Chapter 8

Climate Change Impacts on Water Supply System of the Middle Draa Valley in South Morocco

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8.1 Introduction

Climate change presents a risk for water resource in the developing countries in Africa where agriculture is the main economic activity (Diao et al. 2010). Global climate models suggest that temperatures are expected to increase by 2–6 °C by the end of this century (IPCC 2014). In fact, basins under water stress are located in North Africa in the Mediterranean region (Bates et al. 2008) and the Draa basin in the south of the High Atlas Mountains (Morocco). In 2014, the demand for water exceeded the available supply by more than 25% (Karmaoui et al. 2015a). Fresh water sustains inland water ecosystems (rivers, lakes, and wetlands), providing cultural, regulatory, and supporting services that contribute directly and indirectly to human well-being through recreation, scenic values, and maintenance of fisheries (Aylward et al. 2005). In fact, it is the basis of other ecosystem services, maintains ecological balance and aids socio-economic development.

The paper explores the incidence of socio-economic impacts and climate change on water demand. First, the analysis is carried out using Statistical downscaling models (SDSM software), to draw future projections of two meteorological

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quantities (precipitation and temperature); and the second, Water Evaluation and Planning System (WEAP) is used for the management of water resources. The outputs of these analyses could be helpful to support decision-making in matters related to eventual climate change and anthropogenic impacts on water resources, for future urban, agricultural, and environmental uses. The outputs can support decision making on:

- How can future projections be used into water resources planning at local scale?
- How can decision-making tools be used to quantify the eventual impacts of climate change on water resource in the Middle Draa Valley (MDV)?

The main objective of this paper is to examine how climatic and anthropogenic factors impact water supply; focusing on projections from 2010 to 2099.

8.2 A Brief Introduction to the Study Area

The MDV is an oasean region located in the middle part of Draa Basin. It was declared a Biosphere Reserve by UNESCO in 2000. The region is characterized by low population density (17,5 inhabitants / km^2) and a heterogeneous spatial distribution. Census data for 2014 in the province of Zagora (MDV) reported a population of 307,306 inhabitants, where 256,558 were located in the rural area. Most communes of the Middle Draa Valley recorded a growth rate, but in some communes the population change has recorded negative values as M'Hamid commune in the downstream of the valley. This is due to migration to urban centers and abroad (Karmaoui et al. 2015b).

Surface water resources in the Middle Draa Valley consist of the Draa Wadi fed by Mansour Eddahbi Dam. In the MDV, the oases occupy about 26,000 ha in six palm groves, dominated by the date palm promoting micro-hot and humid climate conducive to diversified agricultural production (Karmaoui et al. 2014a). This region is highly vulnerable to drought events, which are frequent and severe and have devastating impacts on population and economy.

8.3 Materials and Methods

The methodology used in this paper is based on the use of two tools:

- The SDSM model to develop climate scenarios that will be used for the WEAP software;
- The WEAP model to assess the water vulnerability used in Upper Draa Valley (Karmaoui et al. 2014b).

Data (water demand) was collected from the ONEE (Office national d'Electricité et d'Eau potable), the ORMVAO (Office régionale de mise en valeur agricole

Table 8.1 Demand sites of MDV

Demand sites		Sites of supply	
Urban sites	Agricultural sites	Groundwater	Water surface
Ouarzazate	Mezguita	Mezguita	Draa Wadi
Zagora	Tinzouline	Tinzouline	Mansour Eddahbi
Agdez	Ternata	Ternata	Dam
	Fezouata	Fezouata	
	Ktaoua and M'hamid	Ktaoua and M'hamid	

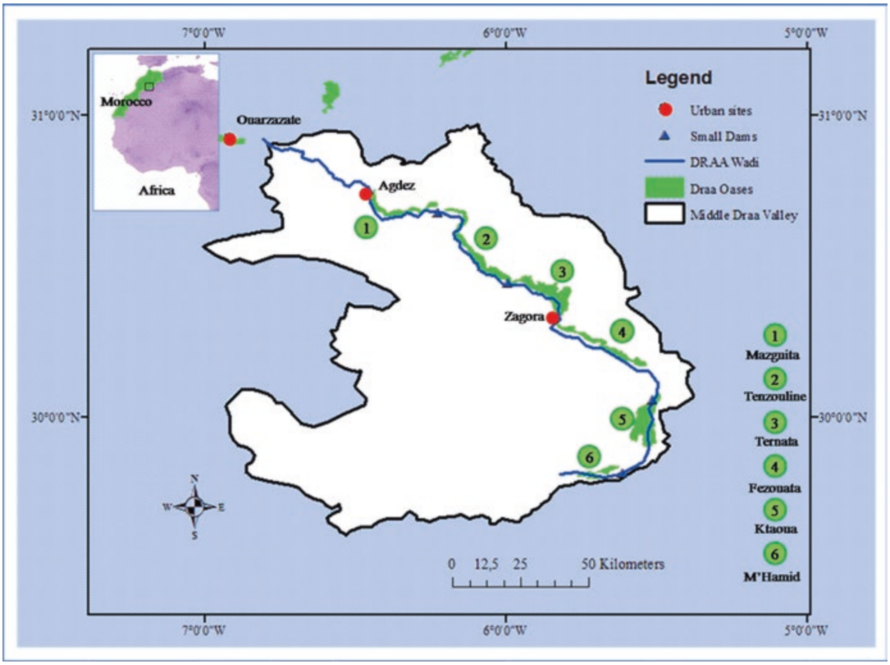

Fig. 8.1 The Middle Draa Valley location

d'Ouarzazate) and ABHO (Agence du basin hydraulique d'Ouarzazate) for climatic data and the dam outflow and inflow.

The adopted modeling process aims at exploring the vulnerability scenarios using the meteorological quantities of precipitation and temperatures in the two climate change scenarios A2 and B2. Table 8.1, Figs. 8.1 and 8.2 show the selected demand and supply sites for this study. Three urban centers derive their water supply from the Draa valley groundwater. Four agricultural sites derive water both from the six-groundwater sites and from the two water surface sites (Draa Wadi and Mansour Eddahbi Dam).

WEAP can be used for urban and agricultural systems. Figure 8.1 shows the study area and the approximate location of the nine demand sites (all demand and

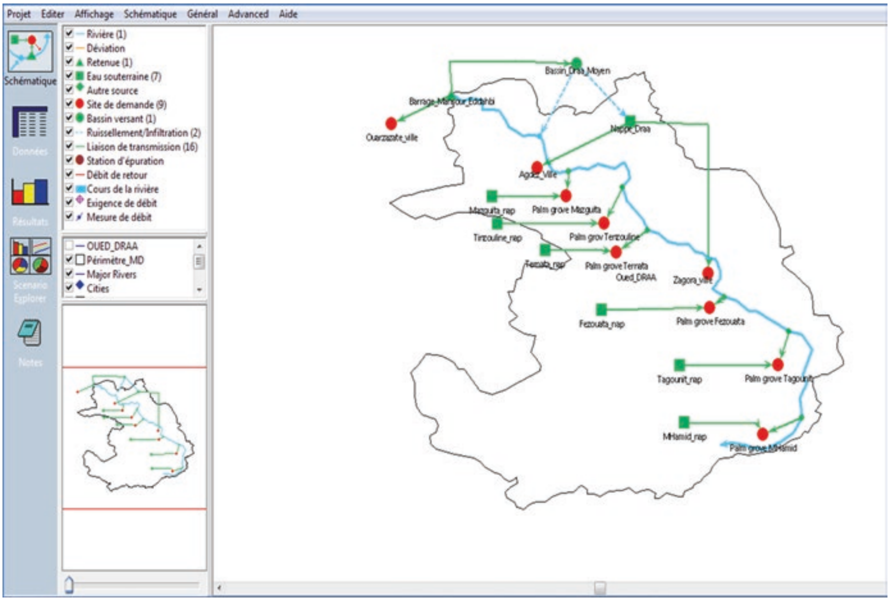

Fig. 8.2 Diagram of the WEAP model including the Middle Draa valley and all demand and supply sites, south east of Morocco

supply sites in Middle Draa Valley) simulated using WEAP. Ouarzazate urban centre (near the Mansour Eddahbi Dam) is also shown in Fig. 8.2 although it is not a part of the Middle Draa Valley, because it shares the reserves of this dam (the main source of water of the Middle Draa Valley). The model schematic (Fig. 8.2) shows WEAP node-network and the GIS layer of the Middle Draa Valley. Water demand is aggregated into three urban demand sites (Ouarzazate, Zagora and Agdez) and six agricultural demand sites (Mezguita, Tinzouline, Ternata, Fezouata, Ktaoua and M'Hamid), see also Fig. 8.1. These demand sites are supplied water from both groundwater and surface water.

8.3.1 Elaboration of Climate Change Scenarios A2 and B2 at Local Scale Using SDSM

The Model of statistical downscaling (SDSM) is a tool conceived to assess the impact of local climate change. These vulnerability scenarios were generated by using the meteorological quantities of rainfall and mean temperatures in the two climate change scenarios A2 and B2. To project the climate change scenario, we have used the SDSM. This software allows predicting the mean temperature and precipitation for the selected period of 2010–2080 based on climatic data of the period 1961–2000. For calibration and validation of data, we calculated the Root Mean Square Error (RMSE) between the monthly mean temperature observed and modeled between January 1981 and December 2000 for the parameter of average temperature, and compared between monthly total rainfall (mm) observed and that calculated by SDSM during the same period, based on data prepared by Babqiqi (2014).

8.3.2 Elaboration of Socio-economic Scenarios for the WEAP Model 'Water Evaluation and Planning System'

WEAP is a software that integrates physical hydrology with priority-driven water resources allocation, and is specifically built to support policy and planning (Mehta et al. 2013). The object-oriented approach and all equations are detailed in Yates et al. (2005). Using WEAP, scenarios can be built and then compared to assess their impacts; all scenarios start from a common year, for which the model Current Accounts data are established (Sieber et al. 2005).

Two principal scenarios are used, which are: firstly, the reference scenario is with population growth at a rate of three in urban area (RGPH 2004). The Reference scenario is the scenario in which the current situation (2010) is extended to the future (2011–2080). The current situation for the reference scenario was set at 2010 since a complete set of data is only available for this year, whereas for the years 2011–2015, data are not available or are only partially available. However, it is worth noting that no major changes are imposed in this scenario and that slight changes occurred only in the cropping pattern during these years (2011–2015). Besides the reference scenario, one other scenario is analyzed. This represents the high rate of population growth that we estimated at 4%. This value is the maximum value recorded in the part that encompasses the valley. In fact, urbanization has a phenomenal dimension with an average (annual) growth rate of 5.75% in 44 years (regional) compared to 3.06% for national urban (the Moroccan country) during the same period (RBOSM 2008).

8.4 Results

8.4.1 Elaboration of Climate Change Scenarios in the Draa Valley

For the case of Middle Draa, the SDSM program reproduces the average temperature with a degree of precision that remains sufficient to assess the impact of climate change on water demand (Figs. 8.2 and 8.3). The RMSE is in the order of 0.31 for the mean temperature. Similarly, the accuracy of the modeled seasonal mean

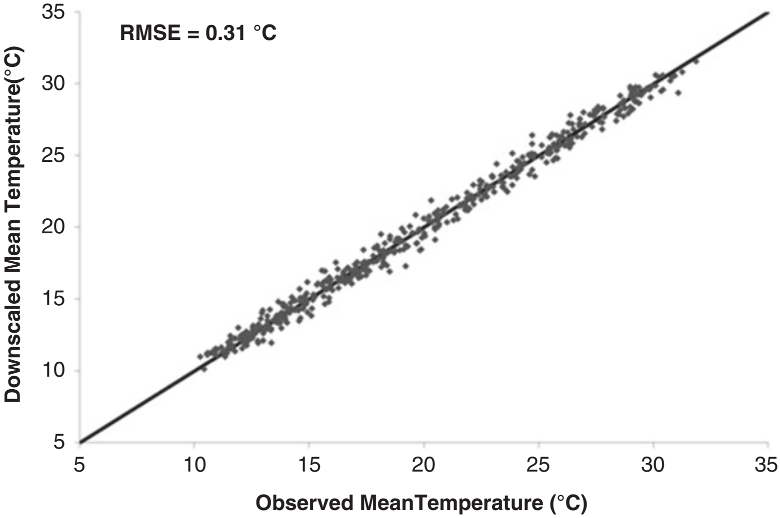

Fig. 8.3 Scatter plot with the RMSE between monthly mean temperatures observed and modeled between the period January 1981 and December 2000

temperatures is 0.37, 0.25, 0.19 and 0.18 °C respectively for spring, summer, autumn and winter.

RMSE values were taken into account to use climate change scenarios developed by the SDSM on WEAP, adjusting the values predicted by SDSM, and by shifting slightly the SDSM near RMSE values. According to Fig. 8.3, there is a strong correlation between past and predicted values by SDSM; this correlation is perfect with a correlation coefficient of 1.

Figure 8.4 shows a comparison between the average monthly precipitation observed and reproduced from the technical downscaling SDSM over the 1981–2000 periods. There is a general agreement between these two types of data. The maximum difference is 8.3 mm and occurs during the autumn season (September, October, and November) when the SDSM underestimates the amount of rainfall actually observed.

Also, Fig. 8.3 shows that while downscaled values have the same trend as the observed values, the actual values are different. The observed values are higher than the downscaled values during most of the months of the year (from November to May). In the months of June to September, the downscaled values are higher than the observed values. Overall, SDSM reproduces the annual rainfall with an RMS error of 4.6 mm. So as in the case of temperature, the accuracy of the SDSM technique is acceptable for most studies assessing the impact of climate change on water resources.

During the period 2001–2080, and under the A2 climate change scenario (Figs. 8.5 and 8.6), in winter for example, the SDSM model predict an increase in mean temperature from 1 to 3 °C, and a decrease of rainfall from 0% to 19%. In autumn, during the same period, we see an increase from 0.5 to 4 °C and a decrease

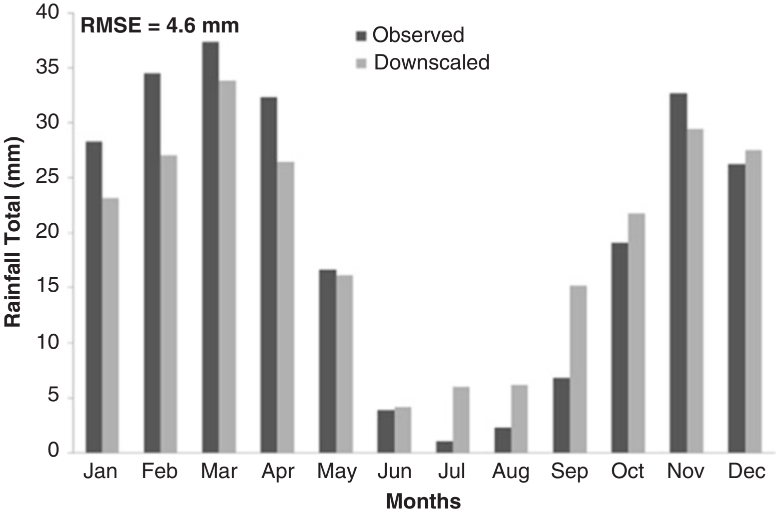

Fig. 8.4 Total rainfall: Comparison between total monthly rainfall (mm) observed and calculated from SDSM under the period of 1981–2000

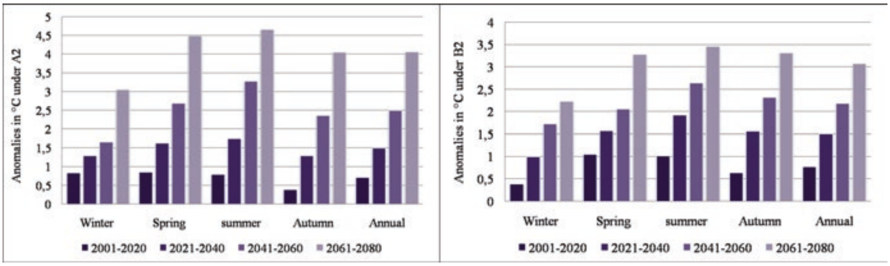

Fig. 8.5 Seasonal and annual anomalies (°C) of mean temperature for the three future horizons 2020, 2050 and 2080 and for both A2 and B2 scenarios at MDV

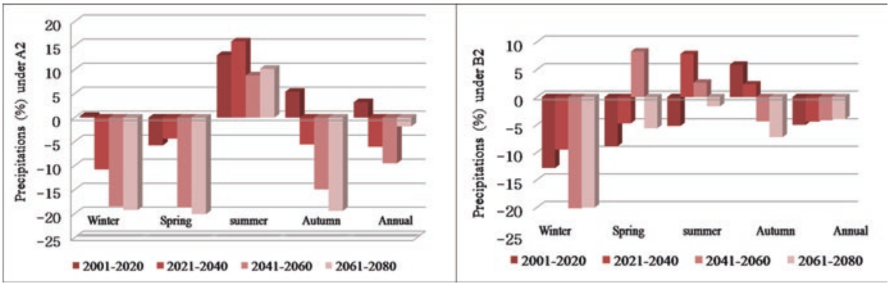

Fig. 8.6 Percentage change in the level of cumulative seasonal (winter, spring and autumn) and annual for the three future horizons 2020, 2050 and 2080 and for both A2 and B2 scenarios at MDV

from 5% to 20% in rainfall. Under B2, and in winter season, the mean temperature will increase from 0.5 to 2.3 °C, the precipitation will decrease from 12% to 20%. In autumn, the mean temperature may increase from 0.6 to 3.2 °C, and the precipitation may decrease from 5% to 7%.

The calculation of future climate anomalies (2011–2040, 2041–2070 and 2071–2099) relative to the current climate (1961–2000) for mean temperature and precipitation shows increased temperatures and decreased precipitation for the mentioned periods. In fact, the results predict an increase in mean temperatures. Temperatures could rise from 1.4 to 3 °C between 2011 and 2070 in scenario A2 and from 1.6 to 2.7 °C in B2. The decrease in precipitation is estimated to be up to approximately 5.1–15% in A2 and 3.9–8.9% in B2.

The changes in precipitation and temperature resulting from climate change are expected to reduce the agricultural and urban water supply and impact water demand significantly. The trends observed under the two scenarios were used in the WEAP software to predict the water supply and demand in the Middle Draa Valley.

8.4.2 Water Model in the Middle Draa Valley

The data on water resources in MDV consisting of three urban cities (Agdez, Zagora and Ouarzazate) and six separated palm groves was compiled and subsequently incorporated into WEAP.

Regarding the water demand for the three urban centers of Ouarzazate, Zagora and Agdez, the model predicts (Fig. 8.7) an increase in water demand in Agdez city

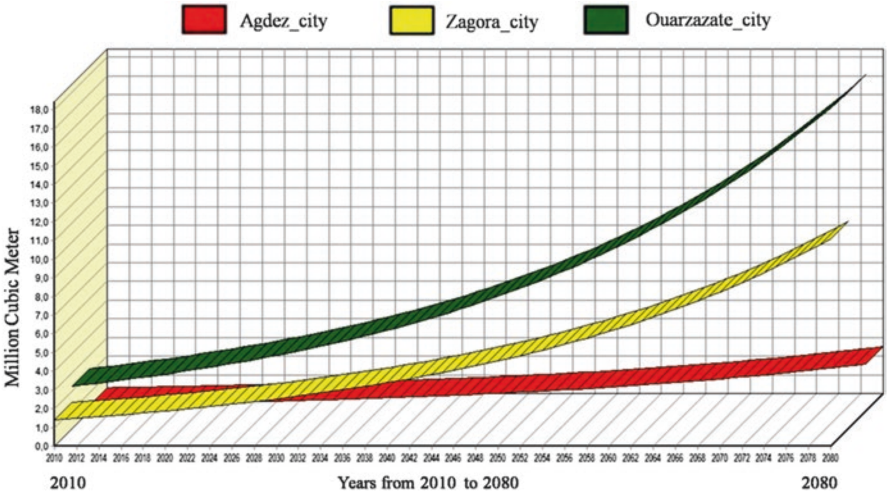

Fig. 8.7 Water demand of the tree cities (Ouarzazate, Zagora and Agdez), under reference scenario

from 0.3 Million Cubic Meters (MM^3) in 2010 to 0.6 MM^3 in 2030 (two times the water demand in 2030 and in Zagora city from 1.4 MM^3 (2010) to 2.5 MM^3 (2030) and in Ouarzazate city from 2.3 MM^3 in 2010 to 4.1 MM^3 in 2030.

For water demand for the three urban centers together (Fig. 8.8) under the three selected scenarios (Reference scenario and two climate change scenarios A2 and B2), the WEAP model predicts an increase in demand from 0.3 MM^3 in 2010 to 2 MM^3 in 2030 to 27 MM^3 in 2060. The B2 scenario indicates that total water demand will increase from 0.3 MM^3 in base year 2010 to 1.2 MM^3 in 2030 and 8.3 MM^3 in 2060. However, under reference scenarios, the demand will increase from 0.3 MM^3 in 2010 to 0.7 MM^3 in 2030 and 2.5 MM^3 in 2060.

Figure 8.9 shows the water demand of the six palm groves (Mazguita, Tinzouline, Ternata, Fezouata, Tagounite and M’Hamid) classified by water availability and

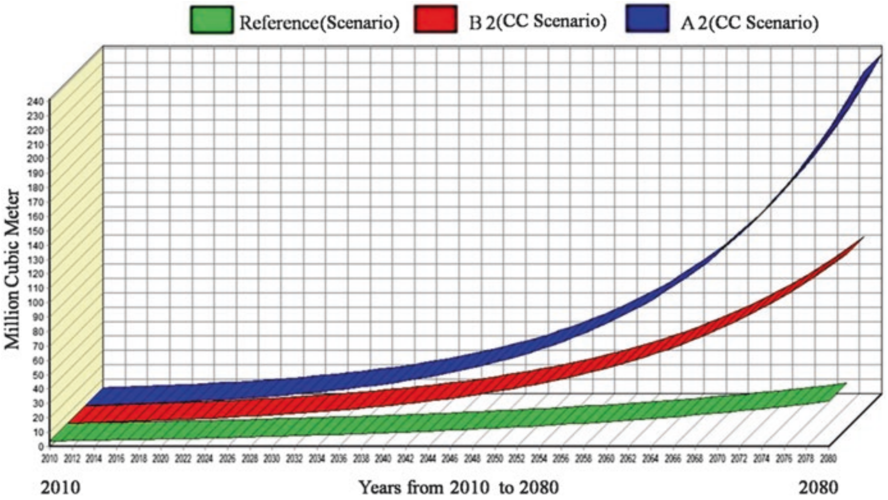

Fig. 8.8 Water demand of all urban sites (the tree cities: Ouarzazate, Zagora and Agdez), under three scenarios (CC: Climate Change A2 and B2 and reference scenario) in Million Cubic Meter (MM^3)

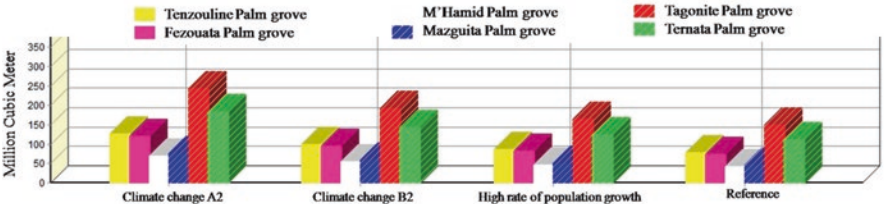

Fig. 8.9 Water demand (not including loss and reuse) for the six palm groves under 4 scenarios (Climate change A2 and B2, High rate of population growth and the reference scenario) for the year 2020

agricultural land. Under the reference scenario, as a result of reduced losses, the water volume delivered to consumers would increase in Tinzouline palm grove for example from 52.4 MM^3 in 2010 to 77.9 MM^3 in 2020 (Fig. 8.9). The increase is about 30% in the six palm groves by 2020. Demand coverage to all these palm groves would increase under Climate change A2 scenario following B2 and the high rate population growth compared to reference model.

The region is hilly and is crossed by nearby Wadis flowing north-west into the Iriki Lake (the extreme downstream). Although much of Draa is classified as a water-scarce region. Water is supplied to the urban area and surrounding rural areas by groundwater sites. The urban population increases by about 3% (RGPH 2004), which potentially swells water usage. Water demand would steadily rise as a result of population increasing at 4% annually from 2010.

The waterworks system infrastructure and operational capacity is the primary challenge in this region. The utility has several plans under way to increase water production. These include: increased water abstraction from groundwater sites; sourcing secondary abstraction sites; extension of the waterworks system network; groundwater abstraction to supply a few local institutions; and hydropower generation to reduce electricity costs. The climate change can affect the land class inflows and outflows (runoff area, precipitation, irrigation, increase of soil moisture, groundwater flow, evapotranspiration and soil moisture decrease) (Fig. 8.9). This impact is a threat to water supply, and food (land productivity) security in this vulnerable region. The changes in land class inflows and outflows starts to be visible from 2050 in the Reference scenario (Fig. 8.10a). However, this unbalance is visible from the year 2015 under climate change B2 scenario for example (Fig. 8.10b); the situation will be serious under climate change B2 scenario. We can also find that the sum of the outflow and the inflow for the reference scenario appears higher than inflow and outflow under climate change scenario.

8.5 Discussion

The A2 and B2 scenarios were used because they are closest to the trajectory of the evolution of Moroccan society and changes associated with climate indicators (Gommes et al. 2008). The models developed in this paper highlight key findings for each demand site (in agricultural and urban sectors). The agricultural sector is the biggest consumer of water resources (Karmaoui et al. 2015a; Heidecke and Thomas 2010). For the distribution of water resources in the different users (sectors), and from the total amount of exploitable water resources; 96.66% is used for agriculture, 2.70% for domestic, 0.28% for tourism, and 0.36% for economic activities (SADAM 2003).

Four scenarios were designed to investigate the effectiveness of policy options in the area (Climate change A2 and B2, reference scenario and the high rate of population growth scenario).

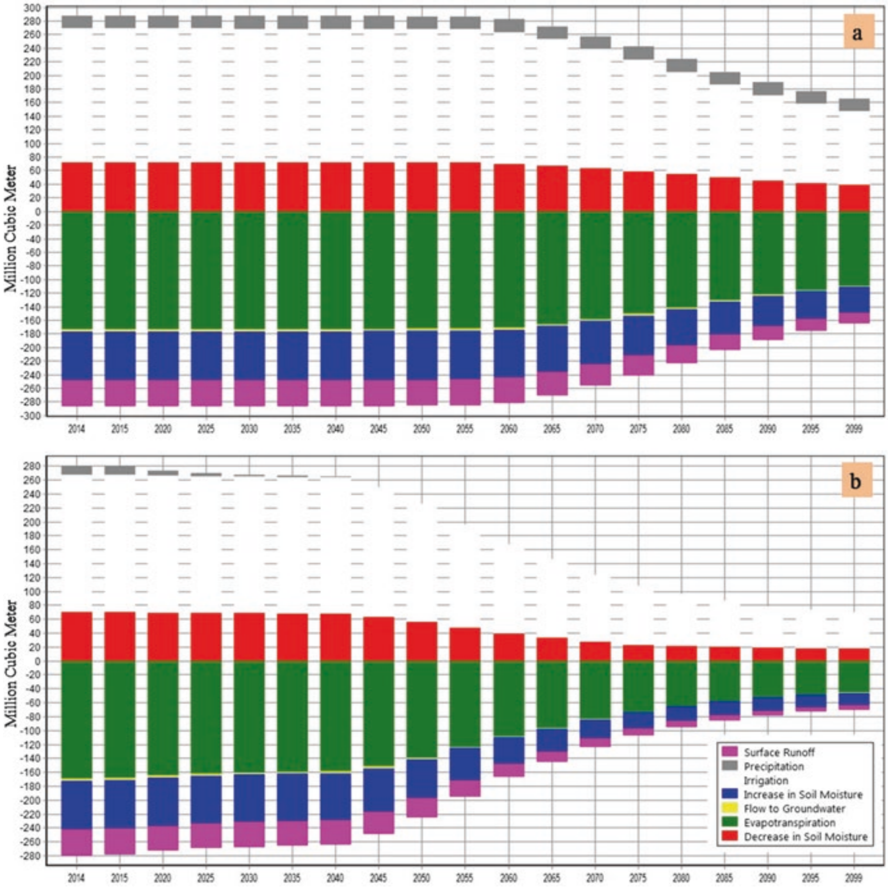

Fig. 8.10 Land class inflows and outflows. (**a**) Reference scenario; (**b**) Climate change B2 scenario from 2014 to 2099. The outflows are represented as negative values and the inflows as positive values

Based on the climatic model developed in this paper, an increase in temperature by 4.6 °C in summer (A2), 3.5 °C (B2) and 3 °C (A2), 2.2 (B2) in 2080. The rainfall in winter, will decrease by 19% under the A2 scenario and by 21% under B2 scenario by the end of 2080. The water resources are becoming scarce due to decrease in precipitation and temperature increase (Fig. 8.10). The coverage rate for water irrigation in Middle Draa valley was 91% in 2004; this coverage became 74% in 2014 (Karmaoui et al. 2015a).

Under climate scenarios, water availability continues to be insufficient because of the repeated droughts. According to Karmaoui et al. (2015a), the Middle Draa Valley will suffer an increase in dry years in the 2010–2099 period. The results of the two models show that under the A2 climate change scenario, there will be more dry years during this period than under B2 scenarios. In addition to drought, this region experiences a high rate of evaporation, which impacts the soil moisture and then the soil productivity and the decrease of vegetation cover. The anthropogenic pressure is the second aspect of degradation in the area. This starts by a traditional irrigation (submersion irrigation) that aggravates the water availability, an increased population growth affecting the water resource (water surface and groundwater). In short- and long-term, climate change and population growth place additional impacts on water resources. Since the construction of Mansour Eddahbi Dam in 1972, the number of motor pumps has increased steadily. It is estimated that in 1977, the six oases had about 2000 pumps, and in 1985 this number had doubled; in 2005, the number of motor pumps had increased to nearly 7000 (CMV 2005) for the whole MDV and more than 10,000 in 2011 (Chelleri et al. 2014). Extraction of water exceeds the natural recharge of aquifers, this poses an important challenge.

Water is scarce in arid and semi-arid regions as in the case of the Middle Draa Valley. Drought and population pressure in this area are impacting this resource. Groundwater is constantly declining for the last 30 years (Fig. 8.11), for the six palm groves of the MDV.

The rapid and continuous decline in groundwater level of M'Hamid is due to the growth of the use of water and the degradation of favorable conditions for groundwater recharge. The deterioration of vegetation cover limits the possibilities of infiltration and consequently, groundwater recharge is reduced (Zainabi 2003).

In this valley, the river system is fed by releases from the Mansour Eddahbi Dam. In parallel with the impact of drought, this dam is subjected to the phenomenon of siltation. Indeed, the capacity of the dam was reduced by approximately 25% in 1998 (Diekkruger et al. 2010). This trend will undoubtedly impact the production of hydraulic energy of this dam.

Another aspect of water shortage is the orientation of farmers to more profitable crops but it would be harmful in the long run, especially the cultivation of watermel-

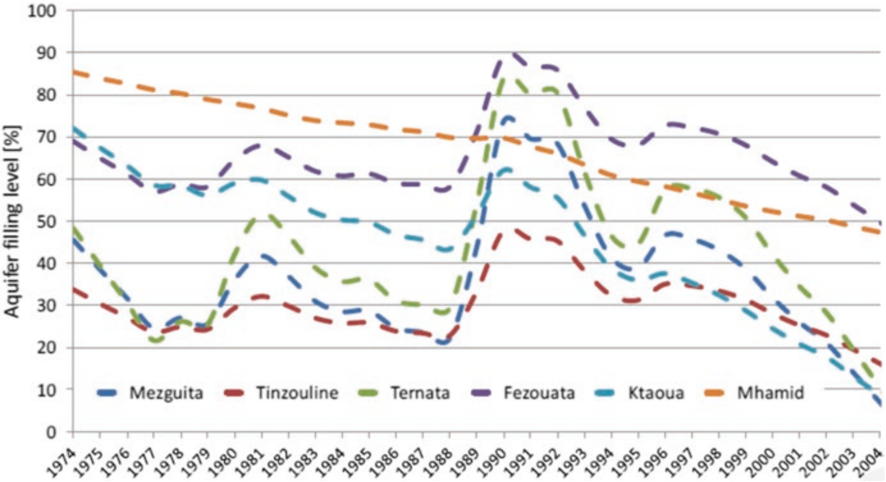

Fig. 8.11 Level of groundwater resources in the MDV (Source: IMPETUS project)

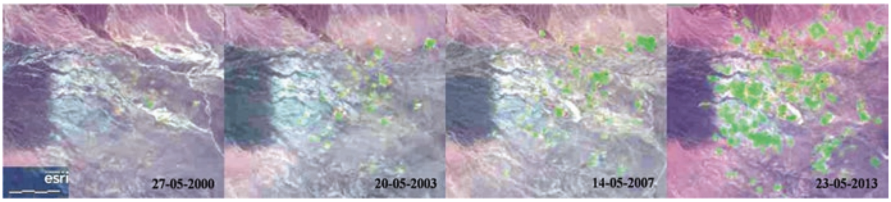

Fig. 8.12 Evolution of watermelon area in the same zone (Feija): raw satellite imagery from U.S. Geological Survey (USGS): www.landsatlook.usgs.gov/. Cloud: 20%. Sensors: TM, ETM+, OLI, Transparency Visible. Spatial resolution: 2 km. (Source: Karmaoui et al. 2014a)

ons, which dramatizes the demand for water (Karmaoui et al. 2014a). In fact, from Fig. 8.12, the watermelon area is constantly increasing. This evolution can be clearly seen in Fig. 8.5 processed by Karmaoui et al. (2014a)

This type of exploitation and all above-mentioned aspects of resource and aquatic ecosystems degradation have increased food insecurity due to which people are migrating to big urban centers and poverty is increasing. This will certainly lead to conflicts and overexploitation of ecosystems and subsequently widespread desertification. Recognizing this situation, we must consider several options including: remove mud from dams; monitor the water quantity and quality; re-use of wastewater; desalination; rainwater aggregation; economic irrigation; and water management.

The importance of such options is being recognized through initiatives such as Moroccan green plan or “Plan Maroc vert”, the national program of water irrigation economy (called PAPNEEI in Morocco), and the provisioning drinkable water Program of rural population (called PAGER in Morocco).

Under the expected climate scenario, water availability continues to be non-sufficient at current water capacity. Ouarzazate represents the most challenging of the three urban sites. The need for major infrastructure to collect water and better water management at farm scale level are most urgent in Draa. Mehta et al. (2013) reported that governments continue to rely on donor support for major infrastructure investments in the water and sanitation sector. In addition, the international donors have sponsored small-scale projects re-establishing both traditional techniques such as rainwater harvesting or financing the development of modern drip-irrigation technologies (Jobbins et al. 2015).

MDV is facing water constraints as to how to use the available water to meet urban and agricultural demands. Policies should integrate the supply and demands to address water stress issues. This paper anticipates hydrologic change in order to choice the management decisions to answer the water scarcity problem in this region. All four scenarios show an increasing trend in water requirements with time. The A2 climate change scenario exhibits the most pronounced increase. These increasing supply requirements are due to increasing summer temperatures for each of the two climate change scenarios. Most notably, these models provide useful indications of the timing of major investment in infrastructure improvements and expansion, and the size of the expansion required.

8.6 Conclusion

This paper presents an impact study of climate change scenarios on the water supply system of the Middle Draa Valley, combining downscaled climate scenarios with a numerical model of water supply system developed through the WEAP software.

Based on the climate change scenarios, the Middle Draa Valley will face prolonged drought from 2014 to 2080. For all scenarios, the increase in crop water demands meant that irrigation districts would not be able to meet their irrigation demands. Climate change will affect the storage levels in both Mansour Eddahbi Dam in upstream and the groundwater reservoir in downstream. The results predict increases in mean temperatures by 1.4–3 °C in scenario A2 and by 1.6–2.7 °C in scenario B2 from 2011 to 2070; and a decrease in precipitation by approximately 5.1–15% in A2 scenario and by 3.9–8.9% in B2 scenario. These conditions will result in increased water demand throughout the region. Irrigation efficiency and shifts in cropping patterns can reduce the demand in the agricultural sector for other sectors like tourism.

For the use of these decision support tools, we must take into account the degree of certainty of the tested scenarios (climate and socio-economic changes) and the complexity of water issues.

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References

Aylward, B., Bandyopadhyay, J., Belausteguigotia, J. C., Borkey, P., Cassar, A. Z., Meadors, L., & Voutchkov, N. (2005). Freshwater ecosystem services. *Ecosystems and human well-being: Policy responses, 3*, 213–256.

Babqiqi, A. (2014). Changements Climatiques au Maroc : Etude du cas de la Région de Marrakech Tensift Al Haouz et implications sur l'agriculture à l'horizon 2030. Thèse de doctorat. Département de biologie, Faculté de Semlalia. Université Cadi Ayyad, Marrakech.

Bates BC, Kundzewicz ZW, et Palutikof J. (2008). Le changement climatique et l'eau, document technique publié par le Groupe d'experts intergouvernemental sur l'évolution du climat, Secrétariat du GIEC, Genève, 236 p.

Chelleri, L., Minucci, G., Ruiz, A., & Karmaoui, A. (2014). Responses to drought and desertification in the Moroccan Drâa Valley Region: Resilience at the expense of sustainability? *International Journal of Climate Change: Impacts & Responses, 5*(2), 17–33.

CMV. (2005). *Distribution de l'eau dans le Draa Moyen*. Morocco: Office régional de mise en valeur Agricole de Ouarzazate.

Diao, X., Hazell, P., & Thurlow, J. (2010). The role of agriculture in African development. *World Development, 38*(10), 1375–1383.

Diekkruger, B., Busche, H., Klose, A., Klose, S., Rademacher, C., & Schulz, O. (2010). Impact of global change on hydrology and soil degradation-scenario analysis for the semi-arid Drâa catchment (South Morocco).In *The global dimensions of change in River Basin*. (pp. 5–13).

GCPH (2004) General census of the population and housing. https://rgph2014.hcp.ma/ Accessed 09 May 2015.

Gommes, R., Kanamaru, H., El Hairech, T., Rosillon, D., Babqiqi, A., et al. (2008). *World bank – Morocco study on the impact of climate change on the agricultural sector, FAO component: Impacts on crop yields* (p. 105). Maroc: FAO and Agricultural Ministry of Morocco.

Heidecke, C., & Thomas, H. (2010). The impact of water pricing in an arid river basin in Morocco considering the conjunctive use of ground-and surface water, water quality aspects and climate change. In *The global dimensions of change in River Basins*.

IPCC. (2014). Climate change 2014: Impacts, adaptation, and vulnerability. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change* (p. 688). Cambridge: Cambridge University Press.

Jobbins, G., Kalpakian, J., Chriyaa, A., Legrouri, A., & El Mzouri, E.H. (2015). To what end? Drip irrigation and the water–energy–food nexus in Morocco. *International Journal of Water Resources Development*, 1–14. Ahead-of-print.

Karmaoui, A., Messouli, M., Yacoubi Khebiza, M., & Ifaadassan, I. (2014a). Environmental vulnerability to climate change and anthropogenic impacts in dryland, (pilot study: Middle Draa valley, South Morocco). *Journal of Earth Science and Climatic Change, S11*, 002. https://doi.org/10.4172/2157-7617.S11-002.

Karmaoui, A., Messouli, M., Ifaadassan, I., & Khebiza, M. Y. (2014b). A multidisciplinary approach to assess the environmental vulnerability at local scale in context of climate change (pilot study in Upper Draa Valley, South Morocco). *Global Journal of Technology and Optimization, 6*, 167. https://doi.org/10.4172/2229-8711.1000167.

Karmaoui, A., Ifaadassan, I., Babqiqi, A., Messouli, M., & Yacoubi Khebiza, M. (2015a). Analysis of the water supply-demand relationship in the Draa valley basin, Morocco, under climate change and socio-economic scenarios. *Journal of Scientific Research & Reports*. https://doi.org/10.9734/JSRR/2016/21536.

Karmaoui, A., Ifaadassan, I., Messouli, M., & Khebiza, M. Y. (2015b). Sustainability of the Moroccan oasean system (Case study: Middle Draa Valley). *Global Journal of Technology and Optimization, 6*, 170. https://doi.org/10.4172/2229-8711.1000170.

Mehta, V. K., Aslam, O., Dale, L., Miller, N., & Purkey, D. R. (2013). Scenario-based water resources planning for utilities in the Lake Victoria region. *Physics and Chemistry of the Earth, Parts A/B/C, 61*, 22–31.

RBOSM. (2008). Réserve de Biosphère des Oasis du Sud Marocain. Plan cadre de gestion de la Réserve de Biosphère des Oasis du Sud Marocain (RBOSM).

SADAM. (2003). Strategie d'amenagement et de developpement des oasis au MAROC. Analyse, Diagnostic, Typologie des Oasis. Première phase, 2003. Direction de l'Aménagement du Territoire DIRASSAT. MATEE-DAT/DIRASSET.

Sieber, J., Swartz, C., & Huber-Lee, A. H. (2005). *Water evaluation and planning system (WEAP): User guide*. Boston: Stockholm Environment Institute.

Yates, D., Sieber, J., Purkey, D., & Huber-Lee, A. (2005). WEAP21—a demand-, priority-,and preference-driven water planning model. *Water International, 30*, 487–500.

Zainabi, À. (2003). La Vallée du Dra- Développement Alternatif et Action Communautaire. World Development Report.

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