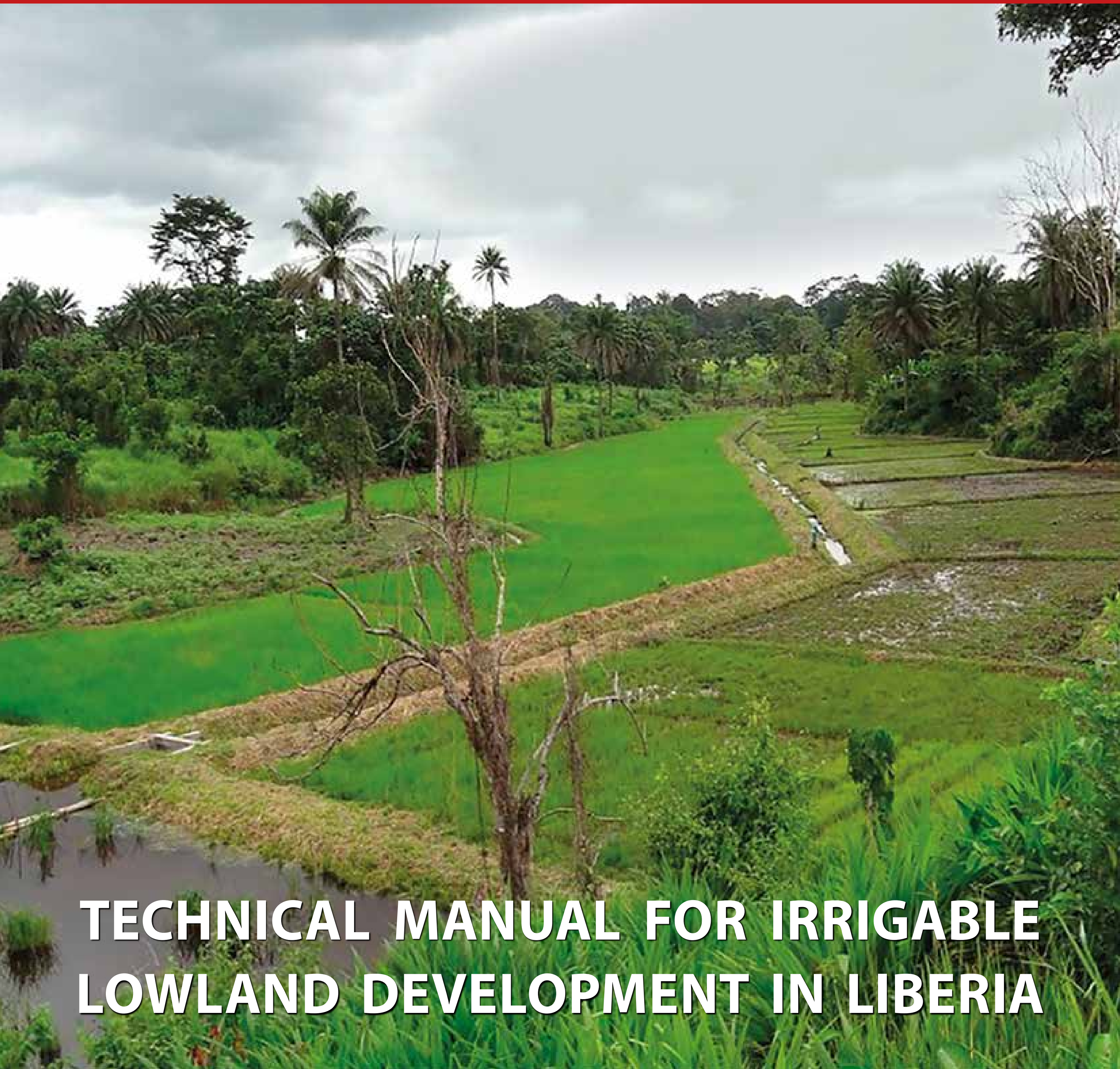
Rehabilitation and Development of Integrated Lowland Rice Farming in Liberia



TECHNICAL MANUAL FOR IRRIGABLE LOWLAND DEVELOPMENT IN LIBERIA

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Integrity – Service - Inclusion

Cover photo: The Main Components of Irrigation Schemes

Imprint

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Front cover picture
Developed Lowland for Rice Cultivation, Sakonnedu, Lofa County

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Preface

This present Technical Manual for Irrigable Lowland Development in Liberia prepared by the Ministry of Agriculture is the result of several years of practical work in the field, including data collection, construction activities, cultivating of rice fields as well as training and capacity building with the farmers' communities, Government partners (MOA, LISGIS and others) and international partners (Swiss Agency for Development and Cooperation SDC, World Food Program WFP, Africa Development Corps ADC), Food and Agriculture Organization FAO, Food and Enterprise Development FED, International Fund for Agricultural Development IFAD, BRAC, CESP and others.

The objective of this manual is to condense the existing knowledge and the expertise gained during actual field work period and to make it available to more actors in the field. The manual is structured in five chapters: the first two chapters provide the rationale and justification for shifting from upland to lowland farming with an overview of the nature and potential of lowlands; the third and central chapter gives practical explanations and good practices regarding the engineering side of lowland development and rehabilitation. The last two chapters (4 & 5) tackle supplementary issues like water management and maintenance of lowland schemes.

The authors firmly believe that lowland farming offers a very valid alternative to the present slash and burn shifting cultivation on the uplands which, under certain circumstances, can lead to deforestation and destabilization of the environment The upland farming of a growing population has a limited agricultural production potential and threatens Liberia's food security and wealth in rich forest resources.

We wish you an enjoyable reading and welcome your feedback and comments from the practical work in the field for further improvement of this Technical Manual.

MOA Technical Team
Voinjama / Monrovia, June 2015

1. The Liberian Traditional Farming System

The traditional farming system in Liberia is generally referred to as "the slash and burn shifting cultivation". Shifting cultivation is the annual migration of farmers in search of fertile farm land for farming purposes, a situation which results into the slashing and burning (brushing and felling) of new farm sites (forest) every year. It is labor intensive, low yielding, and subsistence in nature and has many ills and shortcomings. It is practiced by 90% of all rural farming households across the length and breadth of Liberia. To improve the livelihood of the rural farming public, intervention programs have to be implemented that shifts production from subsistence to sustenance.

Demerits of shifting cultivation in the current context of Liberia

- Shifting cultivation brings about forest degradation and environmental destabilization. Because of the shifting nature, there is high level of migration for fertile land.
- Due to increase in the farming population, there is a growing high demand for land.
- During the process of annual farming, natural habitats of animals are disturbed and/or exterminated.
- Shifting cultivation decreases tree cover and thereby reduces evapotranspiration; resultantly there is lesser cloud formation and decreased rainfall. This is bringing about major weather changes (climate change) that are directly affecting our farming cycle.
- Most crops grown under the traditional farming system are not improved varieties and are therefore long duration crops that are low yielding. Subsequently, annual harvest is not enough to feed the family and provide surplus for sale to meet other social and economic needs of the family.
- The slash and burn shifting cultivation system is very labor intensive; the same work load and processes are repeated every year. The annual process of "broadcast and scratch", generally the method of planting employed with shifting cultivation, loosens the top soil and encourages erosion. Erosion washes away the topsoil and reduces fertility, washing essential soil nutrients to the lower slopes (fringe land and valley bottoms).

2. Justification for Shifting from Upland Production to Lowland Production Farming

Even though upland rice farming system is the way of life of rural Liberian farmers, many factors mitigate against the continuous use of this type of production system. More importantly, contrary to the demerits of the uplands, lowlands have gained importance in the Liberian food production cycles due to some of the below attributes.

- In the wake of diminishing uplands, Liberia has many ideal lowlands (swamps) where erosion deposits the rich topsoil from the uplands, thus making the lowlands more fertile.
- Many farmers already carry on traditional lowland rice production under the continuum farming system and recognize the better fertility and subsequently higher yields under lowlands environments.
- Lowlands become hydromorphic (retain wet surfaces) during the rainy season; this high water table makes it possible for the farmer to carry on dry season farming (double cropping) in the same field.
- Lowlands are naturally fertile and because of the moisture regime, more suitable than uplands for intensive cultivation of rice and other crops during the dry season, i.e. lowlands support continuous rice farming and other crops such as cowpea-(kpaku torweh), peanuts, okra, corn, sweet potatoes, vegetables, etc. (which can grow well on residual moisture) during dry season.
- Lowlands generally respond better to high input production practices.
- Varieties for lowland production are generally higher yielding than upland varieties.
- Lowland sites, once developed become permanent production facilities (some developed lowlands are still under production since 30+ years ago).
- One outstanding merit for lowlands is their increased and sustained productivity resulting from the many possible cycles of rice and other crops produce within the same locality/ area, once developed.

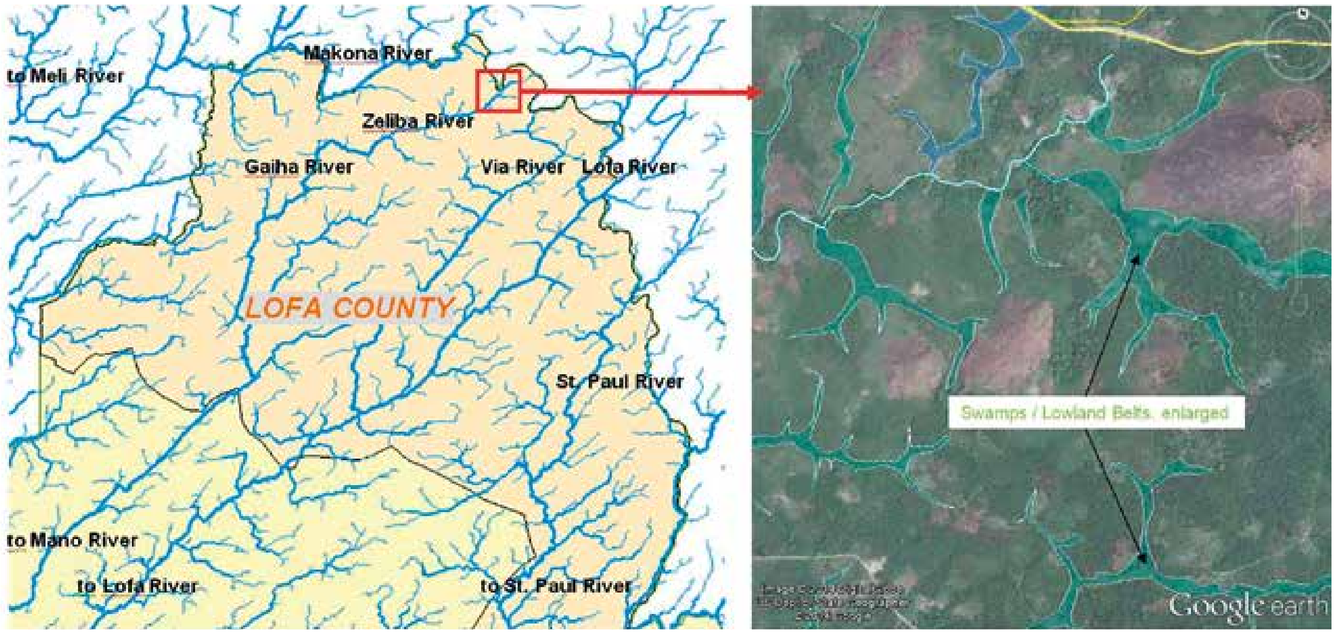


Fig. 1 River Systems of Lofa County

2.1 Hydro-Geography of Lowlands in Liberia

The underground of Liberia consists mostly of rock masses, which belong to the very old (over 2 billion years old) African Basement. These rocks are crystalline/ metamorphic and belong all to the Granite type. During the various forming processes of the earth›s surface, the Basement Plateau was under tectonic stress, which led to a cracking of the rock shield into small blocks along the Northeast-Southwest running tectonic fault lines (weak and cracked parts of the bedrock). This has shaped the network of rivers, waterways and swamps, draining all in the direction of Southwest and following with their courses along the weakened lines of the rock shield.

Liberia's toposequence is characterized by slightly rolling landscapes with a dense network of lowland areas (so-called "depressions"). These lowlands form the drainage network and are mostly saturated with water throughout or most time of the year. Therefore, lowlands are commonly called swamps, even though not all lowlands consist of swamps.

Fig. 2 A flooded road in Lofa County

The drainage network of Liberia has matured over many millions of years. Erosion and sedimentation processes have reached a stable equilibrium, and the water retention capacity is high, thanks to the dense vegetation and low gradients of the drainage network. The surface run-off starts in the upper boundaries of the watershed with steep slopes of rocky mountains and the thousands of hills. The adjacent lowlands however lie nearly flat and have an average gradient of only 3% per mile (30 cm per 100 m length). The depressions function thereby like a trough and get filled with water during storm events, while the flow remains low. At the junctions of several swamp fingers the flow increases, and allows water to form into creeks and defined waterways. The network of the various creeks finally drains into the major rivers, which lie in valleys transformed into flood plains during the main rainy season. The dense vegetation in the upper swamps and floodplains, as well as the big number of dead wood lying in the creeks and rivers reduce flow rates, and add to the retention capacity of the landscape, which is especially beneficial for the flood security of towns adjacent to major rivers.

Climate chart Voinjama - Lofa County

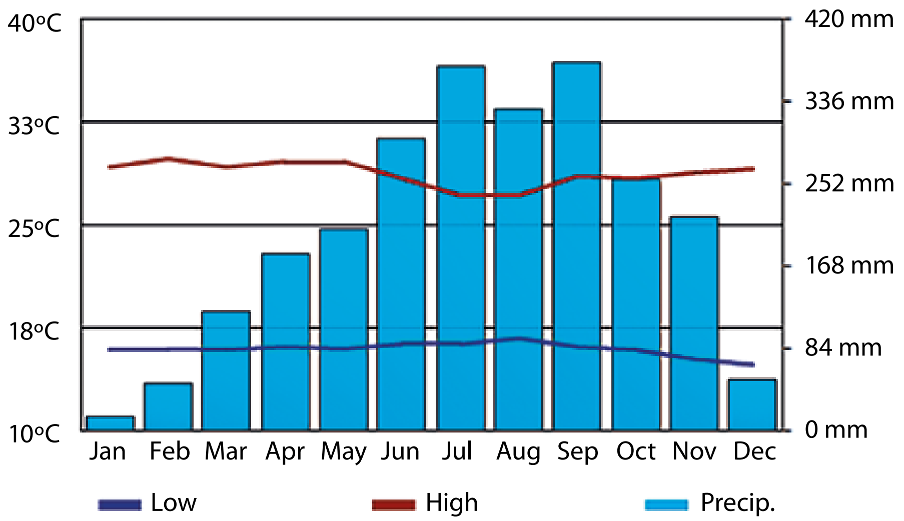


Fig. 3 Climate data of Lofa County: Rain concentrated during the months of May to October.
Source: climatedata.eu

Under normal conditions of the rainy season, the discharge of rivers varies only by a factor of 3 to 5. However, extreme storms can always create intensive flooding. The dense vegetation in the lowland areas helps to retain run-off water (swamps function like a "sponge"). These lowlands offer potential multiple rice cultivation (2 to 3 cropping cycles per year) and crop diversification during the dry season.

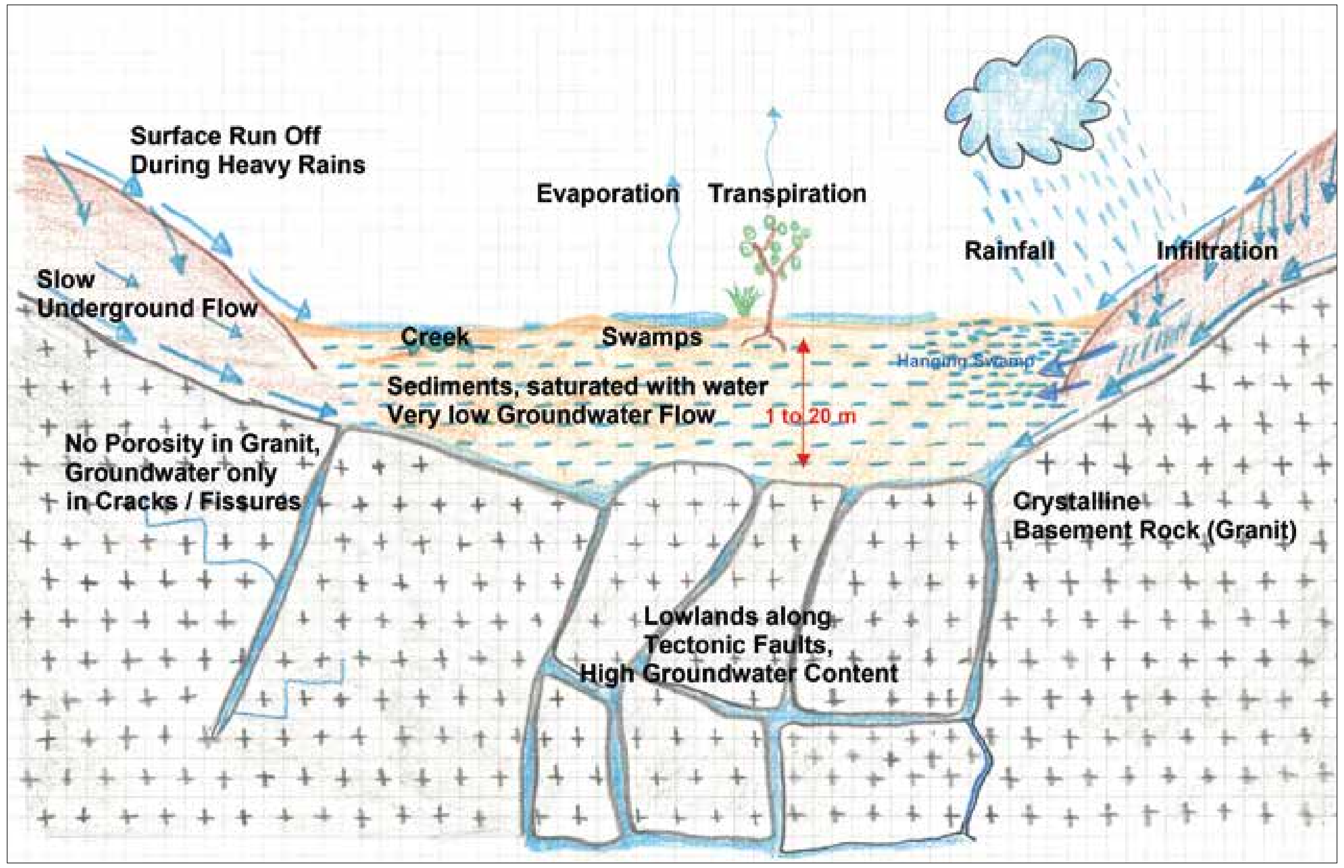


Fig. 4 Cross Profile of Lowland with Surface and Underground Flow of Water

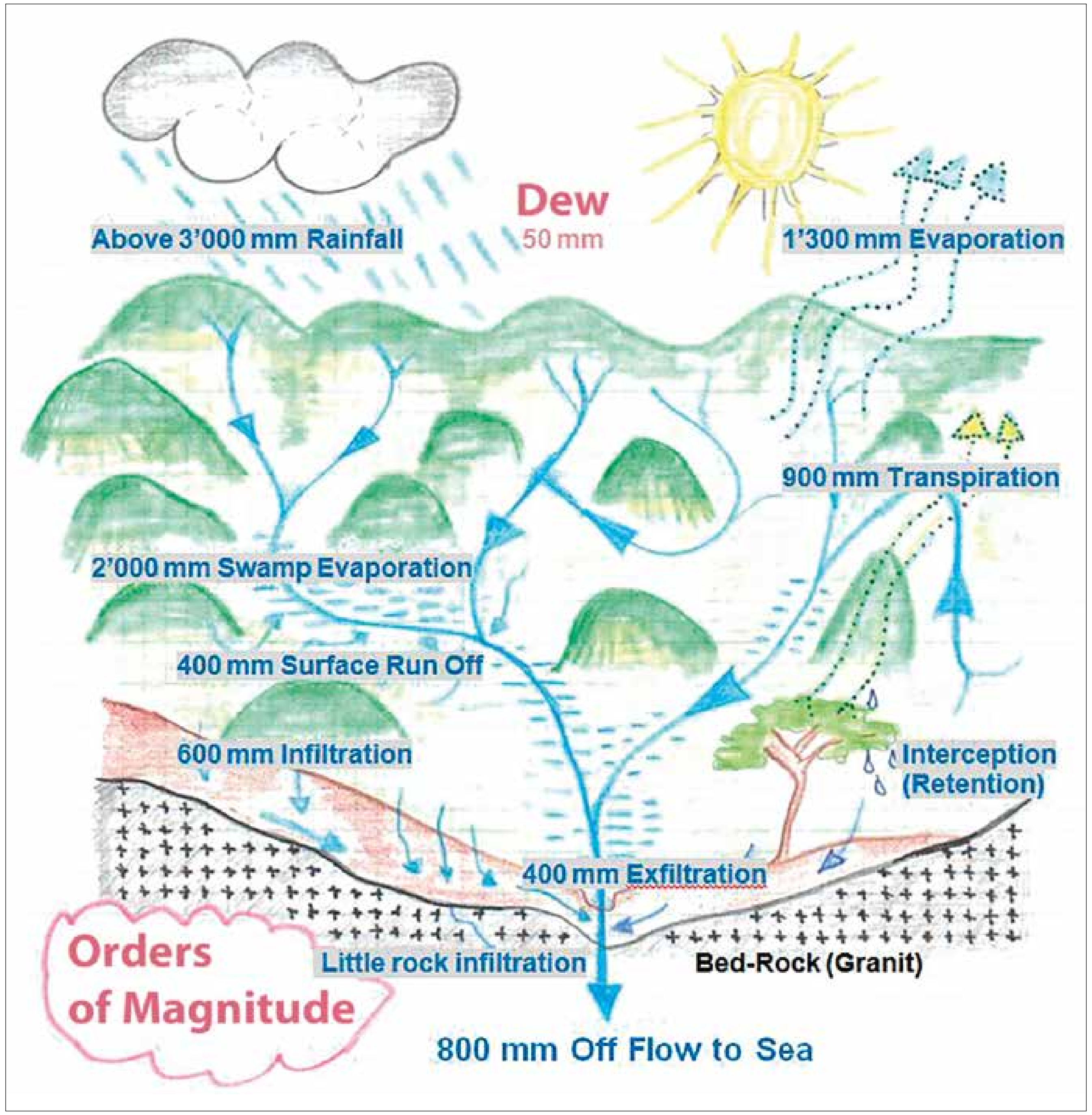


Fig. 5 Hydrological Cycle of Lofa County Landscape

Liberia belongs to the wet humid tropics and has two clearly distinguished seasons: Rainy season from May to October, and a dry season from November to April. During the rainy season, rainfall is abundant and exceeds the losses by evaporation and the consumption of plants (transpiration). During the dry-season rains are reduced and sometimes missing for more than six weeks, which creates water shortage stress on crops and wild plants.

Figure 5 shows the typical movement and amounts of water in the hydrologic cycle with its gaseous and liquid states. The energy of the sun (heat and light) is the engine driving the circulation and transport of gaseous water and clouds in the air. The Mano River Region is one of the regions of Africa with the most intensive rainfall. Liberia' hinterland counties average yearly rainfalls of above 3'000 liters per square meter (> 3'000 mm). Along the coast of Liberia rainfall is even higher (4,000+ liters per square meter). From this rainfall about 1'300 mm do evaporate (sun and air drying), therefore nearly half of the precipitation has a very short duration of liquid state. Another 800 mm are consumed by the plants and later transpired as gas through the pores of leaves (sweating of plants). Despite the dense vegetation, transpiration rate is controlled (when compared with temperate regions), because rainforest plants have to cope with the short but very hot dry season and have therefore all developed transpiration reduction properties such as waxy surface of leaves.

A quarter of the rain infiltrates into the ground, and the rate of infiltration depends on the intensity, duration and season of storm events. Animal life in the soil (worms, ants, termites, worm snakes) creates various burrows in the soil, which greatly facilitates percolations of water during storms. Infiltrated water is either consumed by plants (and later is transpired) or later ex-filtrates after longer or shorter passage through the ground into swamps and creeks in form of seepages.

Fig. 6 Flow of creeks along the highway from Voinjama to Lavalazu, on 22nd April 2014 (time of lowest water flow)

About one quarter of the entire rainfall flows along the drainage net of the lowlands and finally into the ocean.

The content and the flow of water in the lowlands are mostly determined by the individual particularities (geo-morphology, seepage from highland areas) of lowland, and less by the mere size of the watershed. This means that dry-season flow is different from lowland to lowland. While the flow of some swamps stops about a month after the rainy season, other swampy lowlands produce off-flow throughout the year. These sites are most suitable for year round use and intensive farming.

2.2 Potentials and Risks of Lowland Farming

The Ministry of Agriculture estimates that fertile lowlands composed of swamps (land saturated by water) and flood plains cover 20% of Liberia's surface. This means, that approximately 20 million hectares would be available for lowland farming. In Lofa County, one of the three former rice basket counties of Liberia, lowland area covers approximately 7% of the landscape according to the Liberia National Rice Development Strategy LNRDS, 2012. These are 70'000 hectares, which would allow **intensive rice production sufficient to meet national requirements.**

Fig. 7 Google Earth view on the swamp net in Quardugboni District. You can distinguish swamps with no lay-out, upland farms, bush, forest and towns (Kpandu). The scale allows to calculate the approximate surface of the different elements with the assumption that the surface shown is projected on a two dimension plane.

The wider use of the abundant lowlands offers a perfect alternative to the upland shifting cultivation, which progressively turns forest into grass savanna with very little agricultural potential for annual crops.

The lowlands receive most of the water draining from the uplands, including the various particles and dissolved elements. Thereby, the relatively quiet water in the wetlands acts as sink (settlement pool) for soil particles and nutrients. Because of this, lowlands have mostly rich soils and are very productive places for agriculture, unlike the poor soils on the uplands used for slash and burn shifting cultivation.

Our practical work experiences revealed that swamps can be developed in such a way that control of water flow and prevention of uncontrolled flooding is possible at any time of the year. Even during the peak of the rainy season the farm plots can be kept free of stagnant water. The mastering of swamps requires big investment costs, up to 5 times more than slash and burn farming in the uplands. However such initial investment can be used for hundreds of years by the succeeding generations if well maintained.

The waters of the lowland swamps and waterways have a low conductivity (values of 3 Siemens per Meter – 3 S/m – measured in Lofa) and is slightly acidic, with pH values from 4.5 to 6. The water is suitable for irrigation without any risk of salting of soil. However, underground water often has a high iron content, which generally leads to high iron toxicity and requires the selection of iron tolerant crop varieties and other precautions (flushing-out of iron slurry).

Lowlands and the network of waterways are important ecosystems for the rich bio-diversity of Liberia. The aquatic life too, is very rich in terms of numbers and diversity of flora and fauna. Swamps and creeks are home to over 200 different species of fish and crayfish, many of them not yet scientifically described or identified. Swamp fishing provides for poorer rural families the majority of protein

Fig 8 An idealistic landscape (photomontage) with lowland farming, swamp edge cultivation and preserved forests in the uplands. The irrigation schemes are all equipped with a retention pond at the intakes and Head dikes, which reduces run-off during storm events.

intake, and forms therefore an important livelihood component. Fish catch is most easy done during the dry season. During the rainy season with intensive flooding, many fishes migrate from the rivers and creeks to the upper swamps for spawning. The migratory passages in the swamps need to be maintained.

In spite of the increasing campaign for farmers to accept lowland development and production technology, adoption of the technology must acknowledge the prevalence of water borne diseases such as schistosomiasis, intestinal helminthes, leeches, etc. in lowlands that cause severe health hazards for farming families, sometimes resulting to deaths. Swamp works, as well as walking, bathing and fishing in the waters of these lowlands predisposes farmers and farming communities to getting infected with these water borne diseases, i.e. Schistosomiasis, intestinal helminthes, leeches, etc. Little information is available regarding the geographic distribution and ecological preferences of these diseases. It is believed that developed swamps with proper drainage facilities (and temporally dry lying fields) have lower prevalence and intensity of the diseases. Also the wearing of rain boots helps to protect swamp users. There is need to minimize the presence and effects of these lowland diseases. It is crucial to overemphasize the need to support the establishment of a Map and Data-base for water borne diseases to determine location, prevalence and infection rates in large lowland rice production counties of Liberia.

Cichlid-fish in peripheral canal

Catfishes from river and creeks

Cichlid and Barbus from canals

Boys fishing small river fishes (mostly cichlids)

Frogs from swamps and plots

Fig. 9 Swamps provide important Proteins

3. Selection of Lowlands for Irrigation Scheme Development

Lowland selection for development envisages the transformation of an inland valley swamp into useful agricultural scheme for the cultivation of rice and other crops. Before commencing the development of any lowland, one needs to know the history of /or details on the lowland to guide the selection and development processes. In selecting the lowland for development recommended procedures are as follows;

- Visit and get a detail history of the site / Collect past data or record on the scheme if available;

  Primary questions of interest are:

  - Is the lowland narrow/ wide/ flat, undulating?
  - What type of vegetation is in the lowland? (Small / large trees, piassava trees, grass, shrubs, etc.)?
  - Does the lowland have a good and constant water supply?
  - Does the lowland get over flooded?
  - Is the lowland seasonal? Water-fed?
  - What is the type of soil in the lowland?
- Agree with the community on the type of intervention in developing the scheme (social Assessment)
- Carry out infrastructural needs Assessment (Technical, Agricultural)

LOCATING THE LOWLAND

The selected lowland should be close to the beneficiary communities to facilitate access and supervision, as well as have more than 4 hectares to justify initial construction costs and with space for future growth and expansion.

TOPOGRAPHY

There is generally a noticeable change in elevation, soil type and vegetation between the upland and adjoining lowland. Paramount concerns for suitable lowlands will be: Is the topography undulating, rolling, flat, sloped? Is the lowland level? Fairly level? Are there many undulating surfaces or elevations that have to be leveled? Is the lowland fringe steep or gradually slope?

Look at the lowland topography with the vision of what it will look like when developed: Will leveling be easy? Will water distribution be easy to all areas of the plot?

VEGETATION

Look around the lowland. What is the most common vegetation, whether trees, shrubs, grass, legumes or non-legumes? The presence of a lot of small piassava trees provides some indication of a poor quality soil (sandiness). Leguminous plants (cover crops) and mitragyna (Christmas bush) indicate good soil fertility (loamy).

ABSENCE OF LARGE TREES

Too many large trees make development work more laborious, costly and difficult. Where possible, try to avoid too many large trees.

WATER SUPPLY/ REGIME

The production cycle of the lowland depends on the constant supply of water. The history of the lowland provides the requisite knowledge for properly planning lowland development.

- Should exhibit free surface water for at least 6-7months each year to enable two (2) potential rice crops/ annum.
- Catchment area should be sufficient to provide adequate water source without being too large to create major flooding problem. The angles of the slope of the catchment should not be so high to promote rapid run-off.

SOILS

The type of soil is very important in lowland development and production. Is it loamy, sandy, clayey, clay loam, sandy clay, or sandy clay loam? Lowland soils can vary considerably in terms of spread and depth and directly affect the size and shape of the area to be developed. Of paramount importance to development and production in lowlands are water holding/ storing capacity of the overlying topsoil and the type of subsoil.

Topsoil:

The topsoil provides the medium for crop growth and therefore influences the type of crop, duration and cultural practices.

- Sandy soils in general are unsuitable for lowland development because they cannot hold water and therefore make development work useless.
- Loamy soils are the best type of soils for lowland development and production. However, there are mainly three (3) different types of loamy soils in our Liberian lowlands – peaty, clay, and sandy loams:

  a. **Peaty loam** – very fertile, but saturated most of the year leading to incomplete decomposition and therefore little oxidation/organic matter. They are not suitable for canal and bund construction.

b. **Clay loam** – fertile and with high water and nutrient holding capacity. They are very good and ideal for canal and bund construction.

c. **Sandy loams –** least fertile, low water retention capacity, high permeability and heavy leaching. Soil structure is poor and not suitable for construction. Doesn't have much organic matter and therefore does not hold fertilizer/ nutrients at all.

Subsoil:

Subsoils are important in lowland development and production systems because they influence the level of nutrient and moisture retention as well as determine the level and type of structural design for development. Two major types of subsoils: clayey and sandy subsoils.

Clay subsoils – the most suitable for lowland development and are advantageous in bund construction because:

- They do not let water through easily.
- They can withstand high pressure when the water velocity (flow) is high, ie, they do not break easily.
- They can stand pressure, so when build as walkway, they compact and will not collapse easily.
- They retain moisture well and maintain the cross section shape of the canals.

Sandy Subsoils – are generally unsuitable to marginally suitable because:

- They are instable when saturated and cannot be used for bunds.
- Are highly porous and if the topsoil is shallow, it will not keep water in or out of the plots for any length of time.
- Restricts the depth of the main canal to the depth of the topsoil because it erodes from under the topsoil.
- It causes the bunds to collapse inwardly.

Rule of Thumb – For both engineering and agronomic considerations:

- The best type of soil profile is clay loam overlying clay
- More than 30cm of clay loam overlying sandy subsoil is marginal for development
- Topsoil less than 30cm overlying sandy or gravelly subsoil is unsuitable for development

3.1 Considerations in Potential Lowland Irrigation Schemes Selection

The inland valley swamps (lowland belt net) in Liberia are mostly very suitable for agricultural use because they possess fertile soils and act as traps for nutrients washed out from the uplands. There are generally cases of iron toxicity, which require attention and the selection of resistant rice varieties. However, only lowlands with sufficient and near to year-round water supply are suitable for the development of full-scale irrigation schemes. We recommend installing water supply devises only in swamps with flowing water until the end of February at least. This requires flow measurements during the dry season (from January to April) as well as during the rainy season (August to September) prior to initiation of the development.

At sites without sufficient water flow, the use of rain-fed rice fields during the rainy season (in combination with a proper drainage) are more recommendable since the investment and maintenance requirements do not justify the limited advantage of having supply canals and modules.

Success in lowland farming first and foremost depends on the motivation and capacities of the users of the scheme. To achieve this, land-ownership (user-rights/ privileges), qualities of swamp soils, access to market and social coherence within the user group need to be favorable. Furthermore:

- Agree with the community on the type of intervention in developing the scheme (social Assessment)
- Carry out infrastructural needs Assessment (Technical, Agricultural)

3.2 Planning of Lowland Development

The proposed swamp layouts are considered very nature-friendly, because water courses are earthen and impounded fields offer a new habitat for various fishes. The sizes of the schemes are kept small and every scheme starts with an open water pond created by the head dike. These natural stretches with wild vegetation act like micro parks for wildlife. The peripheral canals shall be kept wide, and act as retention pond and additional biotope. Free drop of water (waterfalls) shall be avoided, to facilitate fish migration.

Lowland development involves the transformation of an inland valley swamp into useful agricultural scheme for the cultivation of rice and other crops. For the scope of this manual, much of the emphasis is placed on rice production. After Assessment, project the cost of the intervention, allocating dates to all activities, etc.

Projected cost for development/amelioration of 1 hectare of swamp land

Activity	Quantity	Projected Cost (USD)if done by Contractor	Person Days Required	Favorable Implementation Period
Brushing, burning & clearing	1	Farmers contribution	40	Dec to Jan
Light destumping		Farmers contribution	80	Dec to Jan
De-stumping and clearing	50 trees (> 36cm diameter)	1400	450	January
Field design and layout	1	Technical team contribution	NA	January
Installation of Stone Shell Spillway	1	1200	50	February
Peripheral canal and bund construction	200m length	300	100	March
Floodway canal and bunds construction	150m length	900	375	January
Construction of head dike	100m length	900	300	February
Construction and Installation of flow restrictors	2 pcs	100	4	February
Inner bunds construction	962m length	962	300	April
Leveling of plots	1 hectare	450	150	April
Acquisition and Installation of bamboo pipes	100 pcs	333	10	April
Leveling light Nursery Preparation and Transplanting	Farmers Contribution	Farmers Contribution	10 60	May to June
Contingency	Lump sum	1755	20	
TOTAL		**8'300 $**	**1949 p/d**	

Development expenditure may vary from site to site (number of trees, culvert/bridge installation, variation in length of structures, topography, etc.) but on the average our experiences have taught us that these are fair values for a well-developed swamp.

3.3 Levels and Gradients

Levels or elevations of different point (forming gradients/slopes) in the scheme are very important if the water distribution in the scheme is to be done by gravity. Simply put, water runs from regions of higher elevation to regions of low elevation, and the gradients (steepness of slope) determine the speed of the flow (velocity). The overall natural gradient of a swamp scheme is in the range of 3 ‰ (per mile, i.e. 30 centimeters drop per 100 meters horizontal), this determines also the average longitudinal gradient of canals and water ways. The levels of the peripheral canals are given by slope of the swamp edge, and to main drain/floodway has to be dug as deep as possible.

The most critical levels to be kept are at the headdike, as depicted in Fig. 10 and Fig. 11. The control of these levels requires utmost attention, otherwise the control of water will not be possible, especially at times of flooding and high water flow.

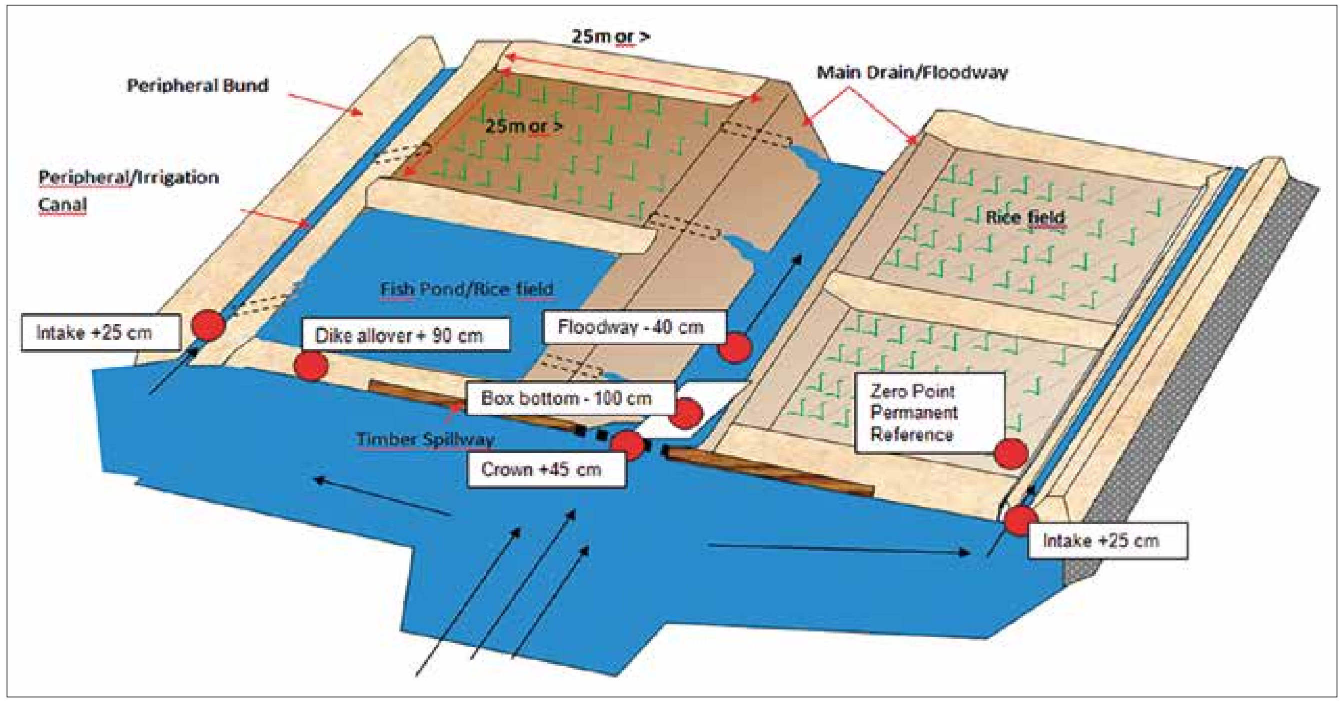


Fig. 10 Critical Levels at Head Dike an Intakes to Peripheral Canals

The levels can be checked by using careful eye observations (note that stagnant water is flat-lying/horizontal) of the impounded (sitting) water in ponds, plots or canals or by using technical gear such as Spirit Level and line, water filled head pan, Hose Level or most exact Surveyor›s Level. All such gear shows you a horizontal line from where you measure differences to the particular spots on the ground.

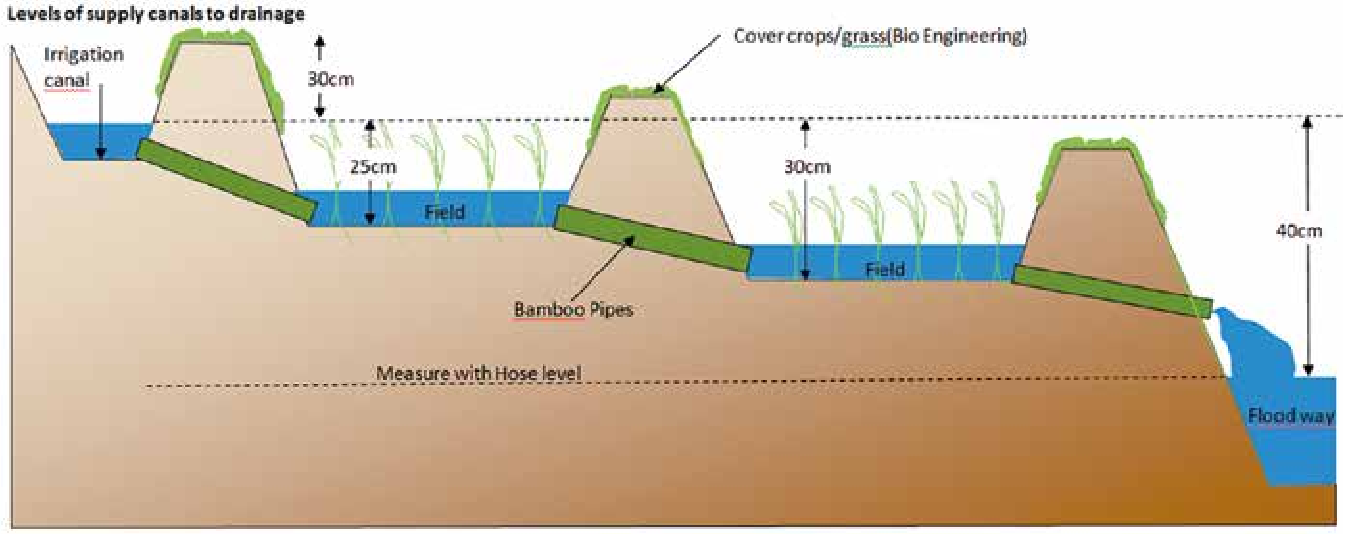


Fig. 11 Levels and Drops between Peripheral Canal and Floodway

3.4 Layout and Mapping

The structural layout of an irrigation scheme depends on the lowland›s topography, shape and the flow behavior of natural waterways. The recommended layout consists of a central floodway and peripheral supply canals at both edges of the lowland (compare Fig. 13 with Fig. 15). For very narrow lowlands or for sites with natural creeks flowing at one edge of the lowland, however, a peripheral floodway plus one opposite peripheral supply canal may be appropriate (Fig. 12).

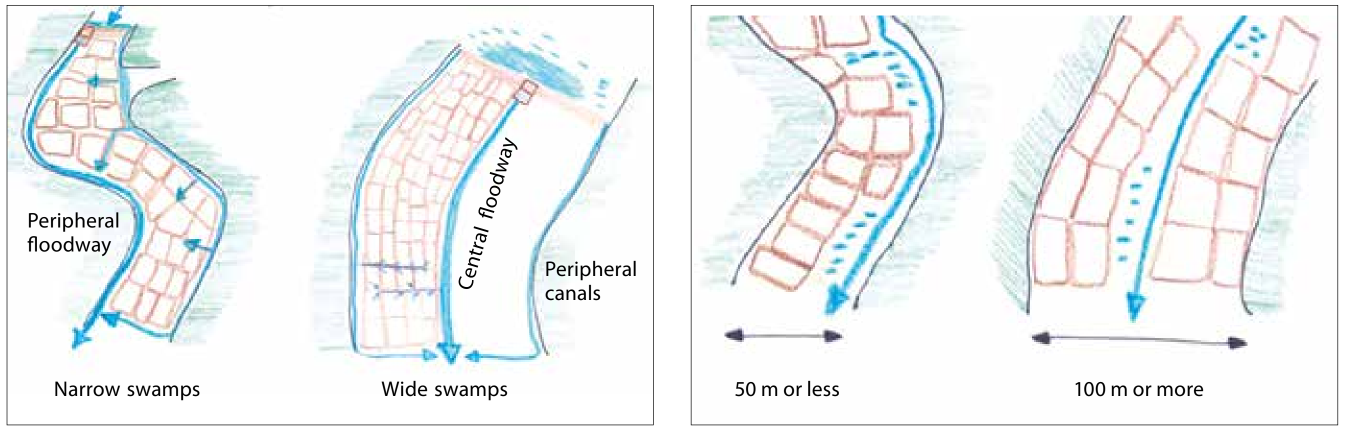


Fig. 12 Selection for Positioning of Floodway: Peripheral or Central
Irrigation scheme with supply canals — Rain-fed scheme with floodway only

It's very essential that developed lowland is also mapped to enhance easy access to plot information, control as well as distribution of water and to enhance research work. Modern technologies have made it easy to map lowlands with the aid of;

- GPS (Global positioning system)-Garmin/Basecamp
- GIS (Geographical information system)
- Google Earth

Every scheme can be mapped after proper leveling information is gathered to look like the figures below.

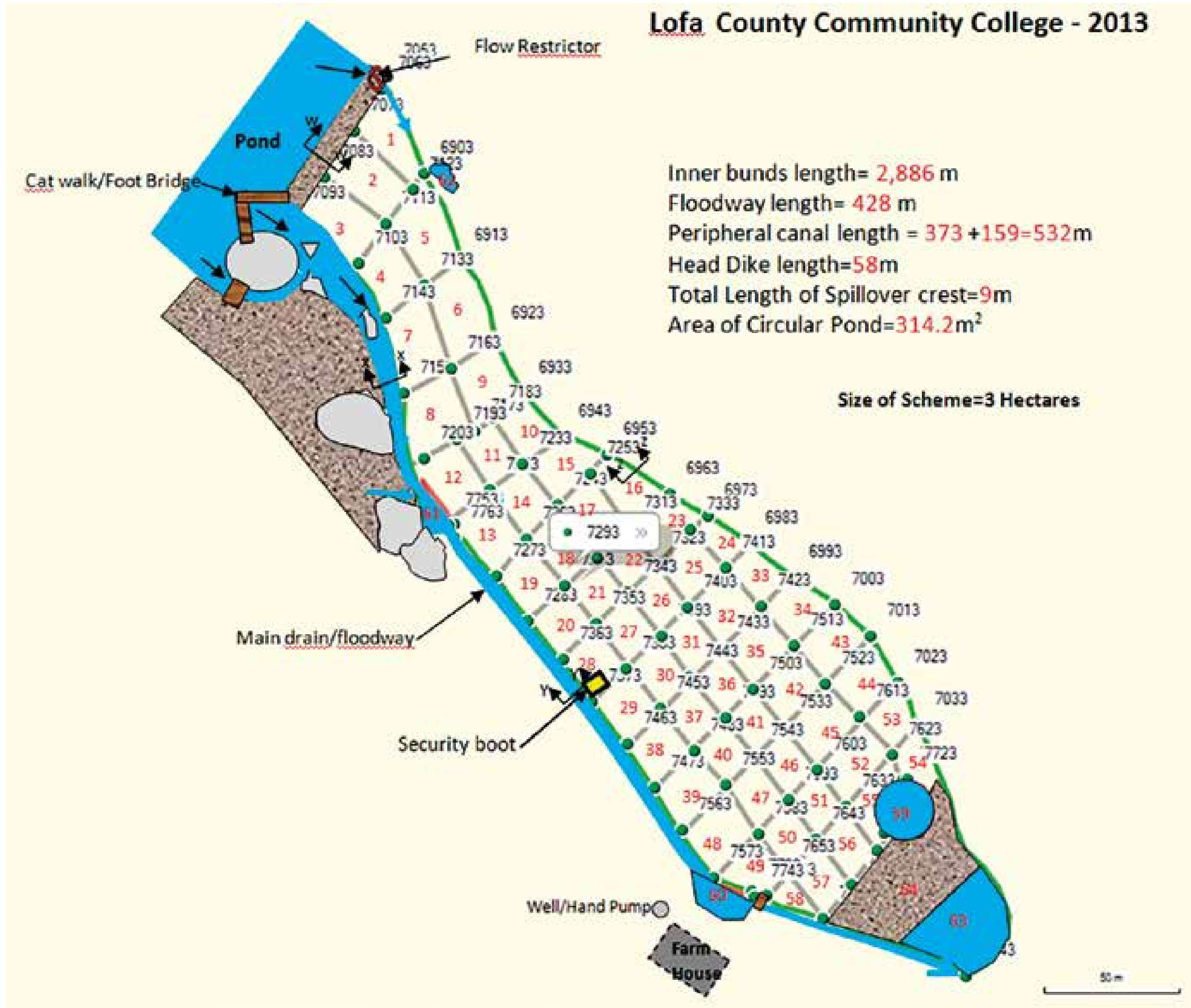


Fig. 13 A detailed swamp layout prepared with the help of a GPS data inserted into Google Earth image

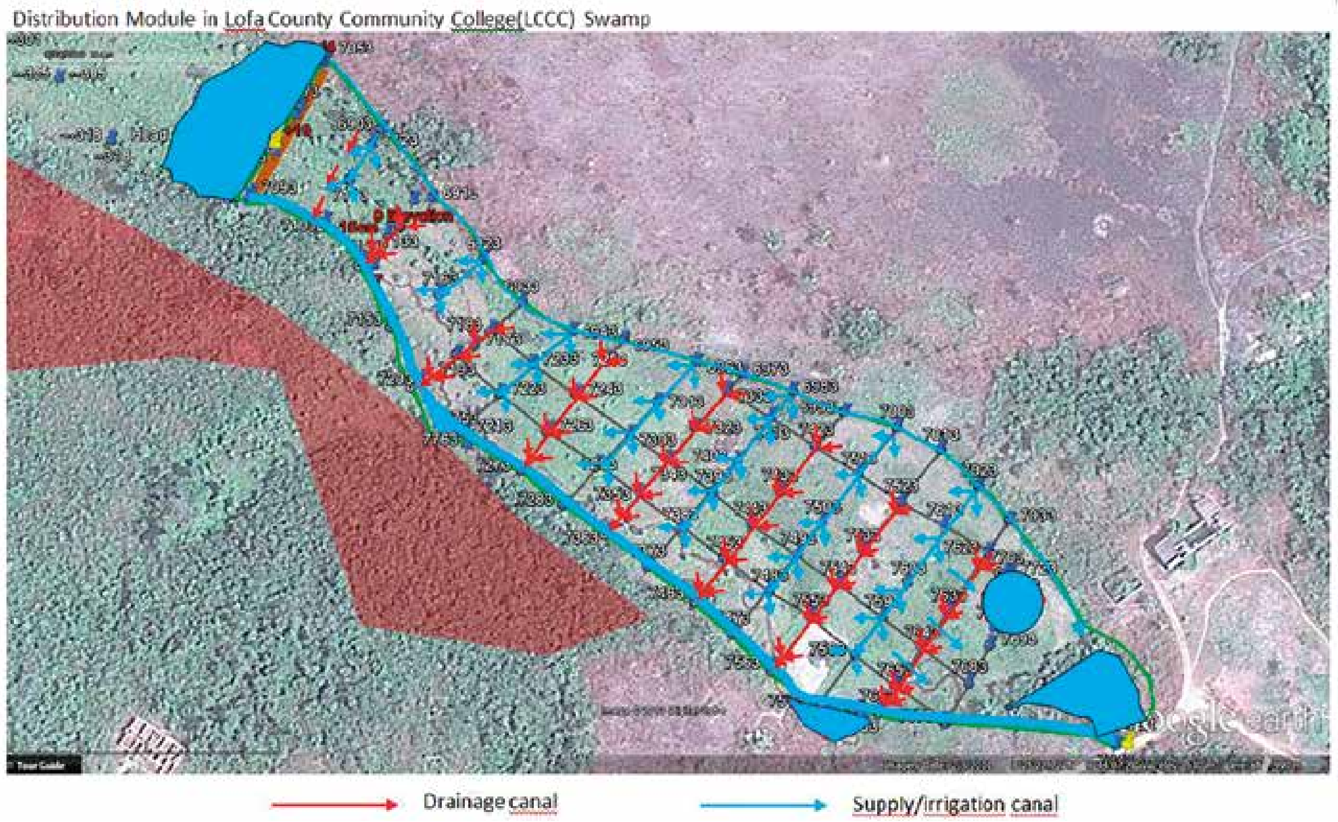


Fig. 14 A lay-out prepared with a print-out from Google Earth and hand-drawings with color pens

Fig. 15 A swamp layout prepared with a print-out from Google Earth and hand-drawings with color pens

3.5 Land Preparation Works

3.5.1 Brushing

This is the process of cutting down all vegetation in the lowland/swamp to be developed. It is usually the first activity that commences the entire land clearing. It is favorably done between December and February.

Fig. 16 Brushing of shrubs, small trees and grasses

3.5.2 De-stumping

This is the process of complete removal of a tree right from the roots. It must be noted that de-stumping is different from cutting at the stump/root top. The reason for proper de-stumping is to enhance plot development and leveling as well as gain more land for the cultivation of rice. Also importantly, destumping

Fig. 17 Explaining the cable pulling device "Come Along" for tree de-stumping

Fig. 18 De-stumping Abura tree with the help of cable pulling device "Come Along"

eliminates trees that would otherwise be breeding/ resting places for birds as well as shade the rice crop against proper sunlight penetration. De-stumping is the most laborious work in the development of irrigation schemes in virgin swamps.

Use the Cable pulling hoist (Come Along) to de-stump trees while still standing (illustrated in above photos, Fig. 17 and Fig. 18). Help from power saw is needed, and best get combined with the production of planks and timber.

3.5.3 Clearing

This is the removal of all remains of the vegetation that was brushed, burned and de-stumped. It's usually done a week after brushing and immediately after de-stumping.

Fig. 19 Clearing of land from debris

3.6 Construction Activities

3.6.1 Floodway/ Main Drain Construction

This is the mass/emergency exit structure of the entire scheme. This is the structure that carries/transmits a huge mass of water with a high flow rate at the peak of the rainy season and during floods. The shape of the floodway canal is trapezoidal as demonstrated below. See Fig. 20 for design and be generous with its dimensions. It is favorably done between January and February.

Fig. 20a Peripheral floodway in Bettijama

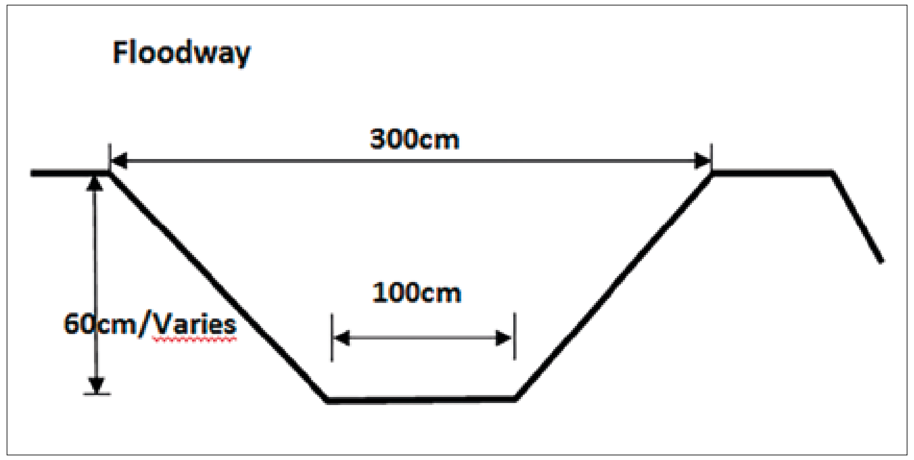


Fig. 20b Dimensions of floodways

Fig. 20c Central Drain / floodway

3.6.2 Head Dike

This is the water control structure that gives the hydraulic/water Head/Height which is very essential for distribution in the entire scheme. It also serves the purpose of water retention to form an artificial pond to promote aquatic biodiversity. Must be built with well compacted layers of earth, preferable hauled from outside swamp. The swamp edge dug-out shall be used to explore and eventually develop groundwater supply. It is favorably done in February.

The earth/material for the spillway is either collected from the up-lands or is excavated from the swamp area above the headdike.

Fig. 21 Examples of head-dikes

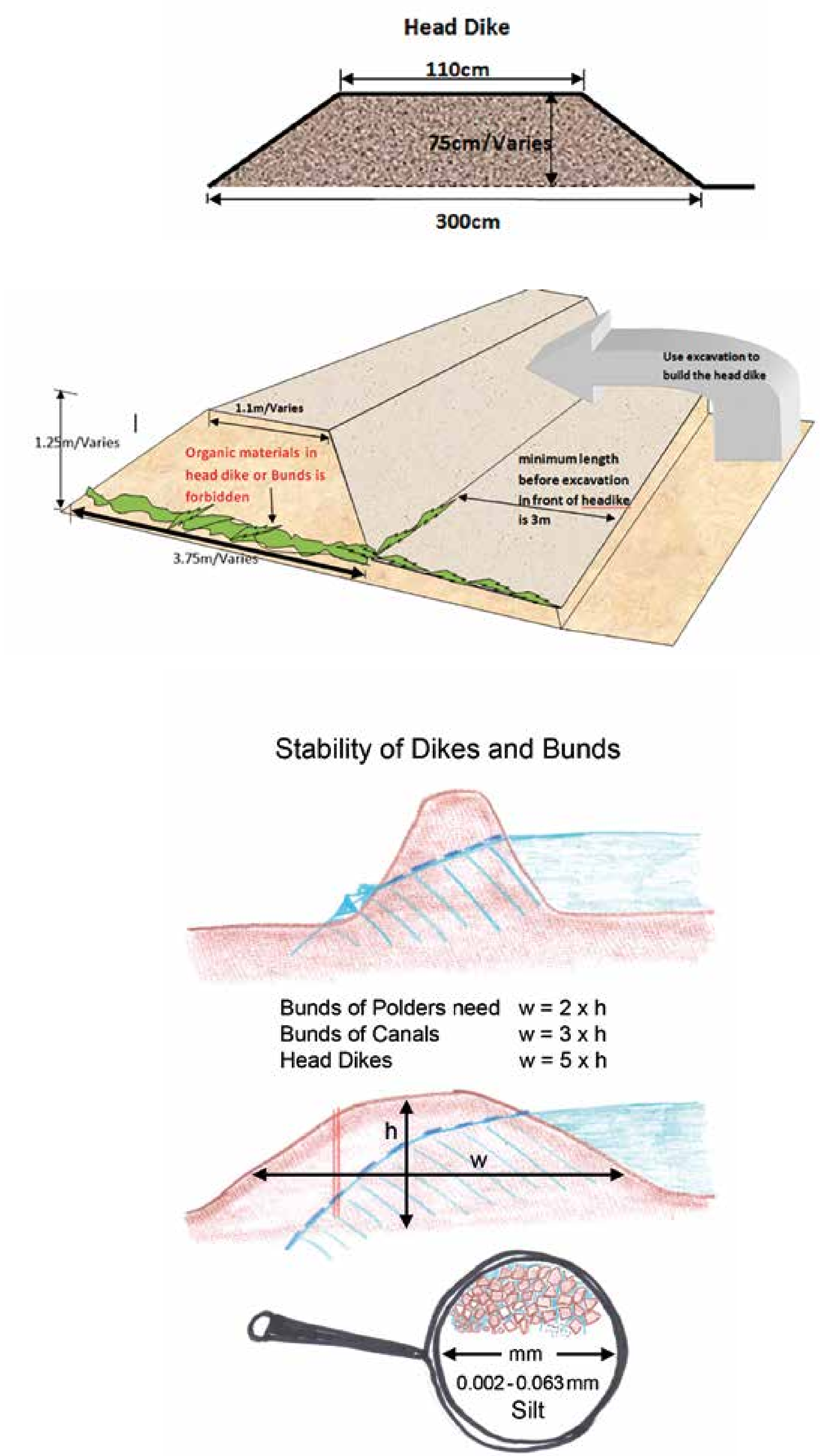


Fig. 22 Dimension of head-dikes

3.6.3 Spillway

This is a water control structure that facilitates the movement of water into the irrigation canals at the same time spill over the excess water to go into the main drainage/floodway. It must be built solid in reinforced concrete, timber or stone masonry. We recommend the use of cement masonry with boulder rocks (Rock Shell Spillways, Fig. 23). Spillways are favorably built between February and March.

The width of the crest decides about its floodwater disposal rate. It is the mouth of the floodway and main drain. As wider as better, but avoid dropping (free fall) of water. The Stone Shell Spillway absorbs 200 to 800 litres of storm water per second. Because of the drop in water level energy is generated and falling water starts to scours, the spillway needs to be solid and kept free from obstacles.

Working Steps and Plans for Construction of Stone Shell Spillway

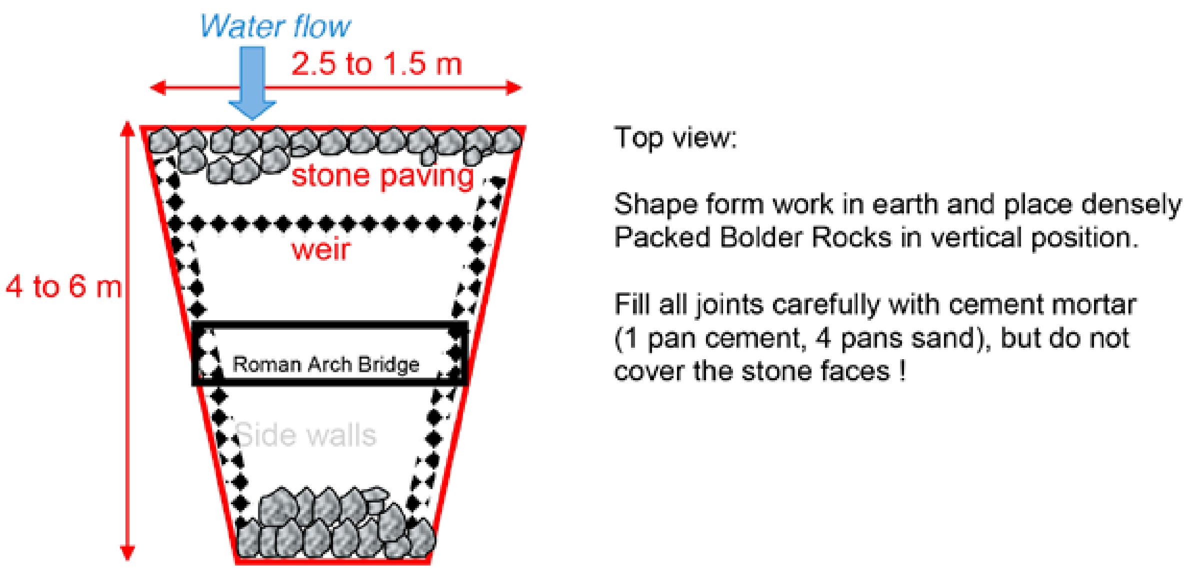
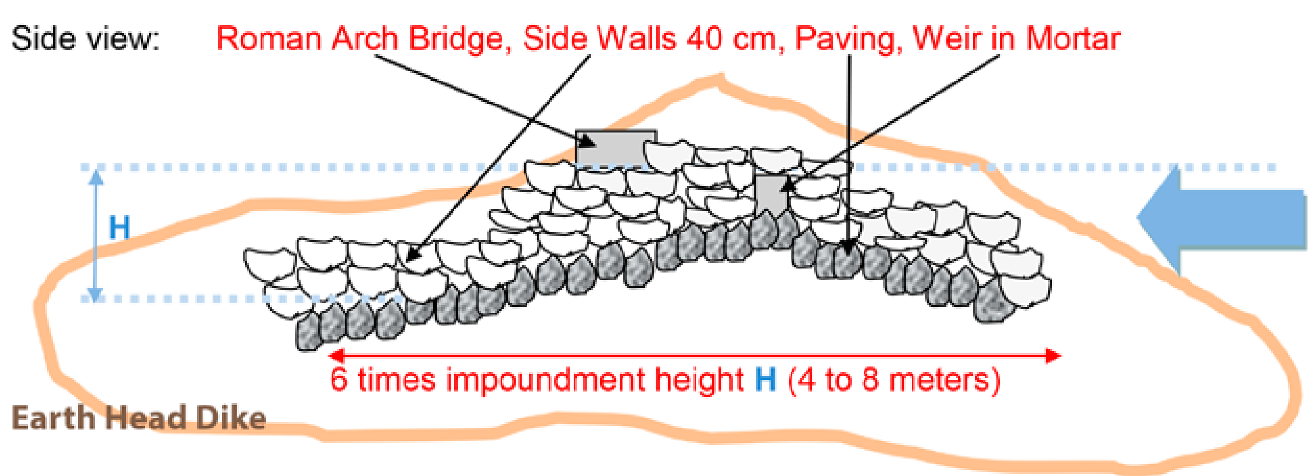
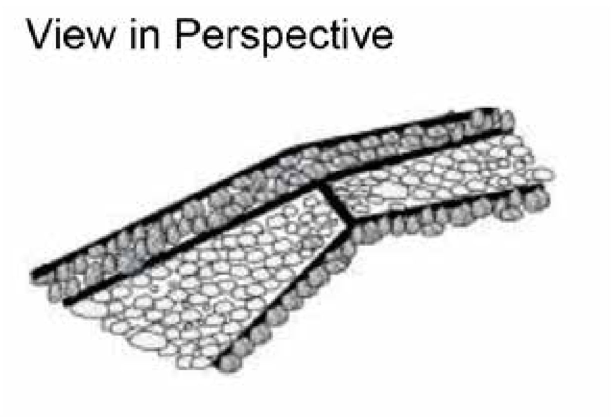


Fig. 23a Dig form-work in compacted soil, both ends 100 cm deep in ground. Arrange space for headpan to empty groundwater. Place good quality stones well tied together.





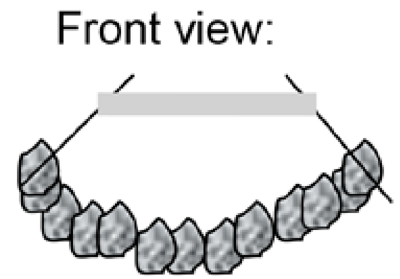


Fig. 23b Fill joints between rocks with quality mortar. Add a second layer if your stones/rocks are lying flat. Use any formwork to construct arch bridge.

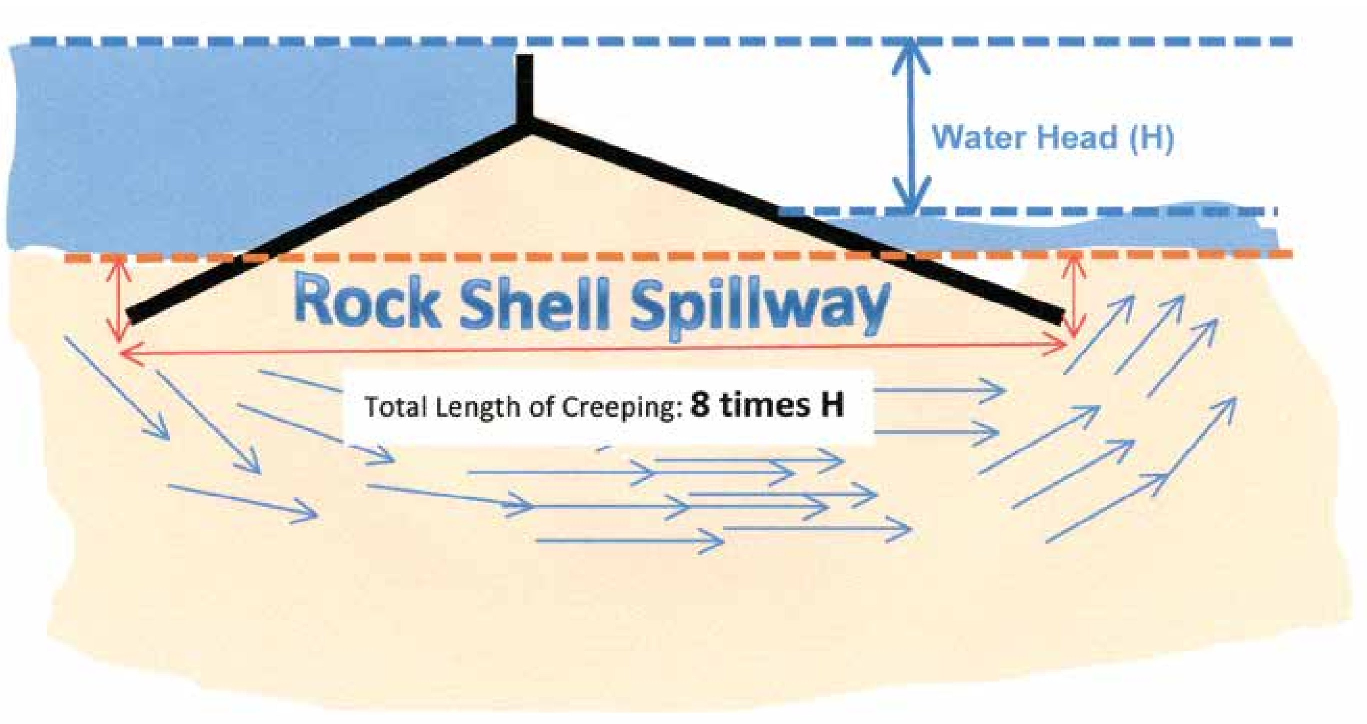


Fig. 23c Completed work needs at least three days curing (splash water over it every hour).

3.6.4 Flow Restrictors

The intake of the supply canals (peripheral canals) are equipped with small cement culverts, which regulate (restrict) the flow to maximal 20 litres per second. This assures that the peripheral canal cannot develop in a wild floodway in times of rain and run-off peaks.

The inlet to the culvert can be closed with a plank, and the flow of water in the peripheral canals can be regulated and stopped, if required.

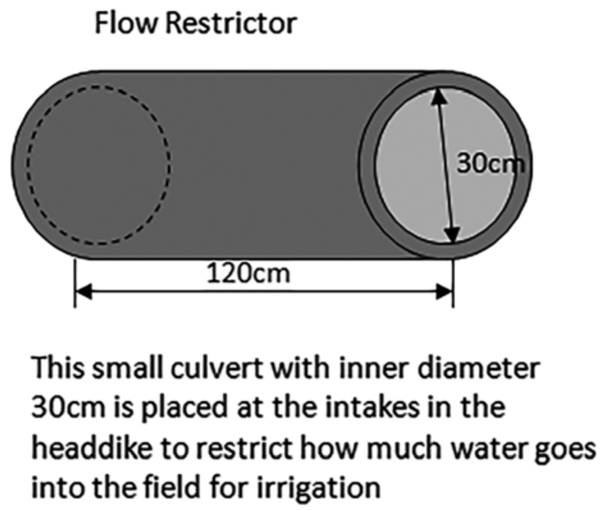


Fig. 24 Flow Restrictors at Intakes of Supply Canal

3.6.5 Peripheral Canal

This is the name of the outer irrigation canal. It's mostly the primary supply canal and in some designs, it has inner branches that serve as secondary irrigation canals. The floor bed of this canal must always be higher than the intended fields/ polders to be supplied with water. Favorably this is done in March.

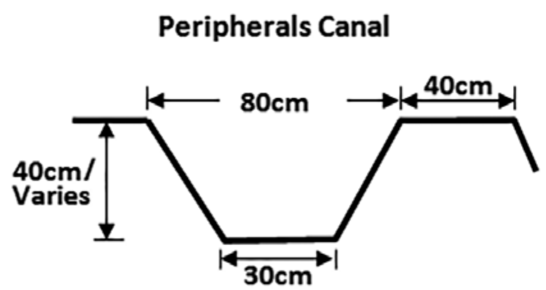


Fig. 25 Using Model for Shaping Peripheral Canal and Dimensions of Supply Canals

The intake of water is normally at the edges of the head dike and starts with a Flow Restrictor in form of a small cement culvert (see chapter 3.6.4)

Their gradient follows the edge of the swamp and its topography. It is around 3 to 4 cm per 10 meters. There topography allows, the peripheral canal can also be constructed by only an inner bund and by using the swamp edge as outer bund. The canal may get the form of a narrow pond and fish habitat. The canal supplies about 20 litres of water per second and can therefore feed around 20 plot-inlet pipes (bamboo or PVC pipes).

3.6.6 Inner Bunds Construction

These are heaps of earth built to demarcate the plots and also to allow the impoundment of the plot with water. Do only use materials from outside the swamp (upland dirt) to avoid dug outs in the plots.

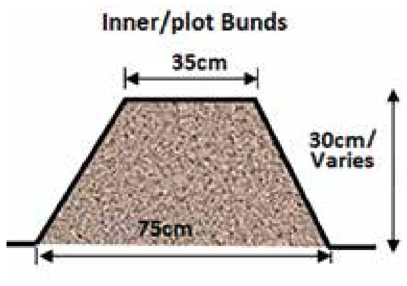


Fig. 26 Inner Bonds and levelling

Fig. 27 Photo with bunds between the plots

3.6.7 Installation of pipes (bamboo or pvc)

This must be done alongside the construction of the various canals for filling/recharging and emptying/draining. We recommend installing only one pipe per plot for feeding from the peripheral canal plus one pipe at the lowest point of the plot. Therefore two pipes are required per plot: Drain Pipe and Supply Pipe. The filling or emptying of the plots will last for a full day and night (24 hrs.).

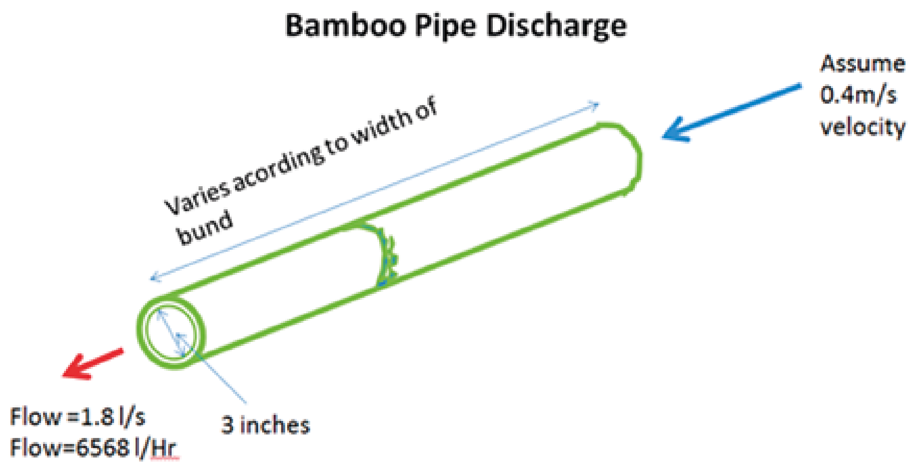


Fig. 28 Bamboo or PVC Pipe per plot for drainage

3.6.8 Plot Preparation for Planting

Puddling; the process of tilling/turning and softening the soil is mostly done with the aid of country hoe and the feet.

Leveling; this is the process of earth movement within a plot to ensure that the polot gets level to promote effective water distribution. The scoop could be used, headpans can also be used.

Fig. 29 Leveling of Plots

3.7 Bio-Engineering

This is the planting of cover crops on the surface of all constructed bunds with the aim to control the rate of erosion or washing of the loosed earthen bunds.

Fig. 30 Planting of cover plants to protect the structure from erosion damages

4. Water Management

Fig. 31 Uncontrolled flooding because of too high flow in the peripheral canal with no flow restrictor is leading to heavy destructions and crop losses

The described and recommended Lowland Development Scheme is equipped with an auto-controlled hydraulic, which supplies peripheral canals with all the water available during dry season, and the crest of the spillway remains always free to allow the overflow of excess water without human intervention.

Fig. 32 Planted plots (note water level in plots)

The operation of the canal and floodway need therefore very little control interventions. Only in times of water shortage, the flow restrictors can be closed (by planks) over night to collect and store water in the pond above the head dike. This allows flow increases during the feeding of plots. Water control, however, has to be done by opening and closing the supply and drainage pipes of the individual plot/polder. This requires high attention as follows:

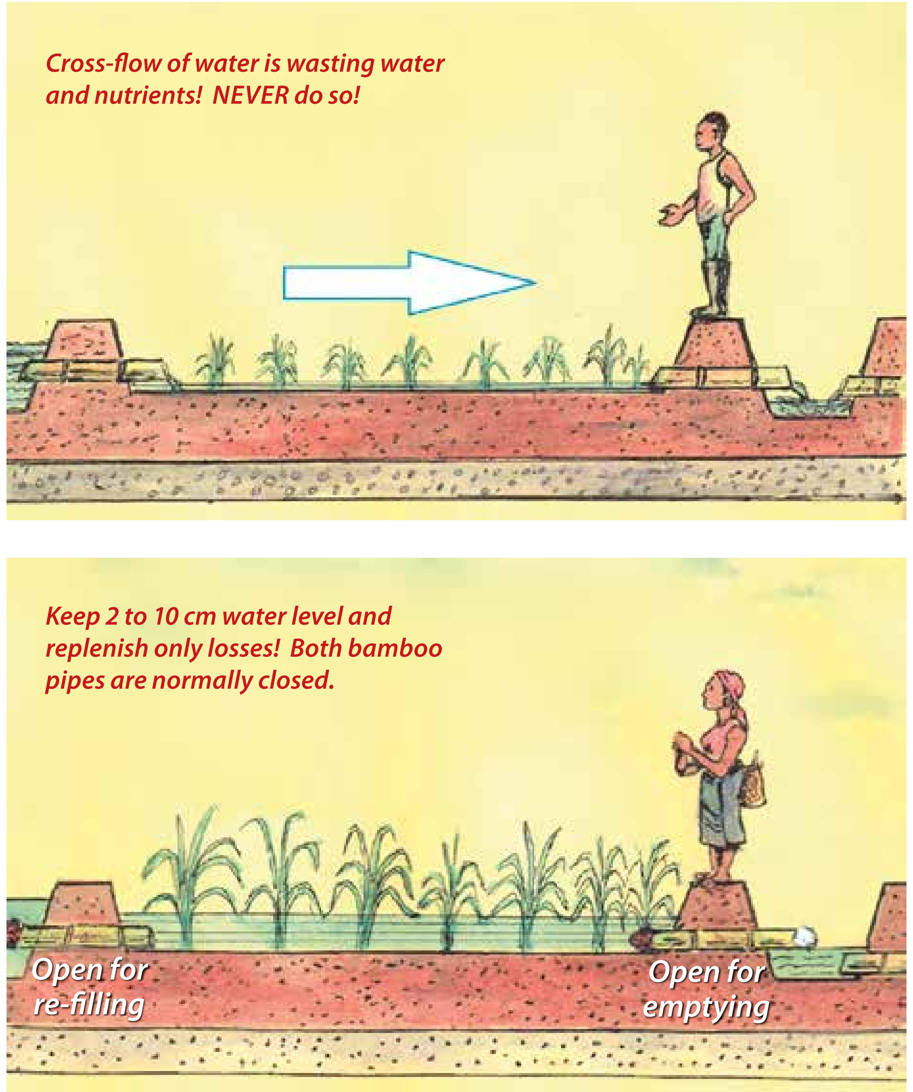


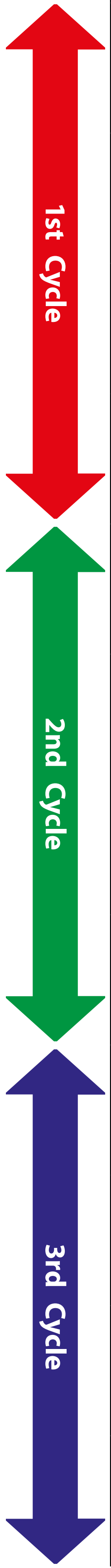
Fig. 33 Water lever regulation: constant water level in plots required

Bamboo or PVC Pipes can be closed with a handful of dirt and leaves. One pipe of the plot must always be closed. You should only fill or empty the plots, but avoid cross flow through the plots with both pipes open. This consumes too much water and washes out fertility of the soil (or applied fertilizer). Be aware that the water temperature is the same in running or in standing water.

During the second half of the dry season (end of January to mid of May), water supply may become scarce at most of the schemes, what requires night storage and water waste avoidance. If triple cropping must be a success then there is a need to have very good water management practice (every drop counts) in place especially during the dry season. With short term variety like Nerica L-19, farmers can follow the below proposed farming calendar. Triple cropping needs a lot of care and devotion on the part of the farmer.

Fig. 34 Water supply and water requirements during cropping cycle

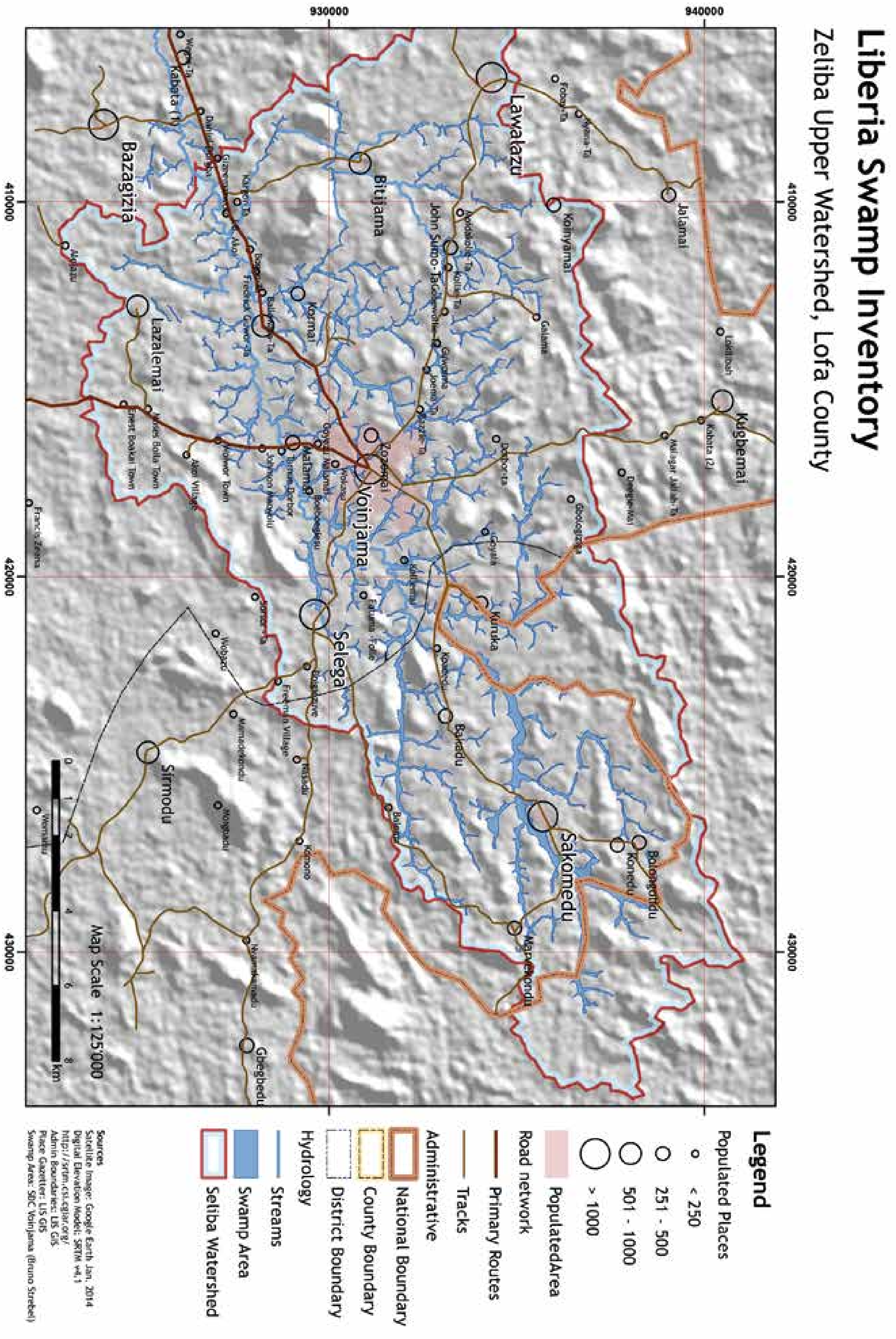
Month	January	February	March	April	May	June	July	August	September	October	November	December
Activity	land preparation	planting	growth	harvest	land preparation	planting	growth	harvest	land preparation	planting	growth	harvest
Water demand	300	200	150	100	300	200	150	100	300	200	150	100
Rainfed	0	550	100	200	200	350	450	400	450	300	200	50
Suplly	300	250	50	0	100	0	0	0	0	0	0	50



5. MAINTENANCE

A regular and constant use of the schemes (e.g. double rice cropping and a follow crop such as beans) is the easiest way of keeping the scheme well maintained. Without the following maintenance measures the scheme will soon degenerate and late repairs would require a lot of additional work.

Water Control Structure	Maintenance Measure	Tools Used
Bunds	Bunds must be brushed and kept in shape regularly (at least once per month and after heavy rains).	Hoe, headpans, wheel barrow, line, measuring tape, axe, digger, pick axe, rain boots, etc.
Dikes	Dikes (Head and Tail) must be constructed properly by layered compaction, trapezoidal shaping and bioengineering to control leak/piping and seepage. Brush and repair regularly.	Hoe, headpans, wheel barrow, shovel, measuring line, measuring tape, axe, digger, pick axe, rain boots, etc.
Floodway/canal	Floodway being the express way of exiting water should have no roots, stumps or obstacle in its way. Should be well profiled and required exit slope should be obtained (50 m out of the scheme).	Hoe, headpans, wheel barrow, shovel, measuring line, measuring tape, axe, digger, pick axe, spade, bucket, rain boots, etc
Bamboo pipe	Always check to ensure that they are not blocked. Replace when damaged.	Spear, spade/shovel, digger
Culverts	After the raining season, de-silt all silted culverts. Note: Installed culverts in roads must enhance drainage and supply capacities depending on their purpose	headpans, file, rake shovel, spade, bucket, rain boots, etc
Wooden Spillway	Replace the Upper/Exposed wooden beams after some years when they are rotten. Note: wood under water will remain forever.	Pin bar, hammer, Nails axe, digger/Pick axe, Spade, bucket, rain boots, etc.
Rock Shell Spillway	Keep free from obstacles and seal cracks if required	Sand, cement, trouvel



Lowland rice harvest in Douworjalamai, Lofa County

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June 2015