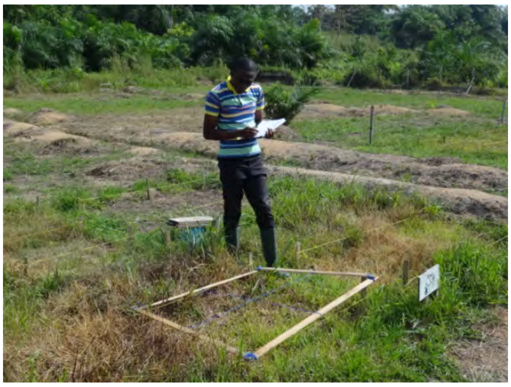
Manual for Improving Rice Production in Africa

- Development of Low Cost Irrigation Facility applicable to Africa -



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1. Background

In Africa, poverty and lack of food prevail owing to the delay in economic development and high rate of population growth. In Sub-Saharan Africa, particularly, the amount of rice imports from Asia and North America has been increasing each year, because rice production in these countries has not been able to meet the increasing domestic consumption of rice. Based on this situation, the Japan International Cooperation Agency (JICA) announced the establishment of the "Coalition for African Rice Development (CARD)" at the Fourth Tokyo International Conference on African Development (TICAD IV). This effort aims to double rice production in Africa in ten years (JICA, 2008).

Among African low marshlands, it is estimated that there are 20,000,000 ha of lands appropriate for rice production (Wakatsuki, 2008). It is essential to grow rice on these low marshlands efficiently, and in a sustainable manner, in order to realize the goal of doubling rice production in Africa. It is commonly seen, however, that strong rains, typical in the tropics, can cause the destruction of water intake facilities, drainage canals, and levees through running water and rainfall. Therefore, the Kwame Nkrumah University of Science and Technology (KNUST) and the Japan International Research Center for Agricultural Sciences (JIRCAS) have developed low-cost water facilities that "local farmers can construct by their own techniques and perform long-term maintenance on," which would lead to the spread of rice production and improvement in income for farmers in Ghana, as well as other African countries.

2. The present conditions and problems of rice field

The national plan of the Ghana Government aims to increase the acreage of rainwater rice-producing area approximately 220% from the level in 2008 by 2018 (92,000 ha to 300,000 ha), as well as to increase production per unit by approximately 40% (2.5 t/ha to 3.5 t/ha) (MoFA, Ghana, 2009). Land preparation and water control (land leveling, levee construction, and irrigation) are necessary to improve yields in the rainwater rice-producing area. The Inland valley project of the African Development Bank (AfDB) (African Development Fund, 2001), Sawah project (Wakatsuki, 2013), and JIRCAS investigation (Japan International Research Center for Agricultural Sciences, 2011) are the projects aiming to improve income for the people in the rainwater rice-producing area of Ghana. These projects are, as mentioned above, designed to construct levees alongside rice fields in the rainwater rice-producing area and irrigate the fields with water running through irrigation canals from a water source. As these projects employ techniques based on the assumption that farmers themselves will be able to construct and maintain the canals, most of the canals with which these projects are concerned are earth canals. In order to examine the present conditions of the earth canals in Ghana, a field survey was conducted on the earth canal. The survey results showed that the functions of the earth canal are diminished through the process as follows (Fig. 1):

(a) Crack development process

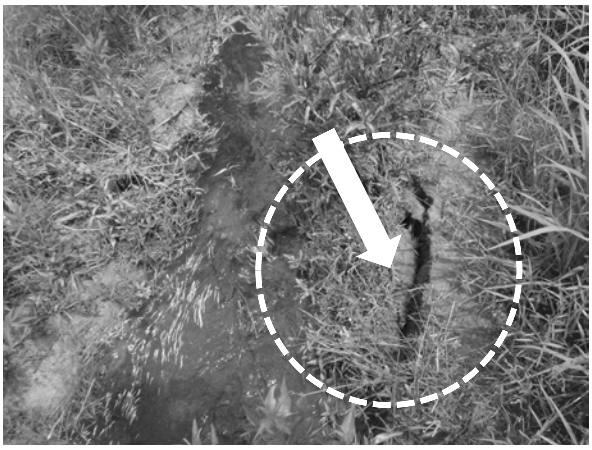
Cracks occur on the levee. The factors affecting the crack occurrence include the levee overhang as its slopes are eroded by running water, the increase in erosion caused by continuous rainfall, and the repeated cycling of dryness and moisture.

(b) Slope collapse process

The cracks on the levee increase with water flow, eventually causing the levee overhang to collapse, leading to the overall collapse of the local canal.

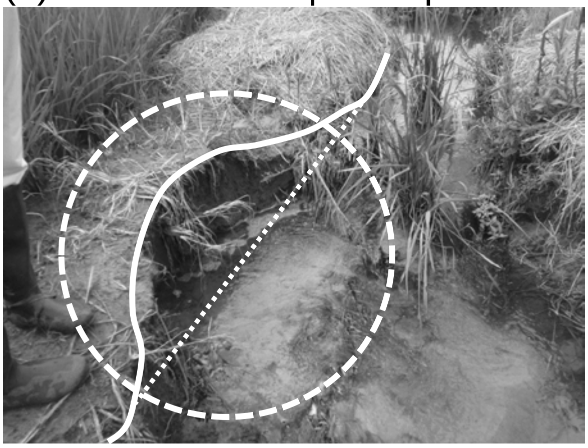
(c) Width change process

When canal width is enlarged suddenly, reverse water currents (vortex flow) occur in this widened area. This facilitates the abrasion of the canal wall surfaces.



(a) Crack development process

(b) Slope collapse process



(c) Width change process

(d) Meandering process

Fig.1 Canal erosion processes

(d) Meandering process

Farmers repair the collapsed places with sandbags, which changes the water flow from a straight line to a meandering pattern. With increased meandering of canals around the borders of cultivation fields, the area for possible cultivation reduces. As the meandering of the waterway advances, the risk of flood increases when the water level is high, because the water flow is obstructed.

The functions of the canal decline when the levee slopes collapse. To prevent the diminishment of canal functions, periodic checks and repairs should be conducted. Under the present conditions, however, maintenance is not readily performed, and the canal function is diminished, leading to the return to the original state of the rainwater paddy due to the lack of water necessary for irrigation.

To prevent the diminishment of earth canal functions, it may be beneficial to 1) introduce canals that can reduce the labor required for maintenance, and 2) enhance the farmers' capacity for maintenance through Participatory Impact Monitoring (PIM), both of which are to be conducted in an integrated manner. Among these measures, this manual focus on 1) and explain the construction and maintain (reinforce) manner, which farmers without capital can utilize, to prevent canal erosion by running water, a primary factor of the diminishment of earth canal functions.

3. Development concept

The diminishment of earth canal functions occurs due to the erosion caused by running water and rainfall. Those canals, which can reduce the labor required for maintenance, should be able to mitigate these factors to overcome the decline in function. Concrete canals are one example. However, the cost required to build a concrete canal is high, and it would be difficult for farmers in developing countries to repair the canal (in terms of cost and technology) once the function declines. Therefore, it is necessary to develop a technology with a low life-cycle cost, including facility installment and maintenance, which farmers can easily use to construct and repair the facility.

In order to prevent erosion caused by running water, it is necessary to 1) make the structure robust in the presence of water flow, or 2) prevent water flow from contacting the structure. Concrete measures can be raised as follows: 1) to reinforce the corrosion resistance of the canal walls and levees, and 2) to protect the canal walls and levees using materials other than soil.

In this manual, canal protection by brick and raindrop protection by cover plants are introduced as 1), and wooden fence is introduced as 2).

4. Canal protection

4.1 Canal reinforcement using bricks made from local soil

Laterite bricks manufactured without pre-treatment readily break down in water. In this manual, the following four methods for delaying this breakdown are discussed. The method should be selected by considering local availability of materials and time available.

① Mix shell lime (Shell lime)
② Mix palm receptacle ash (Palm ash)
③ Mix palm oil (Oil)
④ Burn at low temperature (Soft burning)

Table 1 summary various method to create bricks

Measure	Required time	Cost	Note
Shell lime	1 month	High	A dome-shaped furnace is necessary.
Palm ash	1 month	Low	A large amount of palm receptacles is necessary.
Oil	2 weeks	High	Necessary to purchase oil.
Soft burning	2 weeks	High	Necessary to purchase nails.

4.1.1 Brick materials

1) Laterite

Laterite, which is easily sourced locally, is used as a base material. Laterite is found in cut slopes of roads and anthills. Laterite is red soil. Soil that is not red should not be used.

2) Shells

Shells can be used in places where they can be easily sourced (e.g., on Volta[1]). Snail shells can also be used if a sufficient amount can be collected. Seashells can also be used if the place is near the

[1] Shell is formed in large quantities within the relatively shallow stratum layer (0-3 m from ground surface) around Bator Village in the Volta Region located approximately 90 km from the capital city of Ghana, Accra. According to the United Nations Human Settlements Program (UN-HABITAT), there are reserves of shell, approximately 700,000 t (UN-HABITAT, 1985), along the Volta River.

Currently, a shell is mined mainly as a raw material for white paint (white pigment)..

coast and they can be collected.

3) Palm receptacles

Seed pods left after palm fruits have been collected can be used.

4) Palm oil

Palm oil sold at markets or on streets can be used.

4.1.2 Pretreatment

1) Preparation of laterite

Laterite collected should be fully dried under the sun and if possible sieved (through a 2-mm mesh). If sieving is not possible, laterite should be crushed finely using a hammer or other equipment.

2) Creation of shell lime

Laterite mixed with unprocessed shells does not harden when water is added to it[2]. Therefore, shells must be burned at a temperature higher than 900°C. Because 900°C cannot be attained in open-air burning, a furnace is necessary:

(1) Construction of a furnace (dome-shaped)

Materials: one bag of cement, laterite (locally sourced), support boards, water

Tools: Shovels, trowels, hammers (used to adjust brick length), a level gauge

Method: See Fig. 2

[2] Carbon dioxide (main contents of a shell) does not harden when water is added. Carbon dioxide changes to carbon oxide by adding heat (900 dig) and carbon oxide harden when water is added.

① A frame for covering the furnace with a dome is prepared. This frame, which is cut from wood, is used to create the dome and is burned up by firing.

② The installation place is determined and a groove is dug around the base to stabilize the base.

③ Wooden sticks are placed on the grooves to form a frame. The cement casting area is moistened so that the moisture of the soil cement will not be absorbed by the soil.

Fig. 2 How to construct

④ Soil cement (cement mixed with soil collected at the site) is cast as a base. (Not necessary if the installation place is flat.)

⑤ Laterite, used for the furnace bottom and brick mortar, is collected in the area and water is added to soften it.

⑥ The furnace bottom (10 cm thick) is created on the base using laterite.

Fig. 2 How to construct

⑦ Brick walls are created and the gaps between bricks are filled with laterite. A space for burning wood (fire box) and a space for the chimney are secured.

⑧ Bricks are stacked in columns inside the furnace at the four corners so that the frame can be placed on the furnace. The chimney is now created.

⑨ The frame is placed on the inner columns of the furnace.

Fig. 2 How to construct

⑩ Bricks are placed over the frame, using moistened laterite as mortar.

⑪ The dome-shaped roof places load onto the side walls due to the arch effect. To prevent the collapse of side walls, they are reinforced with thick wires.

⑫ The frame is burned out using a bellows.

Fig. 2 How to construct

(2) Burning of shells (two-stage burning)

Because of their size, it takes time to change the chemical properties of shells by burning (calcium carbonate is converted to calcium oxide) and an inconsistent finish is inevitable if shells are used as is. Therefore, shells should be crushed in advance into pieces of 1–2 cm using a hammer (Fig. 3).

Fig. 3 Shell size by crashing

Crushed shell pieces are burned in the furnace for two hours (first-stage burning), cooled, crushed into smaller pieces using a hammer, and burned again in the furnace for two hours (second-stage burning). A bellows is necessary to attain high temperature.

The calcium oxide obtained will have 56% of the original weight.

3) Creation of palm receptacle ash[3]

Magnesium contained in palm receptacles is converted to magnesium oxide at around 300°C, a much lower temperature than is required for the burning of shells. Therefore, the receptacles can be burned in open air (Fig. 4) to obtain magnesium oxide. Palm receptacles must be sufficiently dried before being burned.

The weight of ash obtained is about 3% of the original weight.

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[3] Palm receptacle contains much calcium and magnesium, and when it changes to ash, the ash harden by adding water.

Fig. 4 Making palm ash

4.1.3 Creation of bricks

1) Shell-lime bricks, palm-ash bricks

(1) Mixing

Laterite and shell lime (or palm ash) are combined in a container in a weight ratio of 10:1 and mixed well. Then, water is added to the mixture at a weight ratio of 10:4 (laterite: water) and the mixture is mixed well. Shredded rice straw is added to the mixture to prevent cracking caused by drying shrinkage.

(2) Shaping

The laterite mix is placed in molds (10 cm × 20 cm × 2 cm) for shaping.

(3) Attachment of anchors

Chopsticks or straight branches (about 5 mm thick and 10 cm long) are inserted into the bricks (six pieces per brick: Fig. 5).

Fig. 5 Shell lime bricks with anchors

(4) Drying

The bricks are dried in shade, protected from rain. This drying process takes about one month.

2) Oil bricks

(1) Mixing

Water is added to laterite at a weight ratio of 10:4 (laterite: water) and the mixture is mixed well. Then, palm oil is added to the mixture at a weight ratio of 100:3 (laterite: oil) and the mixture is mixed well again. Then, shredded rice straw is added to the mixture to prevent cracking caused by drying shrinkage.

(2) Shaping: Same as shell-lime bricks

(3) Attachment of anchors: Same as shell-lime bricks

(4) Drying: Same as shell-lime bricks

4) Soft-burned bricks

(1) Mixing

Water is added to laterite at a weight ratio of 10:4 (laterite: water) and the mixture is mixed well. Laterite derived from a basset should be used. Laterite derived from ant hills is prone to cracking during burning.

(2) Shaping: Same as shell-lime bricks

(3) Attachment of anchors

Soft-burned bricks are made by low temperature burning (500°C–600°C) after drying. Chopsticks and branches, if used as anchors, will burn up during firing. Therefore, nails (about 1–2 mm thick and 10 cm long) are inserted into the bricks (six nails per brick: Fig. 6).

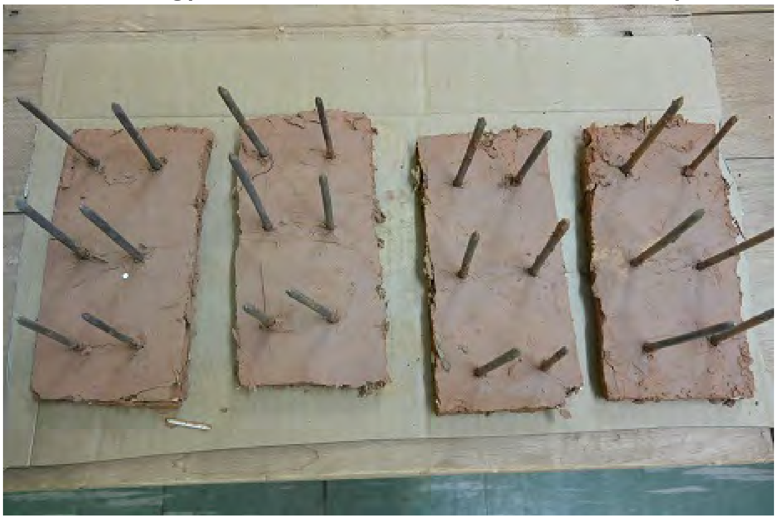


Fig. 6 Soft-burned bricks with anchors

(4) Drying: Same as shell-lime bricks

(5) Burning

Bricks become hard by burning at a temperature of 450°C–650°C[4]. Therefore, a dome-shaped furnace is not necessary. This temperature range can be attained in an open-top furnace. However, because a rapid increase in temperature can cause shrinkage cracking, the amount of wood put into the furnace must be controlled so that the temperature gradually increases. Wood input should stop one hour after powerful flames have been established. A bellows is used to churn up the fire.

4.1.4 Installation of the bricks at waterways

[4] Kaolinite contained in clay endothermically turns into metakaolin at temperatures ranging from 450 °C to 650 °C with losses in water of crystallization (Shiraki, 1965). This phenomenon is called sintering wherein a material is heated at temperatures just below the melting point and the powder particles in the material fuse together. As a result, the interparticle space becomes narrow and the body becomes compact (Institute of Industrial Science, The University of Tokyo, 2000). Sintering enhances the strength of the material and, furthermore, the water resistance of the material is also enhanced as the interparticle space is reduced, whereby the water molecules, on escaping, are unable to return to their original space.

The bricks are installed horizontally to the waterway slopes by facing the anchor side toward the waterway wall. If there are uneven surfaces on the slopes, such surfaces should be leveled before brick installation. If water gets between and then behind the bricks, the bricks may come off. Therefore, mortar is used as a joint (Fig. 7).

Fig. 7 Setting to a canal with mortar

4.2 Reinforcement work utilizing cover-plant

4.2.1 Objectives and policies

The main objective is to prevent raindrop erosion, which is the early stage of the collapse of the irrigation facilities at paddy field. Covering the irrigation facilities with vegetation is aim at achieving a long-term maintenance of canal function. To minimize impacts on ecosystems and psychological obstacles for the farmers involved, local ground cover plant species should be used. This measure targets irrigation canal, drainage canal and levee of paddy fields and more specifically the slopes and crowns of canals except for the wetted perimeter (see Fig. 8 and the green line of Fig. 9).

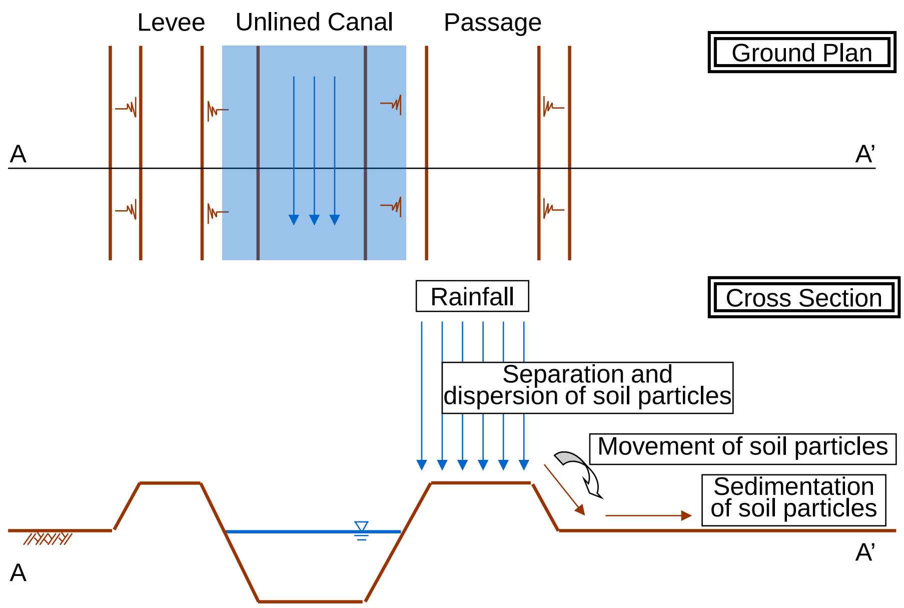


Fig. 8 Mechanism of raindrop erosion

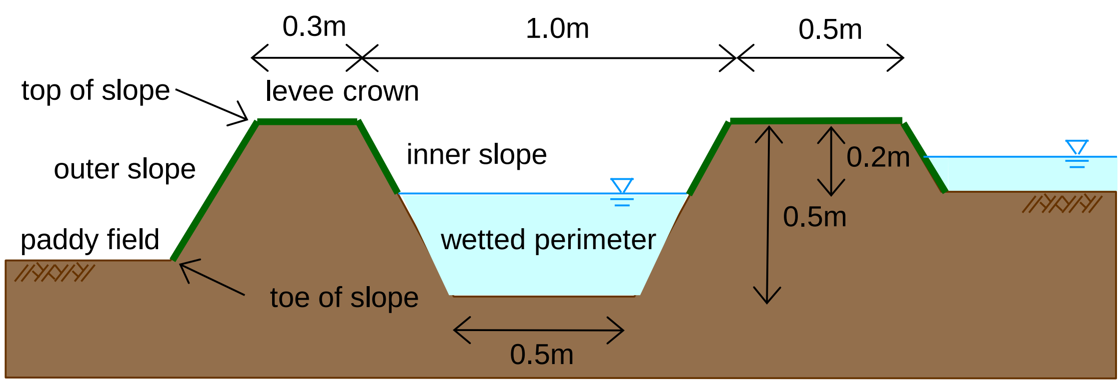


Fig. 9 Applicable place of cover-plant

4.2.2 Property required

Different properties of cover-plant are required because different parts of paddy field irrigation facilities are exposed to different environmental conditions. For example, the crowns require tread pressure resistance as farmers frequently walk on them for farm work. The inner slopes are exposed to drastic changes in soil moisture and submerged for a certain period; therefore, it is important that they are resistant to both drought and moisture. The outer slopes are more prone to soil erosion caused by rain splash and thus require good cover. The common properties required for these parts are listed in order of priority in the table 2 below:

Table 2 Property required for cover-plant

1) Coverability	Good growth, covering effect on the surface early and thick through out the year
2) Enviromental tolerance	Tolerability to particular environment of irrigation facilities such as wet-dry cyclic conditon, strong solar radiation and tread pressure
3) Effect of enstrengthen	Reinforcement of irrigation facilities and integrated retention of the soil on slopes by the development of the root systems
4) Acceptability by farmers	Rough maintenance without requiring high technology from planting through establishment
5) Influence on farming	No competition with rice by invading paddy fields, easy to control of suppression not be host plant for pests and deseases which will affect rice, and no trouble to farming work

4.2.3 Selection

Vegetation that grows at irrigation facilities of paddy field already have resistance to changes in environmental factors such as soil hardness and soil moisture and therefore have advantages over other plants. Prior to implementing this measure, native vegetation species that grow at irrigation facilities are recommended to be determined (see the example of Table 3).

Table 3 Weed identified at the irrigation facilities in Kumasi

Botanical Name	Family Name	Life Form	Growth Form	Vagetation Cover Rate	Cover Degree	Frequency
Centrosema pubescens	Fabaceae	Annual	Perennial	5.0	1	68.8
Ageratum conyzoides	Asteraceae	Annual	Erect	7.0	1	59.4
Mimosa pudica	Fabaceae	Perennial	Prostrate	7.4	1	43.8
Scoparia dulcis	Scrophulariaceae	Annual	Erect	2.2	1	25.0
Leptochloa caerulescens(?)	Poaceae	Annual	Erect	7.8	1	25.0
Echinochloa colona	Poaceae	Annual	Erect	14.1	2	25.0
Calopogonium mucunoides	Fabaceae	Perennial	Perennial	2.4	1	25.0
Panicum pansum	Poaceae	Annual	Erect	10.2	2	25.0
Euphorbia hirta	Euphorbiaceae	Annual	Erect	0.4	1	21.9
Digitaria sanguinalis(?)	Poaceae	Annual	Erect	3.2	1	21.9
Cynodon dactylon	Poaceae	Perennial	Prostrate	3.9	1	18.8
Pentodon pentandrus	Rubiaceae	Annual	Erect	1.1	1	15.6
Stachytarpheta angustifolia	Verbenaceae	Perennial	Erect	0.8	1	12.5
Cyperus difformis L.	Cyperaceae	Annual	Erect	0.5	1	9.4
Commelina africana	Commelinaceae	Annual	Prostrate	0.4	1	9.4
Phyllanthus amarus	Euphorbiaceae	Annual	Erect	0.3	1	9.4
Euphorbia heterophylla L.	Euphorbiaceae	Annual	Erect	0.2	1	6.3
Ludwigia octovalvis	Onagraceae	Perennial	Erect	0.2	1	6.3
Physalis anagalis	Solanaceae	Annual	Erect	0.1	1	6.3
Echinochloa obtusifloa	Poaceae	Annual	Erect	0.4	1	6.3
Heliotropium indicum	Boraginaceae	Annual	Erect	0.1	1	3.1
Hyptis spicigera	Lamiaceae	Annual	Erect	0.3	1	3.1
Ludwigia decurrens	Onagraceae	Annual	Branched	0.1	1	3.1
Fimbristylis miliacea	Cyperaceae	Annual	Branched	0.1	1	3.1
Basilicum polystachyon	Lamiaceae	Annual	Erect	0.1	1	3.1
Chloris pilose	Poaceae	Annual	Erect	0.0	r	3.1
Eclipta prostrata	Asteraceae	Annual	Erect	0.0	r	3.1
Eragrostis sp.	Poaceae	Annual	Erect	0.1	1	3.1
Hedyotis corymbosa	Rubiaceae	Annual	Erect	0.1	1	3.1
Sida acuta	Malvaceae	Perennial	Branched	0.0	+	0.0
Ludwigia hyssopifolia	Onagraceae	Annual	Branched	0.0	+	0.0
Solanum melongena(?)	Solanaceae	Annual	Erect	0.0	+	0.0
Ceratopteris cornuta	Adiantaceae	Perennial	Erect	0.0	+	0.0
Cyperus distans	Cyperaceae	Perennial	Erect	0.0	+	0.0

* Botanical name with question mark has not been identified yet.
* Vegetation Cover Rate and Frequency is average value of 13 times of vegetation survey.
* Cover Grade was recorded accourding to Braun-Blanquet's method.
* Zero of Vegetation Cover Rate means the value less than two decimals place.

Next, the effect of preventing raindrop erosion, which is the primary aim of this measure, needs to be confirmed. To do that, the time taken between planting and establishment needs to be clarified, as well as the coverage rate and rapidity.

Lastly, taking into consideration the grass heights desired by farmers and local availability, covering plants should be selected. The selection criteria and process differ depending on the location. As an example, the selection criteria and process used for Kumasi are shown below (Fig. 10):

	Criteria	Method or adaptable type
Suitability for the area	● Native in the area	Vegetation Investigation
	● Good growth on poor soil	Soil analysis
⇩	● Easy to procure/ availability	Market research
Growth characteristics	● Resistance to herbicide	Perennial
	● Survive to farmers work	Vegetative propagation
⇩	● No need of much maintenance	Prostrate
Environmental factors	● Fast and thick coverage	
	● Tolerant to soil hardness	
	● Strong in competition with weeds	

Fig. 10 Example of selection criteria and process

4.2.4 Recommendable species

Taking inland-valley in Kumasi as an example, the vegetation species considered desirable as cover-plants for paddy field irrigation facilities are listed below along with their characteristics (Fig. 11 and Fig. 12). Vegetation should be selected in accordance with the environmental conditions of the place concerned and the paddy rice farming type desired by the local farmer.

Binomial name	Genus Species	English or Common Name	Origin	Characteristic
A) *Cynodon dactylon*	Poaceae Cynodon	Bermuda grass Dhoob grass	India, East Africa	Blades are grey -green color and short.
B) *Chrysopogon aciculatus*	Poaceae Andropogoneae	Love grass Pilipiliula	India, Polynesia	Leaves are linear and lanceolate.
C) *Stenotaphrum Secundatum*	Poaceae Paniceae	St. Augustinegrass Buffalo grass	Tropical America	Blades are dark green, broad and flat.

Fig. 11 Basic information of cover-plants

Binomial name	Close-up	Body and ear	Characteristics
A) *Cynodon dactylon*			* Resistant to tread pressure, salinity and drought. * Exist on schoolyards, shore, etc. * Widespread in warm regions around the world. * Can also be used as a pasturage.
B) *Chrysopogon aciculatus*			* Distributed over the sunny grasslands. * Used as turfs * Spread by spikelet s ticking with animals and humans. * Reproduce vigorously by rhizomes.
C) *Stenotaphrum Secundatum*			* Resistant to tread pressure and shade. * Grows quickly with long creeping stems. * Commonly cultivated in warm regions around the world. * A variant horticultural species has white stripes.

Fig. 12 Cover-plants and their characteristics

4.2.5 Planting Works

The timing for implementation should be determined considering rainy season and agricultural off-season. Since replanting is required if the vegetation planted does not establish well, judgment could be made three months after planting. Cover-plant is planted in a zigzag pattern with 15 cm interval, a practice which local farmers are familiar with. Fertilizer is not necessary at planting but irrigating immediately after planting is required. For the first one week following planting, daily irrigation in the morning or twice daily in the morning and late afternoon, if possible, is recommendable (Fig. 13).

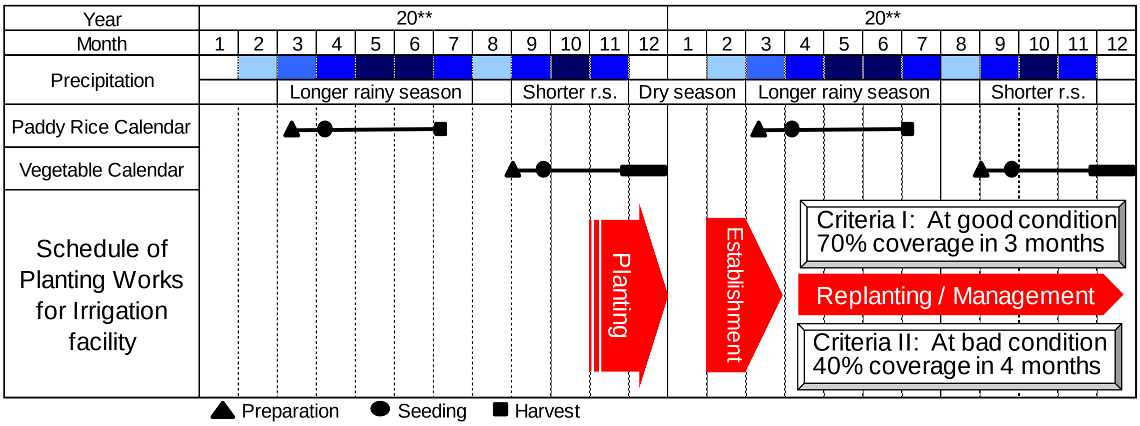


Fig. 13 Schedule of planting works

Photo 3-1 Planting

Photo 3-2 Irrigation

4.2.6 Maintenance

Appropriate maintenance is required to keep the cover-plants healthy. Since a dense turf is needed it is important to control the height of the grass in order to encourage the cover plant to fill-up and form the dense turf (Fig. 14). This can be achieved by slashing which also makes it easy for farmers to move about smoothly without any hindrance. Manual weeding prevents invasion of other weeds, but complete manual weeding is not necessary. It is important to control weed up to the level of allowable limit at the required time. If the cover-plants start to die, efforts should be made to maintain the cover on the irrigation facilities by replanting.

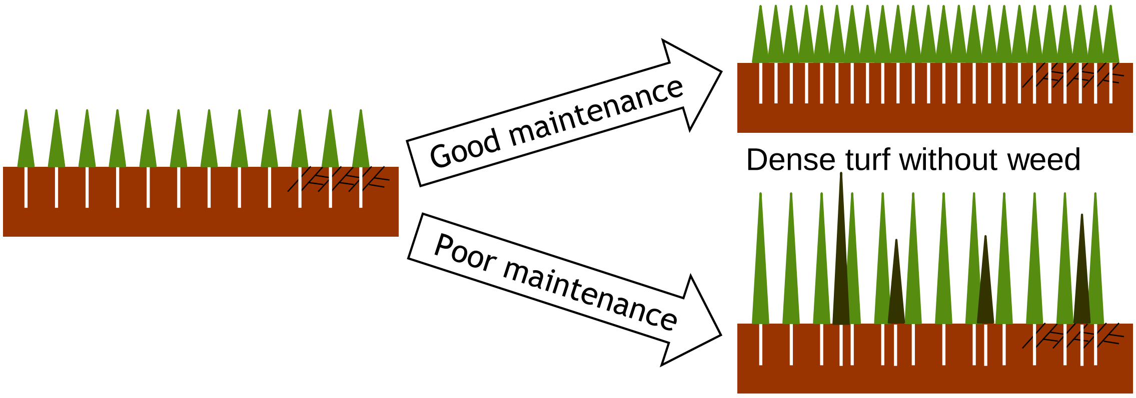


Fig. 14 Good maintenance and bad maintenance

Photo 3-3 Slashing

Photo 3-4 Manual weeding

4.2.7 Control

There are points to keep in mind regarding the prevention of cover-plants spreading into rice paddies, thus reducing rice yield. This invasion of cover-plants can be totally controlled by combining mechanical control methods (e.g., manual weeding, cutlass weeding), cultural control methods (e.g., flooding, burning) and chemical control methods that makes use of herbicides (Fig. 15 and Table 4).

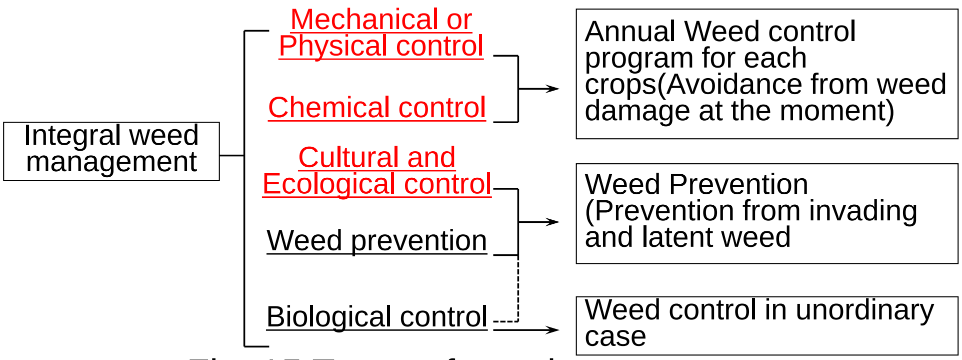


Fig. 15 Types of weed management

Table 4 Herbicides available in Kumasi — Unit : GHC/1bottle(1L)

Product name	Price	Ingredients
HERBEXTRA	7.0	720g/L 2,4-D amin salt
ATRAZILA 500SC	6.0	500g/L atrazine
PRONIL PLUS	10.0	360g/L propanil + 200g/L 2,4-D
GRAMOQUEST SUPER	5.0	276g paraquat chloride(200g paraquat ion)
ADWUMA WURA, Sarosate, NWURA WURA, So Far, SHEY NWURA, sunphosate, glysate and so on.	5.0	360g~480g/L glyphosate + 480g/L isopropylamine salt

* The price was investigated in 2012.

4.3 Wooden fence

4.3.1 Advantages of wooden fence

Wooden fence are effective for reinforcing waterways that are prone to erosion caused by flowing water and the following collapse of cross-sectional surface of waterways. One of the advantages of wooden fence is that they are made of wood—an easily processable and obtainable natural resource—and can easily be installed and repaired.

4.3.2 Types of waterways for which wooden fence are suitable

Wooden fence can be installed for any type of waterway. However, because they are made of wood, they are prone to termite feeding damage and bacterial decay. In particular, termite feeding damage is a serious problem. Therefore, it is not advisable to install a wooden fence conduit on a waterway near woodland or grass inhabited by termites. It is effective to install a wooden fence conduit on a branch waterway or a drainage waterway that is distant from termite habitats or that has a waterway nearby separating it from termite habitats, since termites dislike water.

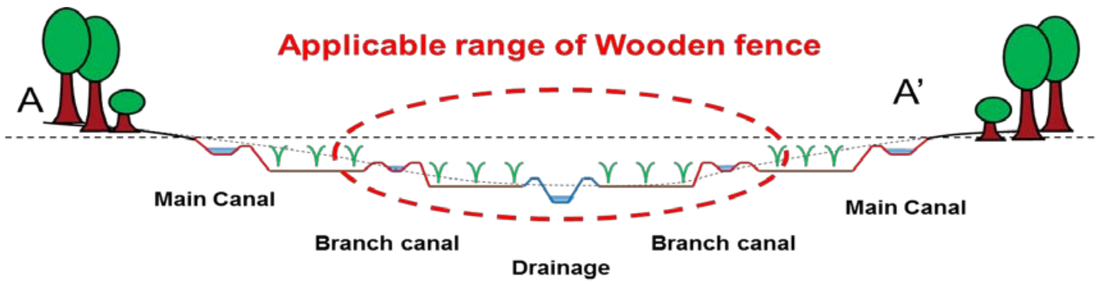


Fig. 16 Types of waterways for which wooden fence are suitable

4.3.3 Installation method of wooden fence

Refer to Chapter 4.13 of “Manual for Improving Rice Production in Africa”.

4.3.4 Maintenance of wooden fence

By regularly inspecting and repairing wooden fence after

installation, it is possible to maintain the water-conduction functions of the waterways, thereby allowing continuous farming.
The standard inspection method and repair timing for wooden fence are outlined below.

i) Inspection method

Table 5 Damage level criteria

Damage level	Observation
0	Sound
1	Partial mild insect-feeding damage or decay
2	Total mild insect-feeding damage or decay
3	Partial severe insect-feeding damage or decay in addition to 2
4	Total severe insect-feeding damage or decay
5	Collapse of waterway shape due to insect-feeding damage or decay

Source: Matsuoka, S. and four others: Forestry Experiment Station Report, No. 329, 73–106 (1984)

inspections are conducted using the damage level criteria provided in Table 5. Inspections are conducted jointly with the managing farmers. To monitor the progress of conduit deterioration, inspection results should include inspection dates and sites.

Wooden fence deteriorates with time, from 0 (no damage) up to 5 (collapse).
Figure 17 shows example images of different damage levels.

0 	Damage level 0 “Sound”
1 	Damage level 1 “Partial mild insect-feeding damage or decay” (Termite tunnels are observed in some parts.)
2 	Damage level 2 “Total mild insect-feeding damage or decay” (Termite tunnels are observed extensively.)
3 	Damage level 3 “Partial severe insect-feeding damage or decay in addition to 2”

4 	Damage level 4 “Total severe insect-feeding damage or decay”
	Damage level 5 “Collapse of waterway shape due to insect-feeding damage or decay”

Fig. 17 Example images of different damage levels

Deterioration of wood often starts with termite feeding damage. This type of damage can be confirmed by the existence of small tunnel-like termite paths made of small wood pieces (termite tunnels) (see red circles in Fig. 17). Termite feeding damage can quickly degrade wood, reducing its strength and ultimately breaking it. Therefore, if termite tunnels have been confirmed during an inspection, the progress of wood deterioration needs to be carefully monitored.

ii) Service life of wooden fence

Taking Kumasi, a city in the Republic of Ghana, as an example, available tree species for wooden fence and their service life are outlined below:

① Available tree species

In Ghana, wood is mainly supplied to consumers through wood markets and small-scale sellers. A survey was conducted for these two types of sellers in the Ashanti region in Kumasi city, concerning pr

ices, tree species, and specifications. The survey was conducted at 22 shops (6 wood markets and 16 small-scale sellers). The top five tree species in terms of the number of shops that sell them are shown in Table 6.

Table 6 Tree species, the number of shops that sell them, and relative prices

Species		Number of shops at which the particular tree species is available (among the 22 shops surveyed)	Relative price (normalized to the price of ceiba)
Local name	Botanical name		
Ceiba	*Ceiba pentandra*	16	1
Wawa	*Triplochiton scleroxylon*	15	1.4
Ofram	*Terminalia superba*	6	2.3
Emire	*Terminalia ivorensis*	5	2.2
Kyenkyen	*Antiaris toxicaria*	5	0.8

(Relative prices were converted from per-m^3 unit prices as of June 2012.)

Here, the service life of ceiba–the tree species with the lowest unit price and the highest number of shops that sell it–is outlined below:

② Service life

A service-life survey for this manual was conducted at an experimental paddy plot in Kumasi. In this experimental plot, the service life of a wooden fence conduit made of ceiba, installed at a branch waterway, was about over two years. However, because wood is prone to termite feeding damage, the service life of wooden fence varies depending on where they are installed. Therefore, this service life should be used only as a guide.

Further, the durability of wood varies by tree species. Table 7 shows different tree species' durability vs. termites and fungi provided in BSEN (British Standards). On introducing wooden fences, this table can be fully utilized for general reference.

Table 7 Tree species' durability vs. termites and fungi

Species		Natural durability	
Local name	Botanical name	Termites*	Fungi**
Ceiba	*Ceiba pentandra*	Class S	Class 5
Wawa	*Triplochiton scleroxylon*	Class S	Class 5
Ofram	*Terminalia superba*	Class S	Class 4
Emire	*Terminalia ivorensis*	Class S	Class 2-3
Kyenkyen	*Antiaris toxicaria*	Class S	Class 5

*Classification of the natural durability vs. termites: D-durable, M-moderately durable, S-susceptible (EN350-2:1994)

**Classification of the natural durability vs. fungi:1-very durable, 2-durable, 3-moderately durable, 4-slighty durable, 5-not durable (EN350-2:1994)

iii) Repair

This survey showed that the durability of the horizontal boards of wooden fence is greater for the lower board than for the upper board. This is because termites dislike water and the deterioration of the lower board, which is submerged during water passage, is delayed.

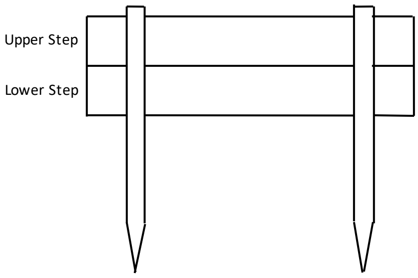
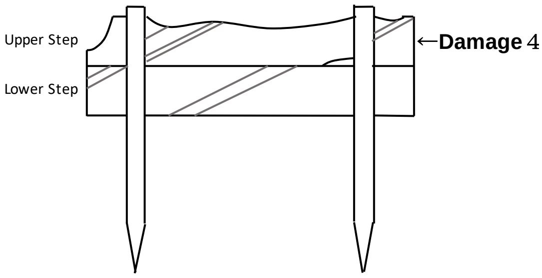
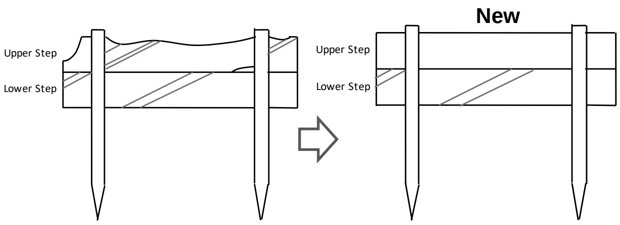
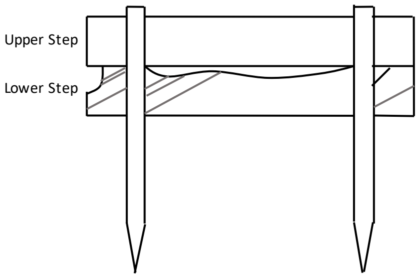
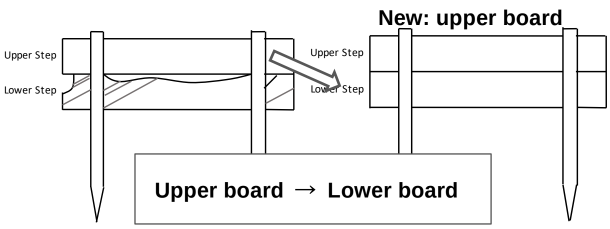
The primary aim of wooden fence protects waterways from erosion. Therefore, repair is needed when the damage level has reached 4 (Collapse of waterway shape due to insect feeding damage or decay).

The recommended repair procedure is listed below (Fig. 18):

① When the damage level of the upper board reaches 4, only the upper board is replaced.

② When the damage level of the lower board reaches 4, the entire wooden fence conduit is reinstalled.

③ When the conduit is reinstalled (②), the upper board that was preciously replaced is recycled and used the lower board.

<table>
<tr><td></td><td>Immediately after installation</td></tr>
<tr><td></td><td>Damage level of the upper board reaches 4.</td></tr>
<tr><td></td><td>The upper board is replaced.</td></tr>
<tr><td></td><td>Damage level of the lower board reaches 4.</td></tr>
<tr><td></td><td>The entire wooden fence conduit is reinstalled, recycling the upper board.</td></tr>
<tr><td>Fig. 18 How to repair a wooden fence conduit</td><td></td></tr>
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