Institute for Environmental Studies (IVM)

Faculty of Earth and Life Sciences

A multi criteria analysis of water management strategies in Kitui, Kenya.

Report 4 within the WatManSup project

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Research paper 4 within the WatManSup project

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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/watman-sup.

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)

Additional technical support:

- University of Nairobi (Kenya)
- EA-TEK (Izmir, Turkey)

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 WatManSup project is formulated to explore the possibilities of combining hydrological models (WEAP and SWAT) and multi criteria analysis (MCA) tools, to support water managers in making decisions on water management strategies. This report describes the MCA of the Kenya case study. In the Kitui district in Kenya a local water harvesting project is carried out concerning the construction of small scale sand dams by communities. These sand dams are small structures built in ephemeral rivers to store excess water of the rainy season to overcome the following dry period. For this analysis information from the WEAP and SWAT model as well as information acquired during field visits and a workshop are used. It is an explorative analysis, because the goal of the project is to explore the possibilities of using Integrated Water Management Support Methodologies (IWMSM) to support water management decisions, not to solve problems. The outcome of this preliminary analysis is that the management strategy of constructing an extra 500 sand dams is beneficial to the inhabitants and has no large negative impact on the environment and people living downstream, they even benefit of increase in base flow. This strategy was compared to the current situation with approximately 500 sand dams in place and the past situation with no dams in place. Furthermore, the best strategy for farmers is to have diversified activities, because this reduces their vulnerability to variation in precipitation. This strategy has a higher score than the strategy where all water is used for brick production, or the strategy where farmers shift to one crop instead of a mix of crops. However, we recommend doing more in depth research before making the real decision. This case study shows that the combination of hydrological models, local knowledge, and a multi criteria tool is a good approach to support local (water) managers to evaluate the effects of different management strategies.

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 consists of 3 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 the impacts of different water management strategies.

In this report the multi criteria analysis for the Kitui case study in Kenya is described. Together with WatManSup Reports No. 2 and 3 (Van Loon& Droogers, 2006 and 2007) it forms the integrated water management approach for this area.

1.2 Aim

The objective of this study is to analyse several water management strategies and their effect on farmers, the environment and water resources, and to explore the suitability of MCA together with the hydrological models as an integrated approach to water management. This is done on two levels of water management. The first level is the farmer scale: How do the choices of the farmers influence their income, the environment and the water resources downstream? The second level is the subcatchment level: How will the construction of more sand dams influence the farmers, environment and water resources?

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

(After: Lasage et al., 2007)

The Kitui district is a semi-arid region situated 150 km east of Nairobi (Figure 2.1). The total land area is approximately 20,000 km², including 6,400 km² of the uninhabited Tsavo National Park. The elevation of the district is between 400 and 1800 metres above MSL. The central part of the district is characterised by hilly ridges, separated by low-lying areas between 600 and 900 metres above MSL. Approximately 555,000 people inhabit the district (DDP, 2002).

In 1997 the income of 58 percent of the eastern districts was beneath the poverty line of 2 dollars a day (PRSP, 2001). The Kitui district is one of the poorest regions of Kenya. The main economic activity is rainfed agricultur. Irrigated agriculture only takes place on small plots on the riverbanks. During prolonged dry periods the farmers are dependent on relief food from donors. In 2004 and spring 2005 up to 50 percent of the inhabitants of Kitui received food aid (FEWS-NET). Besides farming the main economic activities are charcoal burning, brick making and basket breading.

The meteorology of the area is characterised by rainy periods that are highly erratic and unreliable. The precipitation usually falls in a few intensive storms (Nissen-Petersen, 1982). There are two rainy seasons, one from April to June, the so-called ‘long rains’, and one from October to December, the ‘short rains’. On average the precipitation in the Kitui district is around 900 mm a year, but there are large local differences in amount of precipitation due to topography and other influences. The potential evaporation is high, 1800 to 2000 millimetre a year.

In the Kitui district only 6 percent of the inhabitants has access to potable water (DDP, 2002). Water is the most essential development commodity in this area; the major sources are the ephemeral rivers. Water scarcity forces women and girls to walk up to 20 kilometres in dry periods to water sources such as springs and scoop holes.

A local NGO in Kitui (Sahelian Solution foundation, SASOL) assists local communities in building small scale sand dams to store water in sandy aquifers in ephemeral rivers. This technique improves the availability of water. SASOL’s strategy is to reduce the distance to water sources to less then 2 kilometres and make water available for irrigation. Over the past ten years they succeeded to reach these goals in a large part of the district. Some 65.000 people have better access to water and are less vulnerable to droughts.

Sand dams are impermeable concrete structures constructed across ephemeral rivers with the purpose to harvest water. The sand dams differ from traditional dams by not only storing water in upstream reservoirs, but storing this water within the sand and gravel particles (up to 600 µm) accumulating against the dam and forming an aquifer. Coarse gravel and sand can store and retain up to 35% of their total volume as water.

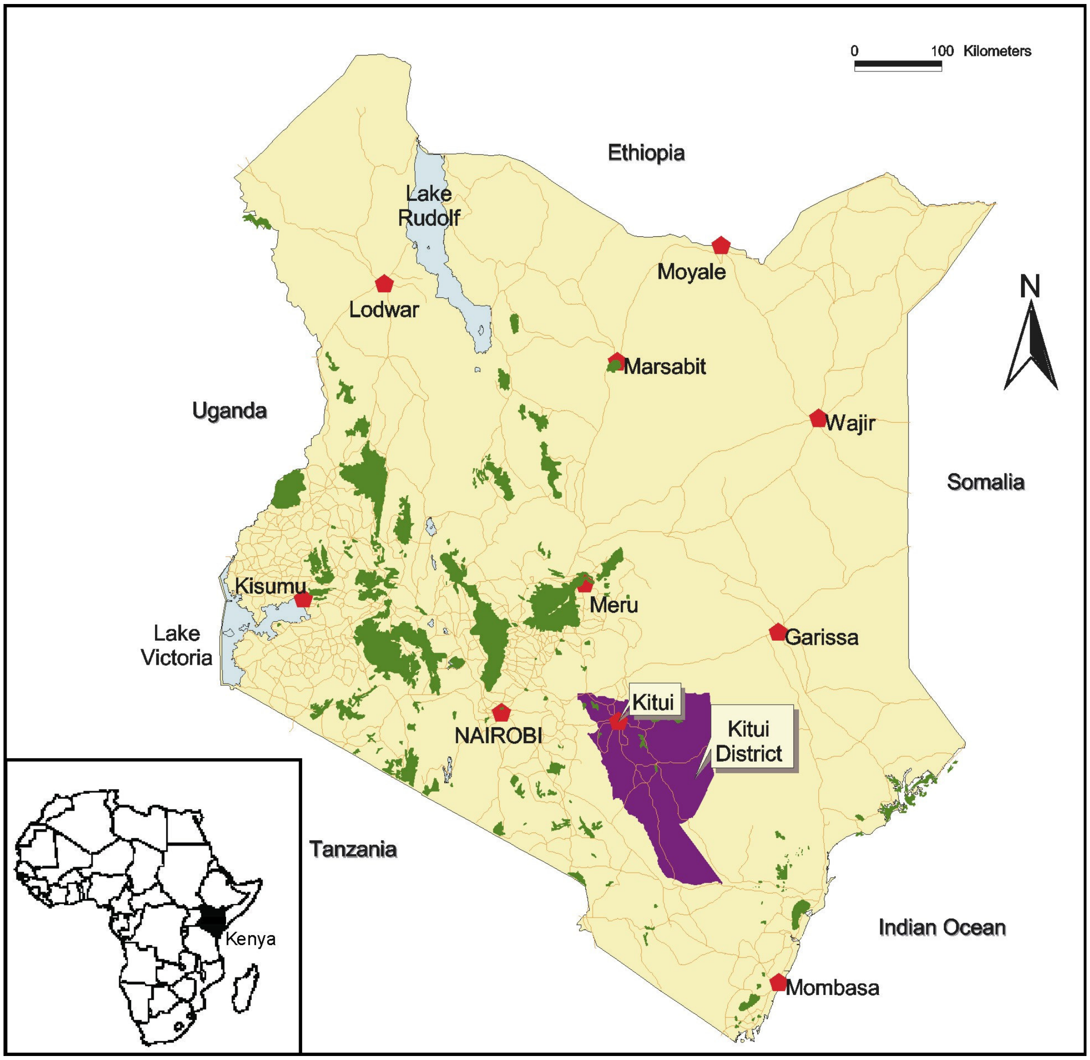

Figure 2.1. Location of the region of Kitui in Kenya (Lasage et al., 2007).

The sub surface reservoir is recharged through flash floods following rainstorms. When the reservoir is filled, surplus water passes the dam without infiltration. The stored water is captured for use by digging a scoop hole, or constructing an ordinary well or tube well. By storing the water in the sand, it is protected against high evaporative losses and contamination (Tuinhof et al., 2003; Guiraud, 1989). As water flows through the sand it is also filtered and biological threats, like bacteria, are reduced (Huisman & Wood, 1974). Another advantage of sand dams compared to regular dams is that less mosquitos are present in the area, due to a of lack of surface water. Hydrological researchhas shown that the dams store only up to 3% of the yearly runoff produced in the catchment area between two dams (Borst & de Haas, 2006), supplying an extra amount of water of 8,000 m^3 a year to the on average 150 people that use a dam. This water is used to bridge the dry periods during the year.

For the Kitui case study we will analyse two levels of management. The first level is the level of the farmers and how water management measures influence their income, the environment and the water resources downstream. The second level is the subcatchment level, which is the level of the water manager. Here we will analyse how the construction of more sand dams influences the farmers, environment and water resources. This approach is chosen because both levels are highly important for the conditions of the farmers, and because the Kenyan partners are interested in both scales.

More information on the hydrological background of the studied area is described in the WatManSup Working Paper No.1 (Van Loon et al., 2006) and Report No.2 and 3 (Van Loon & Droogers, 2006 and 2007), which were written in the context of the project.

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.

2.3 Approach

For the project several management strategies were designed. These strategies consist of measures farmers can take (e.g. switch crops, change planting date, etc.), that might improve their living standard. Improving the living standard is the objective of the famers, this and other objectives are shown in Figure 3.2. These strategies are then tested under different conditions, to see if they are robust. These different conditions are called scenarios. A scenario is a possible future situation; in this case study we defined three scenarios. One scenario represents the current situation, 500 sand dams are in place. One scenario evaluates the original situation without any sand dams in the region. And in the last scenario an extra 500 sand dams are assumed to be build, so that a total of 1000 are in place. 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 or distance to water source). Within a MCA, indicators are called criteria. The measures under the strategies affect the values of the indicators, enabling an assessment of the impact of the strategies. DEFINITE is used to follow this approach in a structured way and the program has more features to make further assessments of the strategies.

3. Scenarios & Strategies

For the Kitui case study we evaluated the robustness of three different water allocation strategies on farm level and three scenarios of water availability on subcatchment level. Water availability in each scenario is determined by the presence of either no dams, 500 or 1000 dams. The scenarios and strategies are considered under current climate conditions using a time series of climate data over the period 1990-2004. The scenarios and strategies are developed in cooperation with the partners within the project.

Climate data, scenarios and allocation strategies are used as input to the hydrological models SWAT and WEAP. The models will 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. We will use a multi criteria analysis tool to compare the effects of the strategies. The workflow of the project is drawn in Figure 3.1.

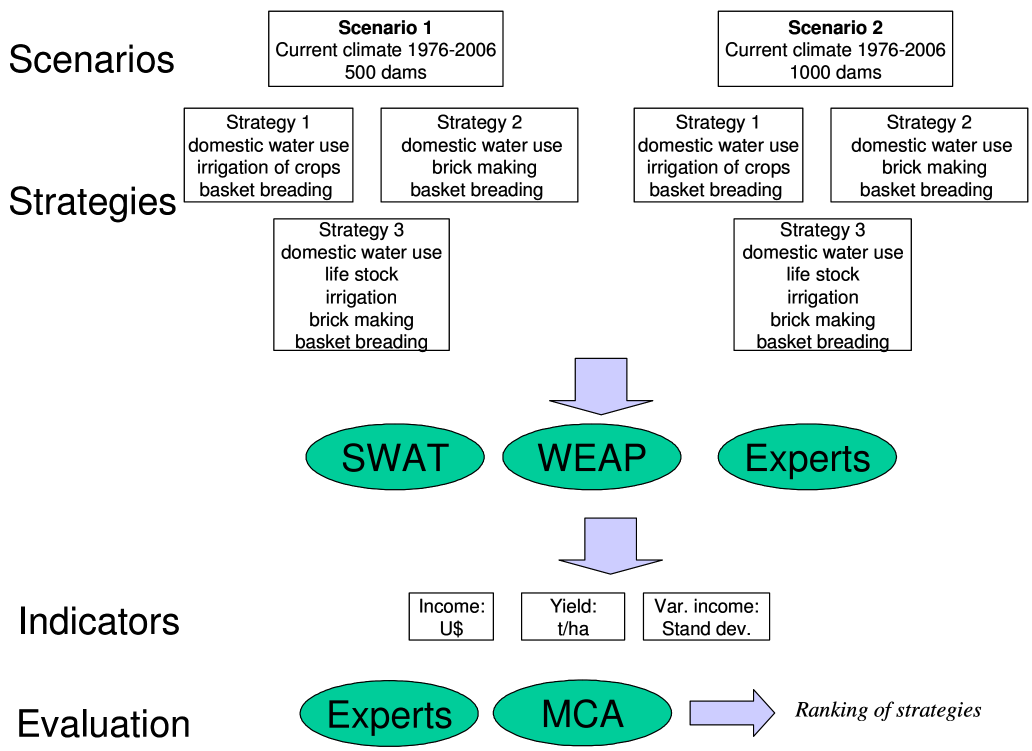

Figure 3.1 Evaluation of strategies against indicators/criteria.

We assume the farmers in the region have specific objectives, like increasing their income and having low risks on crop failure. 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.

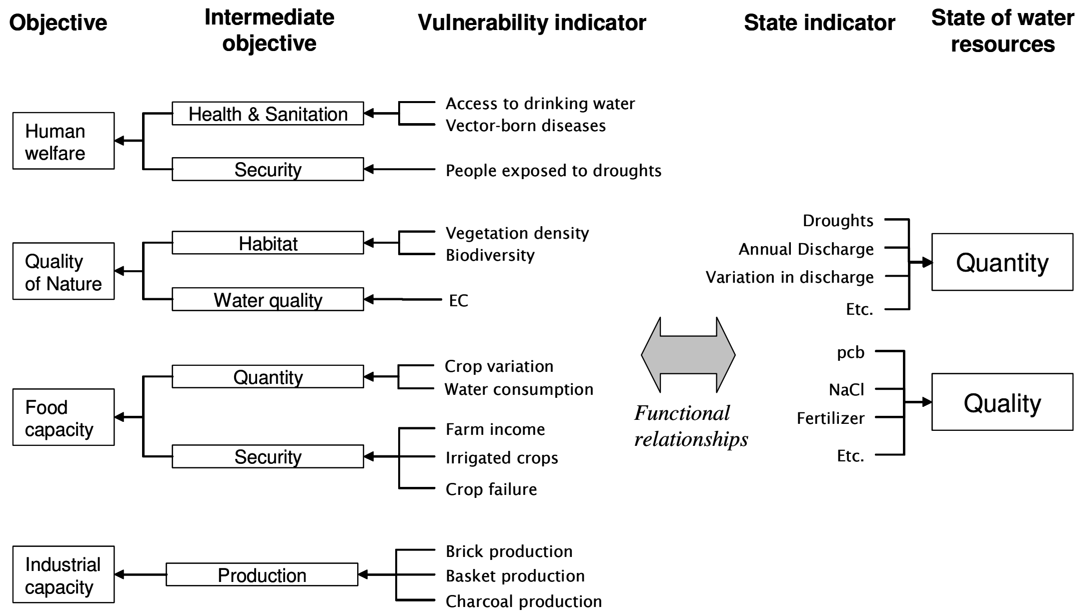

Figure 3.2 Decision tree with objectives and vulnerability indicators on the left and state indicators on the right (Aerts and Droogers, 2004).

3.1 Scenarios

A scenario is a description of a possible future situation. We have selected three scenarios: one presenting the current situation in Kitui, one without any dams, and one where the dam capacity is doubled. A doubling of the dam capacity is achievable in two ways; by constructing more dams, or by increasing the storage capacity per dam. In this project we assume more dams will be build. So, the following three scenarios are used in Kitui case study:

1. 500 dams (number of dams in 2006);
2. No dams;
3. 1000 dams.

The scenarios are put into the WEAP model, generating three sets of water availability data, one for each scenario. The most important positive effect of the second scenario is that there will be more water available for different activities, that are described in the following section. A possible negative effect is the capture of too much water, so that the downstream part of the basin has less water available. The indicators corresponding to the objectives, as shown in Figure 3.2, are be used.

3.2 Strategies

The developed strategies are different in the way the available water is allocated to the activities and how the available time of farmers is spent. During research in the area we found that the farmers have the following goals: to reduce their vulnerability to droughts, to increase their income, and to have a low variability in income and production over the seasons (Aerts & Lasage, 2005). In this study we test how varying the priorities of the farmers activities in the area affect these goals.

The activities are:

a) Domestic use;
b) Life stock;
c) Irrigated agriculture;
d) Brick making;
e) Basket breading.

(after: Lasage et al., 2007)

The following 3 strategies are designed to be tested under the two scenarios:

1. Only irrigation;
2. Only bricks;
3. Base line.

The strategies differ in the priority that is given to the activities. A minimum level of domestic water use is assumed, because the inhabitants always need to use a certain amount of water to survive. Available water is allocated first to the top activity, then to the second and so on until all available water is used. Thus, the least priority activity will be cut first when less water is available. The available water per rainy season comes from the hydrological models. Using expert judgement and the results of prior research (de Bruijn & Rhebergen, 2006; Van Loon & Droogers, 2006 and 2007; and Lasage et al., 2007), the water is allocated to the different uses under the different strategies, keeping in mind the prioritisation of the activities and the amount of water these activities use. We have developed strategy 1 and 2 to get insight in how income might be optimised and how this relates to a strategy that resembles the current activities of the farmers (strategy 3). The strategies are described in more detail below:

1. Only irrigation

This strategy uses the following order in allocation of water and time to activities:

- Domestic water use;
- Irrigation of crops (three crops are tested under this strategy, kale, union and tomato);
- Basket breading.

2. Only bricks

This strategy uses the following order in allocation of water to activities:

- Domestic water use;
- Brick making;
- Basket breading.

3. Base line

This strategy uses the following order in allocation of water to activities:

- Domestic water use;
- Life stock;
- Irrigation;
- Brick making;
- Basket breading.

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 local farmers, which are described at page 7. They allow for assessing 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 the occurrence of droughts. Because the strategies only aim at the water allocation, these physical characteristics of the supply side are the same under all the strategies. On the demand side the differences occur in how the water is used. For instance differences in crop factor between crops, time consumed by activities, differences in drought resistance between activities. For all three different strategies under both the scenarios the indicators get a value for every rainy season.

The following indicators (after: Lasage et al., 2007) are used in the evaluation of the strategies under the different scenarios:

- Access to drinking water
- Farm income
    - Variation in income;
    - Irrigated agriculture;
    - Life stock;
    - Brick production;
    - Basket weaving (is a factor of time saved fetching water and time spent on other time consuming activities, like irrigation);
    - Charcoal production (is negatively correlated with quality of nature).
- Crop failure
    - Variation in crop production / yield;
    - Rain fed (chance on crop failure per growing season, where growing season = rainy season)
    - Irrigated
- % of total runoff stored by dams (Aerts, 2007)
- Standing biomass (amount of biomass in the area besides agricultural crops. This represents the state of nature.)

3.4 Data

Input data necessary for setting up the MCA consists of: meteorological data, hydrological data, crop data, water use data of the several activities in the area. The meteorological and hydrological data were gathered and are described in the WatManSup Reports No.2 and 3 (Van Loon & Droogers, 2006 and 2007).

Information on the water consumption of the farmer activities was acquired from a study by De Bruijn and Rhebergen (2006). This was further elaborated with information from the research of Rempel et al. (2005).

These data were combined. The water use of several crops, like tomato, kale and onion, the potential evaporation during the growing season, and the amount of precipitation in the area were used to calculate maximum harvest of rainfed agriculture. From the total amount of available water in the sand dams, the water used by households is subtracted. The remaining water, is directed to the production of irrigated crops, bricks or livestock.

The results of the MCA were presented to Kenyan counterparts during the Kitui workshop in March 2007 (see 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

3.5.1 Setting up the farmer strategies MCA

For the MCA on the farmer scale we assume that all users of one sand dam will use the same amount of water, this means the total amount of available water of one sand dam is divided equally over 20 households (Aerts & Lasage, 2005). For the evaluation of the effects of the strategies, the water use of one household is assessed. To assess the full potential of a sand dam, these results need to be multiplied by 20.

To set up a MCA criteria, also named indocators, on the alternatives are evaluated need to be defined. For this analysis we used the indocators as shown in Figure 3.3 as criteria. Most of them are related to the income of the farmer, only the biomass criterion represents the environment. The strategies are at the top of the figure; there is a base line strategy, one strategy where the water is used to make bricks, and three strategies where the water is used for the irrigation of different crops (Kale, Tomato or Union). The unit of measurement of the criteria is also shown. Most indicators are in US$, but the ones where no exact number can be given are displayed on a -- /++ scale. The values in the table of Figure 3.3 are based on the hydrological models, expert judgement, and field research carried out in an earlier stage.

	C/B	Unit	Base line	Only bricks	Only irrigation (Kale)	Only irrigation (Tomato)	Only irrigation (Onion)
Variation in income		--/++	+	-	0	0	0
Income brick production	+	US$	25	384	0	0	0
Income life stock	+	US$	0	0	0	0	0
Income irrigated agriculture	+	US$	28	0	33	20	39
Income weaving	+	US$	70	70	50	50	50
Income charcoal	+	US$	20	0	0	0	0
Standing biomass		--/++	0	-	+	+	+

Figure 3.3 Problem definition for the strategies analysis.

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.

Method: Weighted summation Analysis Description: MCA 1: W

	C/B	Unit	Standardization method	Minimum Range	Maximum Range
Variation in income		--/++	maximum	--	++
Income brick production	+	US$	goal	0	600
Income life stock	+	US$	goal	0	600
Income irrigated agricultu	+	US$	goal	0	600
Income weaving	+	US$	goal	0	600
Income charcoal	+	US$	goal	0	600
Standing biomass		--/++	maximum	--	++

Figure 3.4 Standardization.

Not all criteria are evenly important, some are more important then 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 standing biomass more important. At these moments the programme serves as a platform for hosting the discussion.

In this study the variation in weight is the result of the Kitui workshop of March 2007. Every criterion has its own weight (see Figure 3.5). The weights add up to a total of 1. For this analysis variation in income is most important, than all the income generating activities, and least important is the standing biomass criterion.

	C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight
Variation in income		--/++	maximum	--	++	0,267
Income brick production	+	US$	goal	0	600	0,133
Income life stock	+	US$	goal	0	600	0,133
Income irrigated agriculture	+	US$	goal	0	600	0,133
Income weaving	+	US$	goal	0	600	0,133
Income charcoal	+	US$	goal	0	600	0,133
Standing biomass		--/++	maximum	--	++	0,067

Figure 3.5 Assigning weights.

3.5.2 Setting up the scenarios MCA

For the catchment scale analysis we assess three scenarios that might be implemented in the area. These are the scenarios No dams, 500 dams and 1000 dams, see Section 3.1 for a more elaborate description of these scenarios. Setting up the analysis in DEFINITE takes the same steps as described in the previous Section. Figure 3.6 shows the scenarios, criteria and scores as they come from the models and the stakeholders.

		C/B	Unit	No dams	500 dams	1000 dams
−	**State indicators**					
	% runoff stored by dams	−	%	0,00	1,81	2,83
	Period of active base flow	+	Months	4	5	6
−	**Human welfare**					
	Access to drinking water, wet season	−	Km	0,765	0,765	0,500
	Access to drinking water, dry season	−	Km	3,049	0,765	0,500
	Time invested in dam construction by HH	−	days	0	60	120
−	**Quality of nature**					
	Vegetation density		0/++	0	+	+
	Biodiversity		0/++	0	0	+
−	**Houseehold income**					
	Irrigated crops	+	US$	10	20	40
	Brick production	+	US$	0	25	50
	Life stock	+	US$	20	28	28
	Basket production	+	US$	30	70	45
	Charcoal	+	US$	30	20	0

Figure 3.6 Problem definition for scenarios analysis

More criteria are used in this analysis compared to the previous strategies analysis, because more stakeholders are involved and more information is available on this scale. The main groups of criteria are based on the analytical framework as shown in Figure 3.2.

Figure 3.7 summarises the standardization and assignment of weights. Weight level 1 divides the weight between the main categories of criteria. The stakeholders give both Human welfare and Household income the highest weight of 0.333. Weight level 2 divides the weights between the subcriteria within the main categories. The final weight per criterion is determined by multiplying weight level 1 with weight level 2.

Method: Weighted summation Analysis Description: MCA 1: Weighted summation {goal (maximum,conc

		C/B	Unit	Standardization method	Minimum Range	Maximum Range	Weight level 1	Weight level 2	Weight
−	**State indicators**						0,222		
	% runoff stored by dams	−	%	goal	0,00	10,00		0,500	**0,111**
	Period of active base flow	+	Months	goal	0	12		0,500	**0,111**
−	**Human welfare**						0,333		
	Access to drinking water, wet season	−	Km	maximum	0,000	0,765		0,286	**0,095**
	Access to drinking water, dry season	−	Km	maximum	0,000	3,049		0,571	**0,190**
	Time invested in dam construction by HH	−	days	goal	0	360		0,143	**0,048**
−	**Quality of nature**						0,111		
	Vegetation density		0/++	concave	0	++		0,800	**0,089**
	Biodiversity		0/++	maximum	0	++		0,200	**0,022**
−	**Houseehold income**						0,333		
	Irrigated crops	+	US$	goal	0	200		0,222	**0,074**
	Brick production	+	US$	goal	0	200		0,222	**0,074**
	Life stock	+	US$	goal	0	200		0,222	**0,074**
	Basket production	+	US$	goal	0	200		0,222	**0,074**
	Charcoal	+	US$	goal	0	200		0,111	**0,037**

Figure 3.7. Standardization and assignment of weights.

4. Results

4.1 Farmer strategies

After setting up the analysis as described in the previous Chapter, we rank the strategies. The outcome of the analysis is shown in Figure 4.2.

	C/B	Unit	Base line	Only bricks	Only irrigation (Kale)	Only irrigation (Tomato)	Only irrigation (Onion)
Variation in income		--/++	+	-	0	0	0
Income brick production	+	US$	25	384	0	0	0
Income life stock	+	US$	0	0	0	0	0
Income irrigated agriculture	+	US$	28	0	33	20	39
Income weaving	+	US$	70	70	50	50	50
Income charcoal	+	US$	20	0	0	0	0
Standing biomass		--/++	0	-	+	+	+

Figure 4.1. Scores for strategies.

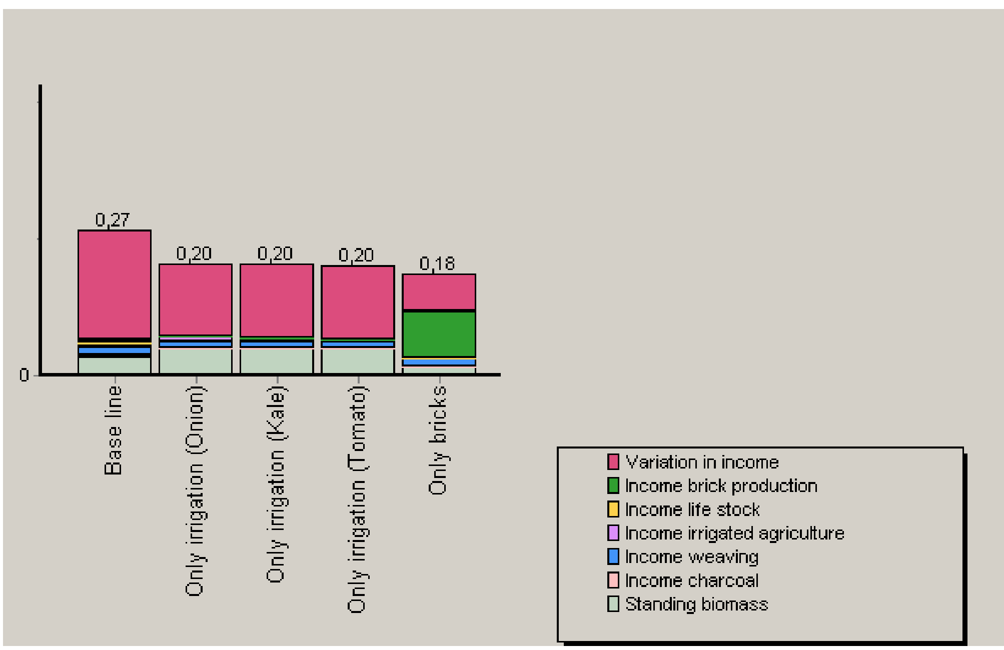

Figure 4.2. Results of the strategies MCA.

Based on the scores and weights of the criteria the best strategy is the base line strategy. Figure 4.2 shows the ranking of the strategies and how this score is achieved. The most important criterion contributing to the score is Variation in income criterion. The irrigation strategies are second with the same score and the strategy with the lowest score is the Only bricks strategy.

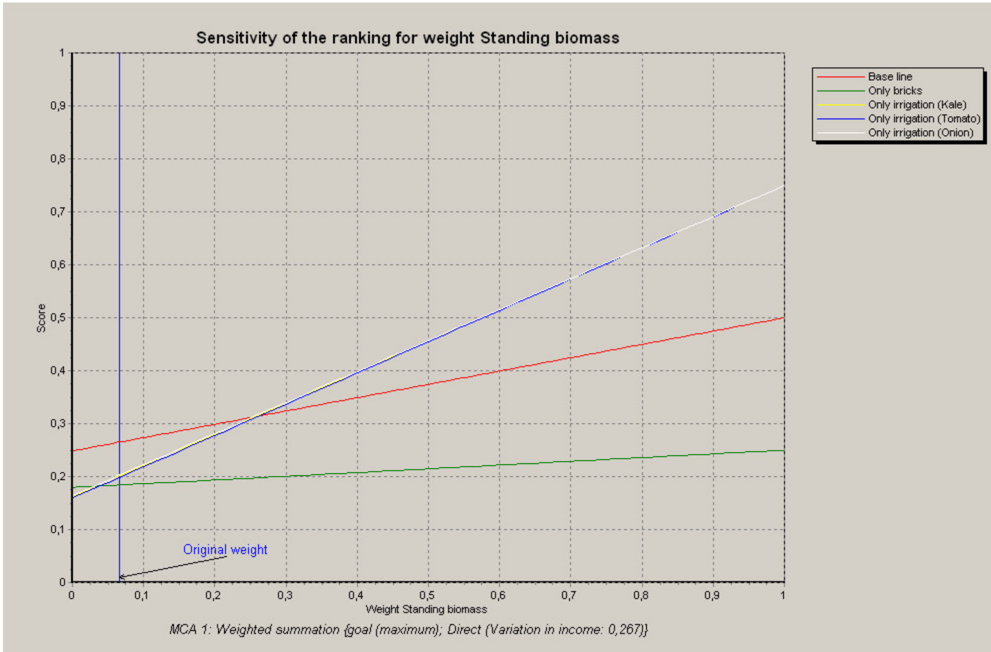

Figure 4.3 Sensitivity assessment.

The weights attached 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 if the ranking would change whether the weight of a criterion is higher or lower. Figure 4.3 shows an example of the influence of changes in weight of the criterion Standing biomass. 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 0.06. If the weight of the criterion would be increased to 0.25 the irrigation strategies would have a higher total score than the base line strategy. At this point the lines of these strategies cross the line of the base line strategy. If the weight would be lowered to 0.04 the irrigation strategies would have a lower total score than the only bricks strategy. This assessment can be done for all the criteria, to see how sensitive the analysis is to changes in assigned weights. 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 do this analysis.

4.2 MCA scenarios

After setting up the analysis as described previously the strategies are ranked, as shown in Figure 4.4. The 1000 dams scenario is ranked first. The No dams scenario is ranked last, with a large difference between its score and those of the other two scenarios. On the most important criteria, Human welfare and Household income, the 1000 dams scenarios has the highest score. The sensitivity analysis shows that only the criterion State indicator can change the ranking of the alternatives. However, this only happens when this criterion is assigned a weight of 0.87, which is not realistic. Changes in weight of the other criteria do not affect the final ranking.

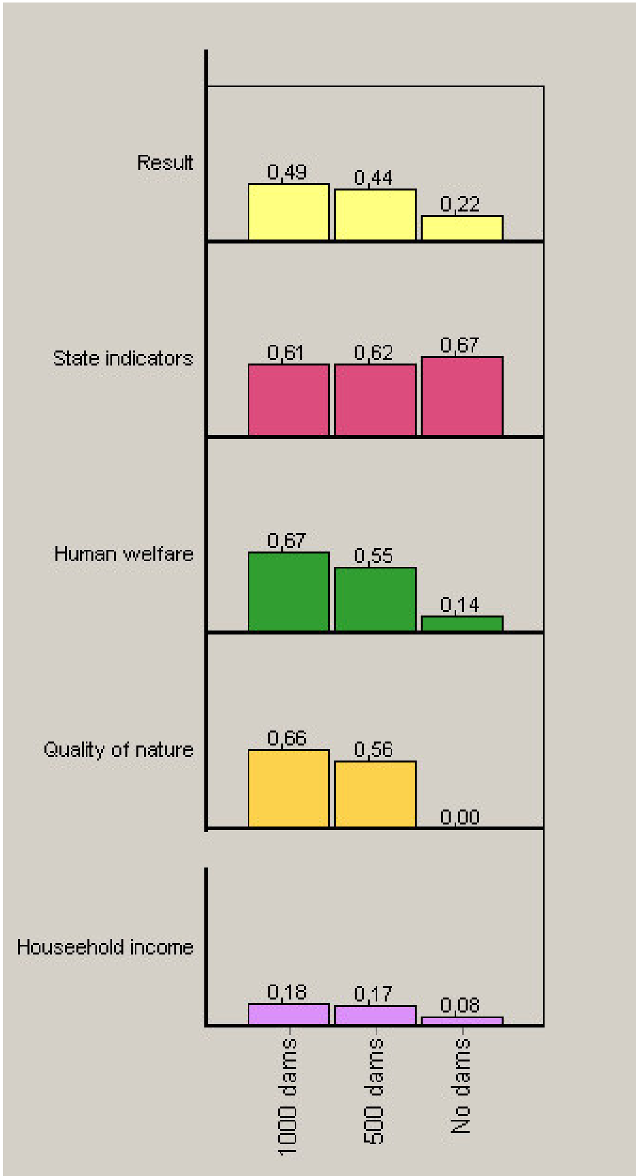

Figure 4.4 Results scenarios analysis.

5. Conclusion and discussion

5.1 Conclusion

Based on a multi criteria analysis of the management of the water resources in the Kitui district, we can conclude that the current farming method is the best, and that the construction of another 500 dams in the district has a positive impact on almost all the activities in the region.

The combination of a MCA with hydrological models (a hydrodynamic and an allocation model) provides a water manager 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. This was also acknowledged by the participants of the Kitui workshop in March 2007. Within a possible follow up project more iterations can be made with the participants and the hydrological models and the analysis can be fine tuned on their needs.

5.2 Discussion

For the analysis of the effect of the different water allocation strategies, other influences on income than water availability, like time spent or education, were not included. Effects of pests on the harvest and other effects were left out of the analysis, giving a maximum income per household. The actual income of the households will almost certainly be lower than this maximum.

Average market prices were obtained from stakeholders in the project. In reality prices fluctuate during the year, and will be low during harvest periods and high at the end of the dry periods. An individual farmer can earn more money by selling at the time the prices are high, but will earn less when the products are sold at low prices.

Within the Kitui case a simple and straightforward multi criteria analysis 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 to assess the functioning of a household, including time spent on other activities. The costs and benefits of building a sand dam can also be assessed with DEFINITE. Furthermore, the effect of the choice of the location of sand dams can be included in this assessment. These are some examples of uses of the DEFINITE programme, which are out of the scope of the WatManSup project.

During the workshop the possibility of using DEFINITE on basin scale was acknowledged, helping the water managers to evaluate the different management possibilities, also to evaluate whether projects contribute to the realisation of the Millennium Development Goals.

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