REPUBULIKA Y'U RWANDA

UBUMWE • UMURIMO • GUKUNDA IGIHUGU

RQF LEVEL 5

TRADE: FORESTRY

MODULE CODE: FORWC501

TEACHER'S GUIDE

Module name: WOOD CHARCOAL MAKING

Table of Contents

ACRONYMS

MINEDUC: Ministry of Education
RTB: Rwanda TVET Board
WCM: wood charcoal making
FAO: Food and Agriculture Organization (united nations agency)
DVD: Digital Video DISK
FDA :Food and drug administartion
IC: Indicative content
GPS: Global position system
RTQF: Rwanda TVET Qualification Framework
MC: Moisture Content

Introduction

Charcoal is a prime source of energy in most African countries, and is a driving force in their economies. Worldwide charcoal production has increased over time, rising by an annual of 3.7% from 1990 to reach 44 million tons in 2014. It is estimated that over 23 million tons of charcoal was produced in Africa in 2012; according for over half (53 percent) of total world production

(FAO, 2011). Charcoal plays a duals role of providing a source of livelihood for rural populations and an affordable energy option for the urban populations as it is mainly sold in urban areas while production is done mainly in rural areas.

Charcoal is a black, porous, carbon-intense solid materials (85 to 98 percent carbon) used as a fuel and is produced by the distillation of wood through a process known as carbonization. Charcoal is preferred compared to the other wood fuel sources for various reasons including:

High calorific value: charcoal has a higher calorific value per unit weight than fuel wood. 1 kg of charcoal has a replacement value of 2.38 kg of firewood or more. The combustion efficiency of charcoal is about 28 per cent.

Thus, conversion of firewood into charcoal for use as a fuel will be better than firewood such as.

Density: Due to its high calorific value per unit weight, it is cheaper to transport charcoal over longer distances as compared to fuel wood. Charcoal occupies less volume making it easy to store compared to fuel wood.

Smoke and sulphur: Charcoal is an ideal smokeless fuel for cooking.
Fully carbonized charcoal is almost smokeless and sulphur-free therefore an ideal fuel for towns and cities where cooking spaces are often small and contained (care must be taken however, to guard against carbon-monoxide poisoning in ill-ventilated spaces- ensure windows are kept open during use).

Deterioration: charcoal is not prone to deterioration by insects and fungi which attach fuel wood.

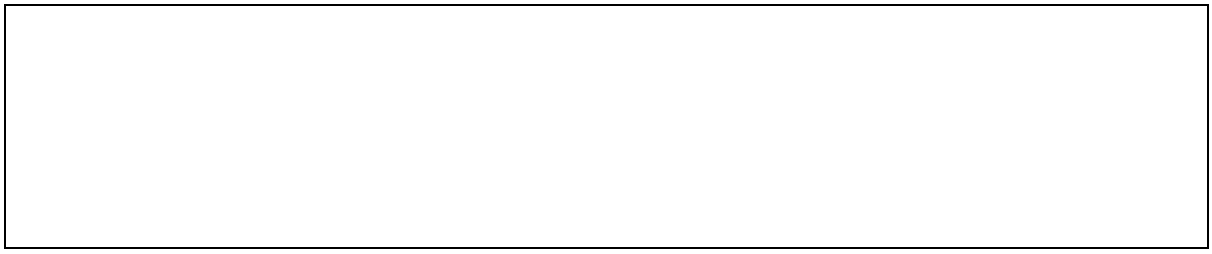
At the end, this module will allow the learner to:

1. Prepare tools, materials and equipment,
2. Conduct carbonization,
3. Harvest wood charcoal and by-product

Module Code and Title: FORWC WOOD CHARCOAL MAKING

LEARNING UNITS:

1. Prepare tools, materials and equipment.
2. Conduct carbonization
3. Harvest charcoal and by-product



Learning Unit 1: Prepare tools, equipment and materials.

Picture/s reflecting the Learning unit 1.

STRUCTURE OF LEARNING UNIT: 1. Prepare tools, equipment and materials.

Learning outcomes:

1.1: Identify tree species for charcoal making.
1.2: Select tools, materials and equipment's.
1.3: Use tools, materials and equipment.
1.4: Prepare wood for charcoaling.

- **Learning out come 1.1: Identify tree species for charcoal making.**

Duration: 2hrs

 Learning outcomes 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify effectively suitable tree species for charcoal making.

2. Differentiate suitable trees species for charcoal making.

3. Demonstrate clearly the criteria of selection for tree species.

 **Resources**

Equipment	Tools	Materials
GPS, compass, PPE, these include: chainsaw, two-man saw, wheelbarrow.	Forest map, Picture**s,** hand hoe, shovel, machete, slasher, pegs, ropes, axe, measuring tape, can't hook, metal file, bags, machete,	Forest stand, wedges, bricks, logs, chimney, twigs, clods and soil, water

 Advanced preparation:

. Forest visit to choose tree species for charcoal

. observation of forest stand composition

. select forest site and organize tools, materials and equipment.

 **ndicative content 1.1.1: Suitable tree species for charcoal making.**

✓ **trees species for charcoal making**

There are two broad types of wood, hardwoods produced by broadleaved species and Softwoods are produced by conifers tree species while broadleaves produce hardwoods. Both produce charcoal but hardwood charcoal is usually stronger than softwood charcoal. Suitable tree species for charcoal making are made by Myrtaceae family e.g. Eucalyptus sp and Mimosaceae family e.g. Acacia sp.


Theoretical learning Activity

- ✓ Visiting school forest and analyse species characteristics
- ✓ Group discussion about species characteristics


Practical learning Activity

- ➢ Group work by 4 trainees to cut tree species for charcoal making


Points to Remember (Take home message)

- Best quality charcoal is made by hardwood.
- Tree species for charcoal making are made by the following families:
  - Myrtaceae
  - Mimosaceae
- Main species for charcoal making are made by
  - Eucalyptus spp.
  - Acacia spp.


Indicative content 1.1.2: Selecting tree species for charcoal making.

Criteria of selecting tree species for wood charcoal making

Maturity:

Mature trees are close to their full height and crown size. Their dimensions are determined by species and site factors.

Age: In general, trees for charcoal making are harvested depending on site fertility and climate conditions.

Size: varies according to the species behaviours and should be checked from tree phenology.

Purpose/end use of charcoal: whether is for household use or sale.

Hardwood: are the most diverse group, they contain both the heaviest and lightest timber for best quality charcoal.

Calorific value: Calorific value is the amount of heat produced by the complete combustion of a fuel. Calorific value is measured in units of energy per quantity of fuel, e.g., kg/g, while density of wood is the weight of wood per volume, e.g. grams per cubic metre (g/cm3).

Calorific value of wood and charcoal from selected tree species

Species	Density of the wood (g/cm3).	Calorific value of wood (kj/g).	Calorific value of charcoal (kj/g).
Eucalyptus maculata	0.603	-	7.4
Acacia mearnsii	0.775.	3.7	7.4
Casuarina equisetifolia	0.820	5.0	7.7
Eucalyptus grandis	0.790	4.5	7.5

 Theoretical learning Activity

✓ Brainstorming about tree species for charcoal within groups discussion

 Practical learning Activity

➢ Visit the forest stand and differentiate soft wood into hard wood group according to their visible characteristics.

 Points to Remember (Take home message)

Theoretically, the legal procedures for the exploitation of plantations in Rwanda are:
• Plantation < 0.5 ha: No attestation or permit required
• Plantation 0.5 to 2.0 ha: An attestation is required, which could be obtained at sector level; this attestation is free of charge
• Plantation > 2.0 ha: A cutting permit is required that must be obtained at district level; a service charge must be paid.
The cutting permit is valid for three months. In addition, the buyer has to pay a tax of 1% of the standing timber value.

- **Learning outcome1.2 : Select Tools, Materials and Equipment**

 Duration: 2hrs

Learning outcome 2. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. identify tools, materials and equipment for charcoal

2. select useful tools, materials and equipment for charcoal

3. Adjust and sharpen selected tools, materials and equipment for charcoal

Resources

Equipment	Tools	Materials
GPS, compass, PPE, these include: chainsaw, two-man saw, wheel barrow.	Forest map, Picture**s,** hand hoe, shovel, machete, slasher, pegs, ropes, axe, measuring tape, can't hook, metal file, bags, machete,	Forest stand, wedges, bricks, logs, chimney, twigs, clods and soil, water

Advance preparation:

. Documentary research

. site visit and site preparation charcoal.

. organization of tools, material and equipment.

Indicative content: 1.2.1. Types of Tools, Materials and Equipment

Types of tools, materials and equipment used in charcoal making
These include:
hand hoe, shovel, machete, slasher, pegs, ropes, axe, chainsaw, two-man saw, wedges, measuring tape, bricks, chimney, can't hook, metal file, logs, wheelbarrow, bags, machete, twigs, clods and soil. Since you are working with fire, keep a water supply nearby and handy to put out any stray sparks (or cool a burn).

Theoretical learning Activity

- ✓ Oral presentation on the tools, materials and equipment used in charcoal making
- ✓ Ask trainees to brainstorm about the types of tools, materials and equipment used in charcoal making.

Practical learning Activity

- ➢ visit the school storage of tools and equipment
- ➢ Trainees in pair listing the different tools and equipment located in school storage and select the proper tools for charcoaling activities
- ➢ demonstrate the different tools and equipment used in charcoaling activities.

Points to Remember (Take home message)

Some tools and equipment are selected according to the activities performed with them. For instance, some are used for tree felling and bucking, others are selected for kiln construction, others are used for harvesting and transport of charcoal.

Indicative content: 1.2.2. Criteria of selecting tools, materials and equipment.

- ➢ Criteria of selecting tools, materials and equipment

A range of tools, materials and equipment used to make charcoal vary according to the method used and the quantity needed to produce, the accessibility of the site, skills of charcoal burners, availability of manpower, tools and equipment, size of tree species, market and budget.

Theoretical learning Activity

- ✓ Oral presentation on the tools, materials and equipment used in charcoal making
- ✓ ask trainees to brainstorm about the criteria for selecting tools, materials and equipment in charcoal making within groups)


Practical learning Activity

- ➢ visit the school storage of tools and equipment
- ➢ Trainees in pair listing the different tools and equipment locate in school storage and select the suitable tools for charcoaling activities
- ➢ demonstrate the different tools and equipment used in charcoaling activities.


Points to Remember (Take home message)

The charcoal value chain in Rwanda complies the following elements from wood production and harvest to final charcoal consumption: • Forest management and wood production • Exploitation and transformation of charcoal • Transport and commercialization of charcoal • Utilization of charcoal

- **Learning out come : 1.3. Use Tools, Materials and Equipment.**

Duration: 3hrs
Learning outcome 2. Objectives: By the end of the learning outcome, the trainees will be able to: Manipulate the tools and equipment for charcoaling activities.

Use the tools and equipment according to the manufacturer's instruction for charcoal making.

Repair the tools and equipment when are damaged.

Maintain the tools and equipment respectively to the manufacturer's instructions.


Resources

Equipment	Tools	Materials
GPS, compass, PPE, these include: chainsaw, two-man saw, wheel barrow.	Forest map, Pictures, hand hoe, shovel, machete, slasher, pegs, ropes, axe, measuring tape, can't hook, metal file, bags, machete,	Forest stand, wedges, bricks, logs, chimney, twigs, clods and soil, water


Advance preparation:

. Documentary research

. Adjust the tools and equipment.

. Organize the tools, material and equipment.

Indicative content 1.3.1. Manipulation techniques.

Manipulation techniques

Tools, materials and equipment should be used according to what they are designed to do so. The respect of manufacturer's instruction is worth to keep tools and equipment working longer and efficiently.

In case of damage, the tools and equipment should be repaired as soon as possible according to the instruction given in their manuals (catalogue).

Theoretical learning Activity

- Trainees in group are discussing about the manipulation techniques of tools, materials and equipment applied for charcoal making

Practical learning Activity

- Within group work, trainees present the manipulation techniques of some tools, materials and equipment used.

Points to Remember (Take home message)

Tools, materials and equipment should be used according to what they are designed to do.

For example, the tools, material and equipment used for cutting trees are not allowed to be used for levelling.
Before to use any tools, materials or equipment, it is better to read the manufacturer's manual.

Indicative content 1.3.2. Safety precaution.

Safety precaution:

The things that lead the tools to be damaged are leaving the tools dirty after use, using a particular tool for a wrong purpose, leaving tools to spend nights outside e.g.

air and moisture cause the rust to them, leaving tools with wooden handles to stay in water for a long time e.g. it can cause the wooden rot, failing to add oil or grease to moving parts of machines like chain saw or wheelbarrow can cause disfunction or Failing to sharpen cutting tools regularly.

Theoretical learning Activity

- ✓ trainees in group are discussing about the safety precaution of tools, materials and equipment applied for charcoal making


Practical learning Activity

- ➢ Within group work, trainees present the safety precaution of some tools, materials and equipment used in charcoal making.

Points to Remember (Take home message)

Safety precaution of tools and equipment

- Avoid all things that lead to the damage of tools, materials and equipment.
- Store them in a safe place (dry and cool place), add oil or grease to moving rust for example in wheelbarrow, Chain saw, etc.
- Sharpen cutting tools regularly for ex. logging axe, panga and so on.

- **Learning out come :1.4 Prepare Wood for charcoaling.**

Duration: 3hrs

Learning outcome 1.4. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. Select appropriately the tools and equipment used for prepare wood in charcoaling activities.
2. Perform correctly felling techniques and bucking operation accordingly for charcoal making.
3. Dry effectively the wood on the appropriate place according to the carbonization method.

Resources

Equipment	Tools	Materials
GPS, compass, PPE, these include: chainsaw, two-man cross cut saw, wheel barrow.	Forest map, Picture**s,** hand hoe, shovel, machete, slasher, pegs, ropes, axe, measuring tape, can't hook, metal file, bags, machete,	Forest stand, wedges, bricks, logs, chimney, twigs, clods and soil, water

Advance preparation:

. Documentary research

. Adjust, fix, sharpen and check the tools, materials and equipment.

. Organize tools, material and equipment.

Indicative content 1.4.1. Logging operations.

➢ **Logging operations**

- It is the process of cutting a felled tree and de-limbed tree into logs reserved for charcoal making. The measures depend on type of carbonization method to use. Bucking comes after debranching. The first operation in bucking is measuring and marking lengths of logs to cut in a precise manner according to the carbonization method to use.
- Woods are bucked into different lengths according to the needed size, generally at the felling place. The work can be done by hand-axe but hand saw is more adapted for this operation.
- To prevent accident or injury, it is important to study the tree conditions and suggest reactions which can be observed during bucking operation.

Theoretical learning Activity

✓ Oral presentation on process of tree felling and bucking techniques.
✓ Group Brainstorming about the tools and equipment used for logging operation.


Practical learning Activity

✓ Perform trees felling and respect the felling direction.

✓ Perform bucking and debranching of trees are used for charcoal making.

 Points to Remember (Take home message)

Bucking operation demand much care to avoid the following risk: The trunk can move laterally The trunk can start to roll The trunk can suddenly fall on the ground The trunk can split

Indicative content:1.4.2. Wood drying

Wood drying

- It is an important step because upon felling, moisture content in wood is approximately 60-80 percent. After three weeks, it is reduced to 30-35 percent (free water evaporated). Loss of weight makes transportation easier and cheaper.
- Drying is not a mandatory step of drying but is highly recommended as it will reduce carbonization time while saving a lot of energy which would have otherwise been used to dehydrate the wood.

Theoretical learning Activity

✓ Visit school forest and select 3 trees to be used in charcoal making

Practical learning Activity

➢ Trainees in pair perform 4 trees cutting and bucking them to be used in charcoal making.

Points to Remember (Take home message)

- All parties of a living tree contain water (±60%). Drying is the removal of water from wood. Two types of water can be found in wood: free water and bound water.
- Free water fills the wood cell cavity and is easily evaporated from the wood. Bound water refers to the water in a wood cell when MC is less than ±30%.
- Bound water is chemically attached to the cell wall. Loss of water results in changes in many of the properties of wood, such as strength and both thermal and electrical conductivity.
- Drying is not a mandatory step of drying but is highly recommended as it will reduce carbonization time while saving a lot of energy which would have otherwise been used to dehydrate the wood.


Learning outcome1. 4. Formative Assessment

Written assessment

Q1. Outline the Advantages of wood drying before charcoal making.

Answer: Reason why we dry wood before charcoaling:

- ✓ Dried timber is lighter, and hence the transportation and handling costs are reduced.
- ✓ Dried timber is stronger than green timber in terms of most strength properties.
- ✓ Timbers for impregnation with preservatives have to be properly dried if proper penetration is to be accomplished, particularly in the case of oil-type preservatives.
- ✓ Dry wood works, machines, finishes and glues better than green timber. Paints and finishes last longer on dry timber.
- ✓ The electrical and thermal insulation properties of wood are improved by drying.

Q2. What is the best method for drying the wood which are prepared for charcoal making?

ANSWER: The best drying method can be air drying or kiln drying. The air drying is natural and use air exposure while kiln drying necessities the introduction of heat within closed chambers.

Practical assessment

Task 1: Prepare wood for charcoal making

CHECKLIST.

ELEMENT TO BE VERIFIED	YES	NO
Indicator: Appropriate preparation of wood for charcoal making according to the carbonization method		
The trees are merely felled lying in the one direction.		
Debranching		
Topping		
Bucking		
Splitting		
Drying		
Observation		

LEARNING UNIT 2: CONDUCT CARBONIZATION

Picture/s reflecting the Learning unit 2.



STRUCTURE OF LEARNING UNIT 2.

Learning outcomes**:**

2.1: Select carbonization method.

2.2: Prepare site for carbonization. 2.3: Load kiln for carbonization. 2.4: Monitor kiln combustion and cooling.

- **Learning out come : 2.1: Select carbonization method.**

Duration: 4 hrs

Learning outcome 2.1. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. Define carbonization method used in charcoal making.
2. Identify carbonization method used in charcoal making.
3. Select carbonization method used in charcoal making.

Resources

Equipment	Tools	Materials
Audio visual equipment, Projector, Computer, Digital camera.	Reference books. Pictures, DVD	-Traditional kiln (Earth mound Kiln, Earth pit Kiln and Basic earth mound Kiln) - Improved kiln (Portable steel kiln, Bricks kiln, Casamance Earth mound kiln and Improved Basic earth mound Kiln).

Advance preparation:

. Documentary research on carbonization methods.

. field visit and observation of carbonization methods

Indicative content :2.1.1. Criteria selection of carbonization method:

✓ **Criteria selection of carbonization method**

The selection of carbonization method considers the following 5 elements:

- Market,
- topography of the land,
- quantity to produce,
- labour and budget.

Market: consumers need the best quality products and these can be obtained according to the method of carbonization used. For example, industries use high calorific value charcoals which are only produced by modern kilns.

Topography: when the site is not accessible, it is difficult to use modern kilns because of problems linked to the transport of tools, materials and equipment. It is merely linked to the quantity of charcoal needed.

Labour and budget: skills of workers, the cost of tools and equipment to use influence on the selection of carbonization method to put in place.

The choice of carbonization method has to conform to the limitations of the project. The cost of labour in the zone has also to be taken into account.

✓ **Carbonization methods:**

There are several methods used in charcoal making. The first one is using traditional kiln, the second use improved kilns.

Traditional kilns: earth mound kiln, earth pit kiln

Improved kilns: brick kiln, metal or drum kiln, Casamance kilns

 Theoretical learning Activity

define different carbonization methods used in charcoal making within groups.

With smart classroom, Observation of the kiln's pictures using computers

Group discussion on the advantages and disadvantages of each carbonization method.

Oral class presentation on carbonization methods.

Practical learning Activity

Field visit on different kilns sites

Trainees in pair discuss about the advantages and disadvantages of traditional kilns compared to improved kilns and give conclusion.

Points to Remember (Take home message)

Comparative advantages and disadvantages of carbonization methods.

- ✓ Improved kilns with traditional kilns:
- ✓ Improved kiln produces best quality charcoal with low consumption of wood, save environment and reduce the air pollution.
- ✓ Traditional kiln produces bad quality charcoal, high consumption of wood, destroy environment and air pollution are increased.

Learning outcome 2.1 Formative Assessment

Written assessment

Q1. Explain why Earth mound kiln is preferred than earth pit kiln?

Answer: Q1. Earth mound kiln is preferred according to the following reasons:

- ✓ Low investment.
- ✓ Close proximity to the source of wood
- ✓ Yield inferior quality charcoal due to lack of carbonization control and soil contamination.

Q2. Illustrate the criteria selection of carbonization method.

Answer: The criteria selection of carbonization method is:

- ✓ labour,
- ✓ budget,
- ✓ Charcoal market

- ✓ Trees species,
- ✓ log size,
- ✓ site configuration,

Practical assessment

Task 1: Select carbonization method to be used in class group work of 5 trainees.

Check list

Element to be verified	YES	NO
Traditional		
Advantages of traditional methods are well identified:		
Easy to construct		
Low cost of materials		
Can be constructed near the source of wood		
Disadvantages of traditional methods are well identified:		
Low quality grade charcoal.		
Carbonization takes long time		
High consumption of wood		
Charcoal contamination by soil		
Improved kiln methods		
Advantages of improved methods are well identified:		
Produce best quality charcoal		
Takes short time		
Yield is high with low consumption of wood		
Disadvantages of improved methods are well identified:		
High cost		
It is difficult to construct.		
Observation.		

- **Learning out come : 2.2 Prepare site for carbonization.**

Duration: 10hrs

Learning outcome 2.2. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. select appropriately the carbonization site for charcoal making.

2. prepare correctly the site according to the carbonization method used for charcoal making.

3.Respect effectively the steps used for site preparation in charcoal making.

Resources

Equipment	Tools	Materials
- Improved kiln (Portable steel kiln, GPS, Camera, projector,	Panga, hoe, spade, tape measure, chimneys**.**	Logs, soil, bricks, twigs, small branches**,**

Advanced preparation:

Avail reference books - Audio visual equipment (Projector, DVD)

– Pictures, videos

Documentary research on carbonization methods.

Indicative content: 2.2.1. Selection Criteria of site for kiln construction.

- Selection criteria of site for kiln construction

✓ Site configuration

✓ Weather conditions
✓ Soil structure and texture
✓ Wood size
A well-drained and roughly levelled area, approximately 3 metres in diameter, should be chosen in close proximity to the wood supply. Loose soil or loamy soil should be available close to the site for sealing off the air supply to the kiln during operation.

 Theoretical learning Activity

- ✓ Oral presentation on carbonization method selection
- ✓ Ask trainees to brainstorm about the selection criteria of carbonization methods within groups.
- ✓ Group discussion on the criteria for site preparation.

 Practical learning Activity

- ➢ Field visit on different kilns sites
- ➢ Viewing films and pictures
- ➢ Trainees in pair compare earth mound kiln with earth pit kiln.

 Points to Remember (Take home message)

- Earth kiln produce low quality charcoal and take low investment
- Requires 4-7 days to produce charcoal. It is the same as Mound kiln. All are traditional kilns.
- Improved earth kiln provides better carbonization control due to inclusion of chimneys.
- Results in higher yields (24-28%) and better-quality charcoal. Improved kiln like Casamance kiln require skilled labour and high investment costs.

Indicative content: 2.2.2. Steps of site preparation

Carbonization site is prepared by :

- clearing the site
- levelling the site according to the method to be put in place.
- The earth mound kiln is preferred over the earth pit kiln where the soil is rocky, hard or shallow, or where the water table is close to the surface.
- By contrast the pit is ideal where the soil is well drained, deep and loamy.

Theoretical learning Activity

- ✓ Oral presentation on carbonization method selection
- ✓ Ask trainees to brainstorm about the steps of carbonization methods within groups.
- ✓ Group discussion on the steps for site preparation.

Practical learning Activity

- ➢ Practical exercises on the steps on site preparation
- ➢ Viewing films and pictures

Points to Remember (Take home message)

- Clearing is to removing unwanted material to the site like stones, bushes and stumps on the ground.
- Levelling is changing the ground level to a smooth horizontal or gently sloping surface.

Learning outcome 2.2. Formative Assessment

Written assessment

Q1. Carry out the criteria selection of site for kiln construction.

Answer: Q1. The criteria selection of site for kiln construction are:

✓ Wood size ✓Site configuration ✓ Weather conditions ✓ Soil structure and texture

Q2. Choose the correct answer by circling the best statement.

The Step for site preparation is:

a) levelling the site
b) construction of the kiln
c) loading the kiln.

Answer Q2. a

Practical assessment

Task: Prepare the site to be used based on the carbonization method guidelines.

Checklist

Element to be verified	YES	NO
site clearing		
site levelling		
Kiln construction		
Observation		

- **Learning out come : 2.3: Load kiln for carbonization.**

Duration:10 hrs

Learning outcome: 2.3. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. Perform correctly load kiln for carbonization techniques.

2. Load effectively the kiln according to the carbonization method.

3. Respect appropriately the steps for loading system the kiln.

Resources

Equipment	Tools	Materials
Audio visual equipment - DVD, projector, chain saws, - PPE, Computer. wheel barrows.	Hand hoes, Chimneys, machetes, bags, containers, sheeting, axes, pegs, spades. ropes, Slasher, carpentry level	logs, bags, containers, twigs, clods, soil, pegs, matches, charcoal.

Advance preparation:

. Documentary research

. site visit and site preparation.

. organization of tools, material and equipment.

. Select carbonization methods.

Indicative content :2.3.1: Earth mound Kiln loading system

- Selection of ignition zone.
- Kiln loading systems
  - horizontal loading
  - vertical loading

Procedures for horizontal loading
Procedures for vertical loading
The fuelwood in the kiln is stacked in a vertical position to a height of 1.20 m (length of wood). The bigger diameter logs must be placed in the centre where prolonged higher temperatures are reached.
Special care must be taken that the holes at the base of the kiln (air inlets) are not closed.

- Construction of traditional earth mound kiln:
- It is constructed easily by using locally materials collected from the harvested site without extra cost and is the most important advantage of earth mound kiln.
- Kiln building begins with the following process:
  - Site preparation and this depends on site topography
  - Stacking of woods at carbonisation site
  - Cutting woods into reasonable length

- Lay out of wooden frame on the ground

Start stacking with respect of log sizes and closing of voids (gaps). Leave spaces in bottom sides of kiln to serve as air-inlets and outlets.
Cover the heap with 15-20 cm thickness layer of grass, and the construction is sealed with 5-10 cm thickness loamy soil.


Theoretical learning Activity

- ✓ Documentary research on procedures of kiln loading
- ✓ ask trainees to brainstorm about vertical loading system within groups
- ✓ Group discussion about the types of loading system.


Practical learning Activity

- ➢ Demonstration and practical exercises on loading kiln
- ➢ Observation on kiln covering materials
- ➢ Trainees in pair differentiate horizontal loading system with vertical loading system. And when are used?

  Answer: horizontal loading system is to stack the logs in horizontal, when the logs have the same length but vertical loading system is to stack the logs in vertical, when the logs have the different length.


Points to Remember (Take home message)

•Traditional Earth-mound kiln still dominates (86%)
•However, awareness of improved kilns is high (70%)
•The most widely-known improved kiln is the Casamance kiln

•>80% of wood drying is air-dried before carbonization
•Yield is almost higher for dried wood compared to green wood.
•Only 10% of producers work through Cooperatives.

Indicative content :2.3.2: Load improved Casamance kilns

- Selection of ignition zone.

Criteria for selecting lighting zone and kiln ignition depend upon on:

- wind direction
- carbonization method and
- size logs.

Preparation and setting of chimneys and containers for by-products recuperation.
The **Casamance** kiln was developed in Casamance region of south Senegal in West Africa.
It is basically a modification of the earth mound kiln. A distinctive addition on the Casamance is the chimney which regulates air circulation and is crucial in improving the carbonization process. The base is made up of two layers of small and medium sized wood.

- Construction of improved Casamance kilns:

The diameter of the base varies according to the volume of the mound.
For a mound of 30 m^3 a base of at least 3 m radius is needed
For a mound of 90 m^3, a base of at least 4 m radius is needed.
For a mound of 100 m^3 a base of at least 5 m radius is needed.
The kiln is covered with grass and shrubs and then loamy soil. The chimney is placed at the edge of the pile as in the diagram, with its base opening connected to the base of the pile.
The site of the kiln should be cleared by rake and roots and stumps pulled out.

Figure : 1. Casamance kiln in construction.

Theoretical learning Activity

✓ Brainstorming on kiln loading system

✓ Trainees in groups are brainstorming about horizontal loading system.
✓ Oral presentation on kiln loading system.
✓ Group discussion

Practical learning Activity

- Site visit for carbonization kiln
- Demonstration and practical exercises on kiln construction
- Observation on kiln covering materials
- Comparison of earth mound kiln and casamance kiln.

Points to Remember (Take home message)

- Casamance kiln: is basically a modification of the earth mound kiln which has been widely used in Senegal.
- It produces high quality charcoal with a recovery rate of 25-30%.
- The kiln is stacked in a circular way with the wood standing upright
- It has one chimney placed at the opposite end of the lighting point.
- Air inlets pipes are placed around the base of the kiln.

Indicative content :2.3.3: Load metal kiln (Retort kiln).

Retort vs Metal kiln

- The Retort is one of the most efficient means of producing good quality charcoal.
- Wood is placed in a large steel cylinder (or Retort) with tightly closed door, and has mechanism to let tar and gases to escape.
- When the wood in the cylinder has been heated to the right temperature, a chemical reaction (carbonization) begins to give off heat and by-products.

Figure 4. Loading Retort kiln

Figure: 5. Loading metal kiln.

Theoretical learning Activity

- ✓ Brainstorming
- ✓ Ask trainees in group to discuss about the types of metal kiln.
  Answer: the types of metal kiln are Portable steel kiln, transportable metal kiln.

Practical learning Activity

- ➢ Site visit for carbonization
- ➢ Observation on kiln covering materials
- ➢ Demonstration and practical exercises on loading kiln
- ➢ Trainees in pair presented the procedures of loading various kiln.

Points to Remember (Take home message)

• The retort is one of the most efficient means of producing good quality charcoal.
• Wood is placed in a large steel cylinder (or"retort") with tightly closed door, and has mechanism to let tar and gases escape.

• When the wood in the cylinder has been heated to the right temperature, a chemical reaction (carbonization) begins to gives off heat and by-products.

Ic

Indicative content :2.3.4: Load Brick kiln system.

- **Construction of brick kiln :**

There are many designs of brick kilns in use throughout the world:
The typical steps involved in brick making process are: clay preparation, moulding, drying of green bricks and then firing.

- Design and construction:

The are various designs for brick kilns, the most common types being the beehive model and the slope model.
The beehive models are circular in diameter and covered by a dome roof. These models are built entirely above the ground and they contain air inlets around the perimeter at ground level.
They are easy to construct and require no concrete foundation or complex building materials.

- A Slope model brick kiln are is similar in shape to a beehive kiln. they have a dome shaped cover, but the sides are generally immersed underground so only the roof is exposed.

Ignition occurs at the top of the dome, and there is usually only one main air inlet, underground at the center of the kiln.

- Both kilns operate using wood-burning fuel. They both perform the same basic functions., heating bricks at extremely high temperatures.
- Once the bricks are cooked, they become stronger and more durable. Bricks or other finished materials are then moved to a cooling side of the kiln where they are finished and removed by clients or kiln's owner.

Loading brick kiln is the same as metal kiln. The kiln is loaded according to the shape.

Figure: 4. Brick kiln loading system.


Theoretical learning Activity

- ✓ Observation on kiln covering materials (example: ask trainees to brainstorm about kiln covering materials within groups)
- ✓ Documentary research on procedures of kiln loading.


Practical learning Activity

- ➢ Demonstration and practical exercises on loading kiln
- ➢ Trainees in group construct improved brick kiln model and traditional kiln model according to the teacher's instructions.


Points to Remember (Take home message)

Wood or logs to be utilized is cut to about 1.00 m - 1.50 m length with a minimum diameter of 0.5 m and a maximum diameter equal to the width of the door. The brick kiln can be loaded with roughly 30 t of airdry wood, of moisture content 25%, and average specific gravity of about 850 kg/m^3.


Learning outcome. 2.3. Formative Assessment

Written Assessment

Q1. Outline the different form of brick kiln are used for construct the brick kiln throughout the world?

Answer: Q1. There are many designs of brick kilns in use throughout the world and most are capable of giving good results.

These are Half-orange, Brazilian beehive, Slope type beehive, the Missouri kiln.

Practical assessment

- **Task1:** Load the kiln using brick kiln method and interpret the results.

Checklist

Elements to be verified	YES	NO
1.Tools and equipment are well selected		
2. Preparation of the site is well done		
3. Selecting carbonization methods are well done		
4. Kiln loading procedures is well followed according to the type of kiln		
5.Selection of lighting zone is done		
6.The kiln is well constructed accordingly.		
Observation		

Learning out come : 2.4 – Monitor kiln combustion and cooling.

Duration: 6hrs

Learning outcome 2.4. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. Monitor properly the kiln according to the carbonization method.

2. Differentiate correctly characteristics of the kiln combustion and cooling.

3. Respect clearly the procedures of cooling kiln according to the carbonization method.

Resources

Equipment	Tools	Materials
- Audio visual equipment (computer, projector DVD) - PPE	containers, spades, chimney.	soils, water, water, brush, Kilns.

Advance preparation:

. Ensure research documents and materials.

. prepare questions to assess trainees

. prepare video images to show trainees

Indicative content :2.4.1. Monitoring metal kiln combustion and cooling.

Quality of kiln combustion

✓ Smoke behaviour

✓ volume reduction

Figure: 5. Monitor metal kiln.

The burn is now under way and for the next 2 _ 3 hours the focus of work is on getting the fire to spread across the centre underside of the kiln; this is why weather conditions are so important, because if the kiln does not burn evenly, the charcoal will not form correctly and then the timber is wasted.

As the smoke pours out the fire grows steadily stronger, until the embers start to drop around the outer edge. In this picture we can see the base of the kiln, which is slightly raised off the ground, giving us a view of the glowing interior, and this is where we can see the embers beginning to drop down.

Figure 6. Monitor the metal kiln before setting chimneys.

The fire comes around, and smoke continues to appear in a huge plume.

At this stage when we know we have a good strong evenly-burning kiln, it is time to begin to reduce the amount of oxygen getting into the kiln, this will slow down the burning process and if we get it right, should make us some charcoal! So, to do this sand is shovelled around the bottom of the kiln to close up the gap at the base.

Next, we need to seal up the lid properly with sand. As you can see from this picture this is a very hot and dangerous job! Large flames are still dancing out from the shoes at the base of the kiln, so great care must be taken. Heavy metal chimneys are now placed into 4 of the shoes to create exhaust flues. The other 4 shoes become air inlets.

Figure 6: Carbonization process of metal kiln

For the next 14 to 20hours we monitor progress, as it's important to ensure the kiln stays sealed. The smoke from the chimneys gradually grows thinner; we are looking for a change in the colour of the smoke from gray to blue, when this happens, we know the burn is complete. Eventually the chimneys will be removed and all 8 shoes are blocked off with sand, thus sealing the kiln completely.
The kiln is left for at least 24 hours to cool down, and during this time we must still keep checking that the sand keeps it sealed.
Once cooled and safe enough to work with again, the lid can be lifted.

Theoretical learning Activity

- ✓ Group discussion on smokes behaviour.
- ✓ Ask trainees to brainstorm about the characteristics of the kiln after lighting.

Practical learning Activity

- ➢ Demonstration of cooling the kiln
- ➢ Audio visual presentation.
- ➢ Trainees in pair compare the kiln with good progress with the kiln is bad progress.

Points to Remember (Take home message)

- Change in the colour of the smoke from gray to blue state that the burn is complete.
- Eventually the chimneys will be removed, thus sealing the kiln completely.
- The kiln is left for at least 12_24 hours to cool down the charcoal.
- Once cooled and safe enough to work with again, the lid can be lifted.

Indicative content :2.4.2. Procedures of cooling kiln.

- **Procedures of cooling the kiln**.

After some minutes a visible dense white stream of smoke starts to come out through the eye.
The white smoke continues for 2- 4days depending on the kiln and logs size.
When the carbonization process is completed, the smoke becomes almost as transparent as hot air
At this point the holes at the base must be closed with mud or covered with earth and sand. This phase is called "purging".
The cooling is accelerated by throwing wet mud on the kiln. Apart from cooling, this helps to cover any hold or crack in the walls, thereby preventing any entry of air.

- The different stages of carbonization are:

Heating up: from the ambient temperature to 100°C
Dehydration: between 100 and 120°C
Exothermic stage which begins at 270°C, reaching 500 to 700°C when carbonization is complete.
Cooling phase during which the chimney is removed and the kiln is then opened and charcoal packed.

Theoretical learning Activity

- ✓ Brainstorming.
- ✓ Ask trainees to brainstorm about the procedures of cooling the kiln within groups.
- ✓ Group discussion on smokes behaviours.

Practical learning Activity

- Demonstration of cooling the kiln
- Trainees in pair perform the cooling the kiln steps by steps.

Points to Remember (Take home message)

Procedures of cooling the kiln based on the carbonization method

- Once the wood is carbonized, it must be cooled. This process stabilizes the charcoal and allows for easy handling.
- The amount of cooling time necessary depends on climate, kiln size, logs size, earth moisture etc.
- Do not use water to cool the charcoal as it affects its quality. However, a bucket of water should be available for precaution in case of an emergency.
- The cooling process can be accelerated by opening a small hole in the cover and pouring in *2* or 3 liters of water. The water will immediately be turned into steam, lowering the kiln temperature without dampening the charge.

Learning outcome 2.4. Formative Assessment

Written assessment

Q1. What is the quality of kiln combustion and cooling of the kiln?

Answer: Q1. visible dense white smokes emitted from the chimney indicates the good progressive of the kiln. The white smoke continues for some days (depending on the water content) and then starts to become blue; a light bluish coloured smoke indicates that the charcoal is carbonized.

Q2. What are the procedures for cooling the kiln?

Answer: Q2. Remove the chimney, closing the air inlets at the base of the kiln, seal the kiln completely and allow the kiln to cool for X hours depending on the size of the kiln.

Practical assessment

Task: Monitor the kiln combustion and cooling process.

checklist

Element to be verified	YES	NO
Smokes behaviours		
Volume reduction		
Removing chimneys		
Kiln compacting		
Inlets and outlets closing		
Observation		

LEARNING UNIT3: HARVEST CHARCOAL AND BY-PRODUCTS.

Picture/s reflecting the Learning unit 3.



STRUCTURE OF LEARNING UNIT 3: Harvest charcoal and by-products.

Learning outcomes:

3.1. Cool charcoal

3.2. Pack charcoal

3.3. Transport charcoal**.**

- **Learning out come 3.1 Cool the charcoal.**

Duration: 4hrs

Learning outcome 3.1. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. identify the steps used for Cooling charcoal.

2. respect all procedures for cooling charcoal.

3. identify the tools, materials and equipment used for cooling charcoal.

Resources

Equipment	Tools	Materials
Audio visual equipment, Computer, projector, PPE, DVDs.	Hand hoes, spades, hand forks, Pictures, weighting devices.	Charcoals, Soils, sacs, bags, ropes,

Advance preparation:

. Read documents about charcoal cooling.

. Observe the kiln behaviours and management

. Gather the tools and equipment used for cooling charcoal.

Indicative content 3.1.1: Procedures of charcoal cooling

Charcoal cooling is done by closing all air inlets hence allowing charcoal kiln to cool. Cooling varies from the method adopted.
For brick kiln and metal kilns water is sprayed onto the walls. Charcoal burned in earth mound and pit mound are cooled by mixing them with humid soil.


Theoretical learning Activity

- ✓ Oral presentation on charcoal cooling
- ✓ Demonstration on cover materials removing and charcoal cooling
- ✓ ask trainees to brainstorm about the procedures of charcoal cooling within groups.


Practical learning Activity

- ➢ practical exercises on cooling
- ➢ Viewing films and pictures on charcoal cooling
- ➢ Trainees in pair perform removing the covering materials on the kiln and cool charcoal using humid soil.


Points to Remember (Take home message)

Procedures of charcoal cooling:
✓ removing of kiln cover materials
✓ mixing charcoal with humid soil and/or watering on the metal kiln
Discharging:
Before discharging the charcoal, when the kiln is sufficiently fired, enough water must be available to avoid re-ignition when opening the door of the kiln.
One drum of about 200 litres is sufficient for one kiln. The kiln is discharged by two or three men.


Learning outcome 3.1. Formative Assessment

Written assessment

Q1. What are the procedures for cooling charcoal and by product?

Answer: Q1.

- Removing of the kiln cover materials and let cool down charcoal within surveillance.
- Mixing charcoal with humid soil and/or watering on the metal kiln.

Q2. Outline the needs materials for cooling charcoal.

Answer: Q2. the needs materials for cooling charcoal are:

- Sandy soil for traditional kilns.
- Cold Water and sand for improved kilns

Practical assessment

Task: Within group work, perform charcoal cooling.

Check list

Element to be verified.	YES	NO
Removing of the kiln cover materials		
Mixing charcoal with humid soil		
Watering on metal kiln		
Observation		

- **Learning out come : 3.2. Pack the charcoal.**

Duration: 4hrs

Learning outcome 3.2. Objectives:

By the end of the learning outcome, the trainees will be able to:

1. pack appropriately the charcoal and by product.

2. select properly the tools and material used for packing charcoal.

3. respect correctly the steps used for packing charcoal.

Resources

Equipment	Tools	Materials
sealing machine threads, PPE, DVD	Weighting balance, Spades, baskets – Sheeting, Containers.	Labels, Pictures

Advance preparation:

. Ensure research Documents and materials

. Organization of tools and equipment needed for packaging charcoal.

. Prepare questions to assess the trainees.

Indicative content 3.2.1: Criteria of packing charcoal and by-product

Criteria selection of packing charcoal and by-products depend on:

- **Quality**

To speed up this operation a sieve chute should be used to separate the large charcoal pieces from the fines and dust.
It is recommended that the bottom section of the kiln be positioned on the leeward side of the charcoal and used to support the sieve chute. This will not only increase the stability of the sieve but will reduce the amount of dust reaching the operator.

- **Market**,
- **Transport means,**
- **Storage conditions.**

✓ Steps of packaging operation: Sack-Filling, Weighing, Sealing and Labelling.

 Theoretical learning Activity

ask trainees to brainstorm about best quality charcoal.

Group discussion about the quality of charcoal and charcoal value chain in Rwanda.

 Practical learning Activity

Practical exercises

- Trainees in pair discussion about the procedures for packing charcoal.
- Demonstration on packing methods
- Viewing films and pictures on packing methods.

 **Points to Remember** (Take home message)

- Each stack of 3 cubic meters of wood gives about 9-11 bags of charcoal. The kiln takes 4 - 7 days to achieve full carbonization and has a recovery of about 27%.
- Criteria of packing charcoal and by-products are:

  Quality, Market, Transport means, Storage conditions.
- Steps of packaging are: Filling, Weighing, Sealing and Labelling.

 Learning outcome 3.2. Formative Assessment

Written assessment

Q1. What are the characteristics of best quality charcoal?

Answer Q1. The best quality charcoal is characterised by the followings:

-it floats in water,

- it burns without flame,

- it retains the grain of the wood,

- It is sonorous with a metallic ring and doesn't crush,

- It is a bad conductor of heat and electricity.

- it is jet black in colour with a shining luster in a fresh cross-section,

Q2. Enumerate the content of labelling for charcoal.

Answer Q2: The labelling for charcoal contains the following information:

- ✓ Name of species,
- ✓ quantity(kg),
- ✓ bags size or container size,
- ✓ provenance+ producers,
- ✓ storage conditions.
- ✓ Manufacturer's date.

Practical assessment

Task1: Pack the charcoal in different bags size and contact wholesaler.

Checklist.

Element to be verified	YES	NO
Quality		
Market		
Storage conditions		
Filling		
Weighing		
Sealing		
Labelling		
Observation		

- **Learning out come 3.3. Transport the charcoal**

Duration: 3hrs

Learning outcome 3.3. objectives:

By the end of the learning outcome, the trainees will be able to:

1. Define correctly the transport of charcoal from the kiln to the distribution.

2. Select effectively the tools and equipment used for transport charcoal.

3. Keep down properly the transport costs.

Resources

Equipment	Tools	Materials
Truck and Trailer, Wheel borrow. Audio visual equipment, Vehicles – PPE.	Containers, bags.	- Charcoals, Pictures and internet. Transport permit.

Advance preparation:

. select transport means or costs

. collect tools and equipment for charcoal transport.

. prepare workplace (accessibility, transport permit).

Indicative content 3.3.1: Transport conditions of charcoal.

- Where large quantities of charcoal are regularly transported between a production centre and the distribution point, bulk transport without bags should be developed in order to keep down packaging, transport and handling costs.
- Charcoal easily absorbs water and, therefore, tarpaulins or other covers must be used during transport, to prevent wetting.

- There is always a risk that charcoal will be wet by rain during the few days it is "curing" at the side of the kiln. Cured charcoal should be transported as soon as practical to reduce this risk.
- Plastic sheet covers or a galvanized iron open sided storage shed can be used where large amounts must be accumulated prior to transport.

 Theoretical learning Activity

✓ Oral presentation on transport conditions of charcoal.
✓ ask trainees to brainstorm about cutting and transport permit.

Practical learning Activity

- ➢ Demonstration on tracking cars
- ➢ Viewing films, internet and pictures of tracking cars
- ➢ Trainees in pair discussion about the requirement for transport charcoal and by product.

Points to Remember (Take home message)

Transport conditions of charcoal and by-products depend on factors like:
✓ Accessibility
✓ Containers
✓ Truck and vehicles
✓ Transport permit

Learning outcome 3.3. Formative assessment

Written assessment

Q1. What is the requirement for transport charcoal from the kiln to the market?

Answer: Q1. the requirement in transport charcoal is the following:

- ✓ Accessibility,
- ✓ containers,
- ✓ truck (transporters)
- ✓ transport permit.

Q2. Listing the common issues characterizing the charcoal production chain in many African countries including Rwanda.

Answer: Q2.

1. Unregulated/illegal resources
2. Rampant and systemic corruption
3. Inefficient conversion technologies
4. A perception that it is a poor man's business
5. Considered 'dirty' and economically unattractive
6. Free access to wood resources, leading to deforestation and degradation
7. The fact that charcoal business is dominated by a few powerful individuals.

Practical assessment.

Task: Transport the charcoal and by-products based on grading systems.

checklist

Element to verified	YES	NO
Safe transport is respected.		
Conditions of charcoal transportation are respected.		
Observation		

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Video links	Related LU
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