Module 4: DRAINAGE, FLOOD AND SALINITY CONTROL
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MODULE 4

DRAINAGE, FLOOD AND SALINITY CONTROL

Introduction

Drainage, or coping with the problem of excess water, is an essential element of water management and crop production, but often a neglected topic when dealing with farmers’ water management. The basic need from drainage derives from the fact that most agricultural crops do not grow well under prolonged waterlogged conditions and are sensitive to water ponding on the soil surface. In general crops prefer moisture condition in the root zone around field capacity. In (semi) arid areas the problems of waterlogging are often accompanied by salinity problems, which further inhibits crop production. Removal of excess water by artificial drainage is necessary if the natural drainage is inadequate and causes prolonged waterlogged conditions and related salinity problems during critical periods. Also crops that grow under wet conditions, like rice, will benefit from drainage.

Besides increased crop production, drainage might serve a wide range of additional purposes e.g., to obtain crop diversification and to overcome farm management constraints. In addition to agricultural benefits, drainage can contribute to the protection and improvement of the environment and rural development. Non-agricultural/social benefits of drainage include the improvement of public health and sanitation condition, lowering maintenance costs of infrastructure and buildings, and improved animal health.

Drainage and salinity control related to irrigation

For areas experiencing prolonged conditions of water shortage irrigation is essential for crop production. With the introduction of irrigation additional water is brought into an area. Poor irrigation water management both at scheme and farm level, seepage and leakage from mostly large-scale irrigation systems in combination with insufficient (natural) drainage, has resulted in rising water tables and has subsequently led to waterlogging and related salinity problems in many irrigated areas around the world.

In irrigated areas, drainage is indispensable to maintain favourable water and moisture conditions for optimal crop growth and control of waterlogging and salinity problems. The provision of surface drainage is normally implemented to remove ponding water from the soil surface. Surface drainage is also helpful to control waterlogging and salinity problems but in general it has limited effect due to its limited depth and intensity. Especially when salinisation is a major concern, the provision of subsurface (pipe) drainage is the preferred remedial measure as for the control of salinity leaching through the soil profile has to be induced.
Under influence of the growing world population and increasing demand for food, large-scale irrigation intensification has taken place to boost crop production of a region or country. To supplement the scarce surface water resources, groundwater is exploited through tubewell developments mainly in the fresh groundwater zones. In many of these areas water tables are actually dropping due to over-exploitation of groundwater resources. Therefore, at present, problems of waterlogging and salinity in irrigated agriculture are mainly confined to saline groundwater zones.

Waterlogging and salinity are mostly dealt with as a twin-menace. Although in (semi) arid areas waterlogging is often accompanied by salinity problems, not all salinity problems do necessarily stem from waterlogging problems. Salinisation of agricultural lands could also result from irrigation with marginal and poor quality (ground) water, weathering of parent material, and seawater intrusion. Especially salinisation as a result of irrigation with marginal and poor quality water is increasing rapidly due to shortages of fresh water resources in many parts in the world. Also salinisation due to seawater intrusion is gaining more importance as a result of large-scale development of surface water resources and thus reducing the outflow to the sea.

**Drainage and flood control**

Areas that are characterized by high temperatures, high rainfall and recurrent flood events have resulted in farming systems traditionally based on rice production. Inundation depth, during and timing determined cropping patterns, crop selection and yields. With the introduction of improved varieties, crop intensification, diversification, and farm mechanization better water control conditions are required. Better water control can be achieved through the implementation of drainage alone or in combination with flood control measures.

Especially in lowlands, delta and tidal areas excess rainfall and floods are the main limitations for crop intensification and diversification. Although, lowlands, delta and tidal zones are in general unsuitable for development due to soil conditions, waterlogging and inundation risks, and their environmental value there is often enormous pressure to develop these areas due to their strategic location. Development of these areas involves flood control schemes, in combination with the provision of drainage and in several cases polder development. The type and extend of flood protection and drainage development in an area depends on rainfall patterns, the type, intensity and depths of flooding, and the advance in rural development.

Floods exist in various types, depths and intensities:

- **Flash floods** are caused by run-off during exceptionally heavy rainfall occurring over neighboring upland areas.
- **River floods** are a recurrent event resulting from heavy (monsoon) rainfall in upland and upper catchment areas combined, sometimes, with snowmelt from high mountainous areas.
- **Rainwater floods** are caused by heavy monsoon rainfall resulting in local run-off to accumulate in depressions and lower parts of valleys.
• Storm surges are raised sea levels normally associated with tropical cyclones causing sudden, but temporary, flooding of coastal areas with seawater or brackish estuarine water.

Besides the natural floods there are also floods caused by human intervention in nature these include: sudden breaching of an embankments; sustained failure of polder drainage pumps during the monsoon season, thus allowing ponding of rainwater within a polder; abnormally high rates of release of water from dams; ponding of water behind road, railway and flood embankments following heavy rainfall; drainage congestion; and river siltation.

The exercises have been divided in four sub-modules.

References

In the preparation of the exercises in the module use is made of the following publication:

• Irrigation water management training manual No. 1, Introduction to Irrigation, 1985, FAO
• Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO

Additional technical information can be obtained from the above-mentioned publication.
Sub-module 4.1: Assessment of drainage, flood and salinity problems

In many cases the relation between waterlogging, water ponding and salinity on the one hand and irrigation, drainage and floods on the other hand are very complex. In exercise 4A (phase: assessment) farmers will identify problem areas and assess the actual problems through cause and effect diagramming. The final output of this exercise is identified potential solutions.

Sub-module 4.2: Drainage

Before farmers can actually make a detailed drainage improvement plan they need to be familiar with the concept of drainage and understand how the different components of the system work. In Exercise 4B (phase: planning) farmers will be familiarized with the concepts of drainage through an exchange visit or by the presentation of audio-visual training materials and select the type of drainage measures that are required for their area. In exercise 4C (phase: planning) farmers will make a design proposal and identify the activities that can be done by themselves and for which activities they need support from an external organization. If part of the design/planning has been made by an external organization, farmers will need to approve them prior to implementation. This will be done in Exercise 4D (phase: planning). After the approval the farmers will need to make an action plan for the implementation which will be done in exercise 4E (phase: construction). Exercise 4F (phase: construction) provides guidelines and methods for regular follow-up of the planned activities. In Exercise 4G (phase: operation and maintenance) farmers will make an action plan for the operation and maintenance activities. Exercise 4F can be used again for regular follow-up of the planned operation and maintenance activities.
Sub-module 4.3: Flood Control

In exercise 4H (phase: planning) farmers will discuss whether flood control is desirable and feasible. When farmers decide that flood control measures should be implemented they will plan the required measures. When control measures concern a large area, farmers will also look for co-operation in the design and implementation from government and other farmers. At the same time they will identify the measures that can be implemented by them without external support. After the plans and designs have been made and approved farmers will need to make an action plan for the implementation, operation and maintenance activities. This will be done in exercise 4I (phase: construction, operation and maintenance). Exercise 4F can be used for regular follow-up of the planned implementation, operation and maintenance activities.

Sub-module 4.4: Salinity Control

On the basis of the established causes of the salinity problems, (exercise 4A) farmers will plan a set of measures to control the salinity problems in exercise 4J (phase: planning). When high groundwater tables cause salinity problems, it is likely that drainage is a component of the salinity control plan. In this case Sub-module 4.3 should be followed as well. For the planning of the implementation activities and follow-up and the implementation of the selected measures slightly adjusted versions of Exercises 4E and 4F can be used.
# Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td><strong>Capillary rise</strong></td>
<td>Upward movement of water in soil through fine soil pores.</td>
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<tr>
<td><strong>Drainage outlet/outfall</strong></td>
<td>The terminal point of the entire drainage system, from where the drainage water is discharged into a river, a lake, or a sea.</td>
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<tr>
<td><strong>Flood control</strong></td>
<td>Control of floods through measures like dikes, river regulation and flood retention.</td>
</tr>
<tr>
<td><strong>Gravity sluices</strong></td>
<td>Structure through which the drainage effluent discharges into a river, lake, or sea normally equipped with a gate to prevent intrusion of water when outer level is higher than inner level.</td>
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<tr>
<td><strong>Inundation</strong></td>
<td>Flooding of land with rainfall or flood waters.</td>
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<tr>
<td><strong>Leaching</strong></td>
<td>Removal of soluble salts from the soil profile by water percolating through the soil.</td>
</tr>
<tr>
<td><strong>Perched water table</strong></td>
<td>Temporarily water table developing on impermeable or poorly permeable soil layers situated at a certain depth below the soil surface.</td>
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<tr>
<td><strong>Percolation</strong></td>
<td>Downward movement of water through soil profile.</td>
</tr>
<tr>
<td><strong>Polder</strong></td>
<td>Level area, separated from the surrounding hydrological regime through dikes to protect it from floods and equipped with drainage pumps to control (ground) water levels within the endiked area.</td>
</tr>
<tr>
<td><strong>Salinisation</strong></td>
<td>Accumulation of soluble salts at or near the soil surface.</td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>Concentration of total dissolved salts in water or soil solution. Salinity becomes a problem when the concentration is high enough to negatively effect crop production.</td>
</tr>
<tr>
<td><strong>Sodicity</strong></td>
<td>High sodium to calcium and magnesium ratio in water or soil solution. Sodicity becomes a problem when the ratio is high enough to cause soil degradation or negatively effect crop production.</td>
</tr>
<tr>
<td><strong>Subsurface drainage</strong></td>
<td>Removal of excess water from the soil surface by diverting it into improved natural or constructed drains supplemented when necessary by shaping and grading of the soil surface towards the drains.</td>
</tr>
<tr>
<td><strong>Surface drainage</strong></td>
<td>Removal of excess water (and dissolved salts) from the soil profile though groundwater flow to the drains so that the water table and soil moisture content in the root zone are controlled.</td>
</tr>
<tr>
<td><strong>Water ponding</strong></td>
<td>Accumulation of water on the soil surface.</td>
</tr>
<tr>
<td><strong>Water table</strong></td>
<td>Upper boundary of the groundwater. Below the water table all soil pores are filled water.</td>
</tr>
<tr>
<td><strong>Waterlogging</strong></td>
<td>Accumulation of excess water in the root zone (water saturated soil).</td>
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SUB–MODULE 4.1

ASSESSMENT OF DRAINAGE, FLOOD AND SALINITY PROBLEMS

EXERCISE 4A: IDENTIFICATION OF FLOOD, DRAINAGE AND SALINITY PROBLEMS, CAUSES AND EFFECTS

Introduction

In many cases the relations between waterlogging, water ponding and salinity on the one hand and irrigation, drainage and floods on the other hand are very complex. Causes and effects are often not obvious. During the Farmers Seasonal Planning major problems have been identified. This exercise will deepen farmers’ understanding and assist them in distinguishing the actual problem, its causes and effects. This will enable the selection of appropriate measures.

Objectives

- Identify main problems causes and effects of waterlogging, water ponding and salinity problems.
- Prepare training material in the form of drawings showing the relation between causes and effects of local flood, drainage and/or salinity problems.

Expected outputs

- Map of (natural) drainage system, source(s) of excess water, flow directions, slopes and obstructions.
- Identified regular flooded, waterlogged and salinised areas.
- Identified main causes and effects of floods, drainage and salinity problems in the area.
- Identified potential solutions.

Materials required

- Layout map of the area prepared by the farmers.
- Coloured cards
- Markers
- Training material

Time required

- Three hours and thirty minutes.

Timing

- After Farmers’ Seasonal Planning.
- First exercise in the season.
Procedure (Steps)

Plenary Introduction (10 min)

1. Explain the specific objectives and expected output.

Plenary discussion (30 min)

2. Present the map prepared by the farmers during the Farmers Seasonal Planning.

3. Discuss with the farmers the meanings of “drainage”, “water ponding”, “waterlogging”, “salinisation” and “flooding” and how they can be recognized in the field.

Plenary group exercise (1 hour)

4. Visit with the farmers one of the locations identified with a possible salinity, drainage and/or flooding problem.

5. Ask the farmers to verify the areas where they (sometimes) experience water ponding, waterlogging and/or salinisation problems. If necessary modification can be made on the map.

6. Ask the farmers in the field to indicate (natural) drainage system, source(s) of excess water, floods, flow directions, slopes and obstructions and ask them to indicate these on the map.

7. Mark the actual problem areas and discuss the main problem(s).

8. List the main problems.

Small group exercise (cause and effect diagramming) (1 hour)

9. Divide the farmers in small groups and give each group one of the main problems, written on a card, to work on.

10. Place the card with the main problem in the center. This will be the starting point to create the cause and effect diagram.

11. Ask farmers to identify the causes of the main problems. Write each cause down on a card and place them below the main problem.
12. Sometimes the causes mentioned for the main problems might not be the root problems, questions need to be ask to find the underlying causes. Write these causes on cards and place them below the first mentioned causes.

13. Repeat the same procedure to identify the effects. Ask farmers what the effects are of the main problem. Write the effects down on cards and place them above the main problem.

14. The exercise is complete when insight is obtained in the root causes and final effects of the main problem.

**Plenary discussion** (50 min)

15. After completing the diagram(s) ask one participant or the representatives of individual groups to present their results to each other.

16. Check whether the diagram is logic and complete.

17. When gaps in farmers’ knowledge are observed these have to be explained and discussed making use of the prepared training materials.

18. Based on the diagram discuss the potential solutions.

Guidelines for (technical) preparations / questions for discussion

How to recognize surface drainage problems?
Surface drainage problems can be recognized by prolonged ponding of water on the soil surface after flooding, rainfall or irrigation. Surface ponding often occurs in depressions, valley bottoms and behind obstructions in natural drainage flows.

Depending on the time and length of water ponding conditions, symptoms in crops are poor germination, poor crop growth, sensitivity to fungal diseases, and in extreme case decay of stems and roots and finally crop failure.

How to recognize subsurface drainage problems?
Subsurface drainage problems might manifest in the same way as surface drainage problems, i.e. prolonged ponding of water on the soil surface after flooding, rainfall or irrigation due to reduced storage capacity and infiltration as the soil profile is already saturated. However, subsurface drainage problems differ from surface drainage problems, i.e. in areas with subsurface drainage problems waterlogging can occur without surface ponding. Waterlogging problems normally occur in flat lands. Sometimes impermeable or poorly permeable layers, located at a certain depth below the soil surface, impede deep percolation. On this layer a so-called perched water table might develop. Normally its occurrence is temporarily, however, it might exist long enough to cause damage to crop growth.

Waterlogging problems are recognized by farmers through observation of wet soil conditions and shallow water table when cultivating their land or observed in open wells and pits. Depending on the time and length of waterlogged conditions, symptoms in the crop are poor germination, poor root development, poor crop growth, sensitivity to fungal diseases, and in extreme cases decay of roots and crop failure. In areas with long periods of drought in which the upward movement of water and salts in the soil profile dominates over the downward flux, waterlogging is often combined with salinity problems.

How to recognize salinity/sodicity?
Salinity and sodicity problems only become visible in the field if they are in an advanced stage. Also for the typical salinity symptoms in the crops to appear the concentration of salts in the soil must be quite high. At low levels the growth will be uniformly depressed and yields will be reduced. Salinity and sodicity problems can be recognized through a whole range of physical phenomena and crop characteristics. High salinity concentrations can be recognized by a white soil crust, a powdery like layer covering the soil surface, white patches and an oily appearance of the soil surface. Typical high sodium concentrations might be recognized by black soil patches on the soil surface, hard soil crust, dense/massive soil structure, and poor water infiltration. Typical salinity/sodicity symptoms in the crops are poor germination, irregular and stunted crop growth, withering of plants and yellow leave burn.

Causes and potential solutions for surface drainage problems
Surface drainage problems are caused by excessive rainfall, irrigation or flooding in combination with insufficient natural outflow. These situations occur in depression
areas or valley bottoms without a natural outlet or when the outlet that is too small for sufficient outflow. Surface drainage problems might also be caused by blocking natural drainage flows by building roads, railway lines, canals etc, across natural drains. Soil crusting, compaction and poor land leveling might also result in surface ponding. Normally latter causes are small-scale, localized and occur randomly.

Potential solutions are:

- Reduce the flow of excess water through improvements on irrigation system and management (see modules 2 and 3) or flood control measures (see sub-module 4.3).
- Improve the natural surface drainage.
- Construct artificial surface drainage.
- Grade the land to enhance surface runoff towards the (natural) drains.

Causes and potential solutions for subsurface drainage problems

Subsurface drainage problems normally occur in flat areas where the hydraulic gradient and the hydraulic conductivity are too small to evacuate recharge of the groundwater sufficiently quick to prevent excessive rise in groundwater table. Rainfall, flood or irrigation water which infiltrates in the soil but which is not used by crops for transpiration nor evaporated at the soil surface will recharge the groundwater. Sources of excessive recharge from irrigation are seepage and leakage from irrigation canals and deep percolation of irrigated field as a result of poor irrigation methods and poor leveling of fields.

Potential solutions are:

- Reduce the recharge to the groundwater through improvements on irrigation system and management (see modules 2 and 3) or flood control measures (see sub-module 4.3).
- Construction of a subsurface drainage system.
- In case waterlogging is caused by a shallow thin impermeable layer, deep ploughing to break the layer could improve the situation.

Causes and potential solutions for salinity/sodicity problems

In (semi) arid areas subsurface drainage problems are often accompanied by salinity problems. Dissolved salts move upward to the soil surface with increasing groundwater tables. Subsequently, salts accumulate near or at the soil surface through evapo(transpi)ratiom of water, leaving behind the salts. Though, not all salinity problems do necessarily stem from waterlogging problems. Salinisation of agricultural lands could also result from irrigation with marginal and poor quality (ground) water, weathering of parent material, and seawater intrusion.

Potential solutions are:

- If water tables are deep and there is no threat of rising water tables, it is sufficient to provide additional water to leach the salts from the root zone.
- If salinity is caused by high saline groundwater tables, subsurface drainage need to be provided to reduce the groundwater table and evacuate leaching water and dissolved salts.
- If sodicity is the main problem apply soil or water amendments to prevent soil degradation.
• Shift to more salt tolerant crops if salinity can not be controlled on acceptable levels
• Irrigation and cultivation management practices to mitigate the effects of salinity on crop production

Causes and potential solutions for floods
Recurrent flood events are natural phenomena in many areas in the world. In itself regular flooding do not form a problem. Traditionally, farming systems were based on rice production and incorporated floods. Damage to crops under these conditions is restricted to abnormal conditions, i.e. when floods occur much earlier or later, or when water level rise higher or quicker than normal. However, with the introduction of improved varieties, crop intensification, diversification, and farm mechanization better water control conditions are required and all floods started to be considered as problematic. Also under influence of the ever-increasing world population there is often enormous pressure to develop tidal, deltaic and other flood prone areas due to their strategic location. These factors have led to increased necessity for flood control and protection measures.

Not all floods are natural. Human interventions in the drainage catchment area have often resulted in increased flooding risks. Examples are deforestation, canalization of river streams and disappearance of wetlands.

Potential solutions are:
• Introduction of flood control and protection measures often in combination with drainage.
• Integrated river basin management to reduce the risks of flooding.
• Introduction of precaution measures to reduce damage to crops.

For more technical information, see also:
• Irrigation water management training manual No. 1, Introduction to Irrigation, 1985, FAO, Chapter 6 & 7.
• Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 2.

Questions for discussion related to drainage
• Do you have problems with water ponding and/or waterlogging?
• Where are these areas situated?
• Is the drainage problem field specific or a problem of the entire area?
• How often does this take place?
• How long do the areas remain waterlogged and/or ponded?
• Does the waterlogging and/or water ponding cause a reduction in crop yield?
• Are there areas that are not in production or taken out of production because of these problems?
• Do the waterlogging and/or water ponding problems have any other negative effects? For example:
  - Poor health conditions.
  - Poor sanitation.
- Increased maintenance to houses and infrastructure.
- Poor animal health.

- What are the causes of the waterlogging and/or water ponding?

Questions for discussion related to floods

- Does flooding of the area take place regularly?
- Which areas are subject to flooding?
- How long and how often does this take place?
- What are the causes of these floods?
- Do they affect crop production and/or farm operations?
- Do extreme flood events occur?
- How long and how often do these extreme floods take place?
- What are the causes of these extreme floods?
- What is the effect of extreme floods on crop production?

Questions for discussion related to salinity

- Do you have salinity problems?
- Do salinity/sodicity problems relate to yield reduction?
- What are the causes of salinity/sodicity problems?
- Are these problems related to specific fields, spots or irrigation water sources or do the problems occur over the entire area?
- When did the problems first appear?
- Is this period related to any major change in irrigation management, hydrologic conditions or natural event?
- How deep is the water table?
- Is the groundwater fresh or saline?
- What source of irrigation water do you use?
- What is the effect of irrigation with this water?
- When are the problems most pronounced?
EXERCISE 4B: SELECTION OF DRAINAGE IMPROVEMENTS

Introduction

Sometimes drainage development is not new in an area and farmers might be well aware of the benefits and functioning of drainage. In other areas drainage might be a new innovation. In latter cases it is not likely that farmers are familiar with the concept of drainage. This exercise will familiarize farmers with the concept of drainage and will enable them to select and plan the required drainage improvements.

Objectives

- To identify the type of drainage improvements required.
- Prepare farmers for the planning of drainage improvements.

Expected outputs

- Identified type of drainage measures required.
- Understanding and awareness about the benefits of drainage and the functions of the different components of a drainage system.

Preparations required

- Prepare brainstorm discussion.
- Prepare discussion on type of drainage measures required.
- Prepare exchange visit. Select an area that has similar physical conditions as the area under consideration.

- If exchange visit is not feasible prepare video presentation supplemented by drawing, maps etc.

Materials required

- Small cards and markers.
- For exchange visit: transport, layout and drawings of the drainage system. Or audio-visual training materials e.g. video, drawings, maps, etc.

Time required

- Two hours 30 minutes when audio-visual training materials are used.
- Full day when a field visit is included.

Timing

- When the drainage problem is visible.
Procedure (Steps)

Plenary Introduction (15 min)

1. Review the previous training session (Exc. 1, Part C)
2. Explain the specific objectives and expected output.

Brainstorming (30 min)

3. Brainstorming on benefits of drainage.
4. Write the benefits on little cards.
5. Group the cards into three categories, i.e. increased crop production, improved farm management, and other benefits including improvement of the environment and contributions to rural development.
6. Supplement benefits mentioned by farmers.

Plenary discussion (20 min)

7. Recall outcome of cause and effect diagramming (Exercise 4A).
8. Discuss with the farmers what type of drainage intervention is required, i.e. surface drainage, subsurface drainage or a combination of both. Also explore the possibilities to solve the drainage problems through changing irrigation management, irrigation practices, improvements to the canal system, grading of land, changes in land use or farm practices, etc.
9. Reach consensus on the required drainage interventions and list the selected measures on a large sheet of paper.
10. Explain purpose of exchange visit or audio-visual presentation.

Exchange visit (3 hours plus travelling time)

The main objective of the exchange visit is to familiarize the farmers with the functioning of the different component of the required drainage system to enable them to plan their own drainage improvements. A secondary objective of the exchange visit is for farmers to exchange experiences with the host farmers. For this reason an exchange visit is preferred over an audio-visual presentation. The following programme is proposed:
11. Welcome (5 min)

12. Introduction: Reasons for the exposure visit and objectives (5 min)

13. Introduction on the drainage system including a brief presentation of the layout and design (20 min).

14. History of the area and changes since the introduction of drainage system presented by one of the host farmers (30 min).

15. ‘Walk-through’ by visiting farmers, host farmers and drainage/irrigation engineers. All different components of the drainage system will be inspected and a little explanation on their function will be given. During the walk through visiting and host farmers will have time to further discuss the function and benefits of drainage (1 hour 30 min).

16. Plenary discussion and questions (20 min)

17. Summary and Closure (Exc. 2, Part C)

**OR: Training session based on audio-visual materials** (1 hour 30 min)

11. Video presentation. Video should clearly show the different components of a drainage system, explain their function and the physical conditions should be similar to those of the area under consideration. Preferably the video should include a discussion on the effects and benefits of drainage.

12. Ask farmers to recall all components of the drainage system.

13. Clarify the function of the components of the drainage system, making use of drawings, maps etc.
Guidelines for (technical) preparations / questions for discussion

Benefits of drainage

The main direct benefit of installing a drainage system, to remove excess water for crop development and growths, is that the soil is better aerated. This leads to a higher productivity of cropland or grassland because:

- The crops have better root development and root more deeply.
- There will be better nutrient uptake and therefore fertilizers will be used more efficiently.
- Activity of micro-organisms will be increased and therefore the decomposition of organic matter will be enhanced.
- In the absence of oxygen certain soil bacteria will transform nitrate, which is a plant nutrient, into nitrogen gas. When the soil is better aerated less nitrate is lost.
- Salinity can be controlled better.

Other agricultural benefits of well-drained soils are:

- The land is easier accessible, with a better bearing capacity and workability.
- The period in which tillage operations can take place is longer.
- The choice of crops is greater.
- The growing seasons will be extended, as early planting will be possible.
- The soil structure is better, which also improves permeability.
- Soil temperatures are higher, so that crops (particularly horticultural crops) and grasses can be grown earlier.

Besides the agricultural benefits there are a number of social benefits that direct contribute to rural development and improvement of the environment. These benefits include:

- Improved public health through reduced risks of vector born and water-born diseases.
- Better sanitation.
- Improved animal health.
- Reduced maintenance cost to infrastructure, buildings etc.
Selection of drainage improvement measures

The best solution for drainage problems is not always the implementation of an artificial drainage system. Depending on the causes of the drainage problem, solution lay sometimes in:

- changes in irrigation management
- changes in irrigation practices
- improvements to the canal system
- grading of land
- changes in land use or farm practices
- removal of blockages in the natural drainage system

If an artificial drainage system is required, alone or in combination with one of the aforementioned options, a choice has to be made concerning the type of drainage measures required. The following points need to be taken into consideration:

- Implementation of surface drainage is sufficient when drainage is only required to remove surface ponding. Surface drainage consists of shallow open drains supplemented, when necessary, by land sloping and grading to make it easier for excess surface water to flow towards these drains.

- Subsurface drainage is required when waterlogging (and salinity) is a major problem. Subsurface drainage either consists of open drains or buried pipes.

**Advantages open drains:**
- they can receive overland flow; and
- can also serve as surface drainage.

**Disadvantages open drains:**
- loss of land
- interference with the irrigation system
- splitting up of the land, which hampers farming operations
- regular maintenance is required

**Advantages pipe drains:**
- no loss of land
- no interference with irrigation system
- land is not split up in small blocks
- less maintenance is required

**Disadvantages of pipe drains:**
- expensive materials
- installation is expensive
- it needs heavy equipment for installation
- they can not receive overland flow
- can not function as surface drainage
• If drainage problems are caused by a perched water table, developed on a shallow impeding soil layer, ripping or deep ploughing could probably solve the drainage problem. When the impeding soil layers are too deep or too thick for these measures, implementation of a subsurface drainage system is required.

Components of a drainage system

Drainage systems whether surface or subsurface consist, at least, of the following three components:

• **Field drainage system**, which is a network that gathers the excess water from the land by means of field drains (also called laterals). In surface drainage, field drains are shallow graded channels. In subsurface drainage, field drains can either be ditches or buried pipes.

• **Main drainage system**, which is a water-conveyance system that receives water from the field drainage system and transports it to the outlet point. The main drainage system normally consist of collector drains and a main drain. When the field drains consist of drainpipes, the collector drains can be either a buried pipe or an open ditch. In case of surface drainage and open subsurface drainage the collectors will consist of open ditches. The main drain is under normal conditions an open canal.

• **Outlet**, which is the terminal point of the entire drainage system, from where the drainage water is discharged into a river, lake, or sea. Depending on the outer water level and the variation over time the outlet might consist of: a free fall structure, a gated structure or sluice (either automatic or manually adjustable), or a pump outlet.

For more technical information, see also:

• **Irrigation water management training manual No. 1, Introduction to Irrigation, 1985, FAO, Chapter 7.**

• **Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 2 & 3.**

Questions for the discussion on benefits of drainage

1. What benefits do you expect from improved drainage conditions?
2. What are the benefits for crop production?
3. Are there other agricultural benefits that you expect from improved drainage?
4. If the drainage situation is improved, do you expect other positive impacts besides agricultural improvements?

Questions for the discussion on selection of drainage improvement measures

5. Would changes in irrigation management or irrigation practices solve the drainage problems?
6. Could improvements to the canal system solve the drainage problems?
7. Could the drainage problem be reduced with land grading or bedding?
8. In case of a local depression, could rice cultivation, fishpond or water reservoir not be a better land use?
9. Could a change of land use be the solution to the drainage problem?
10. Would removal of blockages in the natural drainage system solve the drainage problems?
11. What is further needed to drain the water out of the area into a river, lake or sea?
12. Is waterlogging or water ponding the major problem?
13. Do waterlogging and water ponding both occur and impede crop production?
14. Would it be sufficient to implement a surface drainage system or is subsurface drainage required?
15. If subsurface drainage is required what is the preferred solution, open drains or buried pipes?
16. What are the advantages and disadvantages of open drains and buried pipes?
17. Are impermeable layers common in this area?
18. How deep and how thick are these layers?
19. If you manage to drain the excess water, where will it be drained to?
20. Will it not shift the drainage problem to a different area?

Questions for field visit/ video presentation

21. What type of drainage system can you observe?
22. What are the various components of the system?
23. What is the function of the components?
24. What are the benefits of the drainage system?
25. What are the implications of drainage for farmers’ water management, role and function of water users groups, financial matters, etc?
EXERCISE 4C: PLANNING OF DRAINAGE IMPROVEMENTS

Introduction

Before the farmers can make a start with the planning and preparations for the drainage improvements the following points need to be covered: cause(s) of drainage problems; benefits of drainage; required drainage intervention; and functioning of the different components of the drainage system. The outcome of this exercise is a drainage plan which including a step-by-step plan, which lists the activities that have to be undertaken from planning/design to operation and maintenance. In this plan farmers should also define which activities can be done by themselves and for what activities support from an external (governmental) organization has to be requested.

Objectives

- To plan and prepare for drainage improvements.

Expected outputs

- Layout and plan for the improvements of the drainage situation.
- Step-by-step activities plan.
- Identified tasks and responsibilities that can not be implemented solely by the farmers.

Preparations required

- None.

Materials required

- Copies of the map prepared in Exercise 4A.
- Sheets and markers.

Time required

- Three hours and 30 minutes.

Timing

- When the drainage problem is visible.
- After Exercise 4A and 4B.
**Procedure (Steps)**

**Plenary Introduction** (15 min)

1. Review of the previous training session (Exc. 1, Part C).
2. Explain the specific objectives and expected output.

**Plenary discussions** (10 min)

3. Decide with the farmers which area with a drainage problem will be selected to plan and prepare drainage improvements for.
4. Discuss drainage planning and design considerations.

**Field visit/small group activities** (1 hour and 30 min)

5. Visit with the farmers the selected area and ask the farmers to split up in small groups of 4-5 persons.
6. Give each group a copy of the map prepared in Exercise 4A.
7. If it is required, ask the groups to prepare a more detailed layout map of the drainage problem area, on the basis of the map prepared during Exercise 4A, indicating slopes, drainage flows, agricultural fields, roads, rivers, drainage obstructions, etc.
8. Ask each group to draw the layout of the selected drainage measures (Exercise 4B) and to discuss what needs to be done further to improve the drainage situation.
9. Ask each group to present their layout map and drainage improvement plan.

**Plenary discussions** (40 min)

10. Discuss the different proposals. Pay special attention to: the layout of proposed field drainage systems; length of and distance between the field drains; outlet and land form between the field drains; alignment of the collector drains; drainage outlet; field and collector drain alignment versus existing infrastructure; drainage boundaries versus other existing social/organizational boundaries; size of independent controllable drainage units; implications for drainage management; possibilities for reuse of drainage water; additional requirements to improve the drainage situation.
11. Try to decide on the best and most realistic proposal that the farmers will be able to construct, manage, operate and maintain.
Plenary exercise (1 hour)

12. On the basis of the selected proposal ask the farmers to list down all the steps (activities) that have to be taken from planning/design until operation and maintenance. The purpose is not to go in great detail but to get an overview (feeling) of the activities that can be done by the farmers themselves and for which external help/support is required.

13. Write the steps down in a chronological order grouping them under the headings planning & design, implementation, and operation & maintenance (see example in guidelines for (technical) preparation).

14. Discuss which activities can be solely done by the farmers and for which activities external help is required or which activities have to be completely done by an external organization.


Guidelines for (technical) preparations / questions for discussion

Considerations for planning drainage improvements

- Planning of measures to improve the drainage situation in an area normally depend on the expected benefits compared to the costs. As discussed in Exercise 4B, the benefits do not only comprise improved crop yields but other agricultural and social benefits as well.

- Drainage is not the only factor determining the increase in farm returns. Only when drainage is a major constraints significant increase in farm returns can be expected. Therefore when low input farming is predominant in an area it might not be profitable to implement high cost drainage measures such as pipe drainage. The level of drainage investment should suit the level of agricultural development.

- Unless the area under consideration is located in the vicinity of a natural drainage outlet, a main drainage infrastructure needs to be planned and implemented. Normally planning and implementation of the main drainage infrastructure is beyond the capacity of a single group of farmers.

Layout and design of surface drainage systems

Surface drainage at field level can have two different layouts: the random field drainage system or the parallel field drainage system.

Random field drainage system
This system is applied when shallow depressions occur in the field but where complete land forming is not considered necessary. The random field drainage system connects the depressions by means of a field drain and evacuates the water into a collector drain.
Parallel field drainage system
This system is suitable in flat areas with irregular micro-topography and where farming operation require regular field shapes. The parallel field drains collect the surface runoff and discharge it into a collector drain. In technical terms the spacing between the field drains is determined by the time span within which excess water on the land, resulting from the design rainfall and excess irrigation water must be evacuated to avoid crop damage. In practice the spacing between the field drains also depends on the minimum size of fields that can be cultivated economically, the cost of land shaping, field and farm boundaries, and layout of farm roads and (tertiary) irrigation canals.

Layout and design of surface drainage systems
For subsurface drainage systems the choice between open drains or buried pipe drains has to be made at field level and for collector drains. If the field drains are to be pipes the collector drains can be either open ditches or pipe drains.

Singular drainage system
If the field drains are pipes and all field drains discharge into an open collector drain the system is called a singular drainage system.

Composite drainage system
When all field drains and collector drains are buried pipes, the system is called a composite drainage system.

The choice between singular and composite systems depend on:

- the need to provide an outlet for excess surface water;
- tolerable field size and land loss;
- outflow of pipe drains into a ditch is easy to inspect and blockage affects a small area only;
- ditch collectors require more maintenance;
- pipe collectors require more hydraulic gradient than ditch collectors;
- the costs of installing a composite pipe system are considerably higher than for a singular system;
- open ditches often interfere with irrigation canal systems.

Points for considerations in planning and design of a drainage system

There are a number of points that need to be considered in planning and design of a drainage system:

- Drainage boundaries should not only be determined by hydraulic boundaries. Moreover, from management point of view it is often more important that drainage boundaries coincide with existing social/group boundaries such as boundaries of irrigation water users associations, village boundaries, administrative boundaries, ethnic and religious group boundaries, etc.
- Drainage units should be such that farmers can operate and maintain the system
conveniently and cost-effectively.

- In water shortage areas, if the drainage effluent quality allows, the layout and design of the drainage system should allow farmers to reuse drainage water to supplement scarce irrigation water resources.
- In areas where rice and dry-land crops are grown simultaneous it is desirable that the system is designed in such a manner that small units of the drainage system can be closed to prevent high percolation losses from rice fields.

Example of a step-by-step plan for a subsurface drainage system

<table>
<thead>
<tr>
<th>Steps (activities)</th>
<th>Responsibilities</th>
<th>External organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning &amp; Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning and layout of on-farm system</td>
<td>Entirely done by the farmers</td>
<td>-</td>
</tr>
<tr>
<td>Technical survey</td>
<td>Farmers will assist I&amp;D department</td>
<td>I&amp;D department</td>
</tr>
<tr>
<td>Detailed design</td>
<td>Farmers have to approve design</td>
<td>I&amp;D department</td>
</tr>
<tr>
<td>Planning and layout main system</td>
<td>Farmers have to approve on points that relate to operation of their own system like drainage base</td>
<td>I&amp;D department</td>
</tr>
<tr>
<td>Implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting out the drains</td>
<td>Farmers</td>
<td>I&amp;D technical supervision</td>
</tr>
<tr>
<td>Digging collector drain</td>
<td>Farmers</td>
<td>I&amp;D technical supervision</td>
</tr>
<tr>
<td>Laying subsurface laterals</td>
<td>Farmers will assist</td>
<td>Contractor, I&amp;D tech. supervision</td>
</tr>
<tr>
<td>Construction of hydraulic structures</td>
<td></td>
<td>I&amp;D department</td>
</tr>
<tr>
<td>Main system</td>
<td></td>
<td>Contractor, I&amp;D tech. supervision</td>
</tr>
<tr>
<td>Operation &amp; Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular cleaning collector drain</td>
<td>Farmers</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance of hydraulic structures</td>
<td>Farmers</td>
<td>-</td>
</tr>
<tr>
<td>Operation of hydraulic structures</td>
<td>Farmers up to the collector outlet</td>
<td>-</td>
</tr>
<tr>
<td>Removal blockages in laterals</td>
<td>Request contractors</td>
<td>-</td>
</tr>
<tr>
<td>Maintenance of main system</td>
<td>Contribute according to work distribution</td>
<td>I&amp;D department</td>
</tr>
<tr>
<td>Operation of main system</td>
<td>Involved in joint decision making</td>
<td>I&amp;D department</td>
</tr>
</tbody>
</table>

For more technical information, see also:
- Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 4-7.

Questions for discussion on considerations of drainage planning

1. What are the expected financial benefits of drainage compared to the expected costs for installation, operation and maintenance?
2. Can this group of farmers manage the implementation, operation and maintenance of the planned drainage system themselves or is co-operation with other farmers necessary?
3. Is it necessary to involve the irrigation and drainage department in design and implementation?

Questions for discussion on design considerations for surface drainage

4. Would it be sufficient to drain only shallow depression areas?
5. Is it required to drain the entire area?
6. Are regular field shapes required?
7. What is the minimum field size that can be (economically) cultivated?

Questions for discussion on design considerations for subsurface drainage

8. Is there a need for surface drainage as well?
9. What is the minimum field size that can be (economically) cultivated?
10. Is labour readily available for maintenance activities?

Questions for discussion on general design considerations for drainage

11. Are there any existing social/group boundaries?
12. Is it possible to make the drainage boundaries correspond with these boundaries?
13. What is the maximum size of a drainage unit that can be operated and maintained efficiently by a single group of farmers?
14. Do water shortages occur?
15. Is the drainage water expected to be of good quality?
16. Would farmers like to reuse the drainage water for irrigation during water shortage periods?
17. What measures have to be taken to enable reuse of drainage water?
18. Are rice and dry-land crops grown in the same area?
19. Would it be necessary to keep the water table higher in the areas where rice is grown?
20. Would it be necessary to maintain different water table levels in various seasons?
21. What measures have to be incorporated in the design to enable water table control?

Questions for the preparation of the step-by-step plan

22. What activities have to be initiated and completed before the actual implementation of the drainage plans can start?
23. What activities have to be done to finalize the implementation works?
24. What are the maintenance activities have to be undertaken on a regular or ad hoc basis?
25. What has to be done to operate the system?
26. Can the farmers do the activities that have been identified themselves?
27. In case an activity can not be done solely by the farmers, what part can be done by the farmers and what part can not?
28. Why can farmers not do certain (parts of) activities themselves?
29. Which external organization(s) might be able to assist the farmers in the implementation of the activities?
30. What will be the tasks and responsibilities of the selected external organizations in relation to these activities?
EXERCISE 4D: APPROVAL DRAINAGE DESIGN AND DIVISION IN TASKS

Introduction

If, on the basis of the outcome of previous exercise, (parts of) the detailed designs of drains, canals and hydraulic structures are made by the responsible governmental agency, this exercise should be included as the final designs should always be discussed and approved by the farmers before implementation. Further agreement on the division of tasks during implementation, operation and maintenance between the farmers and the external organization(s) should be reached.

Objectives

- To approve the drainage design.
- Agreement on the division of responsibilities and tasks during implementation, operation and maintenance.

Expected outputs

- Approved design.
- Approved division of tasks and responsibilities.

Preparations required

- Study the designs and extract information important for the farmers and present it in a format that is understood by them.
- Familiarize with the alignment of drains and other structures in the field.
- Invite responsible governmental organization.

Materials required

- Detailed designs.
- Presentation of the design in a simple manner.
- Sheets and markers.

Time required

- Three hours and 15 minutes.

Timing

- After Exercise 4C and completion of detailed designs.
- Before implementation of the drainage system.
Procedures (Steps)

Plenary introduction (15 min)

1. Review of previous training session (Exc. 1, Part C).
2. Explain specific objectives and expected outputs.
3. Present visitors from the responsible governmental organization and other relevant external organizations.

Presentation and field walk (1 hour 30 min)

4. Present the drainage design making use of pre-prepared flip charts.
5. Walk with the farmers and representatives of the governmental organization along the alignment of the drains and point out the locations of important structures.

Small group discussions (30 min)

6. Divide the farmers in small groups of 4-5 farmers.
7. Ask the groups to identify important features on which they will evaluate the design and to write these down on a sheet.
8. Ask the farmers to evaluate the design on the basis of these features by writing behind each feature whether it fulfils their requirements or not.
9. Ask the farmers to give an overall evaluation by indicating whether they accept the design or what has to be changed before they can accept the design.

Plenary discussion and approval of design (1 hour)

10. One representative of each group should present the group evaluation.
11. Discuss differences in evaluations.
12. If certain aspects of the design are not approved by the farmers ask the representative of the governmental organization to explain the rational of certain design aspects and whether changes can be made or not.
13. Ask farmers to come to a final conclusion whether to accept or reject the design.
14. If the design is accepted by the farmers conclude by signing the design documents.
15. Discuss the step-by-step plan for the project phases ‘implementation’, ‘operation’ and ‘maintenance’ as prepared in Exercise 4C with the government officials and representatives of other organizations involved. Reach consensus on the division of tasks and responsibilities.


Guidelines for (technical) preparation / questions for discussion

Important features of the drainage design to be evaluated before approval

- Design groundwater table depth in relation to prevailing cropping patterns.
- Drainage boundaries versus other existing social/organizational boundaries.
- Farmers included or excluded from the drained area.
- Size and shape of plots.
- Expected land losses.
- Interference of the drainage system with irrigation system, other infrastructures and access to fields.
- Maintenance requirements.
- Expected cost for operation.
- Opportunities for reuse of drainage effluent.
- Size of individual drainage units.
- Possibility to close individual drainage units to maintain high groundwater table.

For more technical information, see also:
- Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 4-7.

Questions for discussion

1. Is the design water table suitable for the prevailing cropping patterns and especially for the economically most important crops?
2. Do the planned drainage boundaries coincide with any existing social/organizational boundaries?
3. Are the boundaries acceptable for all farmers?
4. Do the drainage boundaries include or exclude any (influential) farmers?
5. Are the sizes and the shapes of the plots for optimal farm operations?
6. Are the expected land losses acceptable?
EXERCISE 4E: IMPLEMENTATION OF DRAINAGE

Introduction

After the plans and designs have been completed and approved and consensus is reach about the tasks and responsibilities of all parties involved, planning of the activities for implementing the drainage measures need to be undertaken.

Objectives

- To plan activities that have to be implemented in order to realize the approved drainage design.

Expected outputs

- Action Plan defining the activities, responsibilities and a timeframe for implementation of drainage measures.

Preparations required

- Make a short assessment of the cost of possible construction materials and other inputs required.

Materials required

- Large sheets
- Small coloured cards
- Markers
- Pre-prepared tables

Time required

- Three hours and 45 minutes.

Timing

- After Exercise 4D.
**Procedure (Steps)**

**Plenary Introduction** (15 min)

1. Review of previous training (Exc. 1, Part C).

2. Explain the specific objectives and expected outputs.

**Plenary Action Planning** (1 hour 30 min)

3. Discuss with the farmers that the planned drainage measures can be regarded as the final output or goal for which the Action Plan will be made.

4. Ask farmers which intermediate-results or intermediate-outputs have to be achieved to reach the final output. Write the intermediate-outputs on cards.

5. Put the intermediate-outputs in a logical order (one step after the other).

6. Ask the farmers to identify the activities that need to be undertaken to reach the intermediate-outputs.

7. Order the activities in a chronological order and place them behind the intermediate outputs.

8. Write down on cards the party responsible for the different activities based on the outcome of Exercise 4C and place the cards behind the activities.

9. Decide on the timing of the activities and note these down as well.

10. Identify the materials required for each output. List them down.

11. Indicate behind each item who will provide the inputs and whether the items are provided in kind or cash.


**Small group discussions** (1 hour)

13. Ask the farmers discuss in small groups of 4-5 farmers for one of the intermediate-outputs (and only for the activities for which the farmers are responsible) the (a) quantities of materials required (b) estimated costs of the materials (c) labour requirements (d) where to find skilled labour if required (e) labour costs

14. Ask each group to fill in their estimates on a pre-prepared table (Exc. 1B).
Plenary discussions to finalize the Action Planning (1 hour)

15. Discuss the estimations of the different groups and try to conclude on realistic estimates.

16. Discuss responsibility for the organization and implementation of the different tasks and activities.

17. Appoint/elect sub-committees and responsible farmers for the different tasks and activities.


Guidelines for (technical) preparations / questions for discussion

For more technical information, see also:
- Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 4-7.

Examples of Action Planning formats

This table is an example of how to organize the intermediate-outputs and the activities that have to be undertaken to achieve the major output. Further, in this format the responsible party for each activity can be indicated as well as the timing of the various activities.

<table>
<thead>
<tr>
<th>Output: Subsurface pipe drainage system on 50 hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate-outputs</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>1. Alignment and levels of drains set out.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2. Alignment prepared for construction.</td>
</tr>
<tr>
<td>3. Collector drain dug</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4. etc.</td>
</tr>
</tbody>
</table>

This table shows how to organize the inputs/materials required to reach each of the intermediate-outputs. Further the responsible provider of the inputs and whether it will contributed in kind or cash can be indicated in this table.
### Other tasks and responsibilities to be undertaken by farmers

Besides the actual implementation work of the various activities there are a number of tasks and responsibilities that have to be undertaken to ensure smooth implementation. Examples of these tasks and responsibilities include:

- Co-ordination of various activities and time management.
- Ensure that all farmers contribute in kind and/or cash.
- Co-ordinate with the responsible governmental organization.
- Mobilize labour.

### Question related to Action Planning

1. What steps (intermediate-outputs) have to be taken to achieve the final output?
2. What intermediate-output has to be completed first before the next intermediate-output can be completed and so forth?
3. What activities have to be undertaken by the farmers or other organizations to finalize the intermediate-outputs?
4. Who is responsible for the implementation of the different activities?
5. When do the activities have to be undertaken to finalize drainage measures before the next (monsoon) season?
6. What materials/inputs are required to complete each intermediate-output?
7. Are the materials/inputs delivered in kind or cash?
8. Who is responsible to provide the various materials/inputs?

### Question related to finalizing the Action Planning

9. How much of each material is required?
10. What are the costs of the materials (unit prices)?
11. How much labour is required for each activity?
12. Is skilled labour required?
13. Does anybody within the farming community have these skills?
14. What are the costs for labour, both skilled and unskilled?
15. Besides the actual implementation work of the various activities what are other tasks that have to be undertaken to ensure smooth implementation?
16. Who will be responsible for the organization and implementation of the tasks and activities?
EXERCISE 4F: FOLLOW-UP IMPLEMENTATION OF DRAINAGE MEASURES

Introduction

Depending on the size and the type of drainage measures the implementation might take anywhere between a few weeks and several months. During the implementation work it is important to pay in the FST regular attention to the follow up of the Action Plan for implementation.

Objectives

- To monitor progress of implementation according to the Action Plan.

Expected outputs

- An assessment of the progress made on the implementation of the drainage measures according to the Action Plan.
- Corrective measures to be taken if deviations are observed from the Action Plan.

Preparation required

- None

Materials required

- Action Plan as prepared during Exercise 4E.
- Empty Action Plan forms if major deviations have to be made.
- Progress report forms.

Time required

- One hour

Timing

- At regular intervals e.g. fortnightly after Exercise 4E during implementation.
Procedure (Steps)

Plenary introduction (10 min)

1. Review of previous training session (Exc. 1, Part C).
2. Explain the specific objectives and expected outputs.

Plenary discussion (50 min)

4. Present the Progress Report forms.
5. Fill in the Progress Report Forms in discussion with the farmers. Pay attention to reasons for deviation from the initial Action Plan and discuss the corrective measures to be taken.
6. Discuss the functioning of the sub-committees and the participation of beneficiaries. If conflicts occur or Sub-committees do not function as required refer to exercises ...
7. Summarize the revised Action Plan for the following period.

Guidelines for (technical) preparations / questions for discussions

Examples of Progress Report formats

These tables show examples of how to organize the progress reports for activities, contribution of materials and contribution of labour. If deviations occur and corrective measures will entirely change the schedule of the Action Plan it might be wise to fill in new forms.
### Example Progress Report “Activities”

<table>
<thead>
<tr>
<th>Activities</th>
<th>Planned Timing</th>
<th>Progress</th>
<th>Reasons for deviation</th>
<th>Corrective measures to be taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Preparation of pegs</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; week May</td>
<td>Completed</td>
<td>Late start due to involvement of surveyors in another project</td>
<td></td>
</tr>
<tr>
<td>1.2. Surveying alignment and levels</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; week May</td>
<td>In progress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3. Installation of pegs to indicate alignment and levels</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; week May</td>
<td>In progress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1. Cut large bushes and trees</td>
<td>before end May</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1. Excavation of collector drain</td>
<td>1-15 June</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2. Removal of additional soil</td>
<td>1-21 June</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td>etc.</td>
<td>etc.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Example Progress Report “Contribution of Materials”

<table>
<thead>
<tr>
<th>Activities</th>
<th>Planned contribution</th>
<th>Actual contribution</th>
<th>Reasons for deviation</th>
<th>Corrective measures to be taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Preparation of pegs</td>
<td>Wood for 250 pegs</td>
<td>Wood for 250 pegs</td>
<td>Sub-committee responsible for financial contribution not functioning yet</td>
<td>Sub-committee should initiate collection of financial contribution as soon as possible</td>
</tr>
<tr>
<td></td>
<td>Rp. 1000 for 20 liters of impregnator</td>
<td>-</td>
<td>Sub-committee responsible for financial contribution not functioning yet</td>
<td>Sub-committee should initiate collection of financial contribution as soon as possible</td>
</tr>
<tr>
<td></td>
<td>10 axes</td>
<td>10 axes</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td>etc.</td>
<td>etc.</td>
<td>etc.</td>
<td></td>
</tr>
</tbody>
</table>
Example Progress Report “Contribution of Labour”

<table>
<thead>
<tr>
<th>Activities</th>
<th>Planned contribution</th>
<th>Actual contribution</th>
<th>Reasons for deviation</th>
<th>Corrective measures to be taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Preparation of pegs</td>
<td>10 farmers * 2 hours</td>
<td>10 farmers * 1.5 hours</td>
<td>less time required</td>
<td>farmers can contribute more time in other tasks if required</td>
</tr>
<tr>
<td>1.2. Surveying alignment</td>
<td>2 farmers per day * 4 days</td>
<td>2 farmers per day * 4 days</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>etc.</td>
<td>etc.</td>
<td></td>
<td>etc.</td>
</tr>
</tbody>
</table>

For more technical information, see also:
- Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 4-7.

Questions for discussion

1. Were the planned activities for the past period implemented in due time?
2. What was the reason for any delay?
3. Was this delay due to - external factors?
   - non participation of farmers?
   - poor organization?
   - non or poor functioning of sub-committees?
4. What corrective measures can be taken to proceed with the implementation?
5. Do certain activities have to be rescheduled?
6. Does the rescheduling and corrective measures have major effects on the initial Action Plan?
7. What activities have to be undertaken in the following period?
8. Who is responsible for which tasks?
9. Are there any preventive measures that can be undertaken to prevent future delays?
EXERCISE 4G: OPERATION AND MAINTENANCE OF DRAINAGE

Introduction

Once the drainage system has been implemented the system needs to be operated and maintained. Depending on the type of drainage technology used and environmental conditions there are several tasks and activities that need to be undertaken for sound operation and maintenance (O&M).

Objectives

- To plan tasks and activities that have to be undertaken for sound O&M.

Expected outputs

- Action Plan for O&M defining the activities, responsibilities and a timeframe for operation and maintenance activities.

Preparations required

- Carry out a short assessment of all O&M activities.
- Make a short assessment of the cost and other inputs required for O&M.

Materials required

- Large sheets
- Small coloured cards
- Markers
- Pre-prepared tables

Time required

- Three hours.

Timing

- After Exercise 4E before actual O&M starts.
Procedure (Steps)

Plenary Introduction (15 min)
1. Review of previous training session (Exc. 1, Part C).
2. Explain the specific objectives and expected outputs.

Small group exercise (50 min)
3. Divide the farmers in small groups of 4-5 farmers.
4. Ask each group to draw the cropping calendars for the main crops.
5. Ask farmers to indicate periods in which the different crops suffer from access of water and periods that crops suffer from water shortages.
6. Discuss the possibilities to alleviate these constraints through drainage operation management.

Plenary discussion (1 hour)
7. Ask each group to present the cropping calendars and options for drainage operation management.
8. Decide on the most promising drainage operation management.
9. Ask the farmers to identify the activities that need to be undertaken for sound O&M of the system. Note these down on a flip chart.
10. Decide on the timing of the activities and note these down as well.

Small group discussions (30 min)
11. Ask the farmers to go back to the same small groups.
12. Ask the farmers to discuss for the identified regular O&M activities the (a) quantities of materials required (b) estimated costs of the materials (c) labour requirements (d) where to find skilled labour if required (e) labour costs
13. Ask each group to fill in their estimates on a pre-prepared table (Exc. 1B).
**Plenary discussions to finalize the Action Plan for O&M (30 min)**

14. Discuss the estimations of the different groups and try to conclude on realistic estimates.

15. Discuss responsibility for the organization and implementation of the different tasks and activities.

16. Appoint/elect (new) sub-committees and responsible farmers for the different tasks and activities.

17. Note the names of subcommittee members and individual farmers down behind the respective activities on the flip charts.


**Guidelines for (technical) preparations / questions for discussions**

**Considerations for drainage operation management**

On the one hand, drainage is implemented to prevent crop damage due to excessive water. One the other hand, the worldwide continuous increase in water demand has increased the competition for water between industrial, agricultural, environmental and recreational needs. Increased competition for water requires intensive management of water resources. In the agricultural sector this has led to the necessity of conservation and recycling of the available water resources and sound water quality management.

Drainage management can contribute to these goals through:

- Conserving water and reducing drainage effluent through “water table management”.
- Recycling water resources by “reuse” of drainage water for irrigation.

**Water table management** is keeping the water table high through manipulating the drainage system operation so that plants can meet part of their evaporation needs directly from soil water. The permissible water table depth depends on the rooting depth of the crops grown, salinity of the shallow groundwater table and availability of leaching water. If both rice and dry land crops are grown in an area, rice should preferably be grown in independent operational drainage units that can be closed during the rice growing period.

**Reuse** of drainage water for irrigation can take place down stream of the drained area or within the area from where the drainage water is generated. It depends on the drainage water quantity, quality and the crops ‘how’ and ‘how much’ of the drainage effluent can be used for irrigation (Sub-module 4.4: Salinity management). Reuse might consist of direct reuse, blending, cyclic reuse of fresh and drainage water, or sequential reuse in which after each reuse cycle a more tolerant crop is grown. Often generation drainage effluent does not coincide with the demand for drainage water use for irrigation. Under these conditions storage of drainage water might be considered.
Formats for Action Planning for O&M

The same formats as presented in Exercise 4E can be used. In the column “responsibility” the names of the sub-committees or of individual farmers can be written down.

The formats for financial contribution, materials and labour as presented in Exercise 1B can be used.

For more technical information, see also:
- Irrigation water management training manual No. 9, Drainage of irrigated lands, 1996, FAO, Chapter 8.

Questions for discussion on drainage operation management

1. What are the main crops in this area?
2. When are they planted and when are they harvested?
3. During which periods do they suffer from excessive water?
4. Do periods of water shortage occur?
5. During which period for which crops is drainage required?
6. Are there periods that it would be beneficial to keep the water table high?
7. Are there periods that you would like to use the drainage effluent for irrigation?
8. What are the consequences for the operation of the drainage system?

Questions for discussion on the Action Plan for O&M

9. What activities have to be undertaken by the farmers or other organizations for sound O&M of the drainage system?
10. Who is responsible for the implementation of the different activities?
11. When do the activities have to be undertaken?
12. What materials/inputs are required?
13. Should the materials/inputs be delivered in kind or cash?
14. Who is responsible to provide the various materials/inputs?
15. How much of each material is required?
16. What are the costs of the materials (unit prices)?
17. How much labour is required for each activity?
18. Is skilled labour required?
19. Does anybody within the farming community have these skills?
20. What are the costs for labour, both skilled and unskilled?
21. Besides these activities what are the other tasks that have to be undertaken to ensure smooth implementation?
22. Who will be responsible for the organization and implementation of the tasks and activities?
SUB–MODULE 4.3

FLOOD CONTROL

EXERCISE 4H: PLANNING OF FLOOD CONTROL MEASURES

Introduction

In case regular flooding inhibits further development of an area or early floods, flash floods or floods caused by torrential storms cause unacceptable levels of damage to an area, a flood control plan needs to be developed. In the first place, farmers need to decide whether flood control and protection measures are required and feasible. Secondly, it should be discussed what types of measures are desirable and at what scale these plans should be initiated. Finally, depending on the scale and works involved, farmers could look for co-operation in the planning and implementation from other farmers and government.

Objectives

- To prepare a flood control and prevention plan.

Expected outputs

- Decision on whether flood control/protection is desirable and feasible.
- Identified measures and scale of plans to reduce the damage caused by flooding.
- Identified partners for co-operation to carry out the identified activities.

Preparations required

- Discuss the flooding situation with the government officials to find out what has been done in the past and if the government is willing to co-operate in a better flood control.

Materials required

- Copies of the map prepared by the farmers in Exercise 4A.
- Small coloured cards and markers.
- Large sheets of paper and markers.

Time required

- Four hours.

Timing

- Well in advance of the flooding season.
- After Exercise 4A
Procedure (Steps)

**Plenary Introduction** (15 min)

1. Review of previous training session (Exc. 1, Part C).
2. Explain the specific objectives and expected outputs.

**Small group discussions** (30 min)

3. Divide the farmers in small groups of three persons.
4. Ask farmers to discuss the origin and causes of floods and whether flood intensities, frequencies and heights have increased/decreased during the past.
5. Ask the groups to discuss the impact of floods on their farming systems and crop production.
6. The group should write positive impacts on green cards and negative impacts on red cards. Ask them to indicate whether impacts concern regular flooding or exceptional floods.

**Plenary discussion** (30 min)

7. Ask a representative of the groups to present their findings and stick the cards on a board.
8. Group similar impacts and summarize results.
9. Discuss positive and negative impact of flood control and protection measures.
10. Discuss whether flood control/protection works are desirable, what type of measures is required and at what scale they should be implemented.

**Group work - only to be done if flood control/protection is desirable** (1 hour)

11. Divide the farmers in the same groups again.
12. Provide each group with a copy the map prepared by the farmers during Exercise 4A. Ask the farmers to check the area(s) subject to flooding, sources of flooding and direction of flows.
13. Ask the farmers to discuss what they could do (maybe with the help of the government and other farmers) to prevent and control flooding.
Plenary discussion (1 hour 50 min)

14. One farmer should present their plan to prevent and control flooding.

15. Discuss the feasibility of the proposed plans.

16. Summarize the identified actions to prevent and control flooding and ask the farmers to select those actions they would like to be carried out.

17. On the basis of the selected actions ask the farmers to list down all the steps (activities) that have to be taken from planning/design until operation and maintenance.

18. Write the steps down in a chronological order grouping them under the headings planning & design, implementation, and operation & maintenance (see example under Exercise 4C, guidelines for (technical) preparation).

19. Discuss which activities can be solely done by the farmers and for which activities external help is required or which activities have to be completely done by an external organization.


Guidelines for (technical) preparations / questions for discussion

Impacts of floods

Flooding is a natural phenomenon in many part of the world. Traditionally farmers’ cropping patterns are well suited to normal flooding. Flooding cause problems when they are unusually early, high or late, when water levels rise very quickly or when exceptionally heavy rainfall or cyclones occur.

Positive impacts
- Provides water for traditional cropping patterns;
- Replenishes soil moisture for post-monsoon crops;
- Fine-grained sediments increase fertility of the soil;
- Depressions, lakes and ponds will be refilled which is important for fisheries, irrigation and domestic water use.

Negative impacts
- Damage or destruction of established crops;
- Prevent farmers from planting in time or at all;
- Force farmers to plant alternative crops;
- Loss of land by river erosion;
- Loss of land fertility when buried in coarse sand or gravel;
- Salinisation of land when inundated with seawater;
- Damage or destruction of infrastructure and houses;
- Damage or destruction of farm equipment, stocks and livestock.

**Impacts of flood control and prevention measures**

In general terms the role of flood control and protection measures is to protect life and property against damage caused by floods. In agricultural terms the role of flood control and protection measures is to reduce the damage to crops and to increase agricultural potential. Implementation of flood control and protection measures in flood plains and deltaic zones will regulate the depth and timing of flooding. Where large areas are fully protected from floods by embankments, drainage of excess rainfall is normally obtained by gravity through sluices. Under this concept, excess rainfall is drained slowly through the monsoon season. If supplementary pumping is added, so changing to a polder-type of management, the area will be separated from the surrounding hydrological regime and independent water table control can be accomplished.

**Positive impacts**
- Crops are protected against damage from floods;
- Infrastructure, houses, farm equipment, stocks and livestock are protected against damage from floods;
- Opportunities for crop intensification and diversification;
- Improved farm management;
- Possibilities for farm mechanization;
- Prevention of damage to farm equipment, stocks, livestock, infrastructure and houses.

**Negative impacts**
- In general the flood level rises in areas unprotected by dikes or embankments and thus increasing the damage in these areas;
- Beds of rivers confined by embankments might experience a rise due to siltation causing drainage problems;
- If inadequate drainage measures are incorporated in flood protection works the area behind the embankments and dikes might suffer from drainage problems as rainwater will accumulate behind the flood protection work;
- Damage from floods caused by breaches in dikes and embankments are normally very destructive;
- Deltaic and tidal areas are often fragile ecosystems that are easily disturbed by development works.

**Type of flood control and protection measures**

Flood control and protection measures vary largely in scale, spatial coverage and technology. A distinction can be made between flood control measures that aim to reduce and delay the flow and thus the flood height, and measures that aim to protect certain areas from floods.

**Flood control measures**
These measures that aim prevent extreme flood events or to reduce the flood height and normally concern an entire river basin or a distributary. Flood control measures include:

- Stream channel improvement.
• Construction of storage reservoirs.
• Land treatment in the catchment area to reduce and delay run-off.
• Creation of storage capacity in lakes, marshes, and inundation polders.

Flood protection measures
Flood protection involves the construction of dikes and embankments to protect the area behind from flooding. Flood protection measures can range from regional large-scale to small local developments. Flood protection measures include:

• The construction of low submergible embankments to protect the harvest of dry season crops from early floods. The incorporation of surface drainage in this type of flood protection works would enhance early flood recession and create favourable conditions for early planting of dry season crops. However, when drainage is done by gravity, time and speed of recession depend entirely on the outer water level at the drainage outlet.
• Complete protection of areas from floods by embankments in which drainage of excess rainfall is obtained by gravity through gates or sluices. The time and speed of recession depend entirely on the outer water level at the drainage outlet.
• Construction of polders. In polders an area is completely protected from floods by embankments in combination with supplementary pumping. The advantage of polders over flood control in combination with drainage under gravity is that additional lands can be planted and planting can take place earlier in the season (crop intensification). The introduction of subsurface drainage in those lands protected from floods would help to increase paddy production, and in lands, which are suitable for crops other than rice, crop diversification could be obtained.

Flood preparedness and warning systems
Other non-engineering measures to reduce the damage from floods include flood forecasting and warning systems and flood plain zoning.

Precaution measures
There are further a number of precaution measures that can easily be implemented by individual farmers. These measures include:

• Construct raised seedbeds so that seedlings will not be submerged.
• In flood prone areas seedbeds should be resown after transplanting in case floods destroy the first planting.
• Keep a reserve seed stock.
• Plant woody crops that can stand flooding around fields to break the force of waves and keep out floating masses, e.g. dainchya (sesbenia).
• Avoid flood prone sites.
• Make a bund around fields, which is high enough to keep flash floods and early floods out.
• Plant early.
• Choose suitable crop varieties.

Consideration for flood control measures
Flood control and protection measures including polder developments are normally implemented in the context of the overall planning of a larger area, e.g. delta areas or river
basins. Due to this reason, planning and implementation of flood control and protection measures are normally beyond the scope of a single group of farmers. This does not imply that farmers should not be involved in the development process. On the contrary, as implementation of flood protection and control measures will alter the hydrology of an area, farmers should be fully involved in the planning process and farmers needs and wishes should be incorporated in the designs whenever possible. The responsibility for planning of on-farm works, e.g. on-farm drainage as integral part of the flood control works, and small-scale flood protection and precaution measures, should be entirely with the farmers’ groups.

Similar to drainage development, the level of flood control and level of sophistication of the flood control works should suit the general development level of a region.

Questions for discussion on the impacts of floods

1. Are the crops and the cropping patterns adjusted to regular cropping events?
2. Do floods increase soil fertility?
3. For what purposes are lakes, ponds and depressions used?
4. What is the impact of floods on the function of the ponds, lakes and depressions?
5. Are there any other positive impacts of floods on crop production or livelihood of the community?
6. What is the impact of extreme flood events on crop production?
7. Do floods destroy soil productivity through e.g. deposition of stones, inundation with saline water?
8. Does riverbank erosion occur?
9. What other damage is caused by floods rather than damage to crop production?
10. How often do destructive floods occur?
11. Has the frequency, intensity, and/or depth of flooding increased/decreased over the past decades/years?

Questions for discussion on the impacts of floods control measures

12. What positive impacts do you expect from flood control and protection measures for crop production and farm management?
13. What other positive impacts do you expect for the local community?
14. What will be the impact in areas that are unprotected by dikes or embankments?
15. If beds of rivers confined by embankments might experience a rise due to siltation what would be the effect?
16. What would be the impact of embankments and dikes on the drainage situation?
17. What will happen when a dike or embankment breaks during a flood event?
18. What will be the impact of flood control and protection measures on the ecosystems?

Questions for discussion on the desirable type of floods control measures

19. Should measures aim to prevent extreme flood events or to reduce the flood height?
20. Is it feasible to aim at measures that include an entire river or distributary basin?
21. Should the measures aim at protecting a localized area?
22. What size is the smallest independent unit that can implement measures to protect itself from flood damage?
23. Is it desirable to protect an area completely from floods or is it sufficient if crops can be protected against early floods?
24. Is it sufficient to drain the protected area simultaneous with the flood regression?
25. Is additional pumping for drainage required?
26. Would it be beneficial to incorporate additional subsurface drainage measures?
27. What governmental agency and which farmers needs to be involved in planning and implementation of the proposed flood control and protection measures?

Questions for discussion on the additional measures to reduce crop damage

28. What can this group of farmers do independently to minimize flood damage?
29. What precaution measures can individual farmers implement?
EXERCISE 4I: IMPLEMENTATION OF FLOOD CONTROL MEASURES

Introduction

After plans and designs have been made and approved, the activities that need to be undertaken to implement the flood control, protection and precaution measures have to be scheduled. This exercise can be used for both the planning of implementation activities as well as for the planning of operation and maintenance activities, or use Exercise 4G steps 1, 8-16.

Objectives

- To plan activities that have to be implemented in order to realize the selected flood control, protection and precaution measures.

Expected outputs

- Action plan defining the activities, responsibilities and a timeframe for implementation of selected flood control, protection and precaution measures.

Preparations required

- Carry out a short assessment of all activities that need to be undertaken to implement the selected measures and the required resources.
- If designs were made by a governmental organization assure that farmers have approved the designs and agreed on the division of tasks and responsibilities between both parties.
- Make a short assessment of the cost of possible construction materials and other inputs required.

Materials required

- Large sheets
- Small coloured cards
- Markers
- Pre-prepared tables

Time required

- Three hours and 45 minutes.

Timing

- After Exercise 4E and after approval of designs for flood control and protection measures.
Procedure (Steps)

Plenary Introduction (20 min)

1. Review of previous training session (Exc. 1, Part C).
2. Review the plans and designs and discuss the tasks and responsibilities of the different parties involved.
3. Explain the specific objectives and expected outputs.

Plenary Action Planning (1 hour 30 min)

4. Discuss with the farmers that the planned flood control and protection measures can be regarded as the final output or goal for which the Action Planning will be made.
5. Ask farmers which intermediate-results or intermediate-outputs have to be achieved to reach the final output. Write the intermediate-outputs on cards.
6. Put the intermediate-outputs in a logical order (one step after the other).
7. Ask the farmers to identify the activities that need to be undertaken to reach the intermediate-outputs.
8. Order the activities in a chronological order and place them behind the intermediate outputs.
9. Identify the responsibility for the different activities based on the step-by-step plan made during exercise 4H.
10. Write the responsibilities on cards and place behind the activities.
11. Decide on the timing of the activities and note these down as well.
12. Identify the materials required for each output. List them down.
13. Indicate behind each item who will provide the inputs and whether the items are provided in kind or cash.
14. Copy the Action Plan in pre-prepared tables (see Exercise 4E).

Small group discussions (1 hour)

15. Ask the farmers discuss in small groups of 4-5 farmers for one of the intermediate-outputs (and only for the activities for which the farmers are responsible) the (a) quantities of materials required (b) estimated costs of the materials (c) labour requirements (d) where to find skilled labour if required (e) labour costs
16. Ask each group to fill in their estimates on a pre-prepared table (Exc. 1B).

**Plenary discussions to finalize the Action Planning** (1 hour)

17. Discuss the estimations of the different groups and try to conclude on realistic estimates.

18. Discuss responsibility for the organization and implementation of the different tasks and activities.

19. Appoint/elect sub-committees and responsible farmers for the different tasks and activities.


**Guidelines for (technical) preparations / questions for discussion**

**Examples of Formats for Action Planning**

See Exercise 4E

**Questions for discussion**

See examples Exercise 4E replace drainage measure by flood control measure.
SUB–MODULE 4.4

SALINITY CONTROL

EXERCISE 4J: PLANNING OF SALINITY CONTROL MEASURES

Introduction

In case salinity causes unacceptable levels of damage to crop production, measures need to be developed to control salinity or to mitigate the ill effects of salinity on crop production. In Exercise 4A, farmers have identified the causes of salinity and briefly discussed potential solutions, in this exercise a detailed plan to cope with salinity problems will be established.

Objectives

- To prepare plan to control and mitigate the ill effects of salinity on crop production.

Expected outputs

- Identified measures to control and mitigate the effects of salinity on crop production.

Preparations required

- Chemical analysis of soil and water resources.
- Make short assessments of: 1) availability and cost of water soil amendments; and 2) locally available crop species and varieties and their tolerance to salinity.

Materials required

- A copy of the map and the “cause and effect diagram” prepared by the farmers in Exercise 4A.
- Small coloured cards and markers.
- Large sheets of paper and markers.

Time required

- Three hours.

Timing

- After Exercise 4A
**Procedure (Steps)**

**Plenary Introduction** (15 min)
1. Review of the previous training session (Exc. 1, Part C).
2. Discuss briefly the outcome of Exercise 4A on the basis of the map and the “cause and effect diagram”.
3. Explain the specific objectives and expected outputs.

**Small group discussions** (30 min)
4. Divide the farmers in small groups of 4-5 persons.
5. Ask each group to discuss their experiences with or known practices for soil reclamation, measures to control or mitigate effects of salinity and/or irrigation with saline water.
6. Request each group to write down on green cards which measures worked and which measures failed.
7. Ask the groups to select those measures that they expect to work in this area.

**Plenary discussion** (30 min)
8. Ask each group to present the measures that they expect to work for this area.
9. Discuss with the farmers, based on the outcome of the soil and water analysis and knowledge of the physical conditions in the area, whether the measures could technically work and suggest additional measures that have not been suggested by the farmers.

**Small groups exercise** (1 hour 30 min)
10. Divide the farmers in the same groups again. Assign one measure to each group.
11. Explain the purpose of the Strengths, Weaknesses, Opportunities and Limitations (S.W.O.L.) analysis and distribute pre-prepared sheets for the S.W.O.L. analysis (see Guidelines for technical preparation).
12. Explain the four categories Strengths, Weaknesses, Opportunities, and Limitations (S.W.O.L.) to the farmers and explain that they should evaluate the measures on these four points (see Guidelines for (technical) preparation).
13. Ask each group to evaluate the selected measure on the four points and request them to write these down on the pre-prepared sheets.

**Plenary discussion** (30 min)

14. Ask each group to present their S.W.O.L. analysis.

15. Discuss the S.W.O.L. analysis and select a set of measures to be tried out in the field.


**Guidelines for (technical) preparation / questions for discussion**

**Reclamation of salt affected soils**

Whether it is attractive for farmers to reclaim soils and how reclamation will be attained depends on the salt concentration, type of salts, soil texture, availability of water and soil amendments, and the economic environment. Salt affected soils can be divided into saline, saline sodic, and sodic soils and accordingly reclamation techniques are advised.

**Saline soils**

The principle method for reclamation is leaching of salts by ponding water on the soil surface and allowing it to infiltrate. For effective leaching either sufficient natural drainage is required or an artificial subsurface drainage system to discharge the salty drainage water outside the area. As a rule of thumb a unit depth of water will remove about 80 percent of the salts from an equivalent unit of soil depth. Though if large-scale reclamation is planned more reliable estimates have to be made. This can be done through conducting leaching tests on a limited area and the preparation of leaching curves. Amendments are not required in saline non-sodic soils.

**Saline sodic soils**

As for saline soils the major method for reclamation is leaching of salts. Desalination is always accompanied by desodication although the rate of desodication is slower than the desalination process. Therefore, the application of amendments is not per se necessary. It will depend on the soil infiltration characteristics and the salinity of the leaching water whether the application of amendments is desirable. When soils susceptible to crusting or aggregate degradation are leached with low salinity water, application of an amendment might be desirable to enhance the reclamation process. The choice of amendment depends on soil characteristics, price and availability of the amendments and farmers resources.

**Sodic soils**

Basically the reclamation of sodic soils requires the replacement of most of the exchangeable sodium by calcium ions in the root zone. The way to accomplish this depends on the local conditions and local resources. If farmers do not have the resources to buy chemical amendments or they are not available reclamation can be obtained slowly by cultivating sodic tolerant crops and integration of organic residues in the soil. For a reasonably quick
reclamation process, application of chemical soil amendments followed by leaching is necessary. There are three groups of chemical amendments: soluble calcium salts (e.g. gypsum, calcium chloride), acid and acid forming substances (e.g. sulphuric acid, iron and aluminium sulphate, sulphur, and pyrite), and low soluble calcium salts (e.g. ground limestone). The applicability of the various groups of amendments depends on the soil conditions. Acids and acid forming substances are only suitable when the soil contains natural calcium carbonate. While ground limestone will only be effective to be applied to soils having a pH of about 7.0 or below.

**Strategies for the use of saline water for crop production**

The feasibility of using saline water for crop production depends on the quality, quantity, time of availability, and crops grown. Saline water can be used directly for irrigation or in conjunction with fresh water sources. If saline water is used in conjunction with fresh water the saline water can be either be blended with fresh water or used cyclic in which the fresh water and saline water are applied according to the different growth stages or in crop rotations between tolerant and sensitive crops.

**Direct application**

If the salinity concentration in the water does not affect the potential crop yields, or expected yield losses are acceptable, the water source can be used directly for irrigation (see attached tables). Care should be taken that salinity concentration does not build up in the root zone, therefore periodic leaching should be applied.

**Blending two water sources**

The blending strategy is normally applied when the saline water source is too saline for direct application and/or the fresh water source are insufficient. When blending two water sources the mixed water source should have such a salinity concentration and composition that it does not affect crop yields. Like in the direct application sufficient periodic leaching has to be ensured to prevent salinity levels building up in the root zone. Further, the final quality of the blended water should be such that other water uses e.g., domestic water use and use for environmental purposes, is not endangered.
Cyclic use

If two water sources are available the saline water can be used to irrigate salt tolerant crops or during salt tolerant growth stages. In general a pre-irrigation should be applied with the best quality irrigation water, as most crops are sensitive to salinity during germination. Later in the cropping season most crops become more tolerant to salinity. In cyclic application the tolerable salinity concentration in the irrigation water is in general higher than mentioned in most literature sources. As in the other two application strategies sufficient periodic leaching has to be ensured to prevent salinity levels building up in the root zone.

Use of sodic water

The presence of a high concentration of sodium in comparison to calcium plus magnesium and a relatively low total salt concentration, or the presence of bicarbonates in the irrigation water threatens the stability of soil aggregates and subsequently interferes with water infiltration and crop production. To mitigate such problems gypsum is normally added, either directly to the soil or dissolved in the water.

Additional management option to mitigate the effects of salinity on crop production

Selection of salt tolerant crops and varieties

A wide range of relatively salt tolerant crops exists and in many parts of the world salt tolerant varieties have been developed. Selecting more salt tolerant crops and varieties offer possibilities for utilization of saline water resources and saline lands for crop production.

Frequent irrigation application

Frequent irrigations maintain high higher soil water contents while maintaining lower concentrations of soluble salts. As salinity decreases the availability of soil water for plant uptake frequent irrigations will promote better crop growth.

Modify the irrigation method

Each irrigation method has certain advantages and disadvantages for salinity management. Sometimes it could be beneficial from a salinity-control point of view to shift to a different irrigation method. The most commonly recognized advantages and disadvantages of different methods are:

- With surface irrigation methods the infiltration is often not even which can result in isolated pockets of accumulated salts. Further, as the depth of applied irrigation water is quite high, an increase in irrigation frequency will often lead to deep percolation causing drainage and waterlogging problems. Though with basin irrigation large irrigation applications can be applied that will leach the salts over the entire field below the root zone.

- Sprinkler irrigation normally will apply water with a good uniformity. The frequency can be increased to maintain high soil water content. Also if well managed, adequate and uniform leaching can be obtained. The largest disadvantage of sprinkler irrigation is that
sprinklers can cause leaf burn if salts accumulate on the leaves between rotations of the sprinklers.

- With localized irrigation systems the soil moisture can be kept very close to field water-holding capacity. The irrigation can be given in such a quantity that a slight but nearly continuous downward movement of moisture and salts is maintained. When saline water is used for irrigation with localized irrigation the best yields can be obtained. During the season salts accumulate at the edges of the wetted area. When salts are moved by rain serious damage to crops might result. In this case periodic leaching through surface or sprinkler irrigation has to be done. The disadvantage is that this might require a second irrigation system and large quantities of additional water are required.

**Land preparation**

To permit uniform water distribution and leaching field needs to be sufficiently graded. Land smoothing also promotes uniform water distribution of water. Further, shortening of furrow and border length and reducing the size of basins will in general promote better and more uniform water distribution and leaching. The actual length of the furrow or border depends on soil type, slope and irrigation discharge. For optimal salinity control, land grading and smoothing is more crucial when surface irrigation is applied than when sprinkler or localized irrigation systems are used.

**Salinity control during germination**

Salinity reduces or slows down germination making it difficult to obtain a satisfactory crop stand. Therefore it is important to control salinity during the critical period of germination. Placement of seeds, bed shaping and irrigation management are important instruments to maintain low salt concentrations around the seeds during germination.
S.W.O.L. (Strengths, Weaknesses, Opportunities and Limitations) analysis

This tool recognizes that there are usually two different sides (positive and negative) to any given solution or measure. Further it also helps to identify the opportunities and the limitations for implementing certain measures in the field. It encourages discussion on all four aspects. In this way it helps to set the basis for selection of a set of measures and to identify action to be undertaken to enable implementation in the field.

Explanation of the four categories:

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Opportunities</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths are those effects that are expected to have a positive impact on the agricultural production. Strengths are the best aspects of the measure under consideration.</td>
<td>Weaknesses are those effects (or secondary effects) that are actually unwanted.</td>
<td>Opportunities are all possibilities for positive implementation of the selected measures, given both the strengths and weaknesses. Opportunities are the chances to change things for the better.</td>
<td>Limitations are the things that prevent implementation of measures. It is those things that stop farmers from realizing the opportunities. Some limitations can be overcome, others cannot.</td>
</tr>
</tbody>
</table>

S.W.O.L. analysis format and example

**TOPIC:** Salinity control

**MEASURE:** Reclamation of sodic soils

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
<th>OPPORTUNITIES</th>
<th>LIMITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• More land for crop production</td>
<td>• Loss of fuel wood</td>
<td>• Enough labour is available in the community</td>
<td>• Gypsum is expensive</td>
</tr>
<tr>
<td>• Less migration as land can be allocated to landless</td>
<td>• Loss of land which can be sold to brick factories</td>
<td>• Sodic wasteland is communal.</td>
<td>• Irrigation water has to be made available</td>
</tr>
</tbody>
</table>

For more technical information, see also:


**Questions for discussion on identification of measures**

1. Do you have experience in reclaiming saline/sodic soils?
2. What did you do to reclaim the soil?
3. What was the end result?
4. Why did this measure work or why did it not work?
5. Would this measure work under different conditions?
6. If the measure did not work or if you did not try to reclaim saline soils what do you think is required to enable soil reclamation?
7. If you do not have experience in reclaiming saline/sodic soils, do you know if other farmers in the region have tried to reclaim soils?
8. What did they do to the reclaim the soil?
9. What was the end result?
10. Why did their measure(s) work or why did they not work?
11. Would their measure(s) work in this area?
12. Why do you expect the measures will (not) work?

13. If you irrigate with saline water, are there special measures that you take to prevent negative effects on soil quality or crop production?
14. What is the effect on the soil quality and crop production?
15. Are there any measures that could improve the crop yield and/or soil quality?
16. What is required to implement these improvements?
17. How are other farmers in the region using saline water?
18. What is the effect of their method on the soil quality and crop production?
19. If these methods work, could they also work in this area?
20. Why would these measures (not) work here?

21. Do you select special crops or crop varieties?
22. Do you know if any salt tolerant crops of varieties exist?
23. Do they produce better yields?
24. If you have not tried any salt tolerant crop or variety why did you not do so?
25. Do you follow a different irrigation schedule for saline water sources or saline fields?
26. How does it differ and what is the effect?
27. Would it be beneficial to change to a different irrigation method?
28. Did you or farmers in the region try different irrigation methods?
29. What was the effect on the soil quality crop production?
30. What is the effect of land grading, furrow length and basin size on salinity control?
31. Are you aware of any methods that will increase the seedling emergence?

32. Which set of measures might be suitable to be tried out in this area?
33. What positive impacts do you expect from these measures on the agricultural production?
34. Are there any other positive impacts that might result from the measures?
35. Are there any negative side effects to be expected?
36. What are the possibilities and opportunities for implementing the measures?
37. What limitations do you so for implementing these measures?
38. Based on the positive and negative effects, and the identified opportunities and constraints what set of measures can be tried out in the field?