# Deliverable N.: D3.1.2

# Title: Report of upscaling scenarios for BMPs for relevant catchment areas (contribution to A3.2)

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WATDEV CONSORTIUM

The project consortium is comprised of:

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| EGYPT | Heliopolis University (HU) |
| ETHIOPIA | Water and Land Resources Institute (WLRI) |
| FINLAND | Finish Environment Institute (SIKE) |
| ITALY | Centro Internazionale di Alti Studi Agronomici Mediterranei di Bari (CIHEAM-Bari) |
| ITALY | Italian Research Council (CNR) |
| KENYA | Kenya Agricultural & Livestock Research Organization (KALRO) |
| SUDAN | Water Research Centre (WRC) |
| THE NETHERLANDS | International Soil Reference and Information Center (ISRIC) |
| UGANDA | Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) |

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| Abstract (for dissemination) | To be able to further develop the WATDEV modelling toolbox and to provide input in terms of scenarios to be simulated with the toolbox, the overall objective was to identify suitable scenarios according to the perspectives of the local stakeholders at two different levels (local and regional stakeholder groups). First the local stakeholders (i.e. farmers and land users) were consulted in a series of workshops (March – April 2024).<br><br>The specific objectives were to specify the details of the BMPs to be considered in the scenarios and to indicate where they would best be implemented according to the local stakeholders' perspectives. The stakeholders discussed this in groups (mostly according to their farms' location in the study area). Secondly, the regional stakeholders were consulted during the stakeholder Forum (May 2024) with the objective to (i) get insight into the indicators that they are interested in vis-à-vis how they can be incorporated in the modelling toolbox; (ii) specify which types of scenarios are most interesting for each partner and (iii) they were asked to design their optimal scenarios. The stakeholders discussed this in groups according to country. The regional stakeholder sessions showed that different countries are interested in different types of scenarios with most countries being interested in spatial differentiation of BMP application and in combining BMPs on the same location. The results will be further used to develop the modelling toolbox to be able to serve the needs of the stakeholders in terms of scenarios to be quantified by the model. |



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| Keywords | Model scenarios; Stakeholders; Modelling tool |

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## Acronyms and Abbreviations

| | |
|---|---|
| AICS | Italian Agency for Development Cooperation |
| ASARECA | Association for Strengthening Agricultural Research in Eastern and Central Africa, Uganda |
| AU-EU | Africa-Europe |
| CIHEAM | Centre International de Hautes Etudes Agronomiques Méditerranéennes, Italy |
| CNR- | Consiglio Nazionale delle Ricerche, Italy |
| DG DEVCO | The Commission's Directorate-General for International Cooperation and Development |
| EIARI | Ethiopian Institute of Agricultural Research, Ethiopia |
| EU | European Union |
| FAO | Food and Agricultural Organization of the United Nations |
| HCENR | Higher Council for Environment and Natural Resources, Sudan |
| HRC | Hydraulics Research Center- Ministry of Water and Irrigation- Gezira, Sudan. |
| HU | Heliopolis University, Egypt |
| ISRIC | International Soil Reference and Information Center, The Netherland |
| IWUA | Irrigation Water Users Association |
| KALRO | Kenya Agricultural & Livestock Research Organization, Kenya |
| KU | Khartoum University, Sudan |
| MCA | Multi-criteria Analysis |
| NIA | National irrigation Authority, Kenya |
| NRC | National Research Council, Sudan |
| R&I | Research and Innovation |
| SACCO | Savings Credit and Cooperative Organizations |
| SMA | Sudan Meteorological Authority, Sudan |
| SOM | Soil Organic Matter |
| STI | Science, Technology, and Innovation |
| SYKE | Finnish Environment Institute, Finland |
| TARDA | TAna River Development Authority, Kenya |
| WATDEV | Climate Smart WATer Management and Sustainable DEVelopment for Food and Agriculture in North and East Africa |
| WB | World Bank |
| WLRC | Water and Land Resources Center, Ethiopia |
| WMII | Water Management and Irrigation Institute, Sudan |
| WRC | Water Research Centre, Sudan |
| WUA | Water User Association |
| WUE | Water-Use Efficiency |

# Executive Summary

The Climate Smart WATer Management and Sustainable DEVelopment for Food and Agriculture in East Africa (WATDEV) aims to enhance sustainability of agricultural water management and resilience of agro ecosystems to climate change in Easter Africa and Egypt. AICS (Agenzia Italiana per la Cooperazione e lo Sviluppo) is the executive agency, CIHEAM-BARI is leading scientific institution working with ASARECA (Strengthening Agricultural Research in Eastern and Central Africa), KALRO (Kenya Agricultural and Livestock Research Organization), WLRC (Water, Land Resources Centre - Ethiopia), WRC (Water Research Centre, Sudan) and HU (Heliopolis University, Egypt). ISRIC (International Soil Reference and Information Centre – The Netherlands) and SYKE Finnish Environment Institute (Finland) are the modelling partners. The overarching objective of the project is to enhance sustainability of agricultural water management and resilience of agro ecosystems to climate change in East Africa and Egypt. The specific objectives include: (1) National Ministries and Research Institutions improve their knowledge and management of water in agriculture; and (2) Farmers and local actors, cooperatives and Water User Associations implement innovative/sustainable solutions and skills on water management.

A modelling toolbox, that will simulate the effect of selected BMPs (Best Management Practices) on environmental indicators, is being developed by the modelling partners. To be able to further develop the WATDEV modelling toolbox and to provide input in terms of scenarios to be simulated with the toolbox, the overall objective was to **identify suitable scenarios according to the perspectives of the local stakeholders** at two different levels (local and regional stakeholder groups).

First the local stakeholders (i.e. farmers and land users) were consulted in a series of workshops (March – April 2024). The specific objectives were to specify the details of the BMPs to be considered in the scenarios and to indicate where they would best be implemented according to the local stakeholders' perspectives. The stakeholders discussed this in groups (mostly according to their farms' location in the study area). Secondly, the regional stakeholders were consulted during the stakeholder Forum (May 2024) with the objective to (i) get insight into the indicators that they are interested in vis-à-vis how they can be incorporated in the modelling toolbox; (ii) specify which types of scenarios are most interesting for each partner and (iii) they were asked to design their optimal scenario. Here, the stakeholders discussed this in groups according to their country.

The results will be further used to develop the modelling toolbox to be able to serve the needs of the stakeholders in terms of scenarios to be quantified by the model. The regional stakeholder sessions showed that different countries are interested in different types of scenarios with most countries being interested in spatial differentiation of BMP application and in combining BMPs on the same location.

# 1. Introduction

## 1.1 Background

Potential (types of) scenarios, to be implemented and simulated with the modelling toolbox, were developed in close collaboration with local and regional stakeholders. First, local stakeholders were involved and asked for their perception and priority for scenarios in local workshops in the four countries (Egypt, Ethiopia, Kenya and Sudan).

This links closely to activity A3.2 and the workshops were integrated in the local stakeholders' awareness meetings in spring 2024, as a participatory session to identify suitable scenarios according to the perspectives of the local stakeholders. Here, the focus was on the details of the BMPs on the ground, e.g. to specify which crops and trees would form a desired agroforestry system and / or where exactly the BMPs would be implemented.

Then, a session with the regional stakeholders was carried out during the second stakeholder forum in Bari, Italy in May 2024. The focus was on which types of scenarios the different regional stakeholders would prioritize, which is valuable information for the modelling team to further develop the modelling toolbox.

## 1.2 Objectives of the Participatory Scenario Development

### 1.2.1 Overall Objective

The overall objective was to identify suitable scenarios according to the perspectives of the local stakeholders at two different levels (local and regional stakeholder groups).

### 1.2.2 Specific Objectives

The specific objectives were, for the local stakeholders' meetings to:

- Specify the objective of the scenarios
- Specify the details of the BMPs (potentially in combination) to be considered in the scenarios
- Indicate the spatial location of the BMPs

For the session with the regional stakeholders the specific objectives were:

- Get insight into the indicators that they are interested in vis-à-vis how they can be calculated in the toolbox
- Specify which type of scenarios are most interesting for each partner
- Design an optimal scenario (optional)

# 2. Methodology

## 2.1. Workshops with local stakeholders

In three countries (Egypt – 4-5 March 2024; Kenya – 8-9 April 2024; and Ethiopia – 19-20 April 2024) live workshops were held with local stakeholders to identify suitable scenarios.

In Sudan, a live workshop was not possible due to the conflict situation, but similar information was gathered in June 2024.

In each workshop, the following steps were taken:

**1 – Model introduction**

It was explained to the stakeholders that within the WATDEV project, a toolbox is being developed that simulates how the BMPs affect different aspects of the environmental characteristics. It is important to know which models can respond to specific issues on the ground. The models are important in understanding the current situation, predicting what can happen in the future and informing the subsequent control and management of options for adaptive management practices.

In the toolbox preparation four major steps can be recognized: (i) listing of the selected BMP candidates, (ii) identifying the main Model's processes that are linked or affected by the BMPs, (iii) identifying the Model's expected outcomes, and (iv) Proposing a list of Models that responds to the previous criteria. The steps are illustrated in figure 1 below (example for Egypt):

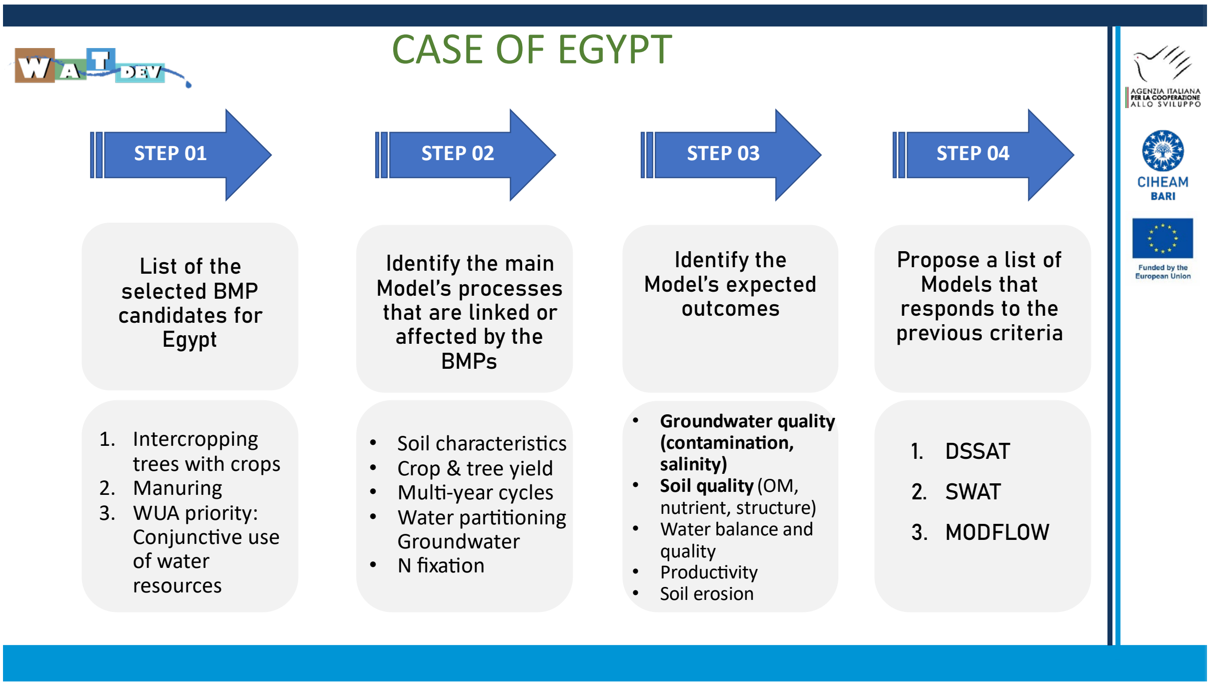



**Figure 1** - Toolbox preparation steps, example for Egypt.

The toolbox will consist of two main coupled models, one focused on the crop dynamics (DSSAT) and one on the overall water and land use dynamics (SWAT-MODFLOW). Important factors considered include: (i) soil conditions, (ii) weather conditions, and (iii) management of the soil.

All these factors are used in the model to predict yield and environmental impacts as shown in Figure 2:

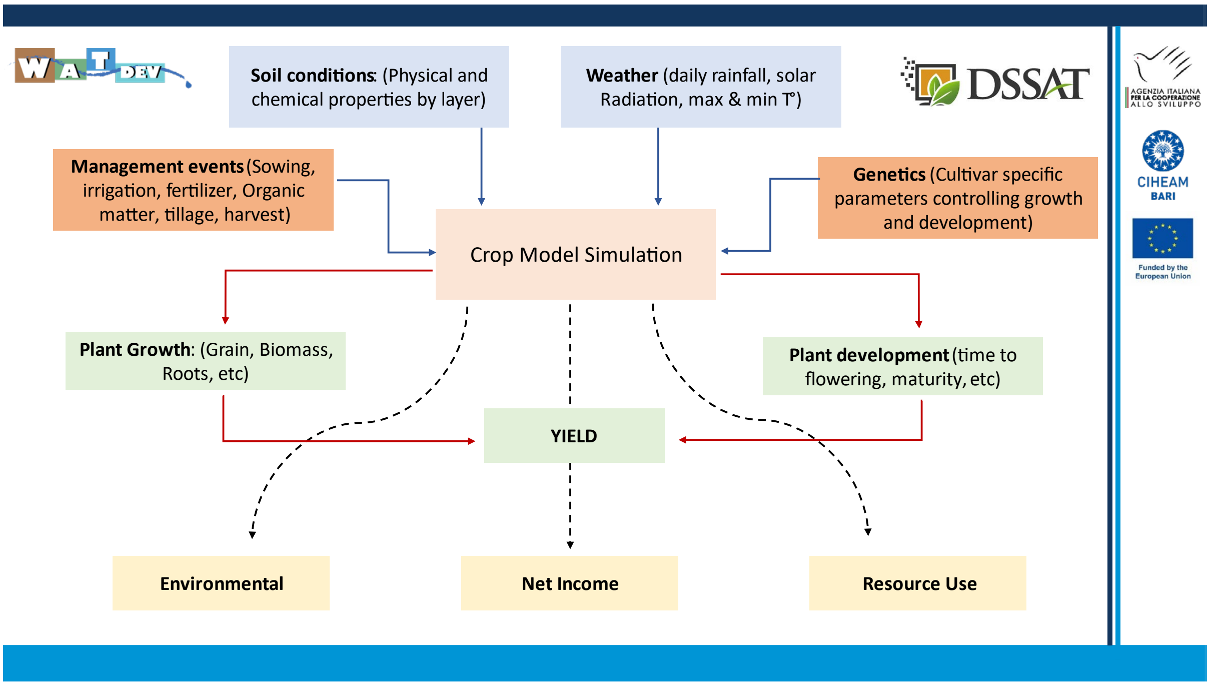



**Figure 2** - Model components and outcomes as presented to local stakeholders during the workshops.

The model uses different spatial units with similar soil and land use conditions. The BMP interventions are defined at the level of the spatial unit, and it is important to link this to water management. Several scenarios are possible including blanket implementation, strategic implementation (where most useful), budget considerations and combinations.

The model can be set up for a defined assessment period where time step is one day and the length is limited by the climate scenario projection (several decades). Different scenarios are possible for example optimization within a specific period e.g. 1 year or multi-annual trends for example for long-term effects of climate change.

The model will be useful in answering questions that key stakeholders, especially farmers have. It is important to know what combinations of BMPs farmers would like to compare to determine what the objectives of the model would be.

**2 – Group exercises for scenario development**

The farmers were then divided into four groups where they discussed preferred BMPs (from various aspects in their areas). Specifically, each group was tasked with responding to the following questions:

- Specify the objective: what do you want to improve?
- What BMPs would you consider?
- Can you specify the BMPs?

  - Intercropping: which crops, which trees?

  - Manuring: which type, what sources?

  - Water management: what changes? (e.g., source, distribution)
- Where would you implement the BMPs?
- Do you envisage a combination of BMPs?

**3 – Plenary reporting**

After the exercises, a representative of each group summarized the main findings of the group.

## 2.2. Participatory sessions with regional stakeholders

On 13 May 2024 the 2nd stakeholder Forum was held in Bari, Italy and one of the sessions was dedicated to participatory discussion of modelling scenarios. The methods and activities were as follows:

**1 – Overview and recap of current challenges in each country and short explanation of the model**

ISRIC gave a brief recap of the challenges as identified and discussed in previous meetings of the modelling group, on basis of which the models were identified. An overview of these challenges per country can be seen in Annex 1. Then, the functioning of the model was briefly outlined (see section 2.1), including the spatial allocation into HRUs (hydrological response units).

**2 – Summary of local workshops**

This was followed by a short summary of the outcomes of the workshops with the local stakeholders in each country (see Annex 2) and section 3.2

**3 – Participatory exercise explanation:**

The main activity was the groupwork. After a brief explanation of the various exercises, stakeholders were divided into 4 groups according to study area (Egypt, Sudan, Kenya and Ethiopia). Each group did the same three exercises:

*I – Indicators:*

A list of (grouped) indicators was provided (see Annex 3) aligned with model and toolbox output capability. Indicators were presented as either directly modelled (DM) or post-processed (PP). The group was asked to indicate for each (group of) indicators:

- Are you interested in this indicator (yes/no/partly)?
- At what timescale do you want to know this (month, year, decades)
- Are there indicators missing that you need the model to produce?

*II – types of scenarios:*

Different types of scenarios were first explained in the plenary session (see Annex 4) and also on the sheets that each group was using in the exercise. The types of scenarios were:

- Blanket application: Apply the same BMP everywhere
- Spatial differentiation of BMP application: apply a BMP only to some fields / areas
- Application of a combination of BMPs: apply multiple BMPs in the same field / area
- Optimization of spatial allocation of BMPs: optimize the fields where BMPs are applied according to a given objective

In this second exercise, the group was asked to discuss and indicate, for each type of scenario:

- Are you interested in this type of scenario?
- Briefly indicate why? How would you use this type of scenario?
- (where relevant) Which BMP would be interested in applying? Please give as much detail as possible
- (where relevant) Indicate on the provided maps where you would implement this scenario

*III – design of most interesting scenario:*

After the exercises on the indicators and types of scenarios, the groups were asked to describe and design the most relevant scenario for their study area, with as much detail as possible:

- Which type of scenario do you chose? (see exercise II)
- Which BMPs do you consider?
- Draw the locations of BMP implementation on the map

- What is the timeline of the scenario?
- What are the most important objectives (i.e. what do you want to achieve)?
- What are the most important indicators (i.e. the model output) that you are interested to obtain from the model for this scenario?

**4 – Plenary reporting**

After the exercises, a representative of each group summarized the main findings of the group and presented them to the entire audience.

# 3. Participatory scenario development: results

## 3.1. Outcomes of workshops with local stakeholders

### 3.1.1: Egypt (4-5 March 2024)

In Egypt, a total of 44 stakeholders participated. From the modelling team, Dr. Luuk Fleskens and Dr. Jantiene Baartman (ISRIC) joined in person as well.

Cropping, water sources & management and manuring were discussed in 4 farmers groups. In summary, the outcomes were:

**a. Intercropping – which crops & trees are combined:**

- fruit (citrus) trees with vegetables (tomatoes, cucumber); or clover, beans, onions, garlic (winter) and maize, peanuts, green pepper, sesames (summer)
- corn with (soy)beans; wheat with watermelon

**b. Composting:**

- Processing incomplete, leading to negative effects (used raw);
- There is a need to know more on how to make best compost and/or
- Obtain compost from authenticated producers

**c. Water management:**

- Flood irrigation is being used (because drip irrigation is costly)
- Drip irrigation is used widely in the eastern side of El-Ismaillia Canal lands
- Source of water: Nile and/or groundwater; basins for dry period
- Groundwater is expensive due to pumping costs
- Water distribution is not efficient
- Water salinity is high
- Water logging is a problem in parts of the area; drainage is needed

The detailed findings per group can be found in Annex 5.

**Figure 3** - Participants of the workshop on 4-5 March, 2024, SEKEM farm, Egypt

**Figure 4** - Group picture of all participants of the workshop in Egypt, 4-5 March 2024

### 3.1.2: Kenya (8-9 April 2024)

The workshop with local stakeholders in Kenya was held in Hola on 8 & 9 April 2024. From the modelling team, Dr. Luuk Fleskens participated. Farmers were grouped in 5 groups according to their Areas. Area 1 was represented by the largest number of farmers (ca. 20). This area is closest to the town of Hola and has the largest problems with water availability as they are the furthest away from the intake. Area 2, 3, 4/5 combined and 6 were smaller groups (4-6 persons). The farmers were asked to form focused group discussions based on their area blocks and the discussions were:

- Identify challenges facing the farmers
- What needs to be improved/implemented in the specific fields
- Making ideal scenarios of the blocks

The challenges in Kenya can be summarized as:

- High pumping costs to take in water
- High sediment load of the water: abrasion of equipment & cleaning of canals

- High conveyance losses of water
- Complaints of the functioning of WUAs

Two specific BMPs are prioritized in Kenya (agroforestry and water management) and the following summarizes the outcomes of the group discussions:

**a. Agroforestry:**

- Agroforestry is envisaged in three specific locations: 1) along feeder canals for stabilisation of canal banks and avoiding soil erosion; 2) in specific designated areas (corridors) as windbreaks; and 3) surrounding irrigated areas as windbreak.
- The tree species selected include fruit trees (mango, citrus, pawpaw, coconut), indigenous trees and fodder trees. Fruit trees are suggested to enhance farm income, indigenous trees for environmental purposes and fodder trees to reduce conflicts between pastoralists and farmers.

**b. Water sources and management**

There are major challenges with water availability in the scheme, especially near the tail end. Suggestions are:

- An extension of the canal to be able to irrigate by gravity or, alternatively, installing solar pumping to reduce the high fuel cost for pumping water from the Tana River into the Hola irrigation scheme.
- Seasonal desilting and cleaning of the main canals to ensure water can reach the irrigation areas.
- Increase storage in the irrigation system by constructing more reservoirs enabling irrigation areas to better control water allocation. This is also specifically a requirement in case of solar pumping, to have night storage.
- Field land levelling to have a better water distribution over the irrigated fields, to reduce water consumption and increase water use efficiency.

**Figure 5** - Group picture of all participants of the workshop in Kenya on 8 & 9 April 2024

### 3.1.3: Ethiopia (19-20 April 2024)

The workshop with local stakeholders in Ethiopia was held in Bahir Dar on 19 & 20 April 2024. Unfortunately, due to travel restrictions related with the local situation, no-one from the modelling team could join in person; but PhD student Mulugeta lead the session. The discussions within the groups revealed that key problems exist and proposed solutions for addressing the challenges identified. Farmers were grouped into three (3) based on their farmland locations in the Koga Irrigation Scheme:

Group 1 (Enguti block) comprised 10 farmers and 3 experts (4 Females and 9 Males).

This area faces issues of uncontrolled grazing and siltation in the canal. This group emphasized that agroforestry practice should not be implemented in the Bered areas of the Enguti Block due to water scarcity.

Group 2 (Tagel Block) comprised 12 individuals including 10 farmers and 2 experts with four females.

This group emphasised on the issues of soil acidity and declining soil fertility as the major problems in the area.

Group 3 (Ambo Mesek) comprised 9 individuals including 6 farmers and 3 experts with two females.

Their area is situated near the main road from Bahir Dar to Addis Ababa and has 800 households. This group also emphasised on irrigation water quantity issues, particularly attributing them to unregulated water usage and water losses by upper irrigation users, as the major problems in the area.

The participants highlighted the dominant/key problems within their areas as follows:

- Lack of agricultural inputs such as fertilizers, seedlings, and pesticide sprayer devices etc.
- Absence of improved fruit and vegetable seedlings
- Inadequate established market chains, predominantly influenced by brokers.
- Challenges related to soil acidity and low fertility.
- Issues with water losses and compliance with irrigation water schedule bylaws.
- Challenges in water distribution and allocation
- Shortage of materials for compost preparation and lime scarcity
- Delayed release of irrigation water post-rainy seasons, particularly affecting vegetable production.
- Shortage of water lifting devices from the groundwater to supplement the Koga irrigation water.

Agroforestry as BMP was discussed in more detail:

Avocado was the most preferred agroforestry tree by the farmers. Agroforestry is envisaged in two specific locations:

1) Planting of trees as hedge/ along canals for canal stabilization and utilizing elephant grass as fodder. In these systems, crops are teff, wheat, barley, cabbage, onion, and maize, turmeric, elephant grass. The trees include avocado, croton, cordia. Avocado is then to be planted with wheat/ teff in four-year cycles, also combined with spices like turmeric.

2) Homestead agroforestry practices with crops such as tomato, ginger, cardamom, carrot. Trees include coffee, rhamnus, banana, mango and avocado.

Crop rotation was also discussed and farmers agreed on the following crop rotation strategies:

- Maize (summer/ rainy season)➔potato using irrigation.
- Maize (summer)➔Wheat➔ Cabbage using irrigation.
- Teff (summer)➔Potato➔ maize using irrigation.

The issues of water distribution and allocation can be addressed through:

- Developing irrigation water use programs for each crop type and implementing proper water allocation plans.

- Addressing water loss and theft by enforcing bylaws through the irrigation water user association platforms.
- Promoting groundwater use as a complement to irrigation water by supporting water lifting devices and necessary materials to mitigate conflicts among users and water scarcity.


**Figure 6** - Presentation of the discussions by one of the groups in Ethiopia (19 & 20 April 2024)

### 3.1.4: Sudan

Unfortunately, due to the ongoing conflict in Sudan, the formal workshop with the farmers could not be organised in spring 2024.

## 3.2. Outcomes of workshops with regional stakeholders

On 13th May 2024 the 2nd stakeholder forum was organised at CIHEAM-Bari which provided opportunity to obtain the perspective and preferences for scenarios of the regional stakeholders of the four countries. After the general introduction on the identified challenges, the model framework and the background and explanation of the exercises (see the section 2.2 and Annex 3&4), the participants were divided into four group with one group per country (Kenya, Sudan, Ethiopia and Egypt). The modelling team members were spread over the four groups to facilitate and guide the discussions.


**Figure 7** - Illustration of group discussions during the 2nd Stakeholder Forum;
top left: Ethiopia, top right: Egypt, Bottom left: Kenya, bottom right: Sudan.

After the group discussions, each group reported in plenary. A summary for each country is given below.

### 3.2.1 Egypt:

*I indicators:*

The Egypt case study stakeholders indicated that all indicators were important, except those related to erosion and flooding; both these processes are not relevant in the Egypt case study area. The temporal scale was mostly seasonal, while the level of nitrate content of surface water would need to be assessed at monthly scale and the amount of irrigation water used should be assessed on yearly timescale.

*II types of scenarios:*

- Blanket application: yes
    - For composting, WUA
    - Because there is the policy that there is a good functioning WUA everywhere

  - Because compost is applied broadly and would be interesting to know its effects
- Spatial differentiation: yes
  - Agroforestry, compost
  - Agroforestry is only applied in certain (light – sandy) soil types
  - Black soil is prioritised for agriculture
  - Compost in terms of the quality that is available
- Multiple BMPs: yes
  - Compost and agroforestry (only in agroforestry areas)
  - WUA: same
- Optimization: no
  - Because this is difficult as each farmer / landowner chooses his/her own crop and management, so it is not possible to do this top-down

*III optimal scenarios:*

There was not enough time left to discuss an optimal scenario for the Egypt case study area. However, the relevant output of scenarios was discussed and resulted in this list:

- Crop yield, economic benefits
- Net Product Value / cost-benefit
- Pollution of water
- Soil health (N, SOM, soil fertility)
- Ground water level reduction / safe groundwater level
- Water footprint for different crops (WUE)
- Improve livelihood of farmers
- Land productivity map for any crop

### 3.2.2 Ethiopia:

*I indicators:*

The Ethiopian team considered all indicators relevant, except for those related with groundwater pollution and quality, and with the atmosphere. All should be assessed either seasonally or yearly; however, it was noted that the indicators for agroforestry should be assessed over the course of multiple years due to its slow development. The team also noted some missing indicators: job creation in "economy", siltation in "surface water", and water logging prevention / drainage in "soil".

*II types of scenarios & III optimal scenarios:*

For the scenarios, the team discussed the types of scenarios and ideal scenarios at the same time. Two scenario sets were described, each with spatially differentiated measures for the area upstream of the reservoir, and the irrigation area itself:

A first scenario proposed irrigation water management for the irrigated area, including (i) allocating crops with different growing seasons (and water requirements) per block; (ii) irrigation scheduling according to blocks; and (iii) groundwater supplements. For the non-irrigated area, the scenario proposes agroforestry, combined with soil and water conservation measures for the area with highest slopes.

A second scenario builds on the first scenario; to the measures proposed, it adds a blanked application to the entire study area of integrated soil fertility management, a combination of (i) intercropping / crop rotation; (ii) organic and inorganic fertilizer; (iii) green manuring; (iv) improved crop varieties; and (v) adding lime to the soil.

These scenarios would be designed to optimize yield, income, resilience to climate variability (by decreasing e.g. crop failure), water quality, soil health, and in the upstream area, soil loss and sediment transport to the Koga reservoir.

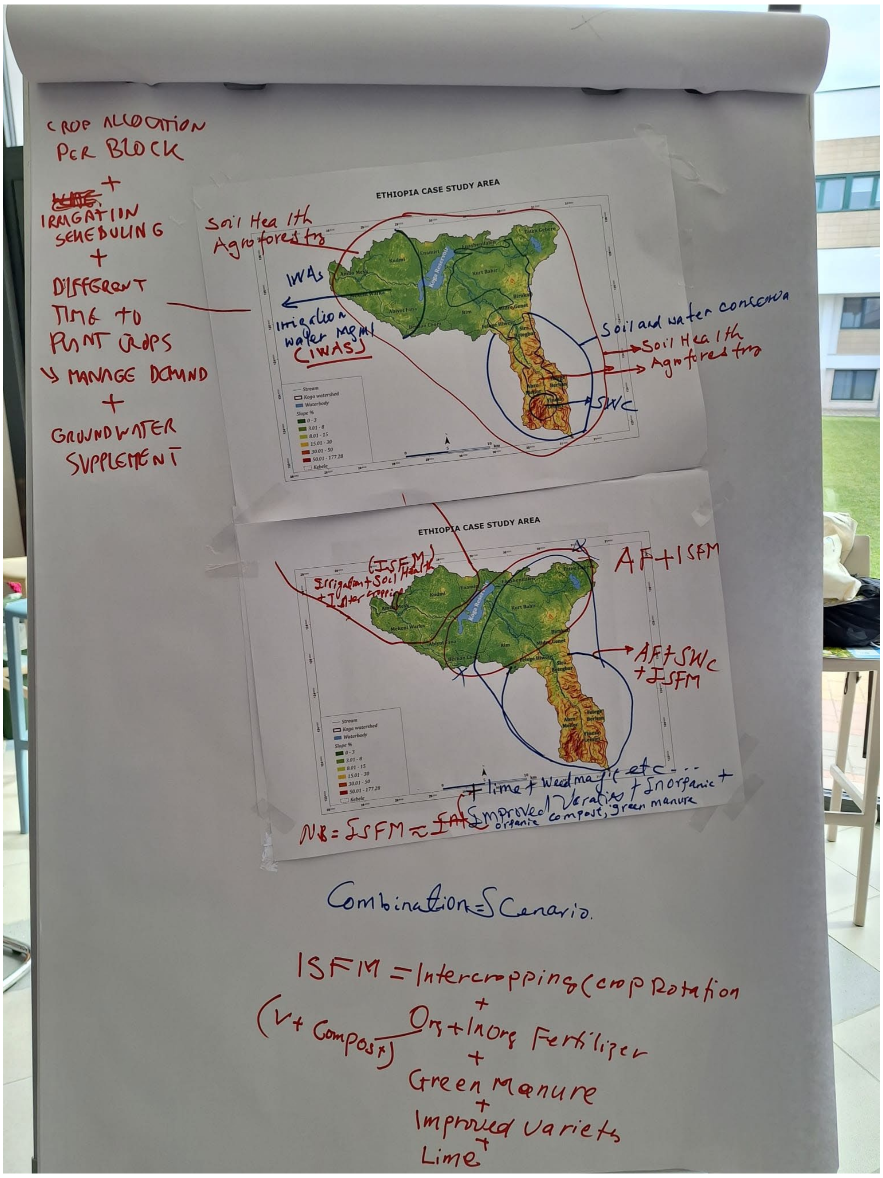



**Figure 8** - Discussion sheet with map of Ethiopian case study area.

### 3.2.3 Kenya:

*I indicators:*

The group indicated that all indicators are relevant except the groundwater-related indicators, as only surface water is used in the area. The timescale of the indicators is seasonal for the crop yield, the price-cost ratio and the soil-crop related indicators (i.e. soil fertility, OM, erosion, crop production and nutrient use efficiency).

For farmers' income, and surface water and atmosphere related indicators, it is annual.

*II scenario types:*

The group was most interested in the scenario types of spatial differentiation and optimization.

The spatial differentiation of measures is needed as agroforestry is rather implemented near settlements, not in fields due to operational difficulties.

The measures related to WUA and water use are applicable to the cropped fields (rice). See also maps in Figure 9. An optimization scenario was also found interesting, with agroforestry and WUA BMPs. The objectives of optimization would be: investment options; first-hand decision making; choice of the enterprise; MCA; carbon sequestration; yield and WUE.

*III optimal scenario:*

The group did not have time left to discuss this, but see also explanation under II scenario types.

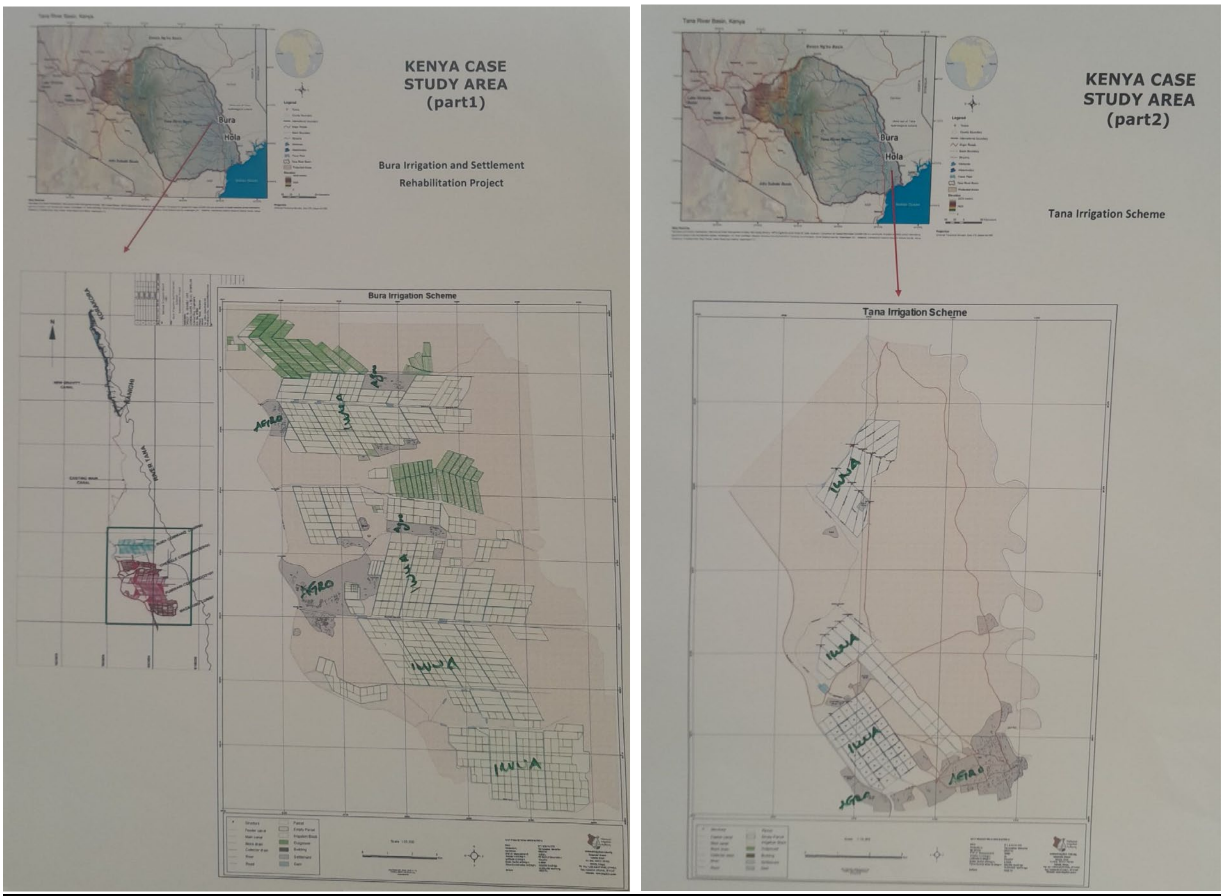



**Figure 9** - Map of Kenya case study site with indication of measures.

### 3.2.4 Sudan:

*I indicators:*

- Relevant – annual scale:
    - Increase crop production: Crop yield (total production (Kg)/Total land area (ha)
    - Increase farmers income: % increase in net farm income
    - Price-cost ratio
    - Water turbidity (6 months)
- Relevant – 5 yr scale:

  - Soil fertility (1-2 years, maximum 5 years)
  - Nutrient use efficiency
  - change “enhance water quality” to water turbidity (seasonal or 6 months)
  - change “Flood frequency” to sedimentation concentration (seasonal or half year)
- Not relevant:
  - Groundwater related indicators
  - Prevent soil erosion
  - Maintain soil health
  - Avoid water pollution
  - GHG emissions – relevant but no data
  - Atmosphere – relevant but no data
- Water quality and irrigation water management is more important; this needs a hydraulic model
- Irrigation system efficiency is important
- To be added: socio-cultural, policy and governance indicators, e.g.
  - job creation (2y);
  - government supporting farmers to implement BMPs (5y)
  - improve the collaboration

*II scenario types:*

The group stated that all types if scenarios are interesting, but if the group had to choose, they would choose the combination of BMPs, see figure 10. There, a combination of improved seeds and WUA measures would be implemented. The main objective is to improve net farm income.

*III: optimal scenarios:*

- The ideal scenario would be the combination of BMPs
- This would include improved seeds and WUA
- These measures would be implemented in the area highlighted on the map in figure 10. This is an area of about 8000 feddan
- Timescale is about 3 years
- The main objective of the scenarios is to improve farmers income

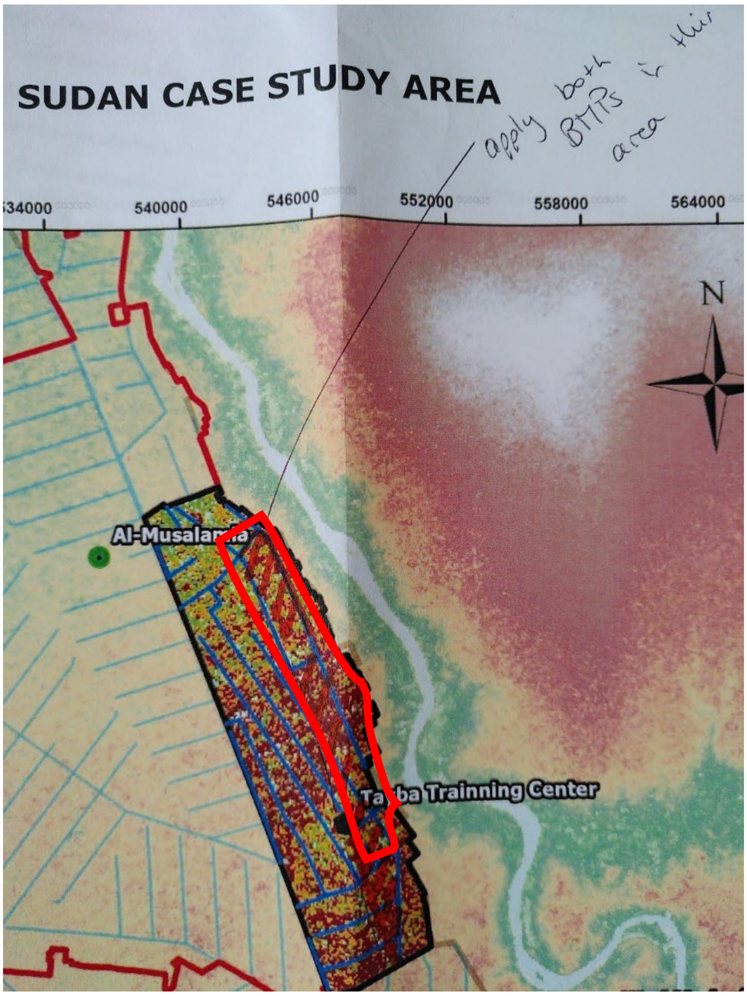



**Figure 10** - Sudan case study – BMP application should be in the red shaded area according to the stakeholders.

## Synthesis:

From the exercises and the presented outcomes by the different groups, the following overview was derived in terms of which types of scenarios they preferred:

**Table 1** - Overview of scenario options preferred by stakeholders across case study areas

| Scenario type | Case study area | | | |
|---|---|---|---|---|
| | Egypt | Sudan | Ethiopia | Kenya |
| Blanket application | yes | no | yes | no |
| Spatial differentiation | yes | no | yes | yes |
| Combining BMPs | yes | yes | yes | no |
| Optimization | no | no | yes | yes |
| | | | | |
| **Optimal scenario** | (mainly output discussed) | combination of BMPs | combination of spatial differentiation and combining BMPs | spatial differentiation and/or optimization |

# 4. Conclusions

The participatory workshops with both the local stakeholders (i.e. farmers) and regional stakeholders allowed to (i) specify in more detail per country which exact BMPs the local stakeholders envision and where; (ii) explore which types of scenarios the toolbox should be able to simulate for the different countries. From the synthesis it appears that different countries are interested in different types of scenarios, but most countries would like to spatially differentiate BMPs in the scenarios and combine BMPs in the same spatial unit.

This gives the modelling team the required information to further develop the toolbox' functionality so that the types of scenarios indicated by the stakeholders can be simulated and the indicators can be derived from the output.

# 5. Annexes

## Annex 1: Summary of challenges in the four countries

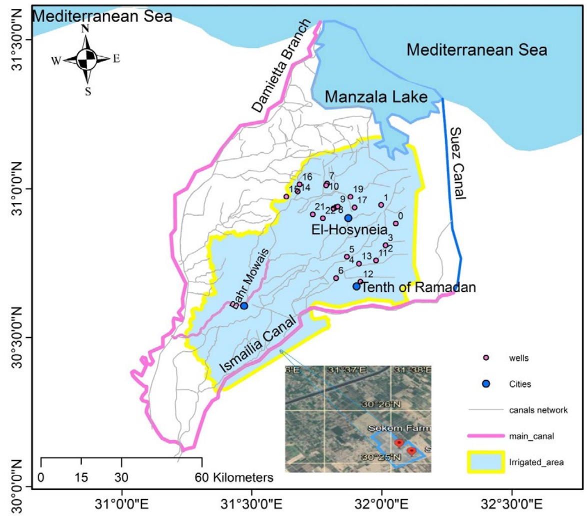
### EGYPT CASE STUDY AREA

**Current challenges**

- Groundwater quality (contamination, salinity)
- Soil quality (OM, nutrient, structure)
- Water balance and quality
- Productivity

**Selected BMPs**

1. Intercropping trees with crops
2. Manuring
3. WUA priority: Conjunctive use of water resources



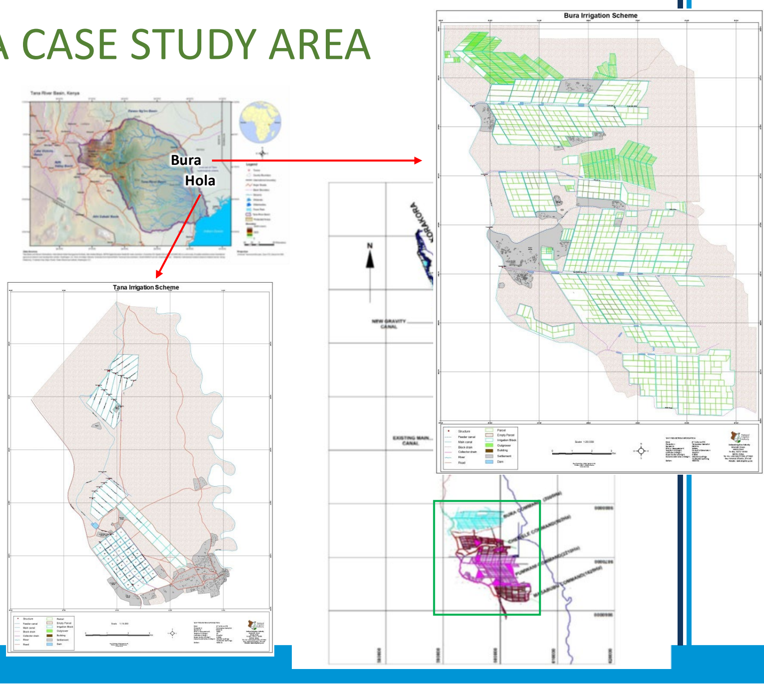

### KENYA CASE STUDY AREA

**Current challenges**

- Water balance
- Water quality
- Soil quality (OM, nutrient, structure)
- Productivity
- Soil erosion

**Selected BMPs**

1. Agroforestry
2. WUA priority: Irrigation scheduling



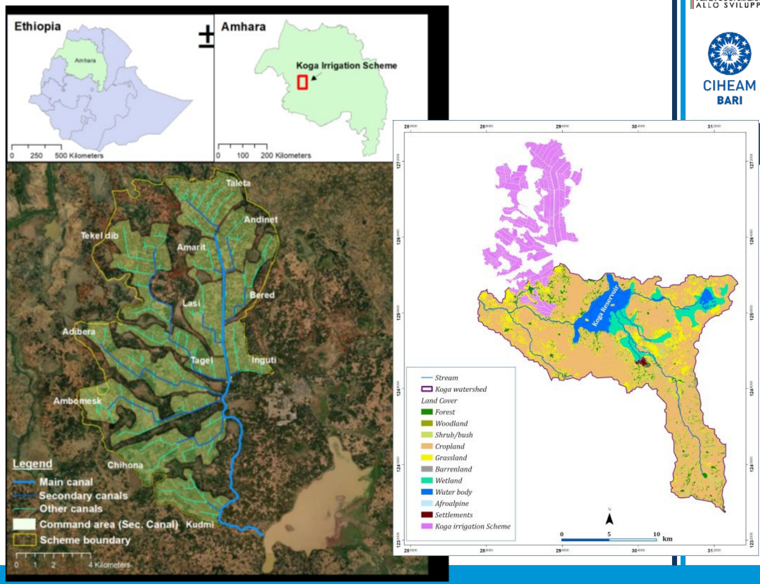
# ETHIOPIA CASE STUDY AREA

**Current challenges**

- Water balance
- Water quality
- Soil quality (OM, nutrient, structure)
- Productivity
- Soil erosion

**Selected BMPs**

1. Agroforestry
2. Crop Rotation
3. WUA priority: Irrigation scheduling



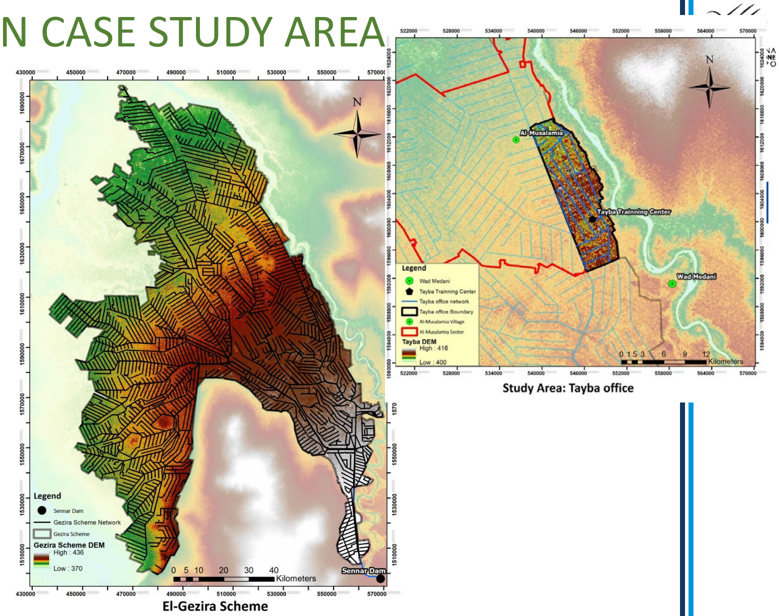

# SUDAN CASE STUDY AREA

**Current challenges**

- Water balance
- Water quality
- Soil quality (OM, nutrient, structure)
- Productivity

**Selected BMPs**

1. Improved seeds
2. WUA priority: Irrigation scheduling



## Annex 2: Summary of local stakeholder workshops outcomes as presented to regional stakeholders on 13 May 2024

### Local workshops with farmers

Egypt (4-5 March 2024)

- Cropping, water sources & management and manuring were discussed in 4 farmers groups

### Local workshops with farmers

Egypt (4-5 March 2024)

- Cropping, water sources & management and manuring were discussed in 4 farmers groups
  - Intercropping:
    - fruit (citrus) trees with vegetables (tomatoes, cucumber); or clover, beans, onions, garlic (winter) and maize, peanuts, green pepper, sesames (summer)
    - corn with (soy)beans; wheat with watermelon
  - Composting:
    - Processing incomplete, leading to negative effects (used raw);
    - Need to know more on how to make best compost and/or
    - From authenticated producers

## Local workshops with farmers

Egypt (4-5 March 2024)

- Cropping, water sources & management and manuring were discussed in 4 farmers groups
  - Water management:
    - Flood irrigation (because drip irrigation costly)
    - Drip irrigation used widely in the eastern side of El -Ismaillia Canal lands
    - Source: Nile and/or groundwater; basins for dry period
    - Groundwater expensive due to pumping costs
    - Water distribution is not efficient
    - Water salinity is high
    - Water logging is a problem in parts of the area; drainage is needed

## Local workshops with farmers

Kenya (8-9 April 2024)

Challenges:

- High pumping costs to take in water
- High sediment load of the water: abrasion of equipment & cleaning of canals
- High conveyance losses of water
- Complaints of functioning of WUAs

Photo by Luuk Fleskens, April 2024

# Local workshops with farmers

Kenya (8-9 April 2024)

**Agroforestry:**

- Envisaged in three specific locations:
    1. Along feeder canals for stabilisation of canal banks and avoiding soil erosion;
    2. In specific designated areas (corridors) as windbreaks;
    3. Surrounding irrigated areas as windbreak.
- Tree species:
    - Fruit trees: enhance farm income
    - Indigenous trees: environmental purposes
    - Fodder trees: reduce conflicts between pastoralists and farmers

# Local workshops with farmers

Kenya (8-9 April 2024)

**Water sources and management:**

Suggestions:

- Extension of the canal to irrigated by gravity to the end, or
- Installing solar pumping to reduce high fuel costs
- Seasonal desilting and cleaning of canals to ensure water can reach the irrigation areas
- Increase storage in the system by building more reservoirs
- Field land levelling to have a better distribution, reduce water consumption and increase WUE

## Local workshops with farmers

Ethiopia (19-20 April 2024)

**Challenges:**

1. Enguti Block: uncontrolled grazing and siltation of canal. Agroforestry not recommended (Bered area) due to water scarcity
2. Tagel block: issues of soil acidity and declining soil fertility
3. Ambo Mesek: irrigation water quantity issues; unregulated water use and water loss by upstream users.

## Local workshops with farmers

Ethiopia (19-20 April 2024)

**Agroforestry:** Avocado tree in two specific locations:

1. Planting of trees as hedge/ along canals for canal stabilization and utilizing Elephant grass as fodder
   - Crops: Teff, Wheat, Barley, cabbage, Onion, Maize, Turmeric, Elephant grass
   - Trees: Avocado, Croton, Cordia
2. Homestead agroforestry practices
   - Crops: tomato, ginger, cardamom, carrot.
   - Trees: Coffee, Rhamnus, Banana, Mango, Avocado.

## Local workshops with farmers

Ethiopia (19-20 April 2024)

**Crop rotation:**

- Maize (summer/ rainy season) - Potato using irrigation.
- Maize (summer) – Wheat - Cabbage using irrigation.
- Teff (summer) – Potato - Maize using irrigation.

## Local workshops with farmers

Ethiopia (19-20 April 2024)

**Water management:**

Suggestions for improvement:

- Developing irrigation water use programs for each crop type and implementing proper water allocation plans.
- Addressing water loss and theft by enforcing bylaws through the irrigation water user association platforms.
- Promoting groundwater use as a complement to irrigation water by supporting water lifting devices and necessary materials to mitigate conflicts among users and water scarcity.

# Local workshops with farmers

- Sudan

**Challenges**

- Due to the war the formal workshop with the farmers didn't get accomplish yet, but it will be discussed.

Local workshops with farmers

- Sudan (June 2023)

**Awareness meeting**

- Farmers were approached by the local stakeholder to view their level of acceptance for the selected BMPs.
- It was a very successful workshop with about 50 attendees from the various stakeholder groups and organizations and the private sector and of course the farmers.
- Many interviews and meetings were conducted virtually with the farmers in the past couple of months and they were part of fulfilling the Feasibility study.

# Annex 3: List of indicators and indication of modelling that the regional stakeholders were asked to fill in (exercise I)

**Stakeholder Forum meeting – Bari – 13 May 2024**

**Activity I: Indicators**

Please find below the table of feasibility indicators. This table is adapted so that only those indicators on which the toolbox can provide output, are included in this list. Thus, on these indicators, the tool can provide output:

- DM = Directly Modelled by the Toolbox
- PP = Calculated by Post-processing in the Toolbox

In this exercise, we would like to know:

- Which model output (or: indicator) is **relevant** for you (i.e.: you are interested to see model output on this)
- On which **timescale**: daily, monthly, seasonal and which **temporal extent** (e.g. for a period of 1 year, 10 years, 30 years?)
- Are there any **indicators missing** that you really would like to see as toolbox output (we can try to include this, but we cannot guarantee this). Please indicate in the box provided below the table

Please indicate the **relevance** and the **timescale** in the two columns in the table below:

| SECTORS | OBJECTIVES | indicators | Feasibility (DM/PP) | Relevant (y/n) | Timescale |
|---|---|---|---|---|---|
| Economy | 1. Make farm costs manageable. | • **Crop Yield (Tons/Ha)**<br>• **Benefit-cost ratio of production**<br>• **Price-Cost Ratio (compares selling price to cost of production)**<br>• **Cost saving (US$) as a result of BMP adoption** | DM<br>PP<br>PP<br>PP | | |
| | 2. Increase crop production. | • **Crop yield (total production (Kg)/Total land area (ha)** | DM | | |

| SECTORS | OBJECTIVES | indicators | Feasibility (DM/PP) | Relevant (y/n) | Timescale |
|---|---|---|---|---|---|
| | 3. Increase farmer's income. | • **Total household Net farm income (GFI- Total production costs & expenses)**<br>• **% increase in net farm income** | PP<br>PP | | |
| Groundwater | 4. Avoid groundwater pollution. | • **Level of Nitrate content of groundwater** | DM | | |
| | 5. Enhance water quality. | • **Level of water salinity (standard methods)** | DM | | |
| | 6. Ensure suitable groundwater access. | • **Intensity of water use by agriculture: Amount of irrigation water (mc) used per unit of cropped land (ha)**<br>• **Technical efficiency (mc) and economic efficiency (€) in water use**<br>• **Depth to groundwater (m) (ground water at much lower depths is more preferred and accessed because of low salinity")** | DM<br>PP<br>PP | | |
| Soil | 7. Prevent soil erosion. | • Area affected by soil erosion (%, $Km^2$): **Proportion of the area affected by soil erosion (%)**<br>• Amount of soil washed away by runoff: **Average soil loss ($t\ ha^{-1}\ yr^{-1}$)** | DM<br>DM | | |
| | 8. Maintain soil health | • **Soil Organic Carbon ($t\ ha^{-1}$)** | DM | | |
| | 9. To help crops grow better. | • **Soil fertility (SOM, N, $P_2O_5$, $K_2O$)** | DM | | |
| Crop | 10. To make crops productive. | • **Production yield of crop per unit of cultivated area ($t\ ha^{-1}$)** | DM | | |
| | 11. To make crops healthier. | • **Nutrient (N, P) use efficiency (kg product/kg N, P)** | PP | | |
| Surface water | 12. Avoid surface water pollution. | • **Level of Nitrate content of surface water** | DM | | |
| | 13. To enhance water quality. | • **Level of water salinity (standard methods)** | DM | | |
| | 14. Keep water flow safe. | • **Annual floods frequency (exceeding a certain threshold)**<br>• **Proportion of land prone to flood risks (%)** | PP<br>PP | | |
| Atmosphere | 15. Minimize greenhouse gases emissions. | • **GHG emissions per ha/yr** | DM | | |
| | 16. Make the air cleaner. | • **Carbon storage and sequestration in the crop ($t\ CO_2\ ha^{-1}$)** | PP | | |

# Annex 4: Explanation of exercise II (regional stakeholder workshop, 13 May 2024)

**Blanket application of BMPs**

A blanket application consists of the application of one BMP in the entire study area. This gives the option to see where in the area the measure has the greatest effect (on various outputs). When comparing with a baseline (no measures), the effect of the measure can be seen.

Example: application of composting on all fields

Photo: compost prepared on Sekem Farm, Egypt (photo by Jantiene Baartman)

Photo: Use of manure in Burkina Faso (source: WOCAT Database)

**Questions:**

1. Are you interested in this type of scenario: yes / no

2. For which BMPs would you be interested in this type of scenario?

……………………… ………………………. ………………………. …………………….

3. Why are you (not) interested in this type of scenario?

Answer: ……………………………………………………………………………………………………………..

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**Spatial differentiation of BMP application**

In this type of scenario, you may decide to apply certain BMPs in certain locations only, and other BMPs in other locations. Usually this is based on either the suitability of certain areas for a BMP or on the effect that a BMP is expected to have.

Examples:

- application of straw mulching on slopes steeper than 20%
- application of compost to high value crops
- improved drainage in waterlogged area

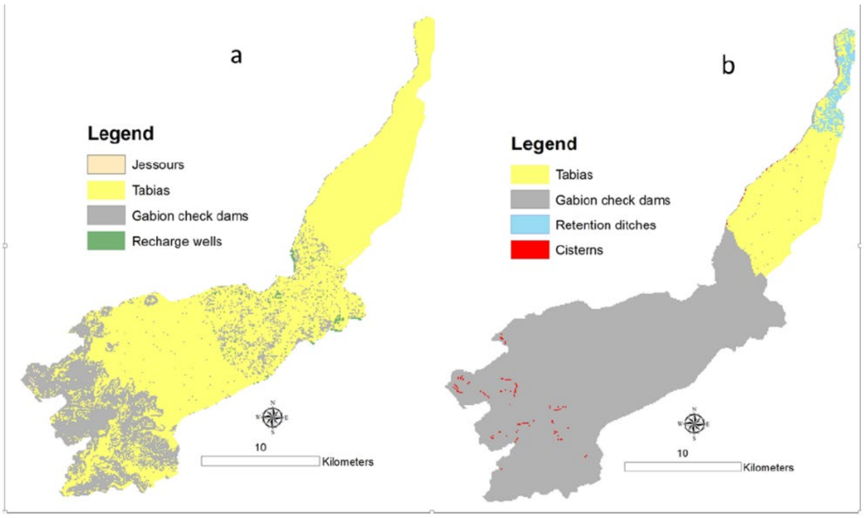


**Figure 11.** WHT with the highest suitability values in each cell for farmers (**a**) and decision-makers (**b**).

Example for suitability of water harvesting techniques in Tunisia (Abdeladhim, Fleskens, Baartman et al., 2022)

**Questions:**

1. Are you interested in this type of scenario: yes / no

2. For which BMPs would you be interested in this type of scenario?

……………………… ………………………. ………………………. …………………….

3. Why are you (not) interested in this type of scenario?

Answer: ……………………………………………………………………………………………………………..

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4. Where would you apply which BMP? Please indicate this on the provided maps

Please explain briefly? ……………………………………………………………………………………………………………..

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**Application of a combination of BMPs**

It might be possible to apply different BMPs in the same area / on the same field simultaneously. The idea is that this enhances the effects of the individual BMPs (i.e. the effect is more than the sum of the individual BMP application).

Examples include:

- application of no tillage and cover crops
- application of composting and irrigation
- application of intercropping and composting



Intercropping and manuring in Kenya (Source: WOCAT database)

**Questions:**

1. Are you interested in this type of scenario: yes / no
2. In which combination of BMPs would you be interested?

……………………… ………………………. ………………………. …………………….

3. Why are you (not) interested in this type of scenario?

   Answer: ……………………………………………………………………………………………………………..
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4. Where would you apply which BMP? Please indicate this on the provided maps

Please explain briefly?

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**Optimization of the spatial allocation of BMPs**

Instead of determining beforehand (as in the previous types of scenarios) where which BMP is applied, it is also possible to use an optimization technique. Then, through this technique and given a (range of) objectives, the best spatial allocation of different BMPs will be determined.
Examples of objectives could include application of BMPs

- Given a total budget of implementation costs (this requires an idea of the costs of implementation and maintenance of BMPs)
- leading to a maximum yield (of certain crops)
- leading to an increased soil quality
- that leads to less water use or better water quality


**Questions:**

1. Are you interested in this type of scenario: yes / no
2. In which (combination of) BMPs would you be interested?

……………………… ………………………. ………………………. …………………….

3. Which objectives would you like to obtain with this type of scenario?

Answer: ……………………………………………………………………………………………………………..
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4. Why are you (not) interested in this type of scenario?

Answer: ……………………………………………………………………………………………………………..
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# Annex 5: Detailed findings per discussion group (n=4) of the local stakeholder workshop in Egypt, 4-5 March 2024.

**Group 1 findings:**

The group was mentored by Dr. Rasha Hosny. Group (1) comprised 19 female farmers. They discussed and presented as follows:

- Intercropping was one of the recommended BMPs for example intercropping garlic and strawberries and then planting a legume like beans or vegetables after harvest. Some farmers preferred the strawberry-garlic intercrop because the crop yield for both crops is almost the same. Usually, one crop is the main crop and the other is a secondary crop.
- Composting was another recommended BMP. The farmers emphasized that this should depend on the soil needs. Water should also be applied carefully to allow for only that which is needed. Farmers were cautioned that if the compost is used when it is not fully processed, then it would have negative effects. They further emphasized that composting should be used during early ages then chemical fertilizer applied a month before harvesting.
- Agroforestry through the integration of citrus trees was also a selected BMP although farmers emphasized that this combination requires a lot of care. During the first 5 years of growing the trees, they plant different vegetables in the spacing between them (3-5m).
- Farmers proposed the use of water basins to store water for the water shortage period and the use of fish farms as an added value to those basins. Water basins are used to store water for later use during the water shortage period.
- Farmers rely mainly on the Nile water in most lands and groundwater in low flow periods or at the end of irrigation canals.
- Farmers embraced all the BMPs and exhibited to apply/implement the BMPs in their communities. The perception is that all the BMPs are critical for their livelihood. The Agroforestry trees (especially citrus and olive trees) would be established in farmer plots and inter-cropped with other crops such as vegetables, alfalfa (pasture), corn etc. Compost manure will be applied to crops produced by the farmers to improve soil fertility and crop yields. Irrigation water is critical for crop production and will be applied to the trees and crops. There are concerns on delivery of water to farmers. Efficient delivery methods such as drip irrigation systems are expensive for most farmers. There is also a need to clearly spell out at what point the responsibility of the farmer starts and what point the responsibility of the government ends with regards to delivery of irrigation water is concerned. Access and use of private underground water sources is expensive due to high fuel costs for pumping the water. These are some of the issues that the water user’s association committees need to sort out to ensure efficient utilization and management of the water resources.

**Group 2 findings:**

The group was mentored by Eng. Hend Hany. Group (2) comprised 10 members (9 male + 1 female). They discussed and presented as follows:

- There is a shortage of surface water, so groundwater is used as a substitute for surface water. Farmers requested support in meeting the increased energy needs and related high costs for pumping groundwater which is the major source of water for irrigation.
- There is a challenge of high fuel and associated costs required for pumping water. The groundwater is getting deeper and as such requires more horsepower pumps to pump it for irrigation use. Irrigation systems are also expensive and cannot easily be accessed by the farmers.
- Some farmers are filtering water sewage but it is not healthy.
- Water salinity is high in the area and this is affecting crop production.

- Citrus trees are profitable to grow in the area but need high care including integrated pest management.
- Water distribution systems are inefficient.
- Farmers highlighted the importance of finding the best-integrated pest management strategy and also ICM, especially for fruits and vegetables such as tomatoes, corn, and cucumbers.
- Composting is used for manuring in its raw form (not fully processed) so it has negative effects. Farmers have limited knowledge of how to use manure and plant waste for making compost. They also need to learn more about establishing strategies for sustainable waste management for their farms.

**Group 3 findings:**

The group was mentored by Dr. Manal Elsaied. Group (3) comprised 5 farmers (4 male + 1 female). The group discussed and presented as follows:

- Manuring (bird manure) is used but not well processed, so it has negative effects. The group used natural fertilizers made from animal manure (pigeon waste) which was not well processed, and this resulted in negative effects. They mixed the animal manure with phosphate and potassium rocks (natural rocks) by fermenting pigeon waste in a tank at a rate of 10 kilograms of waste per 100 liters of water. After that, the filtered solution was taken and used to irrigate the soil. This method is equivalent to 75 kilograms of chemical fertilizer.
- Intercropping is a preferred BMP especially intercropping soya bean with watermelon. The group tried cultivating corn with beans or soybeans, and wheat with watermelon; both achieved good productivity and economic returns.
- Flood irrigation is used due to the high cost of modern irrigation methods such as drip irrigation.
- Farmers requested financial support to adopt BMPs such as modern irrigation methods.

**Group 4 findings:**

The group was mentored by Dr. Wael Khairy. Group 4 comprised 10 male farmers. The group discussed and presented as follows:

- Traditional manuring (incomplete processing) is prepared by farmers and commonly used before soil tillage only once, consequently it has several negative environmental and social impacts. Since the processing of manure is incomplete, it becomes more harmful to soil conservation than the beneficial organic fertilizers or composting materials.
- Chemical fertilizers are used three times per season depending on the type/age of the crops.
- The farmers are convinced that they should buy high-quality compost from authentic sources.
- Farmers intercrop citrus trees with clover, beans, onions, and garlic during the winter season and intercrop citrus trees with maize, peanuts, green pepper, and sesame during the summer season.
- Water logging is a challenge in West El-Ismaillia Canal lands due to seepage. The salinity is moderate and the drainage system is necessary.
- On the western side of El-Ismaillia Canal lands, small diesel pumps are used for irrigation in areas with shallow depths. Rice & maize are cultivated in such areas.
- In east El-Ismaillia Canal lands, there is no drainage challenge but groundwater is deeper, so electric pumps are needed with high operation costs.
- Drip irrigation is used widely on the eastern side of El-Ismaillia Canal lands.
- In all areas, the cost of energy is high, so the farmers' profitability is low. This needs to be resolved via the application of the BMPs.

## Annex 6: Detailed findings per discussion group (n=5) of the local stakeholder workshop in Kenya, 8-9 April 2024.

AREA 1 - Type of crop grown – maize, green grams

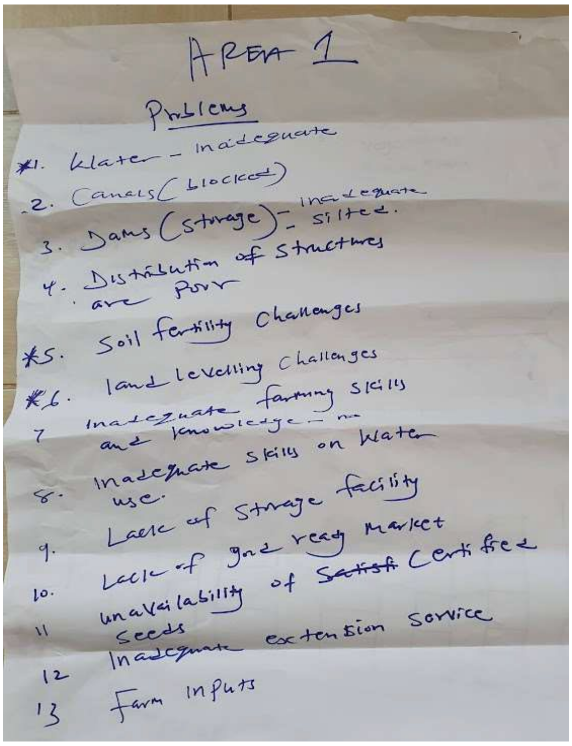
**Problems identified**

1. Water shortage – especially at the furthest end
2. Siltation
3. Soil fertility
4. Levelling issues –furrow irrigation system requires a relatively level land
5. Secondary canals being swept away by the floods

**Ideal scenarios to be implemented**

The farmers settled on the implementation of the following scenarios;

- Agroforestry – they settled on planting the following tree varieties; mangoes, bananas, oranges, indigenous trees, coconut and neem
- In Maendeleo farms which have been planted with vegetables they suggested introduction of other crops.
- Converting Mathenge (Prosopis) to beneficial trees
- Mixed cropping to be adopted




Illustrations of group 1 (area 1) in participatory workshop Kenya, Hola, 8 & 9 April 2024

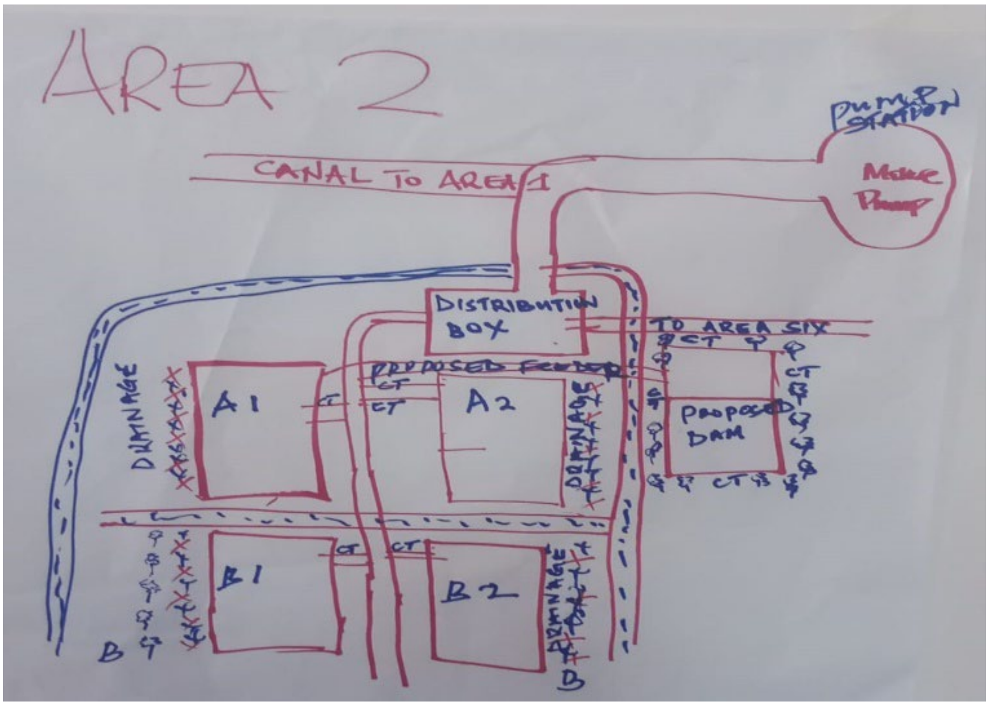
AREA 2

**Problems identified**

Water shortage

The farmers agreed on the following remedies to resolve the issue of water shortage;

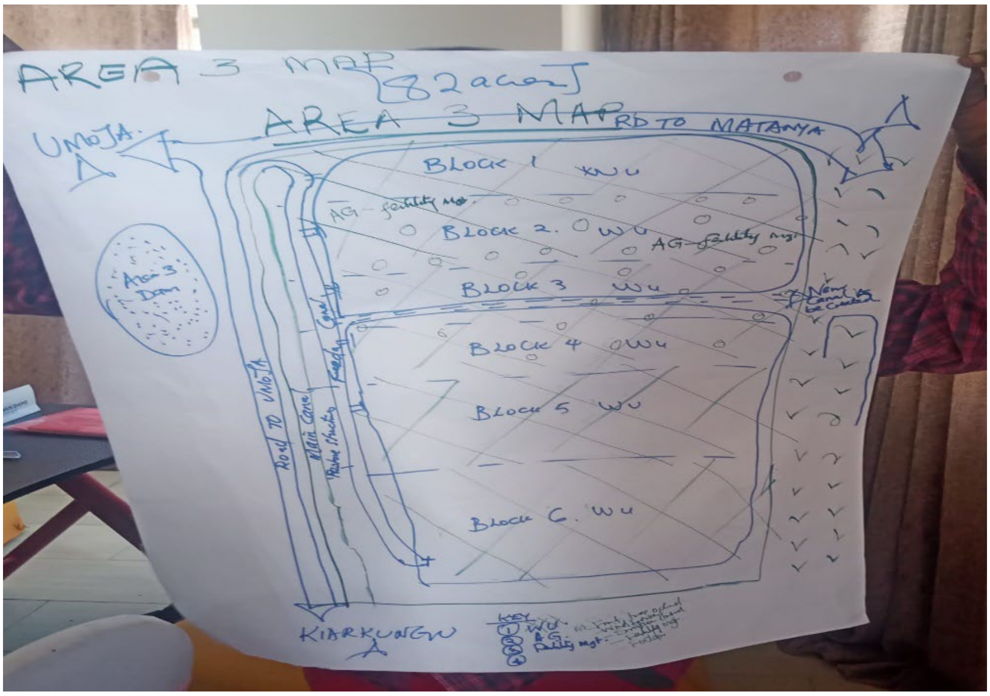
- Lining of the canals
- Expansions of the canals
- Desilting of the canals after every four months (every season)
- levelling of the scheme
- planting trees along the canals which includes mangoes, bananas, citrus and local trees
- they suggested on putting up wind breakers – trees which are also fruits between Matanga and Maendeleo
- putting up a dam (proposed) - which will feed all the four blocks in Area1(A1, A2, B1 and B2)



AREA 3 (82 acres)

**Solutions suggested**

- Division of the area into two for easy supply of water to all the areas. This is due to the issue of land levelling.
- The soil in blocks 2, 3 and 4 have a lot of salts hence the crops not doing well.
- Gates to be put to control the flow of water
- Formation of the WUA
- Leguminous/fodder trees to be planted in blocks 2, 3 and 4
- Planting indigenous trees in Block 4



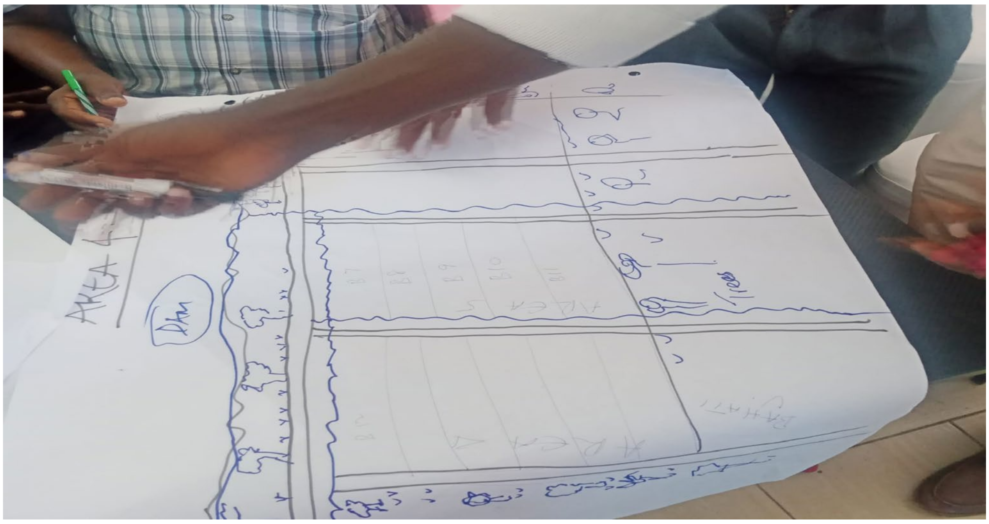
AREA 4/5

**Problems faced**

- Water supply and storage problem
- Siltation in canals
- water management issues
- Water scarcity
- The space available not sufficient for a dam but there is need for one

**Remedies suggested by the farmers**

- Agroforestry
- Capacity building
- Intake pump (pumping hours to be increased)
- Expansion of the canals
- Putting up of a dam
- Desilting and maintenance of the canals
- Training of water uses
- Review of water tariffs - increase the water tariffs from 34 to 35
- Planting fodder trees which will also act as wind breakers to take care of the area
- Improving on agroforestry where they have started planting trees like mangoes, lemon, oranges and passion
- Planting indigenous/fodder trees along the main canal



AREA 6

**Problems faced**

1. Water shortage
2. Conflict between the farmers and pastoralists

**Strategy:**

- Agroforestry – planting trees like mangoes and citrus
- Formation of WUA - will be a conflict resolution centre
- Construction of a dam
- Land levelling
- Increase in labour and skills
- Desilting of the canals to avoid water shortage
- Tree planting along the block boundaries to prevent animals and birds from entering the farm
- A water tank for domestic use
- Conflict between the farmers and the pastoralist - A group (conflict managers) to be formed to resolve the issue since the farmers are the same ones (pastoralists)
- The chief area said that there are already actions under way to resolve conflict resolution