

Institute for Environmental Studies (IVM)

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A multi criteria analysis of water management strategies in the Gediz basin, Turkey.

Report 7 within the WatManSup project

vrije Universiteit amsterdam



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Preface

This report is written in the context of the WatManSup project (Integrated Water Management Support Methodologies). The project is executed in two countries: Kenya and Turkey. Financial support is provided by Partners for Water. For more information on the WatManSup project see the project website: <http://www.futurewater.nl/watmansup>.

The Dutch consortium:

- FutureWater (Wageningen)
- Institute for Environmental Studies (Amsterdam)
- Water Board Hunze en Aa's (Veendam)

Foreign clients:

- SASOL Foundation (Kitui, Kenya)
- Soil and Water Resources Research Institutes of the Turkish Ministry of Agricultural and Rural Affairs (Menemen, Turkey)
- SUMER (Izmir, Turkey)

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Reports so far:

Report No. 1: Water Management Support Methodologies: State of the Art

Report No. 2: Water Evaluation and Planning System, Kitui – Kenya

Report No. 3: Soil and Water Assessment Tool, Kitui - Kenya

Report No. 4: Multi-criteria analysis, Kitui - Kenya

Report No. 5: Water Evaluation and Planning System, Gediz Basin – Turkey

Report No. 6: Soil and Water Assessment Tool, Turkey

Report No. 7: Multi-criteria analysis, Gediz basin, Turkey

Abstract

The challenge to manage our water resources in a sustainable and appropriate manner is growing. Water related disasters are not accepted anymore and societies expect more and more that water is always available at the right moment and at the desired quantity and quality. Current water management practices are still focused on reacting to events occurred in the past: the re-active approach. At many international high level ministerial and scientific meetings a call for more strategic oriented water management, the pro-active approach has been advocated. Despite these calls such a pro-active approach is hardly adopted by water managers and policy makers.

Water managers and decisions makers are aware of the necessity to shift from a re-active towards a pro-active approach, but are confronted with the lack of appropriate methodologies. To be prepared Integrated Water Management Support Methodologies (IWMSM) are needed that go beyond the traditional operational support tools. Note that these IWMSM are more than only tools, but include conceptual issues, theories, combining technical and socio-economic aspects. To demonstrate and promote this new way of thinking the WatManSup (Water Management Support Tools) has been initiated. The IWMSM approach comprises three different components: a water allocation component (WEAP), a physical based component (SWAT) and a decision support component (DEFINITE). This report describes the MCA of the Turkish case study; it uses information from the WEAP and SWAT model as well as information acquired during field visits and a workshop. It is a global analysis, because the goal of the project is to explore the potential of the tools, not to implement a thorough research on a case study.

Turkey's economy is growing fast and the demand for water is vastly growing along. Industrial areas expand and so does the water demand. Agricultural land is still the highest water user. Besides these human uses the RAMSAR wetland site at Kuş Cenneti also requires an amount of water of a good quality. Agricultural lands in Turkey are mainly irrigated through surface irrigation and the area of agricultural irrigation systems is still growing. The dry years from 1989-1994 show that Gediz basin is vulnerable to droughts. Water supply is not unlimited and the agricultural sector suffered from severe economic losses. With future plans for expansion of the agricultural area and the industrial sector growing rapidly, it is clear that the water delivery in Gediz basin needs a closer look. Smart water allocation is important to maintain deliveries to all sectors (Kite & Droogers 1999; Droogers & Torabi, 2002).

1. Introduction

1.1 Short background of the project

Within the WatMansup project we demonstrate how several combined water management tools can support water managers in their job of optimising the use of water resources in an integrated way. This approach uses three components:

- A physical component (SWAT): This part relies on accurate description of the physical processes related to water.
- An allocation component (WEAP): This component is mainly used to evaluate the impact of human interference in water distribution and allocation issues for water shortage as well as water excess.
- And a Multi Criteria Analysis component (MCA): This component allows stakeholders and water managers to assess impacts of different water management strategies.

In this report the multi criteria analysis for the Turkish case study is described. In the Gediz basin the main issues are water shortages during dry years, several water uses competing for the available water, and low water quality. Together with WatManSup Reports No. 5 and 6 (Van Loon et al., 2007; Droogers & Van Loon, 2007) it forms the integrated water management approach for the Gediz case study.

1.2 Aim

The objective of this study is to analyse several water management strategies for the Gediz basin and their effects on agriculture, environment and industry, and to explore the suitability of MCA together with the hydrological models as an integrated approach to water management.

1.3 Outline

Chapter 2 provides a short description on the study area, describes the background of multi criteria analysis and gives a short explanation on the DEFINITE program, the MCA tool used in this study. In chapter 3 the scenarios and water management strategies that will be analysed are described as well as the way they are constructed. The setting up of the MCA is also described in this chapter. The results of the analysis are shown in chapter 4 and in chapter 5 the activities and results of the project are discussed.

2. Background

2.1 Study area

In the Gediz basin, which is located in the west of Turkey (Figure 2.1), irrigated agriculture is the most important water user. Beside irrigation, water is used for industrial production, domestic use and the environment. After a period with prolonged drought during the 1990s it became clear that water resources in the basin are finite and awareness rose that the way the water is managed and how it is divided between the different users is important. Water managers set off to design water management plans for the basin, taking into account the demands of all the water users and the available water. The WatManSup Report No. 5 gives a more elaborate description of the basin and the water users (Van Loon et al., 2007).



Figure 2.1 Case study area (source: CIA the World fact book).

2.2 Multi Criteria Analysis

(After van Herwijnen and Janssen, 2005).

Everybody makes decisions, many times a day. Most decisions come naturally, a well trained reaction to familiar stimuli to which people apply habitual responses. Some decisions are a little harder, because they are not a routine business and have more important consequences. Buying a new car, changing job or leaving for an expensive holiday are decisions which are worth some attention. For these decisions, it seems obvious that we should gather information and ask people for advice before “making-up” our minds. This requires time, effort and perhaps money. The resources allocated for the analysis of the decision depend on the magnitude of its consequences: choosing where to go on holiday is likely to be far less demanding than deciding in which country to settle for the next ten years.

Few decisions have a single objective. The very idea of making decisions suggests the need for considering multiple aspects and achieving a successful blend of performances. Management of water resources is no exception to this general rule. Multiple stakeholders participate in management of water resources. This leads to multiple objectives to be considered by any decision maker involved in water management.

Examples are:

- Selection of a management strategy for a freshwater lake. Objectives are water quality, water quantity, biodiversity, recreational quality, residential quality, cost, etc.;
- Selection of a flood management strategy. Objectives are risk of flooding, biodiversity, visual quality, land use, and cost;
- Selection of a strategy for river basin management. Objectives are water quality, flood risks and navigation, but also visual quality of the landscape and biodiversity.

These situations are different from each other. Nevertheless, they share important similarities. First, individuals evaluate a set of alternatives, which represent the possible choices. The objectives to be achieved drive the design (or screening) of candidate alternatives and determine their overall evaluation. Attributes are the measurement rods for the objectives and specify the degree to which each alternative matches the objectives. Factual information and value judgements jointly establish the overall qualities of each option and highlight the best solution.

2.2.1 DEFINITE

DEFINITE (decisions on a finite set of alternatives) is a decision support software package that has been developed to improve the quality of decision-making. DEFINITE is, in fact, a whole toolkit of methods that can be used on a wide variety of problems. If you have a problem to solve, and you can identify alternative solutions, then DEFINITE can weigh up the alternatives for you and select the best alternative. The program contains a number of methods for supporting problem definition as well as graphical methods to support representation. To be able to deal with all types of information DEFINITE includes multi criteria methods, cost-benefit analysis and graphical evaluation methods. Related procedures such as weight assessment, standardization, discounting, and a large variety of methods for sensitivity analysis are also available. A unique feature of DEFINITE is a procedure that systematically leads an expert through a number of rounds of an interactive assessment session and uses an optimisation approach to integrate all information provided by the experts to a full set of value functions. DEFINITE supports the whole decision process, from problem definition to report generation. The structured approach ensures that the decisions arrived at are systematic and consistent. DEFINITE can be used by the busy professional with no prior experience with such software, as well as the sophisticated user. A tutorial example and examples from the practice of environmental decision making are provided. Menus, information screens and help screens will lead you through the program and will very rapidly make you familiar with its features.

The first version, DEFINITE for MSDOS, appeared in 1994. A wide range of users has applied the program. Within the Dutch government users are almost all ministries, provinces, public bodies and a number of larger cities. Outside the government the main users are consultancy and engineering firms. Finally, DEFINITE is used in universities and other schools of higher education for teaching purposes.

For the Gediz case study we analyse several management strategies on their impact on farmers, the environment and water resources, and explore the suitability of this tech-

nique together with the hydrological models as an integrated approach to water management.

2.3 Approach

When using an IWMSM approach several water management strategies are designed, which will be assessed in an integrated way. These strategies consist of measures the water manager can take, or the water users can take (e.g. switch crops, adjust water allocation, etc.), that might improve the economic results or environmental quality. A systematic overview of these objectives is shown in Figure 3.2. It is possible to test these strategies under different conditions, to see if they are robust. These different conditions are called scenarios, A scenario is a possible future situation; it may vary for instance in climatic conditions or on economic or population growth. In this case study we did not make use of scenarios. To be able to assess the effects of the strategies on the objectives, indicators are used. Indicators are quantifiable representations of the situation of the farmer (like agricultural production), industries or other water users. Within a MCA indicators are called criteria. The measures that together form a strategy affect the values of the indicators, enabling an assessment of the impact of the strategies. DEFINITE supports this approach in a structured way and has features to further assess the strategies.

3. Setting up the MCA

3.1 Workflow

For the Gediz case study we evaluated the effects of four water allocation strategies. Water availability for the different users is determined by the total amount of water and how this is divided over the water users. The strategies are developed in cooperation with the partners of the project. In this case study we work at the level of the basin manager; for the Gediz basin this is DSI (State Hydraulic Works) in Izmir. DSI decides what measures will be taken, taking into account all the water uses in the basin. The most important water users are: irrigated agriculture, domestic use in the cities, environment and industrial use.

The effects of the strategies on the hydrology of the basin are explored in WatManSup Reports No. 5 and 6 (Van Loon et al., 2007; Droogers & Van Loon, 2007). These reports describe the use of the SWAT and WEAP models. Climate data, scenarios and allocation strategies are used as input to the hydrological models SWAT and WEAP. The models provide a distribution of seasonal water availability and show whether or not the allocation strategies are suitable in terms of a set of predefined criteria such as costs, crop production, etc. A multi criteria analysis tool is used to compare the effects of the strategies. The workflow of the project is drawn in Figure 3.1.

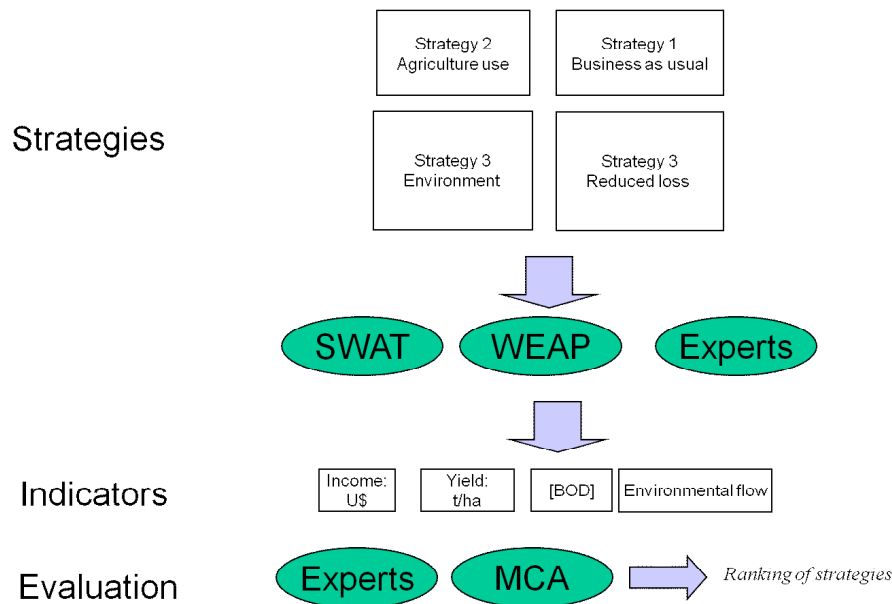


Figure 3.1 Evaluation of strategies against indicators/criteria.

We assume the water managers of the basin have specific objectives, like increasing agricultural production and increasing the quality of nature. The strategies are evaluated as to whether they contribute to reaching these objectives. We used a method in linking

objectives to the state of the water resources, which makes use of quantifiable indicators (Aerts and Droogers, 2004). Figure 3.2 shows an elaborate design of how the objectives are linked to the state of the water resources within this method. Section 3.3 describes the indicators that are used in this study.

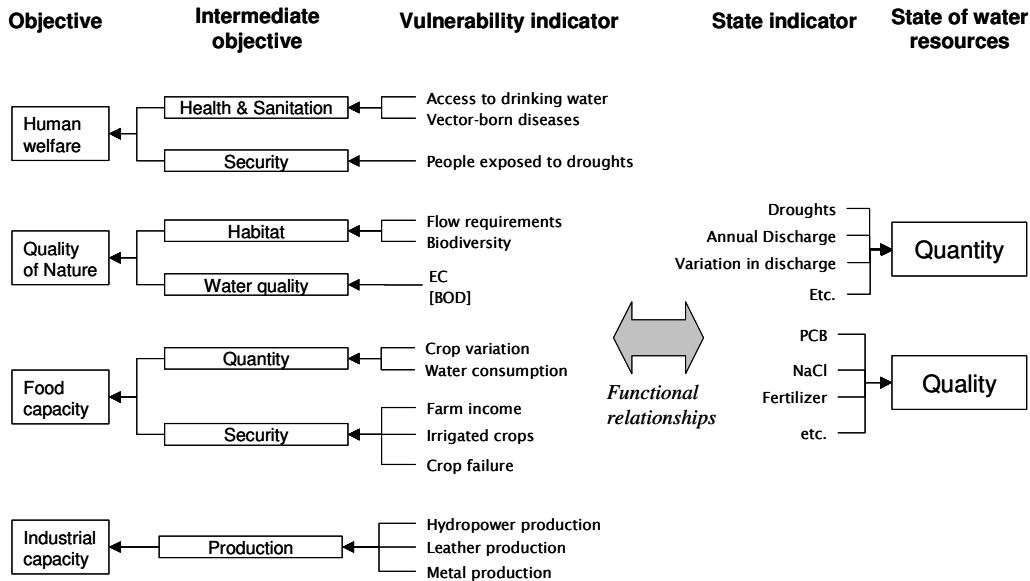


Figure 3.2 Decision tree with objectives and vulnerability indicators on the left and state indicators on the right (based on: Aerts and Droogers, 2004).

3.2 Strategies

The strategies designed for the Gediz case are based on goals of the different water users in the region and on measures DSI is planning to take in the near future. The strategies are designed in close corporation with the project partners. The following strategies are evaluated in this report:

1. Business as usual;
2. Increase irrigation area;
3. Environment;
4. Reduce water loss.

The strategies differ in the way the water is allocated to the users and how much water is available. It are relative simple strategies, mostly consisting of one global measure. In DEFINITE it is also possible to put several measures together in one strategy, however within the scope of this project this was not possible. Below the strategies are described in more detail.

1. Business as usual (BAU)

The BAU strategy represents the current water management in the basin. Agricultural use has top priority; the Kuş Cenneti wetlands have low priority. The main source of domestic water is groundwater. The management of the Demirköprü reservoir is adjusted

to the demand from the agricultural users, resulting in outflows of the reservoir during the growing season.

2. Increase irrigation area

Currently, plans are made to increase the irrigated area in the basin. One of the most promising schemes is the Adala left bank scheme. If implemented, the irrigated area at Adala will increase from 9,000 to 12,000 ha. This additional irrigated area will produce more agricultural products, but will also increase the water demand of agriculture. The extra water used at this scheme will lead to an even larger deficit at the Kuş Cenneti wetlands, downstream, as top priority is given to agriculture. Also water quality will be affected by the extra inflow of fertilizers and pesticides.

3. Environment

In the Environment strategy the downstream wetlands at Kuş Cenneti, a RAMSAR site, get top priority in water allocation. This means the water demand of the wetlands are met first and the remaining water is used for the other activities in the basin, predominately agriculture. Because first the demand of the wetlands is met, less water is available for agriculture, reducing production. The water demand of the Kuş Cenneti wetlands has been subject of research and the results of these studies are used in the WEAP model.

4. Reduce water loss

An efficient use of the water within the irrigation system is important in a water scarce environment. Problems with maintenance and high evaporation standards are responsible for high losses within the irrigation canals. In the BAU scenario 10% water loss in the irrigation canals was taken into account, which is a rough estimate from experts (personal communication with H. Gundogduh). These losses are changed from 10% in the BAU strategy to 0% in the Reduce water loss strategy. Measures to achieve this reduction include piping irrigation canals instead of open canals and the use of drip irrigation by farmers.

In the case study only surface water is taken into account, leaving out most of the domestic water use of the major cities. It is possible to include groundwater in the models, but because of the complexity of groundwater redraws in the area and the lack of reliable information, groundwater was not included within the WatManSup project (see Van Loon et al., 2007).

3.3 Indicators

To quantitatively assess the effects of the strategies and scenarios, indicators are used. The indicators provide insight in the effects of the strategies on the goals of the water manager, which are described at page 7. Furthermore, they make it also possible to assess the impacts on the overall objectives in the basin, as shown in Figure 3.2. We use indicators to link the goals to the physical characteristics of the system. The physical characteristics in this case are: available water, evaporation, and storage in reservoirs. For all four strategies the indicators get a value based on a model run of 15 years, but the scores are average yearly values. The following indicators are used in the evaluation of the strategies:

- Agricultural production: This is the average yearly agricultural production, calculated by multiplying the water use by a gross added value factor of 0.21 US\$/m³ (Harmancioglu et al., 2005);
- Water not used for hydropower: The hydropower plant at Demirköprü reservoir has a maximum capacity of 75 m³/s. At the peak of demand, the outflow tops this capacity and is not used to generate electricity. This loss is calculated by taking the amount of water that is not used and multiply it by the energy it would produce and by the value of one KWatt/hr, which is 0.065 US\$ (Harmancioglu et al., 2005); (Later it became clear outflow of the Demirköprü reservoir is bound to a maximum of 75m³/sec., but it was not possible to set a maximum outflow in the WEAP model. So in the model at certain moments maximum outflow is higher than 75 m³/sec. This was taken into account within the criterion hydro power. Although this does not represent reality, we chose to keep the criterion to show the possibilities of comparing several criteria within one case study);
- Percentage of time environmental flow is met: The demand of the Kuş Cenneti wetlands is known for every month. Sometimes this demand is not met. This indicator takes the total water demand per year and subtracts the water that is available for the wetlands. It is calculated over a period of 15 years, but the indicator value is a yearly average. The minimum value acceptable for sustaining the wetlands is when the environmental flow is met for 75% of the time;
- [BOD], the biological oxygen demand: This is the rate of pollution. The higher the agricultural demand, the more the water is polluted with organic materials. This value is estimated, because it was not modelled.

3.4 Data

Input data necessary for setting up the MCA consists of: hydrological data, crop data, water use data of the several activities in the area. The meteorological and hydrological data are described in the WatManSup Report No. 5 and 6 (Van Loon et al., 2007; Droogers & Van Loon, 2007).

Information on the water consumption of the activities was acquired from literature, for example Harmancioglu et al. (2005), Svendsen et al. (2001), Murray-Rust et al.(2000) and from personal communication with the Turkish partners.

The results of the MCA were presented to the Turkish counterparts during the Izmir workshop in April 2007 (see <http://www.futurewater.nl/watmansup>). During this meeting the participants gave feedback on the choices made in the analysis. Their remarks are taken into account in the final version of the MCA.

3.5 Multi Criteria Analysis

For the MCA average yearly values are used for the indicators. The WEAP model calculated monthly outcomes over a period of 15 years, these data are used to calculate averages per year. The first step in setting up a MCA is defining criteria on which the alternative strategies will be evaluated. For the analysis of the strategies for the Gediz basin, we used the criteria as shown in Figure 3.3 and described in Section 3.3. The strategies are at the top of the figure; there is a BAU strategy, one strategy where the water loss is reduced, a strategy where the environment has top priority, and a strategy

where the total area of irrigated agriculture is expanded, called Adala. The unit of measurement of the criteria is also shown. Two criteria are in millions of US\$, the Environmental flow criterion is in %, and the BOD is displayed on a -- /++ scale, because data is available on water quality. The values in the table of Figure 3.3 are based on the hydrological models and expert judgement.

	C/B	Unit	BAU	Reduced loss	Environment	Adala
Agricultural production	+	Million US\$	111.361	113.223	109.260	114.058
Water not used for hydropower	-	Million US\$	2.554	2.523	2.554	2.572
Environmental flow met	+	% of time	96.5	98.0	100.0	96.1
BOD		--/+++	-	0	+	-

Figure 3.3. Problem definition for the analysis of the water management strategies.

After defining the problem and filling the table, the values for the different criteria need to be standardized. It is not possible to add US\$ and ++, so all the criteria are standardized on a scale of 0 to 1. This means the lowest possible score of a criterion is valued as 0 and the highest possible score of a criterion is valued as 1. Figure 3.4 shows how the criteria of the strategies analysis are standardized. After all the criteria are standardized they can be added up.

	C/B	Unit	Standardization method	Minimum Range	Maximum Range
Agricultural production	+	Million US\$	<input type="checkbox"/> goal	0.000	116.000
Water not used for hydropower	-	Million US\$	<input type="checkbox"/> goal	0.000	116.000
Environmental flow met	+	% of time	<input type="checkbox"/> goal	75.0	100.0
BOD		--/+++	<input type="checkbox"/> maximum	---	+++

Figure 3.4 Standardization.

Not all criteria are evenly important, some are more important than others. DEFINITE gives the opportunity to take this into account in the analysis. When DEFINITE is used in a workshop with different stakeholders, most discussion arises during this part of the analysis. Different stakeholders assign different weights to the criteria. For instance a farmer finds his income the most important, while an environmentalist might find the BOD and environmental flow more important. At these moments the programme serves as a platform for hosting the discussion.

In this study the assigned weights are the result of the workshop of April 2007. Every criterion gets its own weight (see figure 3.5). The weights add up to a total of 1. For this analysis the generated income is most important (hydropower or agricultural) and least important are the environmental criteria. The hydropower and agricultural criteria are assigned the same weight, although at the workshop people valued agriculture higher. However, both the criteria are measured in US\$ and there cannot be a difference in value of a US\$.

	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight
Agricultural production	+	Million US\$	goal	0.000	116.000	0.435
Water not used for hydropower	-	Million US\$	goal	0.000	116.000	0.435
Environmental flow met	+	% of time	goal	75.0	100.0	0.087
BOD		---/+++	maximum	---	+++	0.043

Figure 3.5 Assigning weights.

4. Results

After setting up the analysis as described in the previous chapter DEFINITE ranks the strategies. The outcome of the analysis is shown in Figure 4.1.

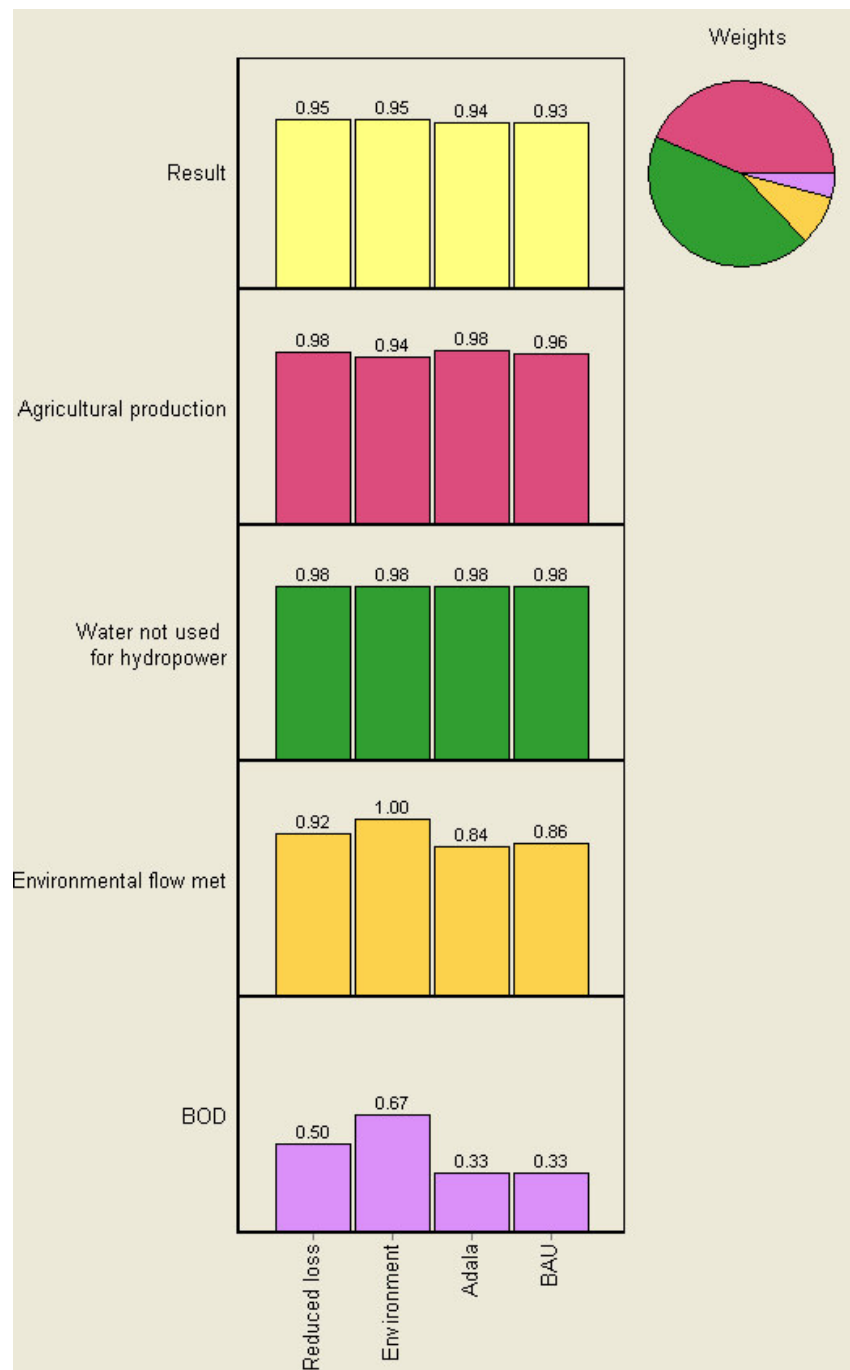


Figure 4.1 Results of the MCA.

Based on the scores of the criteria and the weight of the criteria the best strategy is the Reduced loss strategy. The strategies all have very high scores and the outcomes lie closely to each other. For the criteria Agricultural production and Water not used for hydropower, the strategies have almost the same score. For the other two, there is a bigger difference in scores, but because the weight of these criteria is very low, the impact on the total score is also low.

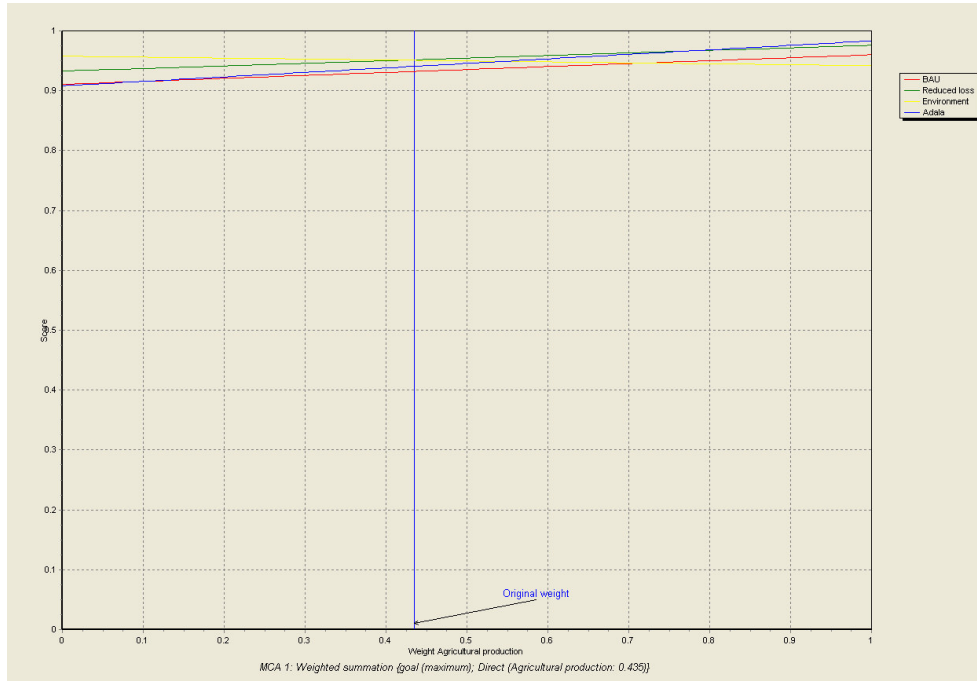


Figure 4.2 Sensitivity assessment.

The weights assigned to the criteria have a large influence on the outcome of the analysis. DEFINITE offers the possibility to assess this influence through a sensitivity assessment. This assessment evaluates whether the ranking would change if the weight of a criterion is higher or lower. Figure 4.2 shows an example of the influence of changes in weight of the criterion Agricultural production. On the x-axis the weight of the criterion is displayed, the y-axis shows the eventual score of the strategy. The blue vertical line shows the original weight of the criterion in the analysis, which is 0.435. If the weight of the criterion would be increased to 0.80 the Adala strategy would have the highest total score and be the best strategy. At this point the line of the Adala strategy crosses the lines of the other strategies. If the weight would be lowered to 0.4 the Environment strategy would have the highest total score. This assessment is done for all criteria, to see how sensitive the analysis is to changes in assigned weights. From the four criteria, the Agricultural production has the largest impact on the outcome. Of the other criteria only Environmental flow can change the ranking one position, when the weight of the score is increased to 0.1. So if the environment is valued a little higher, the Environmental strategy gets the highest score. The same assessment is possible for the scores of the criteria, but as we are certain of the values given to the criteria we will not perform this analysis.

5. Conclusion and discussion

5.1 Conclusion

Based on this multi criteria analysis of the management of the water resources in the Gediz basin, we can conclude that the strategies “Reduced loss” and “Environment” are the best options. They have a higher total score than the strategies “BAU” and “Adala”. If the costs of the strategies would have been taken into account, the Reduced loss strategy would have had a slightly lower score, because investments are needed to reduce evaporation from the irrigation canals. For the Environment strategy there are no additional costs.

The combination of an MCA with hydrological models (a hydrodynamic and an allocation model) provides a water manager with the tools to really make an integrated assessment of the different water management options he has. Within the WatManSup project there was only time to make a quick assessment, but the project showed the potential of the tools. The participants of the workshop in Izmir (April 2007) also acknowledged this. Within a follow-up project the strategies can be elaborated, including more measures like sewage treatment plants, pricing of water, etc. Additionally, there will be more opportunity to iterate with the users and the analysis can be fine-tuned on their needs.

5.2 Discussion

Within the Gediz case a simple and straightforward multi criteria analysis (MCA) was carried out. Only the allocation of the water resources under different strategies was assessed. This was chosen, because the scope of the project was to show how the different tools like WEAP, SWAT and DEFINITE, can be used to make an overall assessment of the allocation of water resources. It will be relatively easy to elaborate the MCA with, for instance, more environmental effects or effects on drinking water.

If more elaborate strategies would be used, the outcome of the IWMSM would be more precise and would thus provide the water managers a more credible advice on the effects of the water management strategies. However, it should be taken into account that more elaborate strategies require information on more subjects and often on a more detailed level, increasing the amount of time needed for the assessment.

Outflow, maximum is $75\text{m}^3/\text{sec}$., but it is not possible to set a maximum outflow in the WEAP model, so in the model at certain moments maximum outflow is higher than $75\text{m}^3/\text{sec}$. This was taken into account within the criterion hydro power. Although this does not represent reality, we chose to keep the criterion to show the possibilities of comparing several criteria within one case study.

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