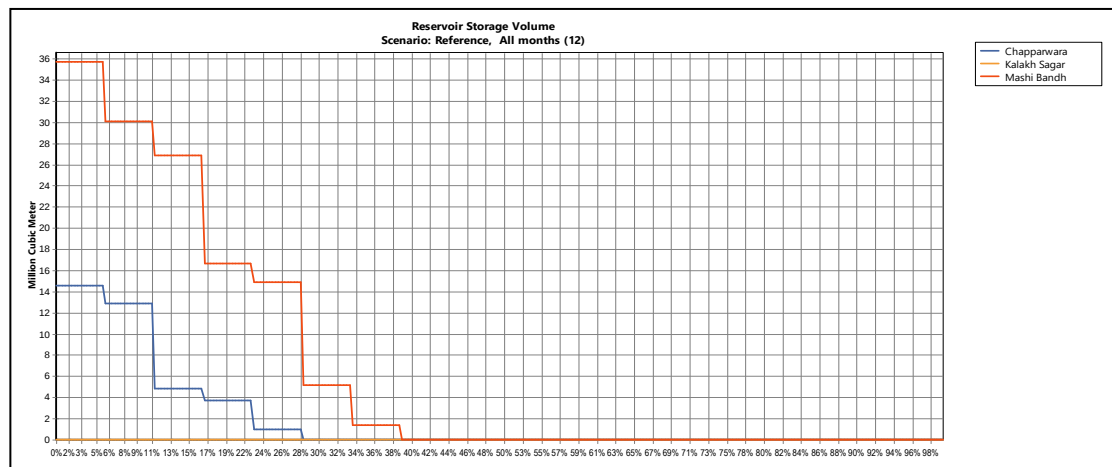
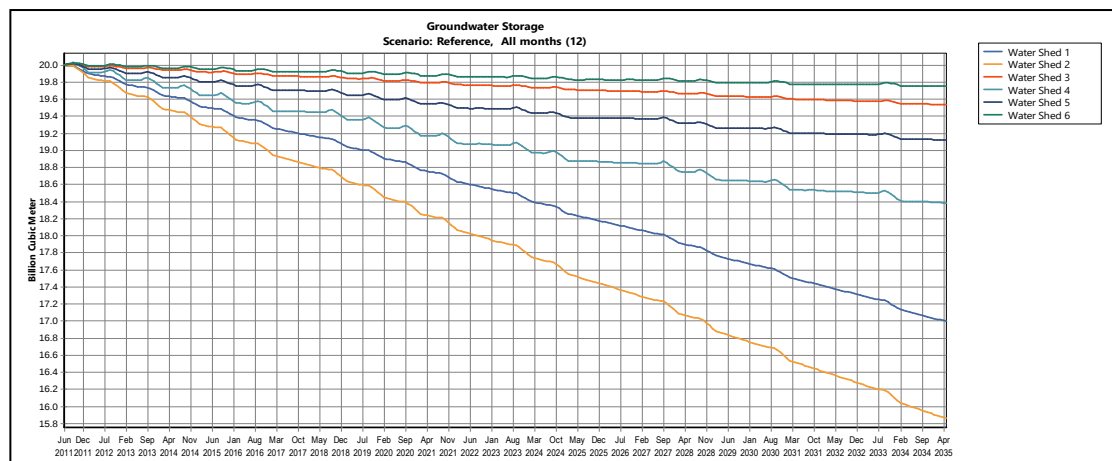
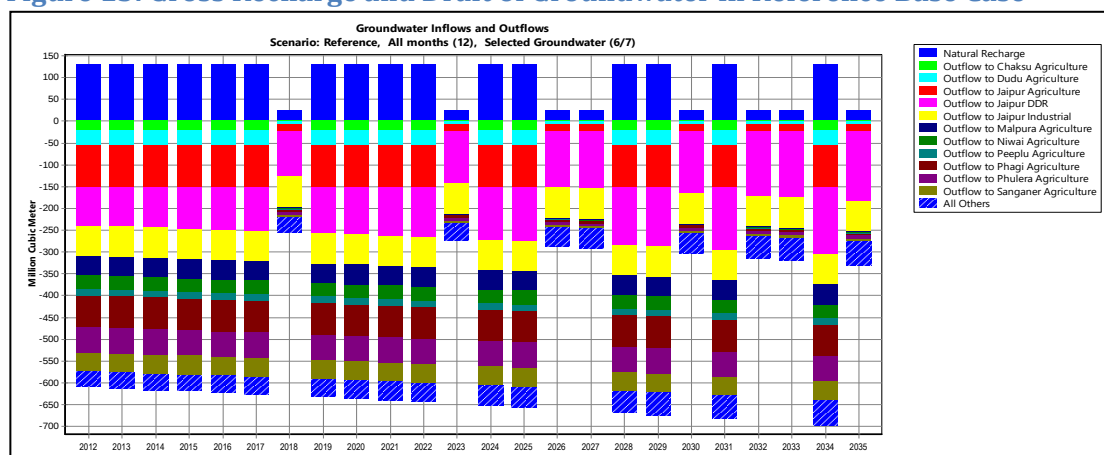


Figure 12: Groundwater Storages in Reference Base Case



The reason for such large decline of groundwater in the basin is also evident from Figure 13 that shows the massive imbalance between overall draft and recharge of combined groundwater resources of all the six Water Sheds. It shows that groundwater draft is approximately six times the annual natural recharge in normal years while it is more than even 12 times of annual recharge in dry years.

Figure 13: Gross Recharge and Draft of Groundwater in Reference Base Case



7.2. Reference Base Case + Climate Change Scenarios

The key manifestations of Climate Change (CC) are increase in inter-annual variability of rainfall and increase in intensities and frequencies of extreme wet and dry rainfall events. As mentioned in the foregoing we selected results of two extreme climate scenarios (one dry and other wet future) that were created as part of earlier study for Banas basin. These scenarios are CGCM3 A1B_Wet and ECHAM5 A1B_dry. Given the uncertainty in climate projections indicating that both the scenarios are equally possible there is a need to plan robust set of interventions for climate-resilient development in Mashhi basin that is geared up for both the types of meteorological patterns. Hence, we present results of demand and supplies for both.

The key driver of domestic demand is the demographic change and hence it is assumed to be same across the Reference Base Case and Climate Change Scenarios. Therefore, we focus our results on how the agriculture supply requirements are likely to change in the two extreme climate change scenarios.

Figure 14: Agriculture Supply Requirement in CC Wet Scenario Relative to Reference Base Case

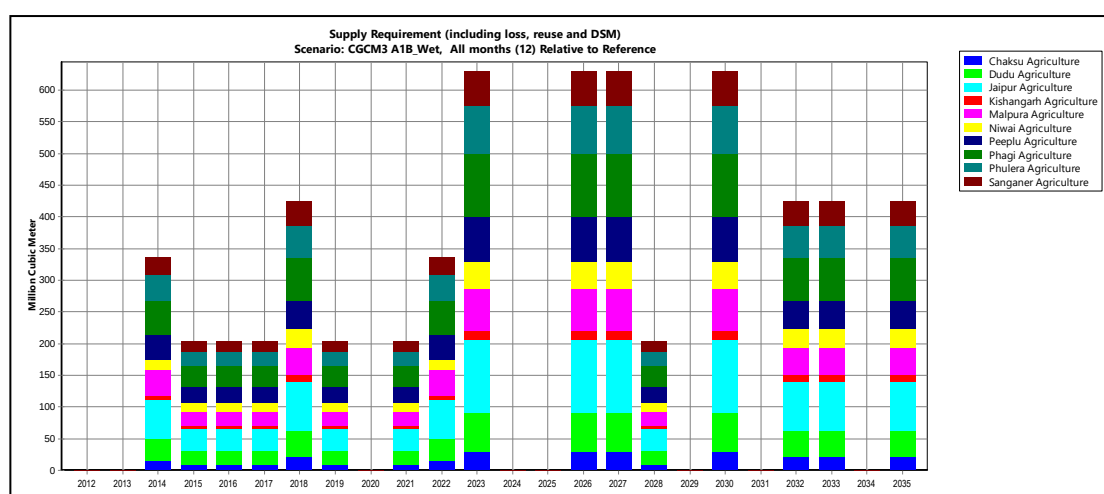
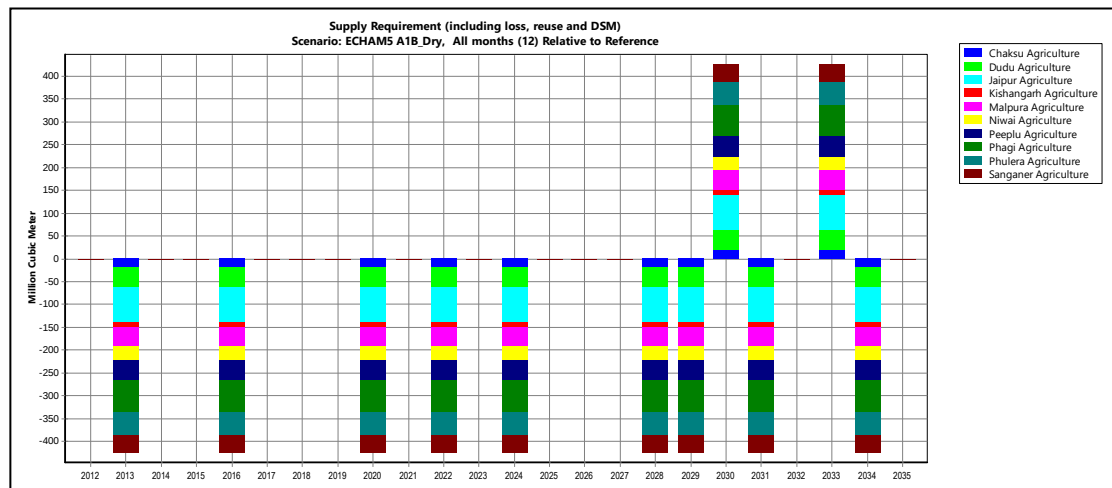


Figure 14 shows agriculture supply requirement in CGCM3 A1B_Wet Scenario relative to the Reference Base Case. It shows increase in agriculture supply requirement in several years to almost double the requirement in the Base Case. This can primarily be attributed to degree of change of water-year-type from Reference Base Case to the Climate Change Scenario--whether that year changes from dry to normal or from dry to very wet, which triggers proportional expansion of cropped area, in some cases even covering the current fallows.

The contrasting result of agriculture supply requirement in ECHAM5 A1B_Dry Scenario is presented in

Figure 15.

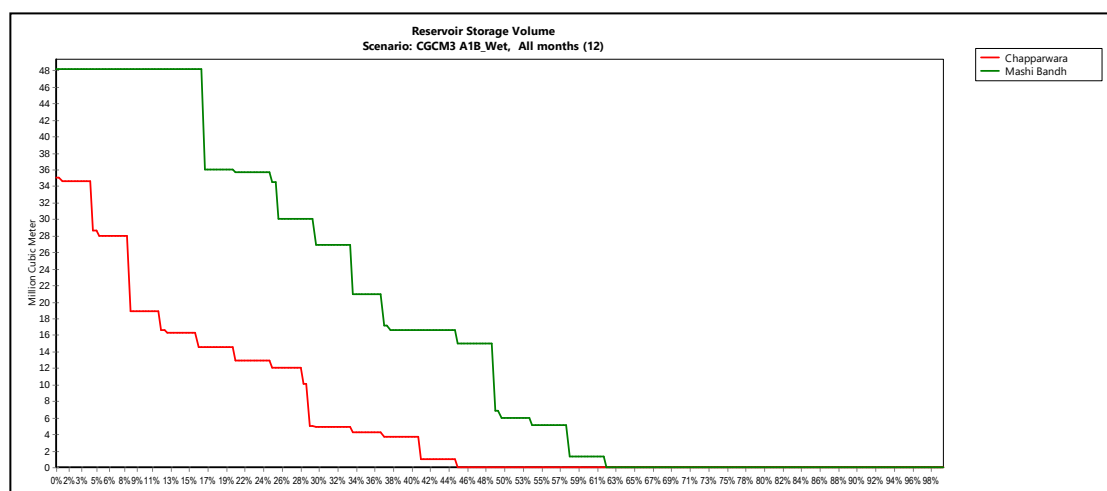
Figure 15: Agriculture Supply Requirement in CC Dry Scenario Relative to Reference Base Case



As evident from the above figure, the supply requirement reduces by almost 60 percent of Reference Base Case in most years. Interestingly, there is increase in the requirement specifically in the two years, 2030 and 2033, as these years are normal years against dry years in Reference Base Case.

The storages in Mashri and Chaparwara for CGCM3 A1B_Wet scenario are shown in Figure 16. As evident the Mashri reservoir is filled to its capacity for almost 20 percent time during 2012-35, which never filled in the Reference Base Case. Even Chaparwara is filled to its capacity, which never happened in the Reference Base Case, though only for three percent of time during 2012-35.

Figure 16: Storages in Reservoirs in CGCM3 A1B_Wet Scenario



Despite such large filling of reservoirs in wet climate change scenario let us see the extent to which the surface water storages (including the two dams and six Tank Sheds) and groundwater contribute to meeting the overall water supply requirement in the basin. Figure 17 shows that even in wet climate change scenario there is very high degree of reliance on groundwater. It is to be noted that these low level of surface water supply levels are over and above the import of 20 percent of total domestic demand from Bisalpur. The low level of dependence on surface water supplies within Mashi basin could be because of lower level of surface water development than that is feasible in the wet scenario. However, any further development of surface water resources in Mashi basin could have adverse impacts on inflows into Bisalpur that is located downstream and outside the basin. Hence, detail investigation on water yields of Mashi basin and Bisalpur catchment at required level of dependability are needed for CGCM3 A1B_Wet Climate Change scenario before arriving at any decision in this regard.

Figure 17: Supply delivered from surface water storages and groundwater in CGCM3 A1B_Wet Scenario (%)

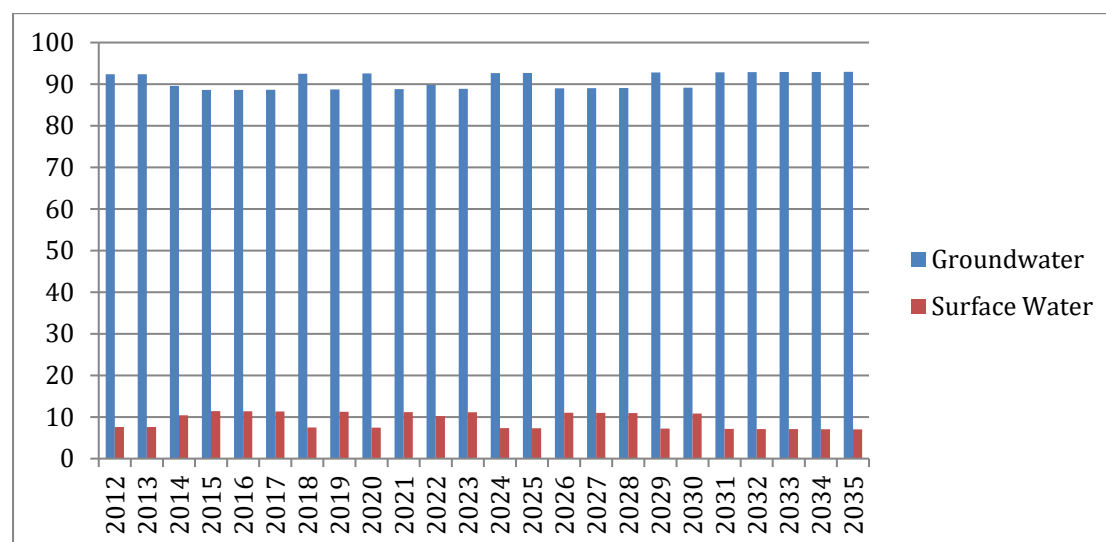
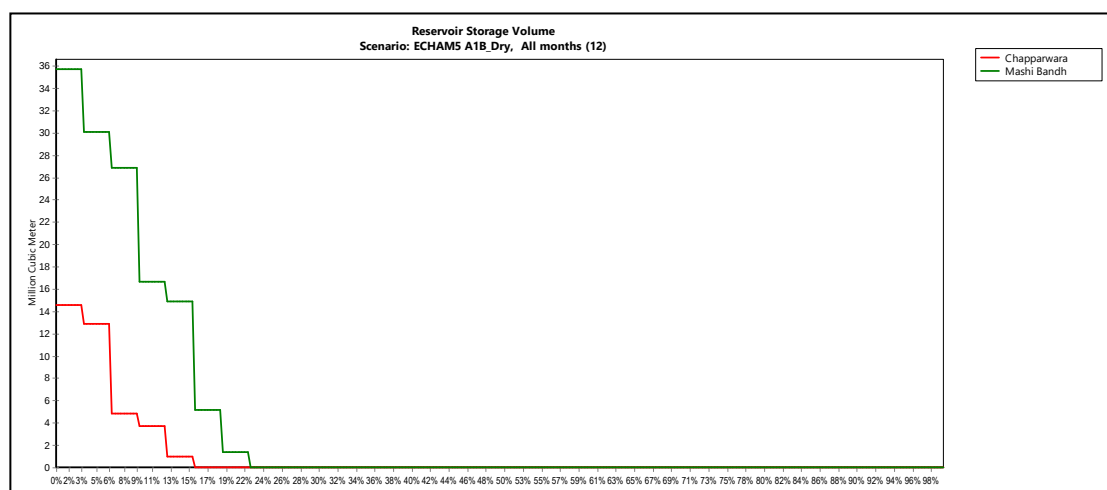


Figure 18: Storages in Reservoirs in ECHAM5 A1B_Dry Scenario



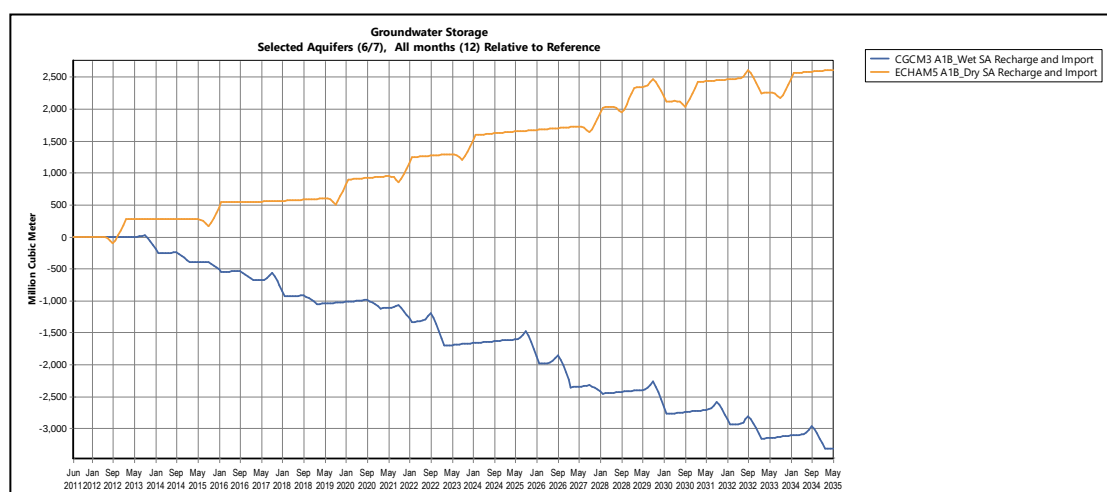
We note a very contrasting picture on filling of surface water reservoirs in the dry climate change scenario as seen in Figure 18. The two dams, Mashi and Chaparwara, hardly receive any water for less than 25 percent of time during 2012-35 while remain filled to 75 and 40 percent of its capacity, respectively, for just four percent of the time during the same period.

7.3. Water Management Scenarios

Supply Augmentation (SA) Scheme:

The supplies are augmented through increased imports to meet domestic water needs of the basin from Bisalpur and artificial recharge of groundwater through 106 minor water tanks clustered in six Tank Sheds (for details please refer description of this scheme above).

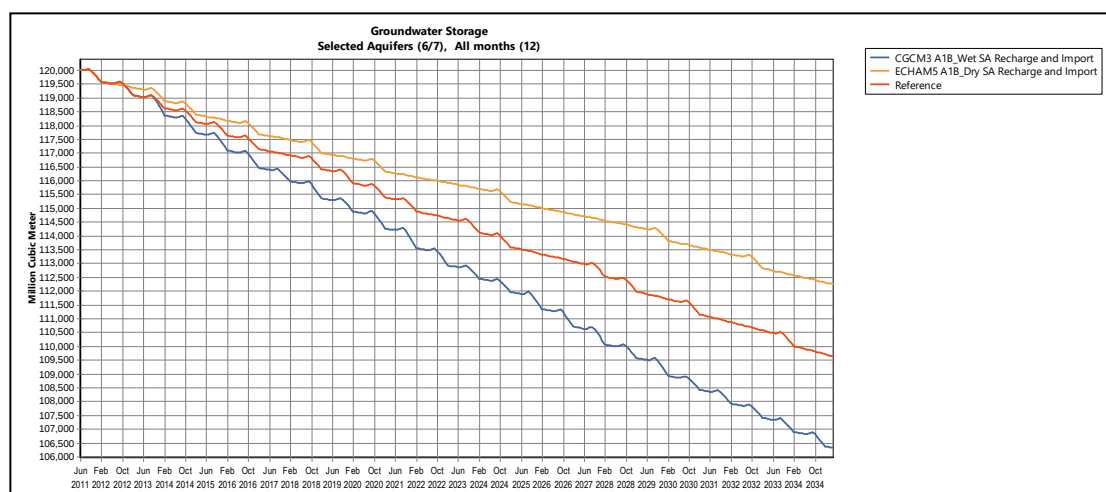
Figure 19: Groundwater Storages Relative to Reference Base Case due to SA scheme in Climate Change Scenarios



The overall groundwater storages in Mashi Basin increase by 2500 MCM in SA scheme as compared to the Reference Base Case in ECHAM5 A1B_Dry Climate

Change Scenario. This increase can be attributed to, in descending order, enhanced water imports from Bisalpur dam leading to reduced drawl of groundwater for domestic use, enhanced recharge during normal or above normal rainfall years, and reduced groundwater pumping due to decrease in cropped area in dry rainfall years. On the contrary the groundwater storages relative show a sharp decline in SA scheme under ECHAM5 A1B_Wet climate change scenario as compared to Reference Base Case. This is primarily due to increased pumping for enhanced agriculture activity basin-wide in normal rainfall years. However, in absolute terms the groundwater storages will decline substantially as seen in Figure 20.

Figure 20: Absolute Groundwater Storages due to SA scheme in Climate Change scenarios

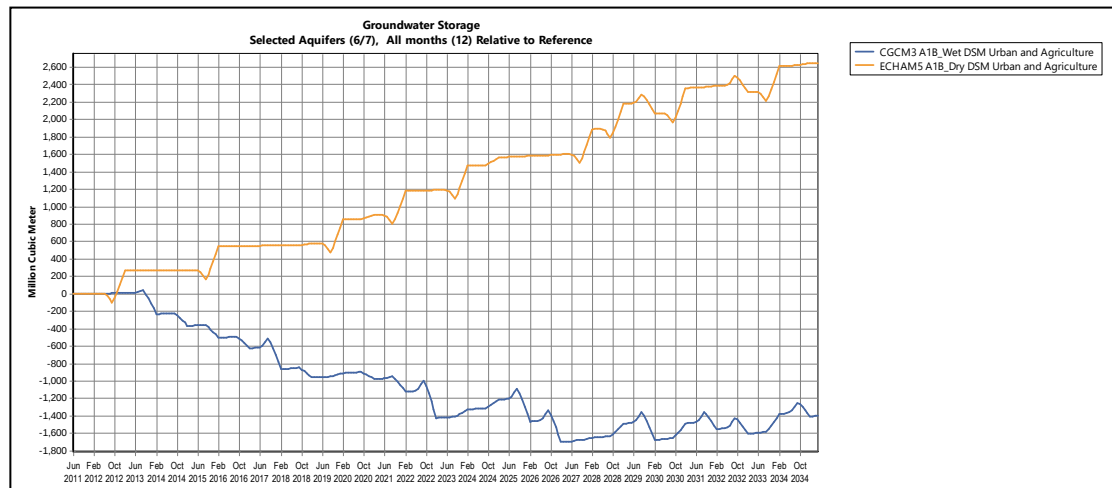


Demand Side Management (DSM) scheme:

DSM scheme is applied to the largest domestic water demand site—the Jaipur DDR where it is assumed the proportion of population adopting water efficient technologies would increase in the following manner: 2016, 0%; 2020, 10%; 2035, 40%). In addition, irrigation water efficient technologies are assumed to be increasingly adopted in Rabi crops: Sprinkler in Wheat, Barley and Mustard; and, drip for “Other Crops” that significantly includes vegetables. The coverage of sprinkler in each of the crop is assumed to increase in the following way: 2016, **nil** %; 2020, 10%; 2035, 60%. The corresponding figures for drip are: 2016, **nil** %; 2020, 10%; 2035, 50%.

Groundwater resource will be much higher reliable source than surface water during the entire period of 2012-35 while it is already over-exploited as noted in 2012 in most parts of the Mashi basin. The set of interventions in the DSM scheme are perceived to reduce the overall water supply requirement hence we look into how the groundwater storages change across the two extreme climate change scenarios relative to the Reference Base Case.

Figure 21: Groundwater Storages due to DSM scheme in Climate Change Scenarios relative to Reference Base Case

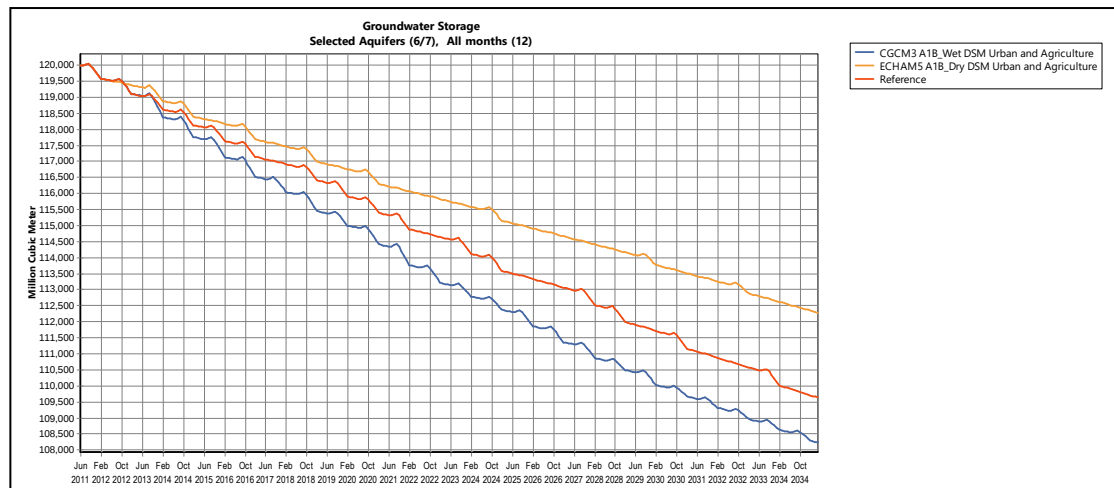


As seen in Figure 21 even DSM scheme shows trends in groundwater changes across the two climate change scenarios that are similar to the SA scheme (Figure 19). While the increase in storage in ECHAM5 A1B_Dry scenario is almost same across SA and DSM schemes, the decline in DSM scheme is approximately half of decline in SA scheme under CGCM3 A1B_Wet scenario despite the associated much higher crop production. This evidences a strong viewpoint that DSM scheme is much more effective and beneficial than SA scheme.

The above picture is of increase/ decline in relative terms i.e. relative to Reference Base Case. However, in absolute terms secular decline of groundwater storages are observed even in DSM scheme across both the climate change scenarios (see Figure 22). Comparing figures of absolute decline of groundwater storages across SA and DSM schemes (Figure 20 and Figure 22) one can deduce that there is practically no difference in decline across these schemes during ECHAM5 A1_Dry scenario while it is almost half in CGCM3 A1B_Wet scenario. This highlights two very important points:

- That the DSM scheme even in much lower state of agriculture activity during dry (ECHAM5 A1B_Dry) climate change scenario can fully offset the water imports for all the domestic requirements in the basin; and,
- That the DSM scheme reduces the groundwater decline to half of SA scheme with the co-benefit of much higher agriculture production during wet (CGCM3 A1B_Wet) climate change scenario.

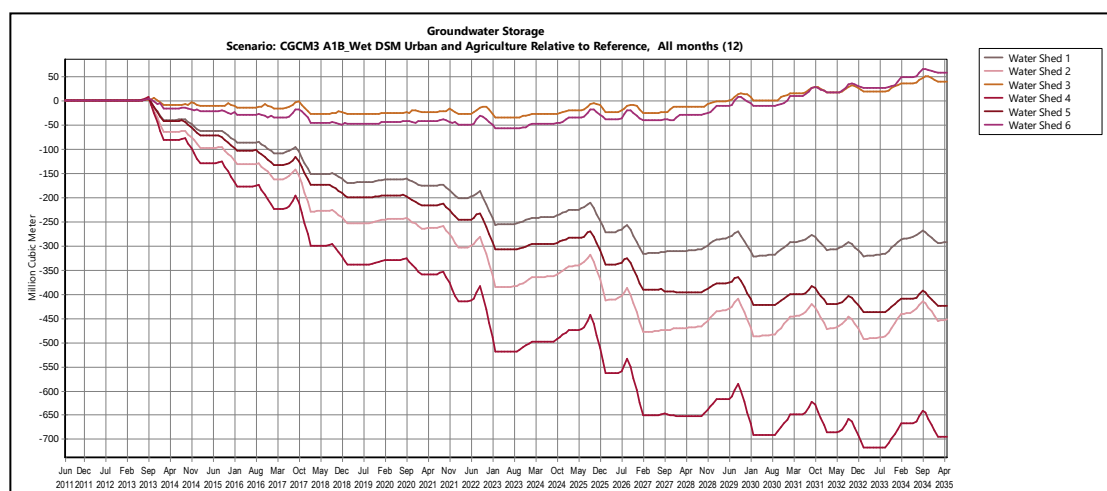
Figure 22: Absolute Groundwater Storages due to DSM in Climate Change scenarios



Now we dive deeper into the variation of declines of various groundwater storages (Water Sheds) in DSM scheme under CGCM3 A1B_Wet scenario. Figure 23 shows least decline, rather it shows increase, in Water Sheds 3 and 6 and high decline in ascending order in Water Sheds 5, 2 and 4. Following points are important specifically related to the Water Sheds showing high decline:

- *Water Shed 4 is the largest watershed of Mashi basin with high level of agriculture activity; and,*
- *Water Shed 2 is not the next lower in area to Water Shed 4 but it has high domestic demand from peri-urban areas around Jaipur, good agriculture activity and significant proportion of industrial water demand in the basin.*

Figure 23: Groundwater storages by Water Sheds Relative to Reference Base Case for CGCM3 A1B_Wet



8. Summary and Ways Forward

The WEAP water balance modeling is carried out for Mashī basin which is a sub-basin of Banas River Basin. Given the uncertainty in climate change projections, two extreme climate change scenarios, CGCM3 A1B_Wet and ECHAM5 A1B_Dry, are considered to assess their impacts on overall water resources of the Mashī basin. We believe it is more appropriate to consider range of impacts on water resources across the two extreme climate change scenarios in planning given the inherent limitations and uncertainty of climate change projections. While in the dry scenario relative increase in groundwater storages is observed in comparison to Reference Base Case or business-as-usual scenario without climate change, the WEAP model shows decline in groundwater storages relative to the Reference Base Case in the wet scenario. This decline in the wet scenario is accompanied by overall higher agriculture production in the basin with the consequences that production of Mustard and “Other Crops” (vegetables) could increase substantially while maintaining the current level of production of Wheat and Barley. Despite assuming moderate and linear increase of coverage of drip and sprinkler to 50 and 60 percent, respectively, as in Demand Side Management (DSM) scheme, the groundwater decline continue but at lower rates. More such iterations will be needed by use of WEAP and consensus arrived on level of imports, artificial recharge, scale of irrigation and domestic water efficient technologies for sustainable water management in the basin. Interestingly, between the Supply Augmentation (SA) scheme (that assumes substantial water imports from Bisalpur for meeting the domestic needs and artificial recharge) and DSM scheme, the model provides strong evidences of manifold advantages and much higher effectiveness of the DSM scheme.

In light of above we suggest the following actions:

4. The results of WEAP modeling be shared and used to catalyse informed multi-stakeholder dialogue for water resources management in Mashī basin. The dialogues will be an avenue to ratify/ change and negotiate the

assumptions used in the WEAP model to arrive at informed decisions pertaining to inter-sectoral allocation and intra-sectoral use efficiencies for managing water resources in a sustainable and equitable way. The stakeholders that we feel important to include are:

- a. Community groups from various gram Panchayat's, apex level federated community groups at Tehsil levels;
 - b. MLAs and MPs from constituencies that include Mashi Basin; Chairman of District Panchayats;
 - c. Agriculture Department, Jaipur Municipal Corporation, Jaipur Development Authority, PHED, Department of Water Resources, Rajasthan State Industrial Development and Investment Corporation and Department of Environment.
5. Lay foundations and take concerted efforts for value-chain work in Mustard and "Other Crops" (vegetables). For this, the community groups engaged in the process can be used. This will ensure that increased production during wet and very wet years transforms into increased incomes for farmers.
 6. Given the uncertainty of climate change projections a Steering Committee for Mashi Basin be setup that guides and monitors overall implementation of the action plan vis-à-vis how climate change unfolds/manifests. We believe the assumptions in WEAP will need to be revisited on periodic basis (at least once in two years) to decide on allocations and use efficiencies across sectors.
