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Water Management Options for Future in Zayandeh Rud Basin, Iran

[1]M. Akbari, [2]P. Droogers and [3]S.H. Sadre Ghaen

[1]Agricultural Engineering Research Institute (AERI), P.O.Box 31585-845, Karaj, Iran
[2]International Water Management Institute, P.O. Box 2075, Colombo, Sri Lanka
[3]Scientific Member, Agricultural Engineering Research Institute (AERI),
P.O. Box 31585-845, Karaj, Iran

Abstract: In looking at these interactions it is useful to have a set of models on hand that enable us to accomplish two objectives: i) understanding current conditions, ii) developing future scenarios that address alternative uses and allocations of water and seeing how they affect water conditions at different scales. This research was carried out to evaluate the effect of different water management options on water productivity in Zayandeh Rud basin in Iran. Results of fixed amount of allocated water to non-agricultural sectors show that, the basin inflow is linear to the six defined projections for water to agriculture. In terms of water management options at system level, the equal allocation practice (S1) guarantees that the area can be cropped is maximal. Deficit irrigation (F2) and improved field water management (F3) options results show the highest water productivity. Stopping rice cultivation will reduce this water productivity substantially, caused by the high price of rice. In terms of system water management options, the current situation (S0) is providing the lowest productivity and allocating water equally between systems (S1) or serve upstream farmers first (S2) appears to be better ways to improve water productivity, which is preferred depends also on the farm water management option adopted. Therefore, during dry conditions we can expect deficit irrigation (F3), with a water productivity of about 0.15 $\$m^{-3}$ in preference to the current practice with a value of about 0.13 $\$m^{-3}$.

Key words: Modeling · water management · basin water productivity · Zayandeh Rud

INTRODUCTION

The growing development of urban and industrial water use encourages increased irrigation performance and productivity, as well as water saving and conservation issues [1]. To improve irrigation management, different models have been used to compute crop water requirements, estimate the soil water balance, determine irrigation scheduling and study groundwater contributions, under different conditions [2, 3]. Based on these types of models, decision support tools and models that simulate aggregate irrigation demand [4] have been proposed recently. These simulations models, whether integrated into a GIS or not, enable water managers and users to assess impacts of water allocation at basin level and, therefore, to improve the respective policies and to locate areas with specific problems [5]. Recently, the simulation model has been applied to irrigation scheduling for several crops in the semi arid Region in Esfahan, Iran.

This paper shows the utility of models in understanding current processes and relationships across a wide variety of different aspects of water management. While this is of considerable utility, it is not the only benefit of using models. Models also permit us to assess the relative benefit and cost of different water management options in the future on the basis that the processes and relationships hold true over a range of different conditions. This is done through the use of scenario analysis that examines not only the direct changes that result from exercising a different option but also the impact and changes at other levels of water management in the basin. This is certainly the case in the Zayandeh Rud basin.

MATERIALS AND METHODS

Study Area: The main irrigated areas in the Zayandeh Rud basin, Esfahan, Iran, 41500 km^2, have been selected to analyze the integrated assessment of water management

Corresponding Author: M. Akbari, Assistant Professor, Agricultural Engineering Research Institute (AERI),
P.O. Box 31585-845. Karaj, Iran. E-mail: akbari_m43@yahoo.com.

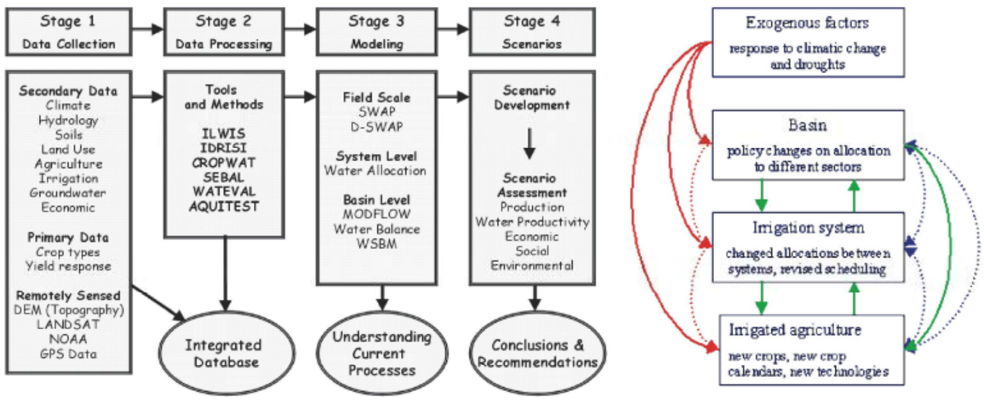

Fig. 1: Sequence of stages required for integrated assessment of water management options at different scales and pathways for assessment of scenarios.

options at different scales. The basin has an arid or semi-arid climate. Rainfall in Esfahan, which is situated at an elevation of 1800 m, averages only 130 mm per year. Most of the rainfall occurring in the winter months from December to April. During the summer there is no notable rainfall. Temperatures are hot in summer, reaching an average of 30°C in July, but are cool in winter dropping to an average minimum temperature of 3°C in January. Annual potential evapotranspiration is 1500 mm and it is almost impossible to have any economic form of agriculture without reliable irrigation. About 180,000 ha of the basin is under irrigation with main crops are rice, wheat, alfalfa, sugar-beet and vegetables. During the last years a major drought occurred in the regional area resulting in very low and even no surface water available for irrigation during several years. The only source for irrigation during these years was groundwater resulting in major drops in levels. Further details can be found in Akbari *et al*. [6]. To assist us in identifying realistic scenarios for which water management options should be tested using a range of integrated models as developed during the project, it is useful to recognize that there are four distinct groups of factors that represent the scale at which changes in present practices or conditions can occur. These four factors are all related to the scenario-projection-water management option, relationship, together with an indication of the most likely types of linkages between each level. The implementation of a project looking at integrated water management at field, irrigation system and basin scale has four sequential stages:

- Data collection and establishment of a structured database
- Data processing through use of a wide range of tools
- Model development and/or application to understand current conditions
- Scenario development and assessment leading to conclusions and recommendations

Diagrammatically the process is shown in Figure 1, although it must be recognized that there is a lot of overlap during the first three stages. However, Stage 4 can not be completed until the first three stages have been completed for all different levels of analysis in the basin because it requires all of this information to undertake the scenario assessment process.

We selected four farm level and three system level options with six projections of water availability to agriculture for water management analysis. Farm level options include current cropping patterns (F0), stop growing rice (F1), improve farm level water management techniques (F2) and deficit irrigation (F3). Three system level options were according to the current practice (S0), equal (S1) and unequal (S2) allocation water between irrigation systems. Six projections of water availability to agriculture were 500, 750, 1000, 1250, 1500 and 1750 MCM. Four farm level options combined with three system level options gives us a total of 12 management possibilities that need to be analyzed for each of the six projections of values of water availability, a total of 72 combinations which require impact assessment.

Primary data collection was restricted only to essential pieces of information that were required for supplementing secondary data or for providing ground truth for remotely sensed data. The secondary data that we were able to collect covered all of the main areas required for an integrated approach to water management assessment and modeling. It should, however be recognized that there are gaps and compatibility issues arising from the use of data derived from a large number of different organizations and agencies, each of which have their own specific purposes for data collection. We recognize that the data we were able to obtain is not ideal, but it turned out to be sufficient for our modeling purposes. Data from various LANDSAT 7 and NOAA satellites were extensively used for base map preparation and a range of crop and water conditions through processing in the second stage of activities. Eight models used in this study, some based on physical laws, some on water balance or mass balance accounting, together with an indication of the scale at which they were used and the level of physical detail included in the model. The final stage of the integrated modeling approach is to use the results obtained in assessment of different scenarios for water management. We have not favored any effort to develop a single model that can do this. Rather, we prefer an approach that transfer results from different models into an integrating spreadsheet, which can produce outputs for a set of pre-determined performance indicators. We have used the irrigable areas as described by Akbari *et al.,* [6] to assess the water allocation rules according for option S1. Finally, the last water management option considered at system level is to allocate water unequally, where upstream farmers extract all the water they want and only the remainder and return flows are available for downstream located farmers. Field scale analysis includes the impact of the irrigation applications and the quality of this water on evapotranspiration, return flows, soil salinity and depleted water and, most importantly crop yields. These analyses were supported by the Soil Water Atmosphere Plant model, SWAP. The model was tested and applied for crop in the Zayandeh Rud Basin [7-11].

Based on this study it was clear that upstream farmers might benefit somewhat from such a switch, but the impact on downstream users was quite substantially as return flows would be reduced. The third scenario defined here is similar but looks in a more comprehensive way, including different crops, economics and equity, what the impact will be of such a shift from furrow and border to drip irrigation techniques. It was assumed that all crops would be irrigated by drip, which is in practice not likely or possible, but this scenario can be considered in a broader sense as a total package of improved field water management practices.

RESULTS

We have divided the results into two groups: single-factor performance indicators and trade-off analyses between indicators. As starting point we will have a look at allocations between different sectors on a basin scale. As mentioned earlier, we concentrate here on water allocation to agriculture assuming that it is not relevant to farmers whether changes in the amount of water they receive is caused naturally or by policy decision. Figure.2-a shows that as a consequence of the fixed amount allocated to non-agricultural sectors, basin inflow is linear to the six defined projections for water to agriculture (500, 750, .. 1750 MCM). The reason for this is that at higher levels of water availability return flows are also high and agriculture is unable to capture all of them. It should be noted that even at projection of 1750 MCM to agriculture, the full demand by agriculture is still not satisfied by canal irrigation due to design limitations of the main canal system. The gap between the percentage of water extracted and depleted by agriculture is widening at increasing water availabilities. The percentage depleted has a maximum of about 70% and is already reached at average water availabilities of 1250 MCM, while the percentage extracted increases even at the highest projection rate (Fig 2-a). Figure 2-b presents for the 72 combinations of water availability and management options the relationship between variation in farm income and the total gross production of the basin. The overall trend is clear that income variation is lower and gross production higher with increasing water availability. Figure 2-c reflects the water values based on average water availability. Estimates for other water availability projections show the same trend. This is somewhat unexpectedly as it has been reported that water scarce areas tend to have higher water productivity figures and vice versa. As mentioned earlier, in reality farmers will adopt some form of deficit irrigation during dry periods and will tend to over-irrigate in times of abundance. So, during dry conditions we can expect deficit irrigation, option F3, with a water productivity of about 0.15 $\$m^{-3}$ in preference to the current practice with a value of about 0.13 $\$m^{-3}$.

The assessment of the different water management options should follow a multi-objective approach. Opting only for the highest cropped area does not result necessarily into the highest overall gross return. Similarly, a high gross return might cause an inequity in income not preferable. As an example of such a multi-objective approach the trade-off between gross production and water productivity is plotted in Figure 2-d for the six water availability projections. As shown clearly in the graph, management affects gross return and water productivity to a large extent and the best management option differs from one water

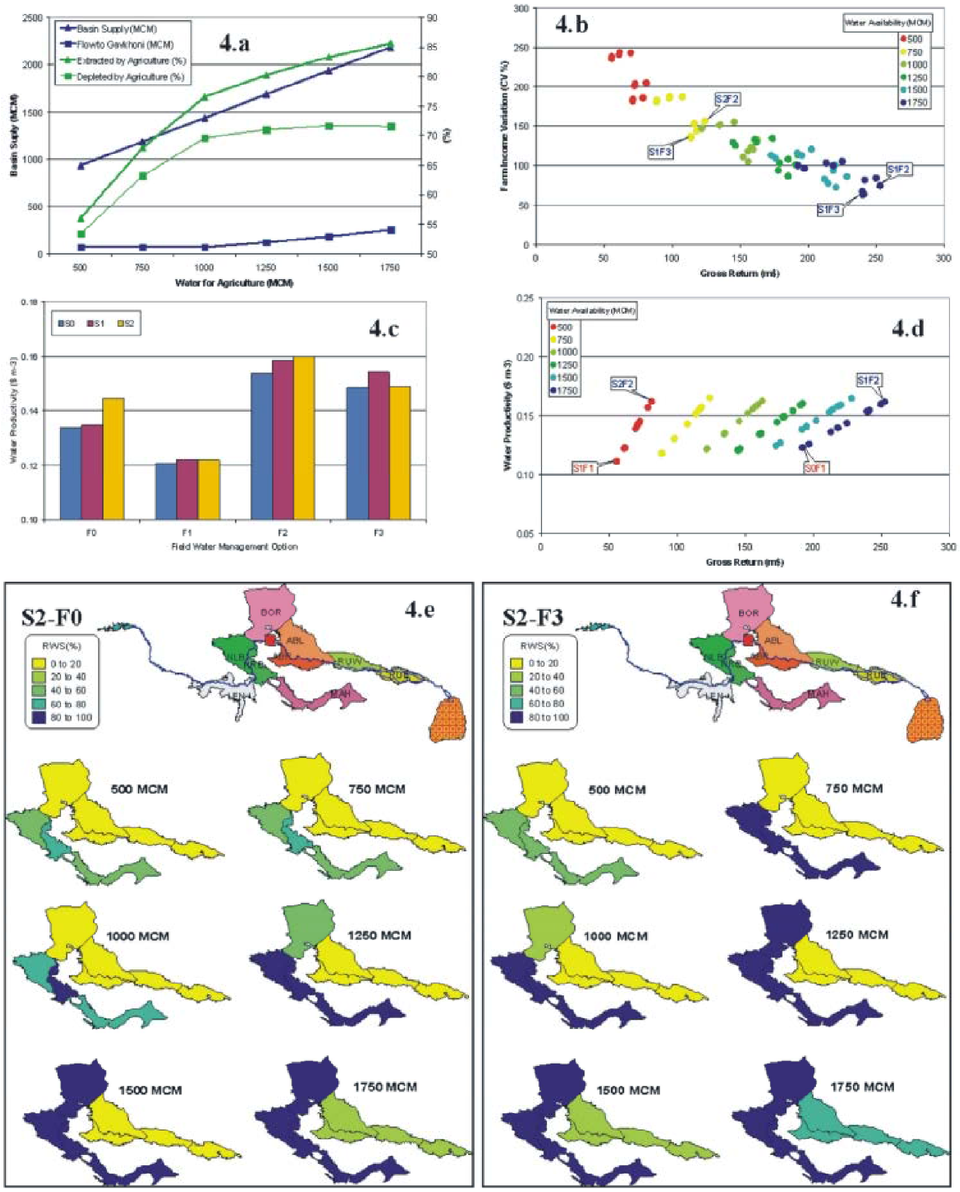

Fig. 2: Basin supply and associated water allocation to agriculture, income variation and gross return, average water productivity and water allocation between systems according to system water management.

availability option to another. Figure 2-e shows nicely how water will be distributed if upstream systems will be served first. At the average water projection (1250 MCM) full supply is realized to the Nekouabad systems and to Mahyar and the other systems are not provided with any water, with the exception of Borghar to a certain extent. Even at the highest water availability, not all systems are served completely and Rudahst and the Abshar systems will receive only 25% of the water they require. It is clear that the basin is scarce and that even at high water projections not all farmers can be served.

The option to adopt deficit irrigation (F3) might be one solution to this basin water deficit. Figure 2-f shows what the impact will be in terms of system water allocation. So Figure 2-f represents the same situation as Figure 2-e except that deficit irrigation is practiced. It is clear that the Nekoubad and Mahyar systems are already fully supplied when only 750 MCM is available. At the highest water availability projection, most systems are fully supplied, but the downstream ones are still only at a level of 65% relative water supply. Overall results of fixed amount of allocated water to non-agricultural sectors shows that, the basin inflow is linear to the six defined projections for water to agriculture.

In terms of water management options at system level, the equal allocation practice (S1) guarantees that the area can be cropped is maximal. Deficit irrigation (F2) and improve field water management (F3) option result shows the highest water productivity. Stopping rice cultivation will reduce this water productivity substantially, caused by the high price of rice. In terms of system water management options, the current situation (S0) is providing the lowest productivity and allocating water equally between systems (S1) or serve upstream farmers first (S2) appears to be better ways to improve water productivity, which is preferred depends also on the farm water management option adopted. Therefore, during dry conditions we can expect deficit irrigation (F3), with a water productivity of about 0.15 $\$m^{-3}$ is preference to the current practice with a value of about 0.13 $\$m^{-3}$.

CONCLUSION

This paper showed the utility of models in understanding current processes and relationships across a wide variety of different aspects of water management. While this is of considerable utility, it is not the only benefit of using models. Models also permit us to assess the relative benefit and cost of different water management options in the future on the basis that the processes and relationships hold true over a range of different conditions. This is done through the use of scenario analysis that examines not only the direct changes that result from exercising a different option but also the impact and changes at other levels of water management in the basin. This is particularly true in water short basins where all water is already used productively. Any increase in one sector will inevitably means less water for other sectors and the cost of such water reductions needs to be looked at in a holistic, basin-wise manner. The approach will address the issue of water scarcity at several different levels. Each of these levels will form a specific component of the project, each of which will be implemented independently to streamline the overall rate of progress. It is insufficient to have models that look only at the impact within one sector or for one class of water users because the potential benefits identified by using that model may be outweighed by larger costs to other users or sectors. Models also permit us to assess the relative benefit and cost of different water management options in the future on the basis that the processes and relationships hold true over a range of different conditions. This is done through the use of scenario analysis that examines not only the direct changes that result from exercising a different option but also the impact and changes at other levels of water management in the basin.

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