TVET CERTIFICATE V in FORESTRY

FOREST PATHWAY

FORFP501

Contruct forest pathway

Competence

Credits: 5

Learning hours: 50

Sector: Agriculture and Food processing

Sub-sector: Forestry

Module Note Issue date: June, 2020

Purpose statement

This module describes the skills and knowledge required to construct forest pathway. The skills in forest pathway construction are of great importance for forest accessibility.

The module will allow the learner to:

- Design forest pathway network
- Construct forest pathways
- Maintain forest pathways

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Total Number of Pages: 36

Learning Unit 1 – Design pathway network

LO 1.1 – Prepare tools, equipment and materials

Topic 1. Identification of tools, equipment and materials

The general network of forest pathways is the set of pathways and unloading pathways foreseen within a considered area (zone). The required tools, equipment and materials for performing the forest pathways designing are:

Tools and Equipment: GPS, Ranging Poles, Pegs, Compass, Theodolite, Clinometers, Dumping Level, Machete, Hand Hoes, Tape Measures, Ropes, Sledge Hammer, Compactors, Graders, Spade, Bulldozer, Laterite, Trucks, Wheelbarrow, Pickaxe, Metal/Mine Bar, Gabbaret/ Channel, Poles

Materials: Stones, Cement, Sand, Gravel, Paint, Laterite

Topic 2. Selection criteria of tools, equipment and materials

- ✓ **Task to perform:** Tools and equipment are chosen in accordance with the specific task to perform. Example: machete and axe are used for land clearing while hoe and spade are used for land excavation.
- ✓ **Topography**: The land is the fixed basis data that influences a general network of forest pathways. The topography of land determines the unloading techniques to use. Then, the soil nature influences on the construction techniques and on the realization cost. Thus, it is very important to know the land so that to make an optimal choice.

  The type of vegetation and soil fertility of different zones are the good indications (signs) that can help us to make a good choice. On will elaborate the variant permitting to go against to the most fertile parts of the perimeter (unit).

- ✓ **Climate/season**: To avoid tools/equipment depreciation, some tools and/or equipment are adopted. Example: four wheel machines can better work in dry seasons whilst chained bulldozers adapt well in rainy seasons.

- ✓ **Precision of the tool/equipment**: In order to minimize errors, more precise tools/equipment are adopted.
- ✓ **Skills of the operator:** The operator have tendency to choose the tool/equipment that is easy for him/her to manipulate.
- ✓ **Availability of tools and equipment or materials:** some tools and equipment are not available on the local markets regardless their cost.
- ✓ **Financial means:** The available financial means are often limited. It is useful to be able to compare the cost of obtained different variants (based on the survey done) and make the different between their cost and profit.

Topic 3. Handling tools and equipment

All tools and equipment should be handled correctly which enhance the efficiencies of tools/equipment. Incorrect use is detrimental to the tools/equipment and may be dangerous to the user and other peoples. Therefore, adjustment of tools/equipment consists of depth and spacing of implements, fixing of screws.

Maintenance of tools/equipment refers to cleaning, sharpening, oiling, safe keeping and proper storage, welding.

LO 1.2 – Delimitate the site

Topic 1. Determination of geographical location

Geographic coordinates system is coordinate system that enables every location on the earth to be specified by a set of number or letter. A common choice of coordinates is latitude, altitude and longitude. Latitude and longitude are imaginary lines drawn on map. They help us to accurately locate places. We say they are imaginary because they do not physically appear on the ground. They are measured in degrees.

- ✓ **Altitude**

When the height of a point is its vertical distance above or below mean sea level (as the reference plane), it is called the altitude of the point.

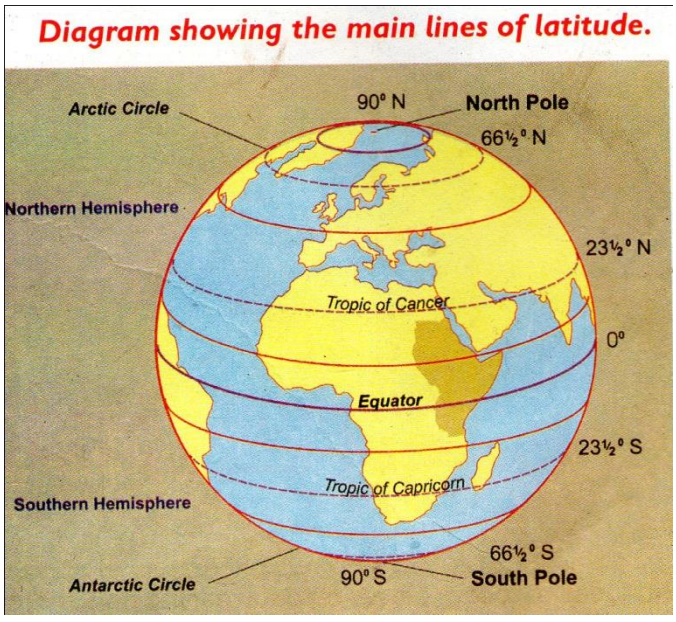
Altitude or elevation is defined as the vertical distance from a datum plane, usually mean sea level, to a point above the earth surface, expressed in meters above sea level.

Elevation is taken from a topographic maps or Digital Elevation Model (DEM), or measured with a barometric altimeter (calibrations needed) or G.P.S. a receiver (calibrations needed).

- ✓ **Latitudes**

Latitudes are imaginary lines drawn across maps running from east to west. The main latitude is the equator at **0°**. It divides the earth into equal parts. The part north of the equator is called the northern hemisphere. The part south of the equator is called the southern hemisphere.

The lines of latitude increase in degrees from the equator. They increase northwards and southwards up to **90°**. The lines of latitude north of the equator are labelled with the letter **N** which indicates north of the equator. Those which are located in south of equator are marked with the letter **S** which indicates south of the equator. To locate a place using latitudes, we consider how many degrees it is north or south of the equator.



Picture N^{O} 1.Main lines of Latitude

The main lines of latitude are:

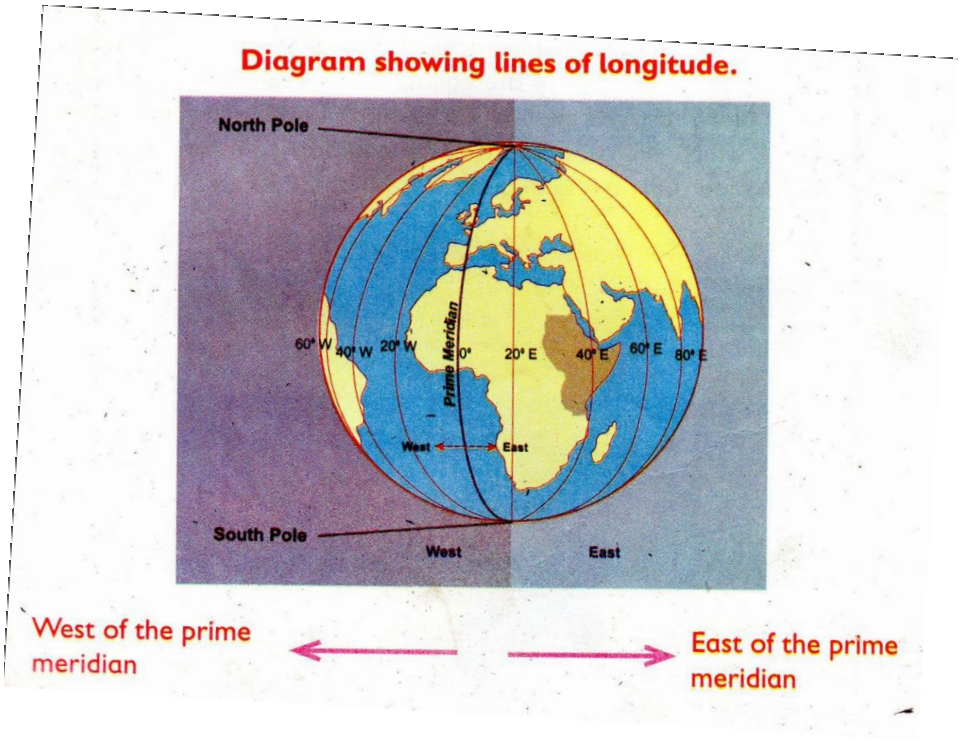
- The equator: **0°**

- Tropic of Capricorn: 23.5° **S**
- Tropic of cancer: 23.5° **N**
- Antarctic circle: 66.5° **S**
- Arctic circle: 66.5° **N**

✓ **Longitudes**

These are imaginary lines drawn on maps running from North to South. The main longitude at **0°** is called Prime Meridian or Greenwich Meridian. This is because on a world map, it passes through the city of Greenwich in England. In Africa, it passes through the city of Accra, the capital of Ghana in West Africa.

Other longitudes are measured from the Prime Meridian. They increase eastwards up to **180°** and westwards up to **180°**. Longitudes West of the Prime meridian are labelled with letter **W.** It indicates west of the Prime meridian. Longitudes east of the Prime meridian are labelled with letter **E** which indicates east of the Prime meridian.



Picture N$^{\underline{O}}$ 2. Main lines of Longitude

We can use longitudes to locate places by determining how many degrees they are East or West of the Prime meridian.

	Latitude	**Longitude**
Direction	East-west, parallel to the equator	North-south; converging at the poles and widest at the equator
Parallel lines	Yes	No
Range	0 to 90° North and South	0 to 180° East and West
Denoted by	Greek letter phi (Φ)	Greek letter lambda (λ)
Hemisphere	All locations along a common latitude fall in the same hemisphere of the earth (northern or southern)	Locations along a common longitude may be in different hemispheres.
Denotes distance from	equator (north or south)	Prime Meridian (east or west)
Time zone	Locations that share the same latitude do not necessarily fall into the same time zone	All locations on the same longitude fall in the same time zone
Number of lines	180	360
Notable lines	Equator, Tropic of Cancer, Tropic of Capricorn	Greenwich Meridian
Applications	Classifying temperature zones	Classifying time zones

Table 1: Latitude versus Longitude comparison chart

Topic 2. Marking procedures

- ✓ Clearing of site: it consists of removing all obstacles present on the land to make the next activities easy.
- ✓ Marking of boundaries: It consists of identifying the limits and borders of the road zone. In so doing the following measurements need to be taken and filled in the forms.

- Measurement the of horizontal angles
- Measurement of vertical angles
- Measurement of horizontal distance

LO 1.3 – Examine the site

Topic 1. Physical examination of the site

- ✓ **Soil fertility and vegetation**

The type of vegetation and soil fertility of different zones are the good indications (signs) that can help us to make a good choice. On will elaborate the variant permitting to go against to the most fertile parts of the perimeter (unit).

- ✓ **Hydrology and exposition**

For the purpose of environment protection road should not cross over the wetlands (marshes and swamps) nor seeping soils wherever possible. Slope orientation is defined as the bearing /azimuth, usually expressed in degrees (^{o}) or according to 4 or 8 cardinal directions, of the downhill direction of the imaginary line following the steepest slope gradient (where water could run off) used to determine the slope, measured with a Compass.

Topic 2. Location of negative and positive fixed points

One calls a fixed positive point a place to reach while a negative fixed point a place to avoid. These fixed points (positive and negative) are localized in the network unit during the land visits. The location of fixed points (positive and negative) is done according to soil fertility and vegetation, unloading mode that want to say in the interesting places , susceptible to achieve the goal of an optimal forest pathway of the fertile zone while taking into account to the unloading concept.

Examples of positive fixed points: land gradient with 2-7%, hard soil

Examples of negative fixed points: wetlands, terrain with low bearing capacity, steep land and/or unstable slopes, landslide/prone areas, flood plains, infrastructures, terrain with >10%.

LO 1.4 – Design forest pathway network

Topic 1. Criteria of selection of favourable place for forest pathway network

✓ **Existing road network**

The network of roads/pathways should allow the easy access to the perimeter (unit) and easy transport of the forest products towards the (purchase) industrial centres. It must be joined to the existing road/pathways

✓ **Budget**

The available financial means are often limited. It is useful to be able to compare the cost of obtained different variants (based on the survey done) and make the different between their cost and profit

✓ **Technical skills**

The skills of technicians have crucial impact in selecting favourable places for forest pathway network because if not done properly it leads to economic losses.

Topic 2. Admissible technical norms of forest pathway

In forest pathways construction, some technical norms are restrictive (limitative), in particular the maximum longitudinal slope (<10%). This factor is very important, considering the high difference in level within the forest pathway unit.

The standards norms for forest pathway are width varying from 3.5 to 5m; longitudinal slope varies from 2 to 7% and side slope/embankment is 10/1 or 5/1 in rocky soil and 1/1 or 2/1 in normal soils.

Topic 3. Slope line marking

A slope line is a line that follows the ground level (on the soil surface) with a certain percentage of slopes. When the ground is regular with few vegetation, the staking out of the slope line could be done at every **50m**.

If the ground is irregular with more vegetation (obstacles), the pegs should be driven at every **10** or **20meters**.It is important to clear the slope line using paint on some trees or other mark (sign) on the trees.

The slope variation must be shown on the pegs and then, a path can be made between every two pegs in order to make the slope line more visible. The survey of slope line is made on two levels: on the ground and in the office.

- ✓ **On the ground:**

  One use the forms in which the following data are filled: ***Points number, Distances (m), Slope (%)*** and ***Remarks***

Point N^{o}	***Distance(m)***	***Slope (%)***	***Remarks/Observations***
1 to 2	20	-2	
2 to 3	13	-6	
3 to 4	17	-6	
4 to 5	20	+6	
5 to 6	5	-7	
6 to 7	5	+7	
7 to 8	25	-5	
8 to 9	20	-4	

Table 2: Ground data record

- ✓ **In the office:**

The form is filled on the office level. It is made by the data collected from the ground and other three columns showing the ***cumulative distances, cumulative elevations*** and ***the level on the ground.***

Point N^{o}	***Distance***	***Slope***	***Cumulative***	***Elevations***	***Level on the***	***Remarks/Obser***

	(m)	*(%)*	*distances(m)*	*(cm)*	*ground(cm)*	*vations*
1 to 2	20	-2	20	-40	-40	
2 to 3	13	-6	33	-78	-118	
3 to 4	17	-6	50	-102	-220	
4 to 5	20	+6	70	+120	-100	
5 to 6	5	-7	75	-35	-135	
6 to 7	5	+7	80	+35	-100	
7 to 8	25	-5	105	-125	-225	
8 to 9	20	-4	125	-80	-305	

Table 3: Calculation of ground level

After those calculations, one can represent graphically the slope line. Remember that the selected **scale** for the cumulative distances is **1/2000** and **1/200** for the cumulative elevations (levels).

Thus, after the choice of the scale, one fills two forms:

The first contains the followings: Points number, Cumulative distance (on the ground) and cumulative distance on the plan.

The second form contains the point's number, cumulative levels (on the ground) and cumulative levels on the plan.

Point N°	***Cumulative distance (m)/ground***	***Cumulative distance (cm)/plan***		***Level on the ground(cm)***	***Level on the plan(mm)***	***Remarks/Observations***

1 to 2	20	1.0		-40	-2.0	
2to 3	33	1.65		-118	-5.9	
3 to 4	50	2.5		-220	-11.0	
4 to 5	70	3.5		-100	-5.0	
5 to 6	75	3.75		-135	-6.75	
6 to 7	80	4.0		-100	-5.0	
7 to 8	105	5.25		-225	-11.25	
8 to 9	125	6.25		-305	-15.25	

Table 4: Calculation of ground level on the paper

Learning Unit 2 – Apply forest pathways construction

LO 2.1 – Stake out forest pathways

Topic 1. Staking out procedures of forest pathway

The method of determination of the slope (based on the topographic, geological and climatic conditions) permits to carry out the definitive picketing of the slope line. The slope measurement is often done using back reading method.

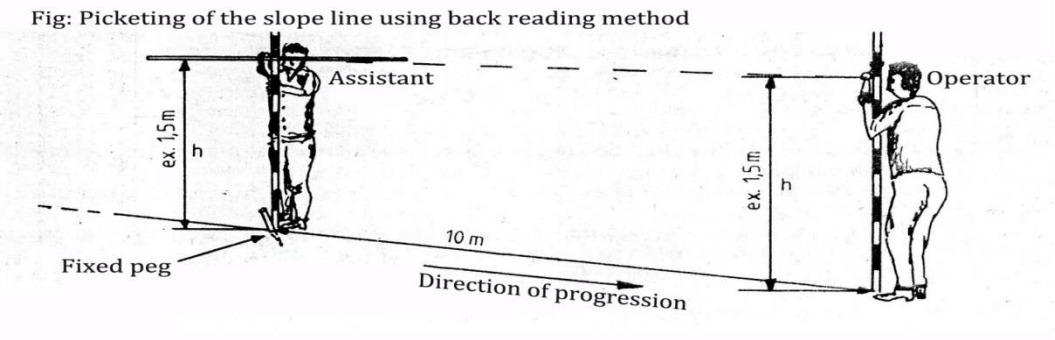


Figure N^{o} 1.Picketing of the pathway by using back reading method

This technique presents several advantages such as:

- ✓ One measures on a fixed point (already definitive);

- ✓ There are no verbal instructions given by the operator to his/her assistant. So the operator displaces himself;
- ✓ In the case of an irregular land, the operator finds the wanted slope more quickly;
- ✓ One can control the level at the same time of staking in (driving) of pegs.

The definitive staking out of a forest pathway delimits every point of the pathway by the level pegs (LP) having the notch, placed on the outside of pathway and the slope pegs (SP) placed to the summit (top side) of the cut slope. There are three main factors that determine the distance between level pegs and slope pegs such as:

- ✓ Width of the pathway to construct;
- ✓ Slope of cut slope (side slope); as well as
- ✓ Slope of land.

To mark the slope line the operator proceed as follows:

- ✓ To measure 10m (in general) from the last determined point;
- ✓ To measure approximately the wanted slope (2to7%);
- ✓ To clear the place where is going to be the peg; The aim of clearing of that place is to eliminate /reduce the irregularities of land and to remove away the soft soil layer;
- ✓ To look for the precise place to have the wanted slope. Thus, the operator moves on the free place while controlling the distance between the points;
- ✓ To drive /fix the numbered peg having the notch that shows the level of future forest pathway;
- ✓ From the level peg (LP), to measure the slope of land perpendicularly to the axis of the pathway to construct. The slope is considered of 5 to5% while rounding up systematically to superior value in order to guarantee the slope of cut slope of 2:1.For example 41become 45.
- ✓ To read in the table of measures for forest pathway construction the distance corresponding to the measured land slope;
- ✓ From level pegs (LP), measure the read distance and drive (fix) the slope peg (SP) on this place;

✓ To restart the operation for the neighbour point.

The standard dimensions of pegs to use are: length of 70 cm, diameter of 3-5 cm.

LO 2.2 – Estimate financial means and human resource

Topic 1. Estimation principles of tools/equipment and human resource

A man-hour is the amount of work performed by the average worker in one hour. It is used in written "**estimates**" for estimation of the total amount of uninterrupted labour required to perform a task. For example, felling a big tree in normal conditions might require two man-hours if hand tools like an axe is used.

Man-hours do not take account of the breaks that people generally require from work, e.g. for rest, eating, and other bodily functions. They only count pure labour. Managers count the man-hours and add break time to estimate the amount of time a task will actually take to complete.

Working days: days per week a worker/ person works. In Rwanda, the working days per week are 5days while the working hours per day vary from 8 to 9 hours. Thus, the working days per month are estimated at 25 days.

A simple formula: Total man-hours ÷ actual work days ÷ working hours/day = No. of forestry workers

Example: Your estimate says the project will require 4,000 man-hours to establish forests. The contract is six months, which, by the way, is not really 180 working days—unless your forestry workers work seven days per week. On average, there are only 20 working days each month. So, six working months is only about 120 working days.

→ **Now apply the formula: 4,000 hours ÷ 120 days ÷ 8 hours**

→ **= 4.17 forestry workers (call**

Keep in mind, your estimate's 4,000 hours does not include any time for lost productivity.

The 4,000 hours is only a figure from your extended take off and is strictly based on what it will take to build the job. You'll be lucky to get six fully productive labour hours per day, per forestry worker, so you need to factor for the lost time.

A better formula: Total man-hours ÷ actual working days ÷ Working hours/day = No. of forestry workers. Now your Forestry workers count is up to 5.5, Might as well make it six. Guess what. You gained another two forestry workers per day.

Lost time formula: No. of actual working days × No. of lost hours/day × No. of forestry workers = No. of hours needed to add to your estimate (really)

But wait, there's more! Even though you are going to get only about six productive hours per day from each forestry worker, you still need to pay them for eight. So, unless you like giving away money, you need to add back in the lost unproductive labour. **120 days × 2 hours × 6 forestry workers = 1,440 hours of lost time.**

Topic 2. Staking out of corners

In forest pathways construction, the corners are the curves with a big angle in the centre (≥160grades) and a small radius (minimum 9m). The corners are used in general when two positive fixed points cannot be joined with an admissible longitudinal slope.

In order to avoid the too big volume of soil to remove (cut) and the very elevated construction cost, the corner must be established to the favourable places, where the slope of land is weak. These places are considered as positive fixed points. The picketing of a forest pathway before and after the corner will be done after the implementation of the corner.

Procedure:

1. To the designated place, one chooses the more indicated zone for the corner construction. The favourable place for the corner construction is the place where the slope of land is weak. On the topographic map showing the contour lines, that favourable place is characterized by spaced contour lines. It is necessary to imagine the finished construction in order to make a better idea for the beginning, centre and radius of corner.

Fig:Place (favorable and unfavorable) for corner establishment

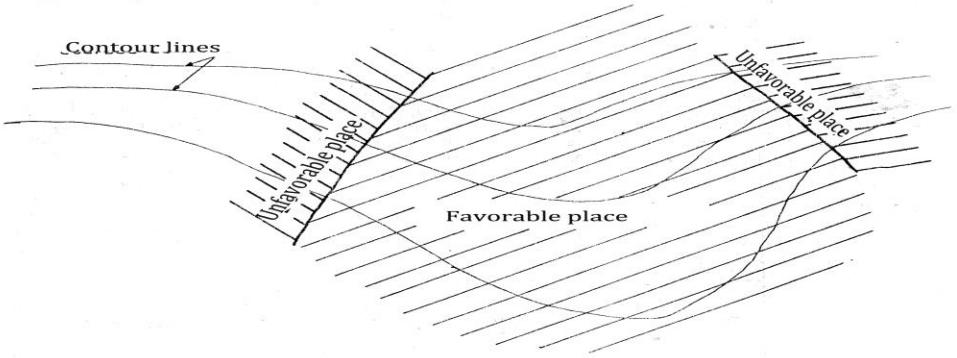


Figure N^{o} 2. Favourable place for corner construction

2. To the place of corner, the slope line looks like an elbow. As we have seen that the forest pathway construction is made by soil cutting, the elbow is located on the downstream from the centre of corner. One chooses the place of an elbow according to the realization projection and the picketing of slope line will be done at about 40m before and after the elbow. On that place, the slope must not be superior to 8%.

Fig:Establishment of elbow on the slope line

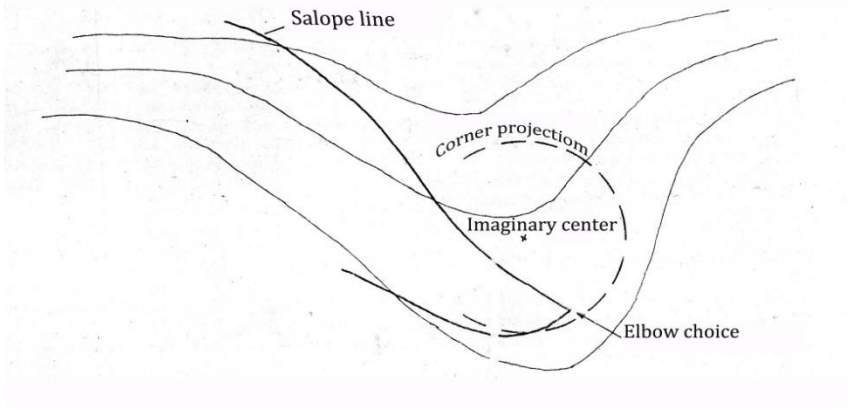


Figure N^{o} 3. The shape of the slope line in the corner

3. Choice of temporary beginning of the corner (X_1): where the x_1 is located on the slope line before the elbow.

4. Temporary picketing of the first centre (C_1) of the corner: The centre of the corner is perpendicularly to the axis of forest pathway to the beginning point of the corner.

The radius is chosen according to the land, but it must not be lower than 9meters.In general, one chooses 10meters in order to permit an easy running of truck.

The radius is measured from the centre to the axis of forest pathway. The slope line represents the external side of forest pathway. It is necessary to move /displace a half width of forest pathway to construct toward the cut slope.

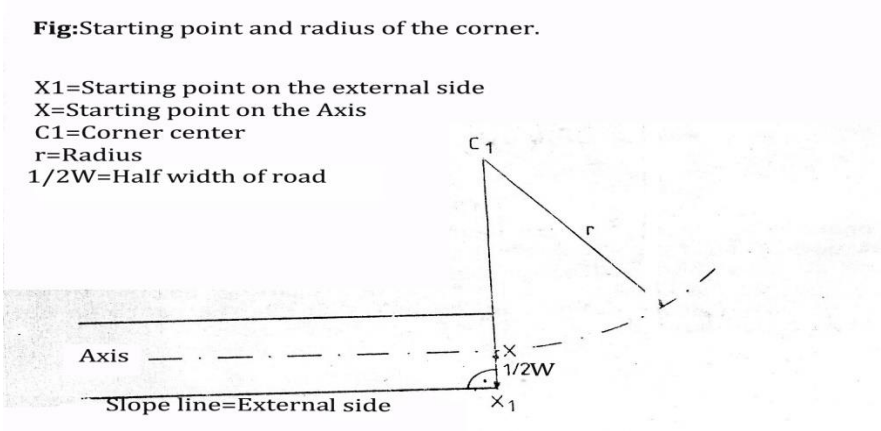


Figure N^{o} 4. Picketing of the first centre of corner

5. Staking out of the first points on the axis:

X, C_1 and radius (R) are determined. For that picketing, one uses "**L** method" where the first person stands on C_1, and second person stands on **X** and unwound (roll out) the tape measure to a distance that is equal to **R**adius+**5**m. The third person stretches the tape measure and fixes the peg at 5m from the precedent point.

Note: The distance must be measured horizontally. If it is not possible, it is necessary to correct it according to the slope of land.

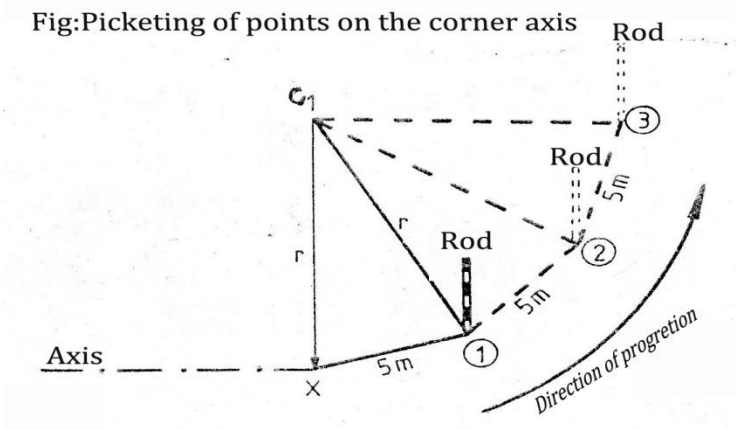


Figure N^{o} 5. Picketing of the points on the corner

6. Calculation of the mean slope of the corner:

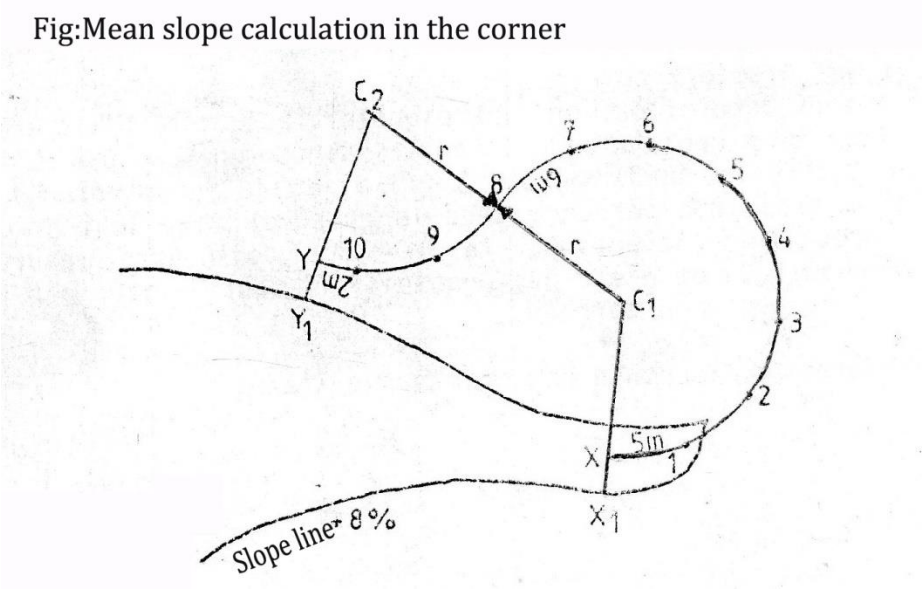


Figure N^{o} 6. Calculation of the mean slope on the corner

After the picketing of the first points on the axis, the total length of the corner is calculated by making the sum of all measured distances on the corner's axis; in our case, the total length on the corner's axis=(5m×9) +6m +2m=53m. Thus, it remains to know the difference in level (elevation) between the beginning point (X_1) and the ending point (Y_1) of the corner. Finally, the mean slope is calculated by dividing the calculated elevation between X_1 and Y_1 points by the total length on the corner's axis. Remember that the admissible longitudinal slope on the

corner of a forest pathway is 8%. In our case, distance from X_1 toY_1 =39m. Elevation between $X_1$and Y_1=39m ×8% =3.12m. The mean slope =$\frac{3.12m}{53m}$ ×100 = 5.8 = 6%.

Note: If the calculated mean slope on the corner is superior to 6%, it is necessary to repeat (redo) the picketing.

How to repeat the picketing if the calculated mean slope is superior to 6%?

If the calculated mean slope on the corner is too high, there are two possibilities used to reduce it while keeping the same slope line:

- ✓ To increase the radius: If we increase the radius, the centre (C_1) of the corner moves towards the uphill side and the length of corner's axis increases.
- ✓ To displace the beginning (starting) point of the corner towards the direction of elbow of the slope line: If the beginning (starting) point of the corner is displaced towards the direction of elbow of the slope line, the centre (C_1) and ending point (Y_1) of the corner move toward the elbow and the elevation between X_1 and Y_1decreases.

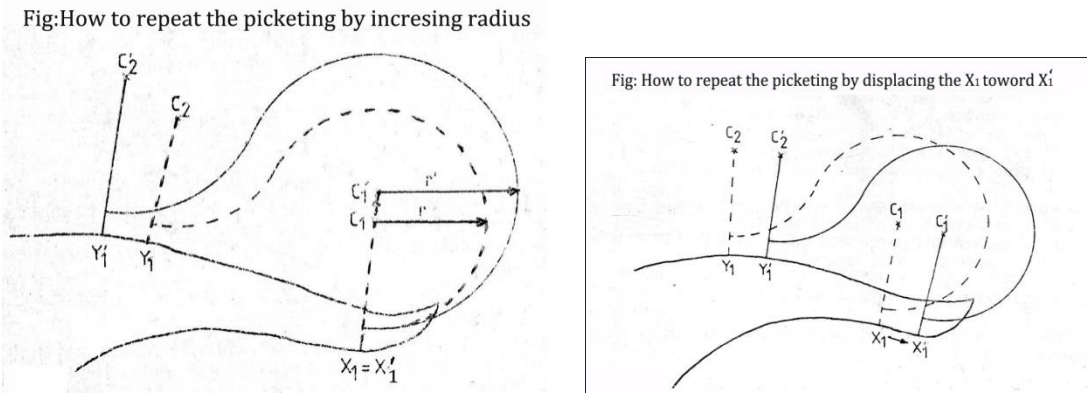


Figure N^{o}7. How to redo the picketing if the mean slope is > 6%

7. Calculation of the height on the axis and digging:

When the mean slope of the corner is acceptable, one can calculate the ground level, height on the axis and digging for every point on the corner. First of all, one measures the slope of land between all points. Having the slope of land for every point and the distance between the points all can be calculated as follows:

Point N°	X_1	X	1	2	3	4	5	6	7	8	9	10
Distance (m)		2.5	5	5	5	5	5	5	5	6	5	5
Slope of land (%)		50	5	10	8	15	15	12	11	-2	-3	-7
Elevation (cm)		125	25	50	40	75	75	60	55	-12	-15	-35
Land level (cm)	0	125	150	200	240	315	390	450	505	493	478	443
Slope on the axis (%)		0	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Elevation on the axis (cm)		0	29.5	29.5	29.5	29.5	29.5	29.5	29.5	35	29.5	29.5
Level on the axis (cm)	0	0	30	59	89	118	148	177	207	242	274	300
Digging (cm)	0	-125	-120	-141	-151	-197	-242	-273	-298	-251	-207	-14

Table 5: Calculation of digging

Remark: Digging is obtained by making the difference between the level on the axis and the level of land.

8. Determination of the site location for slope pegs:

The procedure to follow is:

a) To measure the slope of land for every point on the axis. As for the normal case, the slope of land is measured perpendicularly to the axis.

b) To draw on the graph paper (scale of 1/100) the profile across for every point on the axis. That profile across shows the following elements:

- Profile type (pathway width and cut slope);
- The axis;
- Digging and
- The line of land with the measured slope.

c) On the drawing, to measure the distance between the axis and the summit (top site) of downstream (d_1) and he distance between the axis and the summit (top site) of uphill (d_2).

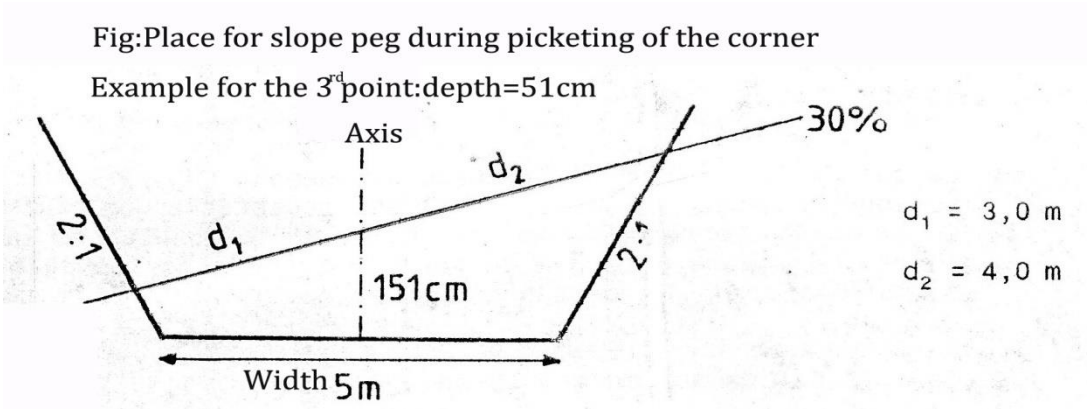


Figure N°8. Location of slope pegs and level pegs

Example for the 3rd point: Digging= 151cm, pathway width=5m; Slope of land=30%

9. Picketing of cut slopes (uphill and downstream)

One stretches the tape measure from the centre toward the axis points and one report on the land the inclined distances measured on the drawing.

10. Localization of pegs

As for the definitive picketing of forest pathway, the soil surface should be cleared on the site location of axis pegs and the centre (s). The slope pegs (SP) are joined between them by a trace (on the soil surface) that respects the final form of corner.

11. Calculation of soil volume to cut:

On the drawing of profile across, one calculates the surface representing the soil cut (m^3/m). One takes the sum of height multiplied by 1meter section what gives the profile surface. The volume of soil cut between two profiles across is calculated using the following formula:

Soil volume = $\frac{Profile\ surface1+Profile\ surface2}{2}$ × Distance between two profiles.

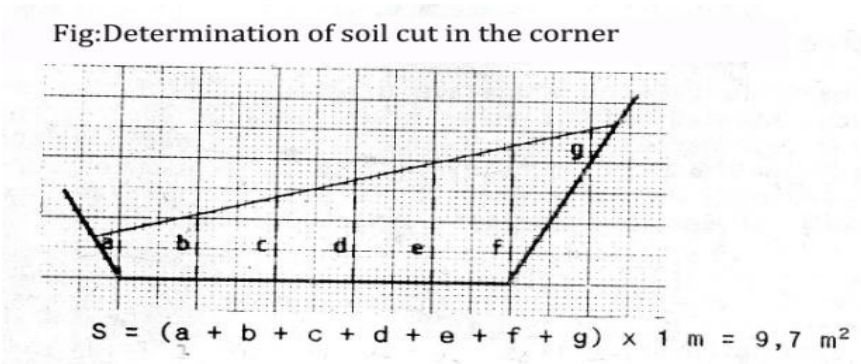
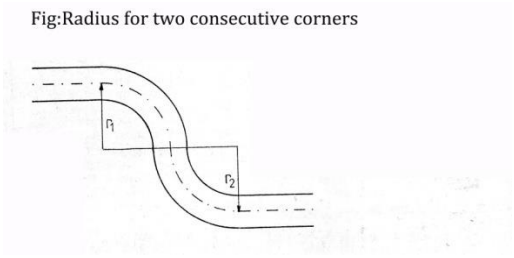


Figure N°9. Calculation of the quantity of soil to cut

Note: The two consecutive corners should be constructed in the form of an arc circle and their radius should not be lower than 20m (except in the tight corners where the minimal radius is 9m).

Some widening is to consider in the tight corners. Two attached corners must have similar radius to permit a comfortable circulation of vehicles.

Fig:Radius for two consecutive corners



On the tight corner and corners in zigzag, the admissible slope must not pass 8% (unusually 10%) so that to avoid a too strong deterioration of the forest pathway. According to KUONEN (1983) the slope on the corner axis is calculated through the following formula: **Slope on the axis = Admissible internal slope ×** $\frac{\boldsymbol{Internal\ radius}}{\boldsymbol{Radius\ on\ the\ axis}}$.

Thus, for a forest pathway having a corner with 10m radius and 5m width, the slope on the axis will be calculated as follows: The slope on the axis = 8 $(\frac{10m - 2.5m}{10m})$ = 6%

LO 2.3 – Terrace forest pathways

Topic 1. Terracing procedures

This part concerns the technical aspects for the forest pathway construction and makes part of the acquired experiences in this domain. Every aspect or part of construction is treated separately; the features, objectives and instruction of construction as well as the most frequent mistakes are mentioned.

During the forest pathway construction, the following steps must be performed:

- ✓ To reclaim and clear the distance between level pegs (LP) and slope pegs (SP) and cut the vegetation above the slope pegs until 1meter;
- ✓ To put the cut vegetation (including trees) below the pathway so that to keep the soil during terracing;

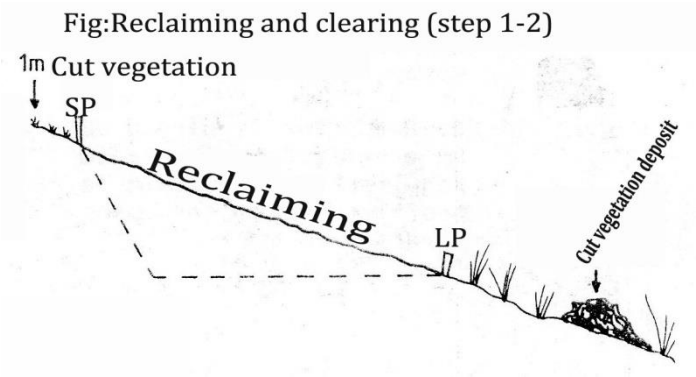


Figure N°10. Reclaiming of the place where the pathway will be constructed

- ✓ To dig a pathway () of 1m large between the level pegs while respecting the longitudinal slope;

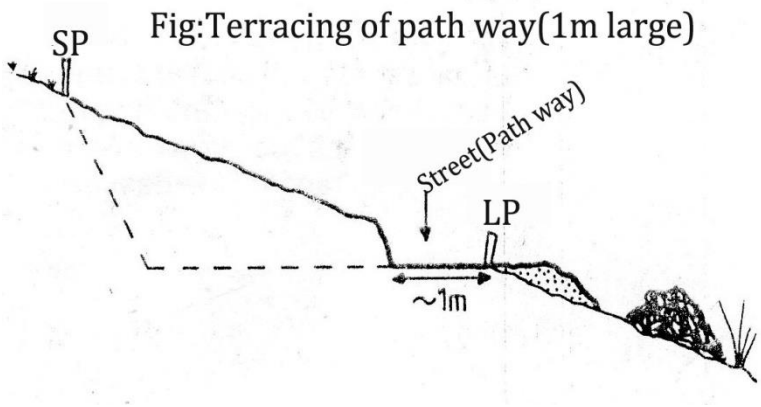


Figure N° 11. Terracing of the street of 1m large

- ✓ To begin the digging (terracing) starting from the slope pegs,
- ✓ To descend progressively while pushing the soil behind the level pegs while respecting the slope of cut slope;

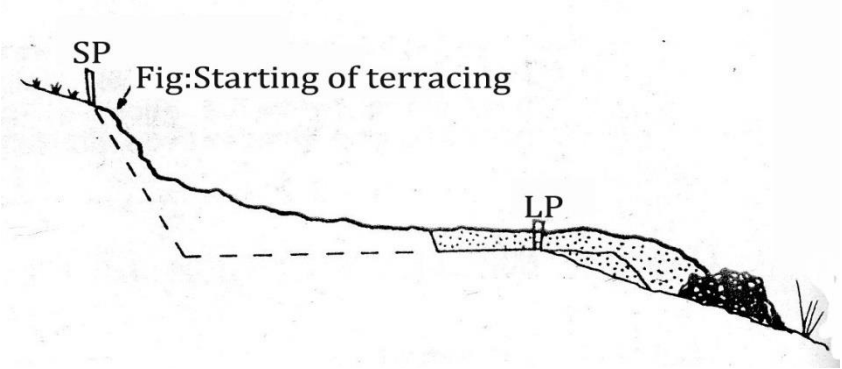


Figure N°12. Beginning of the terracing works

- ✓ To continue to dig soil until the required width is reached. To stop before arriving to the definitive pathway level so that to respect the slant of pathway;

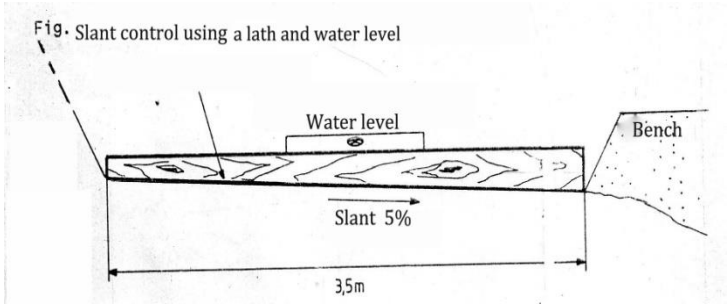


Figure N°13. Slant control through lath and carpenter level

- ✓ To assure the rain water evacuation system by creating the trenches (openings / outlets) in the bench;

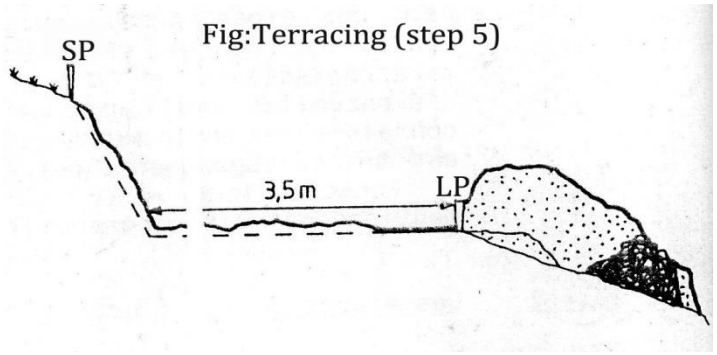


Figure N°14. Travelwal (running surface) levelling

- ✓ To regularize the slope of cut slope (Embankment) from the bottom to the summit;
- ✓ To respect the pathway level identified by the notch of level pegs and make level (levelling) the travel-way while respecting the wanted profile (in general 5%);

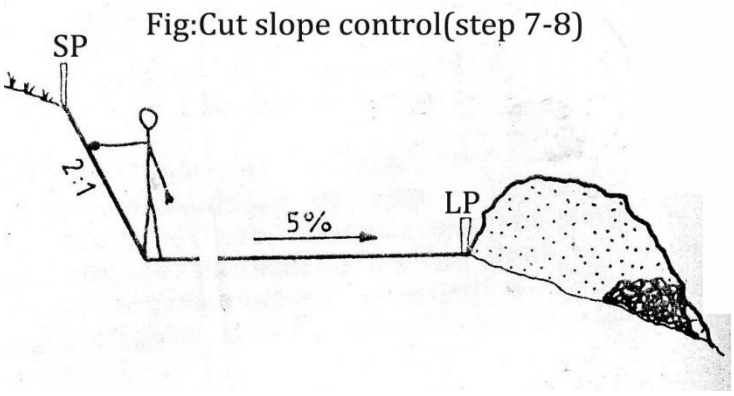


Figure N°15. Cut slope (embankment) regularization

- ✓ To prepare the benches while respecting a height of 50cm, internal slope:2/1and make level on its top side;

Fig:Bench construction(step 9)

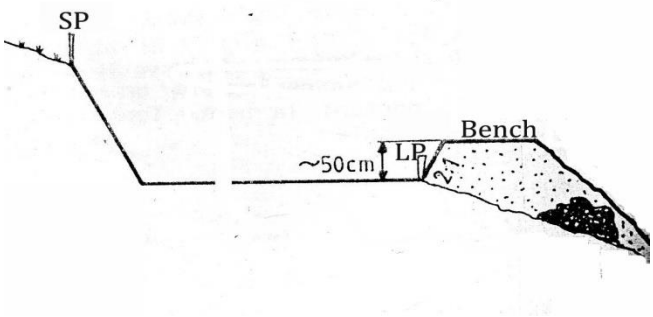


Figure N°16. Bench construction

- ✓ To finish the openings in the benches (outlets), width on the bottom:50cm, lateral side slope:2/1, water evacuation slope:10%;
- ✓ To proceed to the finishing works: gravels spreading on the travel-way, pavement of openings in the benches using the flat stones.

Fig: Spreading of gravel layer on the travelway

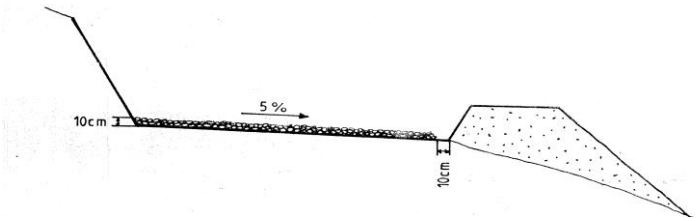


Figure N°17. Surfacing the travel way (running surface)

Topic 2. Types of pathway profile

- ✓ **Travel-way having flat profile**

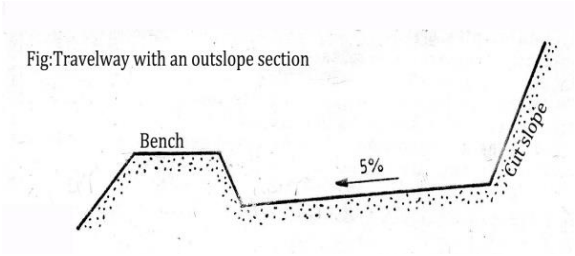
This type of forest pathway having the flat profile is little frequent used as it very difficult to evacuate water on the travel-way level.

Advantages of a forest pathway having a flat profile (Balanced earth work section):

- There is a minimal clearing width on the site;
- There is a little skidding risk of vehicles/trucks.

✓ **Travel-way having an out sloped profile**

- ***Characteristics:***
  - ❖ Width: 3m or 4m large;
  - ❖ Slant downstream inclined to 5%;
  - ❖ Regular without depressions or bumps;
  - ❖ Constructed on the stable land (hard soil).



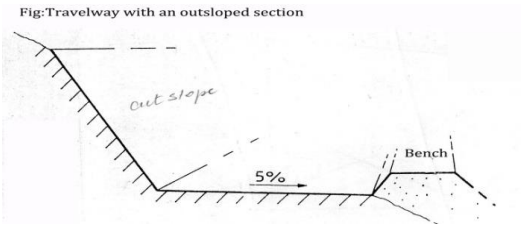


Figure N°18. Travel way with an out-sloped profile

b) Objectives:

- To allow a vehicle or truck to nun easily;
- To ensure the fast running of rain water;
- To manage vehicles/trucks;
- To guarantee the traffic security.

c) Instructions of construction:

- To follow the stages of forest pathway construction (see 2.3.1.);
- To control the slant of travel-way using a pole/ lath and carpenter level at every 2 or 3meters;
- Each team of workers uses a pole of 3.5m or 4m.

d) Frequent mistakes:

- False slant;
- Bumps and depressions on the travel-way;
- False width (more or less than 3.5m or 4m);

✓ **Travel-way having an in-sloped profile.**

In general, one changes the slant of the forest pathway on the places where there are the tightened corners having the centre on the uphill side so that to avoid the skidding of vehicles/trucks. Therefore, it is important that the profile of forest pathway remains the same (identical) on the whole length of corner.

It is necessary to plan the widening of forest pathway for ditch construction or the widening due to the tight corner. The travel-way having an in sloped section is used in the case we want to avoid that the rain water does not run (flow) in the downstream direction just above the habitations or the parts rightly over the corner. Normally, after every change of slant, it is necessary to install a gutter that will evacuate the rain water coming from uphill ditch. Then, one retakes the initial profile thereafter (slant unique downstream).

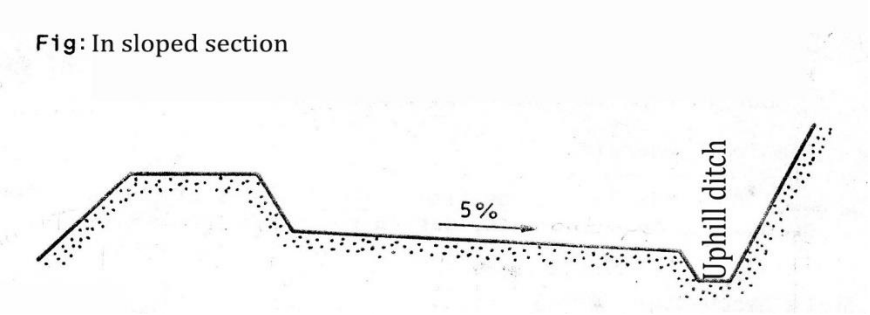


Figure N°19. Travel way with an in-sloped profile

- ✓ **Travel-way having a crowned / rounded profile.**

In general, the travel-way with a crowned section is little frequent used in forest pathway construction. This type of profile is used for the forest pathways passing on the top line (ridge) where the rain water could be poured directly on two sides of pathway (left and right sides). If the travel-way with a crowned section is applied in normal conditions for other reasons, it is necessary to plan the widening of that forest pathway for uphill ditch digging.

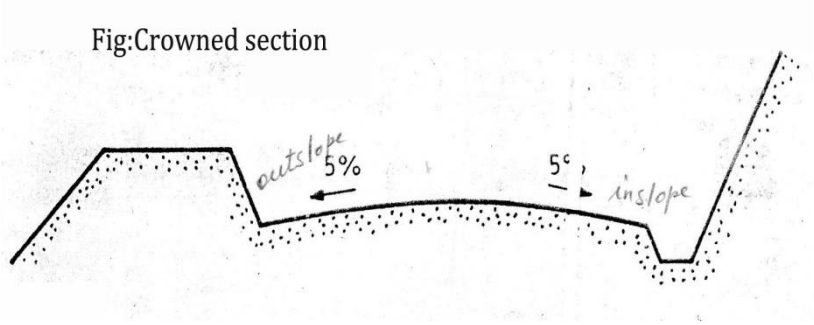


Figure N°20. Travel way with crowned profile

Topic 3 Selection of surfacing materials

The objective of surfacing pathway /road is to give it a surface which is more stable, harder wearing and less slippery than the material of which the main formation is made. If the road is being built in a material which has these qualities adequately, there is no need to apply an additional surfacing layer; make the surface of what is there.

There are two principal types of material which a road can be surfaced, those with binders and those without. Crushed stones and gravels have no inherent binding quality. Quarry gravels and rotten rock will usually contain some proportion of binder in them, and clay is used purely as a binder. Each material has its particular properties in use.

- ✓ **Broken stones**

The broken stones are obtained by crushing the stones by using hammer. This is the cheapest way for finding out the surfacing material.

This is hard, will provide a non-slip surface but lacks any binder. If applied directly to a clay formation, this is best done when the clay is still wet after rain. It can then be spread and rolled in immediately and this will ensure that it is well bound by the clay. Well done, this type of surface can be almost as good as a tarmacadam road and will last well for as long as the moisture content of the formation is correct.

- ✓ **Gravel**

Like broken stone, gravel will be lacking in any binder. It will have the advantage of being rounded which make it much kinder on the tyres of the trucks /vehicles using the pathway /road but will also provide a marginally poorer grip in wet weather. Spread as broken stone.

Volcanic soils or gravel taken from river bank are the cheapest surfacing material for the forest pathways and feeder roads.

- ✓ **Laterite soil**

On rural projects the native soil itself will form the primary building material for the forest pathways / feeder roads. It is important therefore to be able to recognize which soils are suitable and which soils are likely to give trouble. Fortunately, most soils are good for agriculture for the very same reason that they can be good for road making namely their structure.

Well-structured soils have excellent bearing quantity when normally moist, though they will break down under heavy loads if either too wet or too dry.

Best are the heavy, well crumb-structured tropical clays derived either by bearing in situ, or by weathering, erosion and re-deposition elsewhere, from ultra-basic and basic volcanic rocks and limestones. They range in colour normally from dark chocolate brown through medium browns, pink browns and reds to deep cerise reds.

Topic 4. Soil erosion control around the forest pathway

- ✓ **Side slope (embankment) stabilization**
  - To install /plant the fixing plants on soft or unsteady parts (for example after big slips).
  - To create terraces in the form of stairs to avoid sliding of embankment
  - To construct a stone beach that works as barrier
- ✓ **Fill slope stabilization**

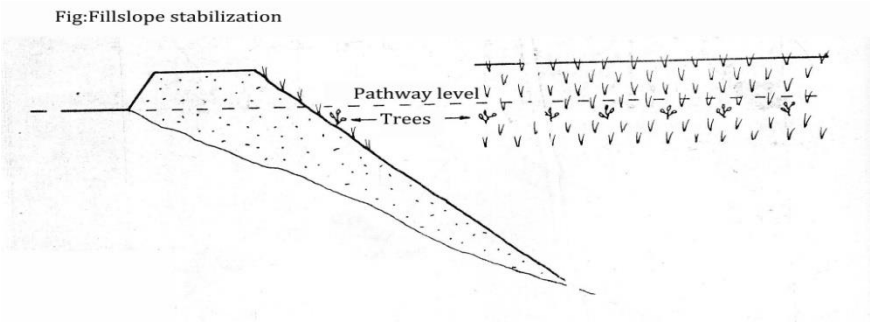


Figure N^{o} 21. Fill slope stabilization

a) Characteristics:

Direct sowing, cuttings or planting of adequate plant species. These activities are carried out on the upper part of fill slope at least from 3 to 5m, (according to the length of fill slope).

b) Objectives:

- To ensure/ stabilize the bench;
- To reduce the risk of soil erosion;
- To avoid disconnecting (land sliding);
- To have the logs for gutters repairing in the future.

c) Instructions of construction:

- To plant tightly(using short spacing);
- The tree species having many roots will be planted below the travel-way level;
- To plant in the rain season.
- To construct a stone beach that works as barrier

List of tested species and the obtained results:

A) Direct sowing (on lines or broad sowing):

Dodenea viscosa (Umusasa), germination rate varies from 40 to 50% after 5months.

Acacia mearnsii, high germination rate: superior to 80% after 1month (seeds treatment is necessary).

B) Cuttings planted on lines (depth: 20cm, spacing: 40cm x 50cm):

- *Erythrina abyssinica*, resumption varies from 70 to 90% on good soils. Advised diameter for cuttings: 10cm.

-*Ficus thoningii*, resumption varies from 75 to 100% on all types of soil. Advised diameter for cuttings 2 to12cm.

-*Drascena sp*, resumption varies from 80 to 100% on good soils. The goats browse the young shoots.

-Iboza riparia, resumption varies from 90 to 100% on all types of soil.

-*Senecio manii*, resumption of 100% on good soils.

-*Morus alba,* resumption varies from 90 to 100% on all types of soil, but its vitality is weak!

-*Penisetum maximum*, good resumption, (to cut regularly).

C) Plants to roots or **clods**:

-*Eucalyptus sp*, very good resumption on all soils.

-*Eragrostis* (clods gangway), good resumption, but does not colonize the soils,

-*Kirumbi grass*: Good resumption.

-*Tripsacum sp*: Good resumption on good soils but weak vitality on poor soils.

-*Setaria sp*: Good resumption, but it is little vivacious and must be cut regularly.

LO 3.1 – Construct water evacuation system

Topic 1. Construction of water evacuation structures

✓ **Ditch**

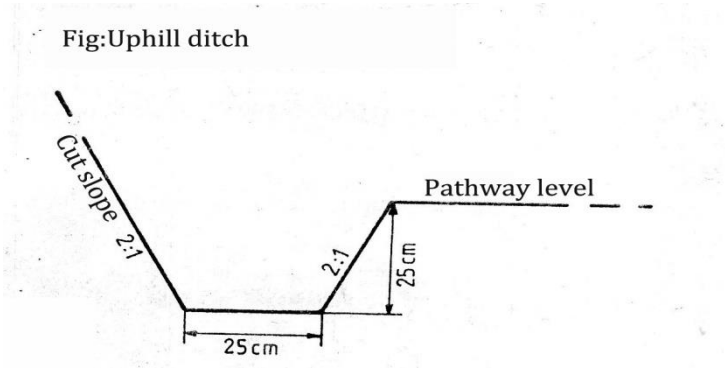


Figure Nº 22. Uphill ditch

a) Characteristics:

- Width to the bottom: 25cm;
- Depth: 25cm;
- Regular longitudinal slope;
- Side slopes (Embankments): 2/1.

b) Objectives:

- To conduct rain water towards gutter;
- To allow the maintenance of ditch using a shovel or spade.

c) Instructions of construction:

- To dig ditch as soon as levelling of travel-way is done;
- To control the dimensions of ditch with shovel or spade;
- To verify the functional of ditch at the time of rain;

d) Frequent mistakes:

- The dimensions/ sizes of ditch are not respected (too small or too large);
- The longitudinal slope is not regular (rises and coming down);
- The side slope (embankment) is cut vertically;

✓ **Gutter**

During forest pathway construction, a gutter is the edge of pathway/ road where rain water flows away.

Characteristics:

- Gutter may be covered or not, respecting the travel-way level;
- Constructed using hard and healthy wood: minimum length: 2m, minimum diameter: 25cm;
- All logs used to construct gutter are supported by two load bearing logs;
- If covered: soils layer having at least 25cm thickness, with stones between the logs. Then, the lateral logs reduce the risk of soil erosion;
- The four signalling posts (15cm diameter) established in four corners. Other function of four signalling posts is to keep firmly the load bearing logs.
- Depth: 50cm under the logs;
- Width to the bottom: 50cm;
- Water evacuation slope: 5 to 10%.

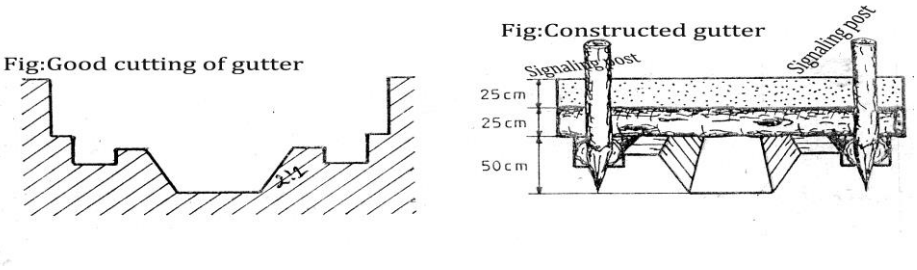


Figure N^{o} 23. Gutter

These standard measures permit a good water evacuation as well as an easy control of gutter status (one can enter into the gutter to check the logs status). The construction of gutter requires a specialized team of workers while controlling the logs and gutter dimensions. If the land is crumbly, it is recommended to cover the entry of water and the bottom of gutter with the flat stones. The following tree species are recommended to be used for gutter construction: *Eucalyptus saligna, Eucalyptus tereticornis* and *Acacia melanoxylon*.

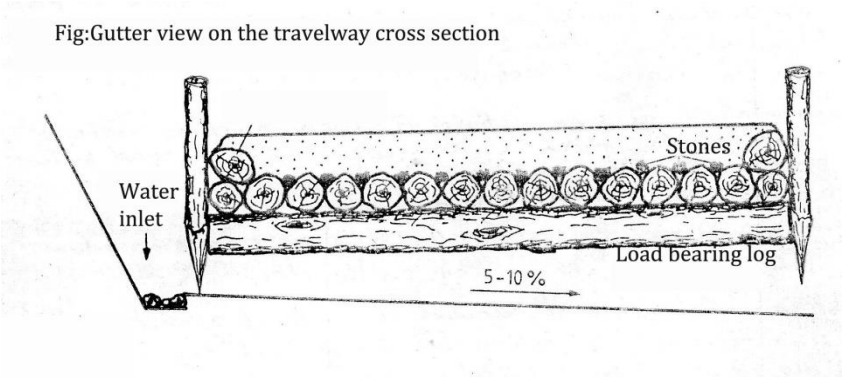


Figure N°24. A constructed gutter

- ✓ **Opening in the benches (outlet)**

  Outlets are the cuts done into the bench so that to facilitate the water evacuation from the travel way (running surface). They are created at every 10 metres and have the following characteristics:

  Width on the bottom: 50m;

  Internal side slope: 2/1;

  Water evacuation slope 5 to 10 %.

- ✓ **Bridge**: Bridge is a structure that is built over a stream or river so that people or vehicles can cross from one side to another. The bridge sites can be classified by whether they are on the river's torrent course or flood plain course, whether the banks are of rock or of soil, whether one span or several spans are required and, if several spans, whether the river bed is soft, stony or of rock.

  Site type will largely determine the foundations to be used. If the site is rocky, piling is impossible. If the bridge is to cross a deep narrow valley it is likely that the bridge foundations can be placed well above any conceivable water level and piling will be unnecessary. If the foundations are liable to be washed over by the river when it is in flood, something more substantial like gabions or reinforced concrete footing will be required.

  Bridge widths should ideally comfort to road widths since road widths are going to be related to traffic density. A single lane width bridge is logical on forest pathways / feeder roads, provided that it is wide enough for all the trucks that are going to use and maintain the pathways to pass over it with reasonable clearance. For main roads, width enough for vehicles to pass one another is desirable.

  Before the construction of a bridge, the following criteria should be considered:

  - Watershed dimensions,
  - Precipitation: highest water level in the river (per year) and the discharge of the river. This information allows the forest technician to data about the surface water width, water depth and river bed width.
  - Sub-soil quality (rock, gravel, firm soil, sandy or clay soil)
  - Topographical condition,
  - Traffic intensity: on the forest pathways, the traffic intensity is not high, few vehicles run on the pathway per week, but during the forest harvesting activities, the circulation and weight of trucks will be increased.
  - Available economic means.

Learning Unit 3 – Maintain forest pathways

LO 3.1 – Assess the state of forest pathways

Topic 1. Inspection of forest pathways

Normally, the damages must be repaired as early as possible, as soon as they are observed. It is necessary to inspect the forest pathway status during and after the rainfall. Firstly, one controls the water evacuation system to ensure that ditches, gutters and openings in the benches accomplish their function.

When it rains or when the forest pathway is wet, it is not better to execute the maintenance works on the travel-way, cut slope and fill slope. Some particular works such as the replacement of rotted logs on the gutter can be done during the period at which they are less works.

The inspection of forest pathway can be done on daily, weekly, monthly, quarterly and annually basis. It consists of checking of the pathway profile (flat, in-slopped, out-slopped, and crowned), the recommended size of pathway parts (embankment, fill slope, width) and status of pathway structures such as uphill ditch, gutter, outlet, and bridge.

LO 3.2 – Clean up the forest pathway

Topic 1. Maintenance of forest pathway structures

The maintenance concerns the following forest pathway structures namely uphill ditch, gutter, and outlet.

- ✓ **Procedures to maintain gutter:**
- To remove the accumulated material to the entry and exit of gutter (desilting);
- To replace the rotted logs by the hard and healthy logs. The dimensions (sizes) of gutter permit to enter in for checking the status of logs.
- To verify/ check if the soil layer above logs is on the same level with the travel-way level. If necessary, to rectify the travel-way level.
- ✓ **Procedures to maintain outlet:**
- To uproot the vegetation growing in the openings (weeding);
- To remove away the accumulated material on the bottom side of openings(desilting);
- If necessary, to give back the ideal profile.
- ✓ **Procedures to maintain outlet:**
- To empty the ditches so that they recover their ideal profile (desilting);
- The removed material on the bottom of ditches must not be spread on the travel-way surface, but thrown behind the benches.

✓ **Procedure to maintain embankment:**

- To cut the vegetation without pulling them;
- To remove away the descended material that is accumulated on the travel-way side;
- To control the slope of cut slope eventually to repair the places of slips;
- To install /plant the fixing plants on soft or unsteady parts (for example after big slips).

LO 3.3– Rehabilitate the damaged forest pathways

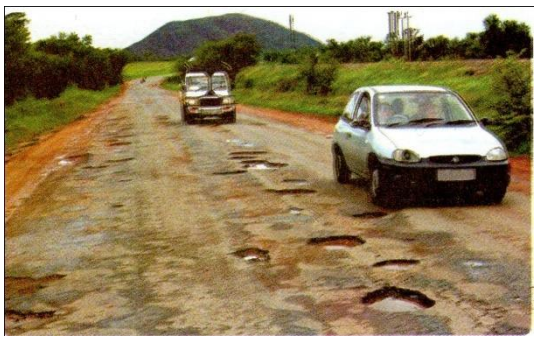
Topic 1. Rehabilitation procedure

✓ **Travel way rehabilitation**

The maintenance of the travel-way is primordial for water evacuation in the transversal outflow.

- To redo the travel-way so that to give back the wanted profile;
- To uproot the vegetation growing on the travel-way and throw them behind the benches.

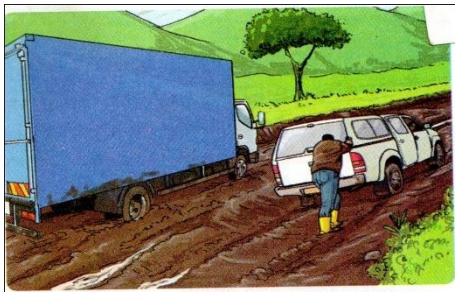
a) Holes on the travel-way:



Picture N^{o} 3. Holes on the travel-way (running surface)

- To fill in them using a good material (firm and hard soil). Not use fine or sandy soils but use gravel or broken stones!
- To break down too big stones on the travel-way. They provoke the holes on the travel-way.

b) Wheel ruts:



Picture N°4. Wheel ruts on the travel-way (running surface)

The wheel ruts are deep tracks that the wheels/tires of vehicles trace on the travel-way if the soil is not well compacted. The repairing of wheel ruts is done as follows:

- To repair as holes;
- A preventive measure for their maintenance is to educate the drivers to pass on the whole width of travel-way rather than to use the same traces always.

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