NATURAL RESOURCES CONSERVATION AND DEVELOPMENT

NTQF Level -II

Learning Guide #32

Unit of Competence: - Demonstrate Routine Site Assessment and Measurements

Module Title: - Demonstrating Routine Site Assessment and Measurements

LG Code:- AGR NRC2 M01 LO1-LG-32

TTLM Code: AGR NRC2 TTLM 0919v1

LO 3: - Perform erosion assessment and measurement(s)

Instruction Sheet	Learning Guide #32

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics –

- Identifying and searching information
- Identifying alternatives resources

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to**

- Identify and searching information
- Identify alternatives resources

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described in number 3 to 20.
3. Read the information written in the "Information Sheets 1". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-check 1" in page 5.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 1).
6. If you earned a satisfactory evaluation proceed to "Information Sheet 2". However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
7. Submit your accomplished Self-check. This will form part of your training portfolio.
8. Read the information written in the "Information Sheet 2". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
9. Accomplish the "Self-check 2" in page 7.
10. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 2).
11. Read the information written in the "Information Sheets 3 . Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
12. Accomplish the "Self-check 3" in page 11.
13. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 3).
14. If you earned a satisfactory evaluation proceed to "Operation Sheet 1" in page 12. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
15. Read the "Operation Sheet 1" and try to understand the procedures discussed.

16. If you earned a satisfactory evaluation proceed to “Operation Sheet 2” in page 13. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
17. Read the “Operation Sheet 2” and try to understand the procedures discussed.
18. If you earned a satisfactory evaluation proceed to “Operation Sheet 3” in page 14. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1.
19. Read the “Operation Sheet 3” and try to understand the procedures discussed.
20. Do the “LAP test” in page 15 (if you are ready). Request your teacher to evaluate your performance and outputs. Your teacher will give you feedback and the evaluation will be either satisfactory or unsatisfactory. If unsatisfactory, your teacher shall advice you on additional work.

Information Sheet-1	Following occupation Health safety procedures

1.0. Following occupation Health safety procedures

Hazards are identified as in Learning out comes two. Therefore, right identification of those hazardous events would help in taking appropriate preventive measures. Moreover, in the case of working with such kind of hazardous events it is better to make first aid kits easily accessible at work place in case of emergency is relevant. A lack of corporate commitment to health and safety will result in OHS remaining a marginalized and insufficiently funded workplace activity. A six point approach has been devised to help you implement effective occupational health and safety systems. This plan can help prevent accidents, incidents, injuries, and work-related ill health. The six points are:

- ✓ Develop an occupational health and safety (OHS) policy and related programs;
- ✓ Set up a consultation mechanism with employees;
- ✓ Establish a training strategy;
- ✓ Establish a hazard identification and workplace assessment process;
- ✓ Develop and implement risk control;
- ✓ Promote, maintain and improve these strategies.

Safety practices may include, but not limited to

- Use of Material Safety Data Sheets (MSDSs)
- Use PPE, such as; hard hats, hearing protection, gloves, safety glasses, goggles, face-guards, overalls, gown, body suits, respirators, safety boots
- Correct labelling of hazardous materials
- Handling and storing hazardous material and equipment in accordance with labels, MSDS, manufacturer's instructions, enterprise procedures and regulations
- Regular cleaning and/or decontaminating of equipment
- Fitting machinery guards
- Signage, barriers, service isolation tags, traffic control, flashing lights
- Lockout and tag out procedures

Self-Check -1	Written Test

Name: ___________________________ Date: ________________

Short Answer Questions

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Write the occupation Health and safety (OHS) procedures? (2points)

2. List at least 5 PPE used during erosion assessment and measurement. (3points)

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet-2	Assessing all relevant data

2.0. Assessing all relevant data

- Primary data
- Secondary data

Assessing all relevant data to soil erosion assessment and measurement based on prepared site format will be discussed as follows. Data to be assessed can be classified into two:

1. **The physical context**
2. **The socio-economic context**

1. The physical context

1.1. Data collection

Data collection techniques

a. Documentation or on-going record keeping (e.g. checklists, journals, etc.) that provides details of your project are always good if they are consistently kept and accurate. This is by far the most useful method for collecting organizational progress data. You want reports on numbers, activities, feedback, your reflections etc. in your evaluation and evidence to support other evaluation results.

B. Questionnaires are a set of questions designed to gather information. They are useful when your audience is able to read and write, it is culturally appropriate, you have an engaged audience (i.e. workgroup or team), you personally know the people you want to collect the information on or for. Using a questionnaire without names on it might help to make sure information is kept private. If you want to get information from others who are remote to you, and it is not easy to get them in one place at one time consider using a mail questionnaire.

Choosing and interpreting a standardized questionnaire is something you might want to get an expert to help you. It is a good idea only to use a standardized questionnaire if you are sure that you will be able to use the information because the evaluator does not know who has answered the questionnaire. This means you can ask more questions that are sensitive.

However, people answering the questionnaire may not understand some sections or may have questions and you will not be there to clarify or it might be difficult to read what people have written. Some people might be more likely to complete and return your questionnaire than others, e.g. people who have difficulties reading and writing are less likely to participate and return completed questionnaires.

c. Hand-Out Questionnaires are another option. They are inexpensive, quick to administer, good for getting feedback, e.g. you can ask people how they felt about training workshops or activities they have just completed. Many people who you ask to complete the questionnaire will do so.

If people are completing the questionnaires in front of you, they may feel they have to give answers they think you want.

d. Mail Questionnaires can be sent out to a large number of people. If sent to people, then they have time to think about their answers.

The number of questionnaires you get back could be very low and it is very time consuming trying to get people to post completed questionnaires back to you.

e. Face-to-Face Interviews are a set of questions designed to gather information read out aloud to the participant face-to-face. They are good when you are not known to the interviewee, the interviewee is easily accessible (they live close by), it is culturally appropriate or there is only a small number of people you want to collect particular information from because face-to-face interviews take a lot of time to organize and carry out. People are more likely to agree to take part, which allows you to look more deeply into complex issues, ensures the interviewee understands the questions and can provide a lot of detailed information. In addition, the interviewee does not have to be able to read or write well.

It may be difficult to ask personal or sensitive questions and people might not tell the truth if they know the interviewer or the interviewer knows them. If you have different people doing the interviewing then they may ask the questions in different ways, making it harder to compare interviewee answers. It can also be expensive, for example, the time it takes to organize and do the interview and the costs of travelling to meet the interviewee.

f. Telephone Interviews are again a set of questions designed to gather information read out over the phone with the participant. This works well when you are sure everyone you want to talk to has a phone, you have permission to have people’s phone numbers, people live far away and you can’t get them into the same room to ask questions and it is culturally appropriate and the questions you are asking are simple and straight forward.

If you have a large number of calls to make, it will be very costly in terms of time and money but many people who you ask to interview are likely to do so. People are more likely to agree to take part, there are low to medium costs, allows you to clarify questions the interviewee may have, the interviewee does not need to have good reading or writing skills, can provide a lot of detailed information. The interviewee might not know who the interviewee is so they may feel more comfortable answering personal questions.

It is not always a good approach if people have hearing difficulties or do not speak your language very well or when you are trying to explore complex or sensitive issues. Not all people have phones; therefore, you might limit your sample to people who have phones, as those without phones will not be able to participate.

g. Focus Groups are another good way of gaining information. This is a discussion between a small group of participants (6-12) with a facilitator to get information about views and impressions. Consider this method when it is culturally appropriate, the participants are easily accessible (they live close by), there is someone experienced who can run the focus group or you want to reach different groups and compare their thoughts and ideas.

Focus groups are inexpensive, participants don't need to be able to read or write and is good for exploring more complex issues people can openly talk about their experiences. The focus group leader can answer any questions participants have. It is good for exploring new areas, reasons for change or lack of change.

h. Case Studies are a detailed description of a single event, person or place that illustrates your project. They are good when presenting the results of your evaluation; your project is focusing on particular groups as it helps people to identify with the particular groups within the project. You must be certain that the person in your case study cannot be identified and have a good example that illustrates or "showcases" your project.

Usually case studies have a minimal cost, and are a good way to present your project in a way that your organization will understand. Nevertheless, you need to be very careful to make sure that your case is not identified. Capture a range of people so that you can make representative generalizations and conclusions.

i. Story telling is when a person or group tells a story on a topic. This is useful when you are certain that your subject case cannot be identified. It can show results effectively and display your project in a way that your community will understand.

j. Photos, Pictures and Videos are a way of showing, at a point in time, how things look. It is effective when you have a clear visual outcome of your project; you are presenting to a board and/or writing articles for the local newsletter. There is a minimal cost, can show results effectively, are simple to document progress and it is easy to see how your evaluation has made a difference. Remember that you must gain permission if you photograph people and it is only appropriate if you need visuals.

k. Other Data Sources is information collected outside your project (e.g. public records, industry records). It is useful when you want to check the accuracy of some information that you collected or you are conducting a project where routine data may support your objectives.

It has already been collected so you do not have to do all the work to collect the information. However, you need to check if you need ethical approval and permission to access this information and that the information has been collected reliably. Finally ensure that you really know what the data means and from whom has been collected from.

l. Process Mapping is used to show the processes or activities involved in a project, process, team or system in a flow chart. It shows the workflow within a process and relationships between people and groups in the process.

This information can be helpful in identifying areas for improvement because it can provide accurate and detailed process information. Observations may however be influenced by how you feel about a certain event. You need to make sure you just record the facts. There is a risk that the mapping may not be completed on a regular basis or accurately.

Always think carefully about which method is most appropriate to achieving the information you need to organize and keep and which can be ignored. Keep the following four criteria in mind as you make your selections and apply them again when making your final choices as to suitability of material.

1. Who the users will be?
2. What their information needs are.
3. What materials are available?
4. How information can be disseminated?

***Note**:-It is important to collect only essential information. Too much information can be confusing.*

1. **The physical context**

Data/information to be collected

The data may be obtained following consultation with the relevant national services. The type of the basic data to be collected and the services that may supply this information are as follows:

(a) Cartography

- topographic maps. The most widely used scale is 1/200,000 or 1/100,000.

Certain regions may be covered by maps using a scale of 1/50,000 or 1/20,000

-Aerial photographs. Many countries have been covered by aerial photograph: on black and white panchromatic film at a scale of approximately 1/50,000;

-satellite photographs (LANDSAT pictures). These may provide interesting information at the regional level.

(b) Geology

Geological maps at a scale 1/1,000,000, 1/500,000 or 1/200,000. These are usually available from the national geological services , universities, etc.

(c) Pedology

General pedological maps, where they exist, often have a small scale (1/1,000,000). For certain projects, pedological maps may be available with larger scales, and they can be obtained from geological or agricultural services.

(d) Climatology

Usually, all countries have a precipitation observation network which measures daily precipitation. Climatologically stations make more detailed data collection covering rainfall intensity, temperature, evaporation, hygrometry, wind speed and direction, etc. These data can be obtained from meteorological services, airports and agricultural departments.

(e) Vegetation

Data about the type and distribution of natural vegetation and the density and main species that can be used for afforestation purposes can be obtained from agricultural, water, forest and animal breeding services.

(f) Hydrology

Characteristics of the hydrographic network and the hydrological regime. Type of hydrometric observations carried out.

2. The socio-economic context

2.1. Data collection

The main data to be collected deal with:

(a) Demography: population in the zone in question, agricultural population, number of working people, trends;

(b) Farming systems: type of farming (family, industrial, etc.), areas farmed, production (type, yield, costs), agricultural income;

(c) Land use: agriculture, livestock farming, forest, industrial or urban zones;

(d) Agricultural policy, development plans, current legislative measures.

Factors affecting soil erosion

The factors controlling the working of soil erosion systems are climate (mainly rain fall), Soil properties, topography, the vegetation cover and human influence. In order to understand when and how much erosion is likely to occur each factor is shortly discussed below**.**

1. **Climate :**
   - Rainfall erosivity, amount, intensity, duration distribution and frequency (detachment of soil particles)
   - Wind speed (detachment of soil particles)
   - Temperature (evaporation, soil moisture, infiltration / runoff)
2. **Soil properties**
   - Erodibility, texture, soil organic matter, permeability (detachment of soil particles, runoff)
   - Soil structure (infiltration speed)
   - Soil depth (volume of infiltration)
   - Surface roughness (runoff speed)
   - Soil moisture, soil water (infiltration / runoff)
   - Soil fertility and water holding capacity (protective plant growth)
   - Surface stone cover (rain splash)
3. **Topography**:
   - Slope angle (runoff speed)
   - Slope length (amount and speed of runoff)
   - Slope shape (concentration and speed of runoff)
   - Exposition (soil moisture, infiltration / runoff)
4. **Effect of plant (vegetation) cover**.
   - Plant ground cover (splash, runoff velocity, accumulation)
   - Plant height (drip and splash)
   - Roots (infiltration)
   - Organic matter (erodibility)

E.g.The relation between rainfall and soil cover

Soil cover	soil loss (Kg/ha/year)
Bare ground	1400000
Mosquito net over ground	1200
94% forest cover	2100
64% forest cover	10300

5. **Soil management**
   - ☞Crop rotation (fertility, ground cover)
   - ☞Tillage direction (runoff)
   - ☞Machines (compaction, infiltration)
   - ☞Timeliness of planting (cover)
   - ☞Fertilization (cover)
6. **Human influence/land use.**

The analysis of the factors influencing erodibilty of the soil has led the discussion to the question of how erosion can be controlled. Soil erodibilty is the resistance of soil against erosive force of water/run-off/ or wind. Soil erosivity is the ability of rainfall/run-off to erode soil particles from soil mass and is the function of rainfall/wind characteristics.

Erosion is the function of erosivity and the erosivity depends entirely on rainfall and so is outside our control. Erodibilty depends partly on the soil properties which again we cannot change, and to a greater extent on land use and crop management both of which are entirely under man`s control.

Accelerated erosion can only start when man clears natural vegetation on a large scale in order to obtain arable land, grassland, fuel wood and leaving space. The amount of soil erosion, which occurs under given condition, is influenced not only by the soil itself, but also by the treatment or management it receives. A soil loss would be greater when used for cultivation of row crops running straight up and down the steepest slope, while identical soil under well-managed pasture the soil loss would be less.

There is no point in preserving soil and using it. The demand of the world is for its resources to be used as efficient as possible without waste. Undoubtedly the best aid is to encourage efficient land use and encourage conservation.

Self-Check -2	Written Test

Name: ___________________________ Date: ________________

Short Answer Questions

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1.0. How human influence/land uses affect soil erosion? (2points)

2.0. What are the relevant data to soil erosion site assessment and measurement ?(3points)

3.0. Differentiate between rainfall erosivity & soil erodibilty (5points)

***Note:* Satisfactory rating >2.5 points Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ____________

Rating: ______________

Information Sheet-3	Locating assessment & measurement points and services

3.0. Locating assessment & measurement points and services

Locating the soil erosion site assessment & measurement points and services positions accurately on the surface of the earth helps us to delineate the eroded area. Maps are derived from point measurements of elevation in geographic coordinates (X, Y, Z). They are associated with point data (measurement profiles). To express your location in grid coordinates or geographic coordinates use Hand GPS or Digital GPS.

This is possible by

1. Locating points or location geo-referenced from satellite image/aerial photo and searching track points using GPS.
2. Locating points on the topographic maps
3. Locating points using hand GPS /digital GPS on erosion hotspot areas boundary.
4. Manual locating points of erosion hotspot areas using tape-meter (pacing) and pegging.

Sufficiency of readings should be taken to ensure reliable data of the location of the soil erosion site assessment & measurement points and services.

Name: ________________________ Date: _______________

- **Short Answer Questions**

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Why we locating the soil erosion site assessment & measurement points and services positions accurately on the surface of the earth? (3points)

2. Why sufficient readings should be taken during data collection of the location of the soil erosion site assessment & measurement points and services. (2points)

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ___________
Rating: ____________

Information Sheet-4	Accessing measurement points

4.0. Accessing measurement points

Measurement points are accessed by removing covers and locks as appropriate. Why measurement points accessed are to have ground truth and conducting measurement for quantifying soil loss. Measurement points' located mark on topographic map is sometimes inaccessible and obstruct. Those points obstructed by covers and locks can be maintained by removing the covers and locks. But those points inaccessible due to topographic features and other natural phenomena have to be reported to the supervisor.

Name: ___________________________ Date: ________________

- **Short Answer Questions**

Self-Check -4	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Why accessing soil erosion site/points? (5points)

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet-5	Recording environmental condition

5.0.Recording environmental condition

Recording environmental/Site conditions and any other observations with appropriate accuracy, precision and units is mandatory unless which may impact on data quality.

Conditions affecting quality of data

- Human resources.
- Lack of Institutional problems.
- Inadequate sector coordination.
- Insufficient community involvement.
- Inadequate operation and maintenance.
- Insufficient information and communication.
- Financial difficulties

Environmental condition affecting quality of data:

- Climate
- Land form/topography

Accuracy of data

Contents should be based on scientific facts, on exact, verified information and free from errors. If information has to be selected or filtered, then the most essential data must be retained.

Precision of data

Contents should not be presented in an incomplete or an ambiguous fashion. If content is rather complex, then it should be explained and remain totally comprehensible.

- It means that the data have to be understandable for another reader.

Recording data with its unit help us:

- To have definite and accurate reading
- To make data handling simple
- To document data for a long time
- To make it understandable

Name: ___________________________ Date: ________________

➢ **Short Answer Questions**

Self-Check -5	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What are conditions affecting quality of data? (10pts)
2. What is to mean accuracy & precision of data? (10PTS)
3. Why we record data with its unit? (15pts)

Note: **Satisfactory rating >17.5 points Unsatisfactory - below 17.5 points**

Answer Sheet

Score = ____________

Rating: ______________

Information Sheet-6	Recognizing obvious errors and taking appropriate corrective action.

6.0. Recognizing obvious errors and taking appropriate corrective action.

There are two types of error:

1. Sampling error
2. Non-sampling error.

1. Non-sampling errors include listing **errors** and omission, response and measurement **errors**, **errors** of coding and data entry.

2. **Sampling error** refers to **errors** that are attributable to the fact that the estimates are being made from the sample rather than testing the entire universe.

Taking appropriate corrective action

- First, recognizing obvious errors you made during soil erosion site assessment and measurement and
- second, taking appropriate corrective action to the collected data before running analysis and making interpretation and even if possible repeat the assessment and measurement process.

Name: ___________________________ Date: ________________

- **Short Answer Questions**

Self-Check -6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What mean by sampling error? (5pts)
2. Write the types of errors that may face you in data collection? (5pts)

Note: **Satisfactory rating >5 points** **Unsatisfactory - below 5 points**

Answer Sheet

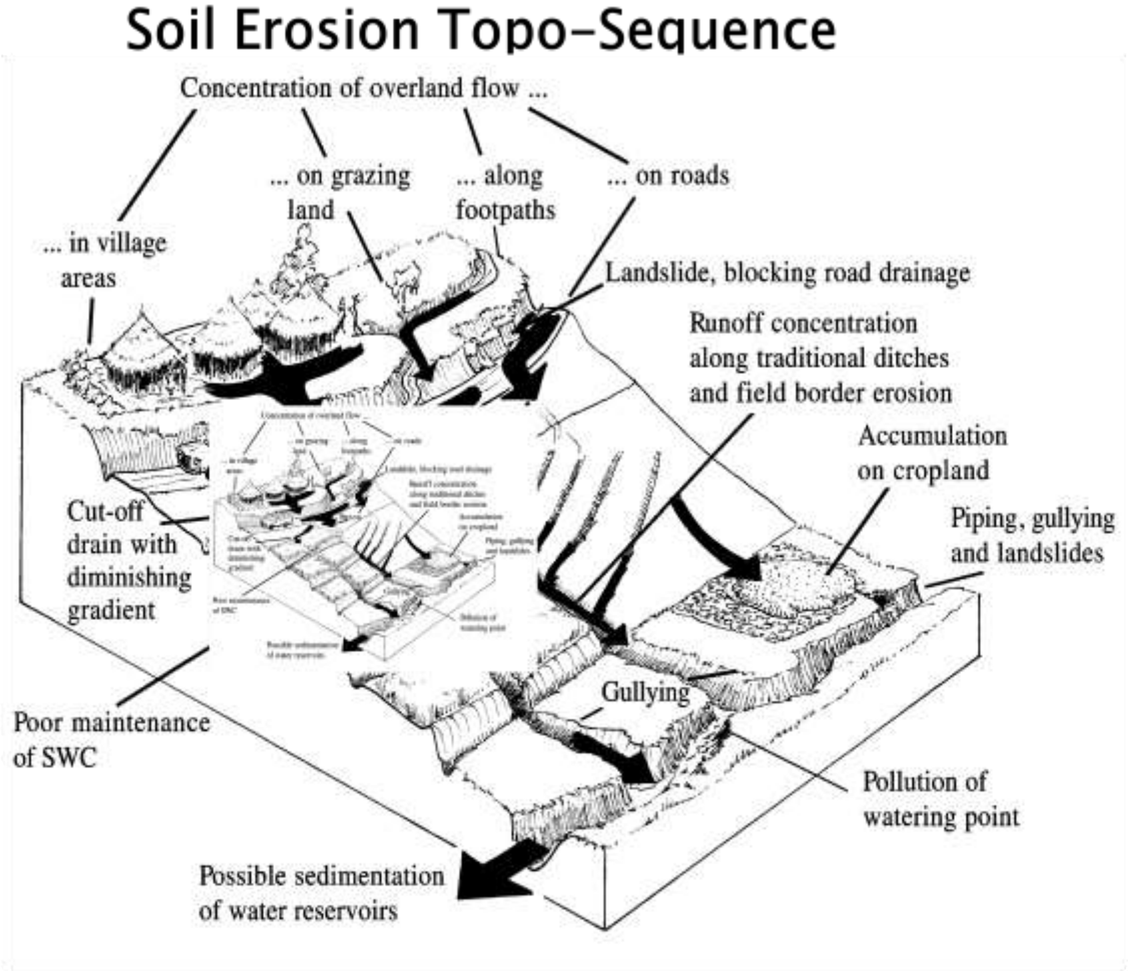
Score = ____________

Rating: ______________

Information Sheet-7	Identifying erosion Hot Spot Areas

7. Identifying erosion Hot Spot Areas

7.0. Introduction



Graph: K. Herweg

The presence of soil erosion in arable, forest and pasturelands is a prime indicator of soil degradation by water or by wind; often caused by a reduction in protective vegetation cover. It may reflect imbalance in the co-achievement of productive capacity and ecologically sustainable land management, i.e. intensification for increased production without adequate means to restore land resources and ecological functions. Soil erosion through topsoil loss is an indicator and cause of reduced land fertility, and hence potential productivity. It may also hinder access to land for crop/forest production. Moreover, the transported sediments and nutrients may cause problems downstream in terms of sediment deposits and reduced water quality. Despite the recognised importance of controlling and reversing soil erosion through soil and water conservation practices, there are few attempts to systematically observe and measure soil erosion as part of an integrated assessment of degradation and management (soil, vegetation, water and ecosystems) as this learning guide tries to do.

For the most part, the methods presented here are designed to be used in the field, during the assessment by the multidisciplinary technical team, and in the presence of land users - crop, pasture, forest - and, if possible, representatives of local government. This will aid interpretation of the observed erosion features and their impacts, for example, in regard to recent management, weather patterns and policy and technical interventions, if any.

Soil erosion is a commonly used indicator of negative land quality or condition as it is more visible than some other types of degradation such as nutrient mining or salinization. The immediate causes of soil erosion are wind and water as energy sources that translocate soil particles but unsuitable land use and management practices greatly exacerbate the problem (indirect causes), particularly on land prone to runoff and exposed to strong winds and soil movement (e.g. steeper slopes, loose or bare soil, inappropriate cultivation, etc.).

- **Erosion by water** is the detachment and transport of soil particles down slope through a number of processes, driven principally by the energy and the concentration of the water as it passes over the land.
- **Erosion by wind** is the detachment and transport of soil particles by wind action and commonly considers also the effect of the abrasive action of the particles as they are transported and of the soil deposits or sediments.

Measurement of wind and water erosion may include descriptions and measures of the erosion and deposition features but above all should focus on the impacts of the soil movement, *e.g.* the effects on the land potential through the loss of soil and nutrients and the effects of the transported and deposited particles, for example: silting of wetlands or floodplains, sandstorms, moving sand dunes, sediment load in rivers and streams). While erosion and hence loss of soil particles and nutrients will negatively impact on land productivity in the upper part of a catchment, it may provide fertile silts and nutrients downstream in the floodplains, i.e. having a positive impact on productivity.

What to measure

This section provides a set of simple, field usable indicators and measurements to observe, quantify and report on soil erosion at detailed assessment sites in the various land use systems and land use types (bare field, rainfed or irrigated cropland, pasture / rangelands, natural or planted forests, etc.). The specific tools need to be selected on the basis of the soil erosion features observed in the field: sheet erosion, rills, gullies/ravines, exposed rock, sediment deposits, sand dunes, etc.The field measurements are robust, relatively rapid (once the team members are familiar with the tools), cheap and replicable. The aim is to compare erosion status and trends under different sites (varied topography, exposure, etc.) and different land uses and management practices.

The methods aim to achieve clarity and uniformity in recording visible soil erosion features, in terms of three distinct but inter-related qualifiers and quantifiers:

- **Field observations** that describe soil erosion by wind or water using four descriptors of the erosion feature: type, state, extent and severity.
- **A field scoring method**, based on the descriptors in the field observations, to provide a more quantified basis for inter-site comparisons.
- **Field measurements** of specified dimensions of erosion features to provide quantification of rates and quantity of soil loss in a study area

These **3 methods** of erosion site assessment and measurement draw for soil degradation Assessment.

The information gathered on soil erosion can also be related to the community map and other land use and topographic maps of the study area to understand wider implications of soil erosion in the landscape. Through discussions with land users and informants the assessment team should try to estimate the main effects of the erosion and sedimentation processes on productivity and other ecosystem services, on-site and off-site, including damage to infrastructure and effects on human welfare (e.g. sandstorms).

The outputs of the soil erosion assessment could include:

A. an overview of the major erosion features (type, state, extent and severity) affecting different land use types and land use systems in a selected study area and, to the extent possible, an indication of their potential impacts on- and off- site (productive land area lost, reduced productivity etc.).
B. identification and understanding of the main direct and indirect causes of erosion in the study area through observations of local causative factors and their interactions and cumulative effects:

  - rainfall amount and intensity,

  - slope of land,

  - soil type (sands and silts being more erosion prone than clays and loams;

degree of soil cover (litter, crop, tree, residues) as related to land use, time of the year (bare fields post harvest or after land preparation), crop/ pasture/forest age and management practices (young, emerging crops, and young or well-thinned forest have less cover to protect the soil), extent of land clearing, etc.

C. the planning and design of soil and water conservation measures and land management practices for:
   - the affected sites to prevent or mitigate the main causes of erosion identified in the study area (direct and indirect) and, where feasible, to repair the erosion features and restore productivity or
   - new areas being opened up to production or undergoing land use changes, to ensure minimal erosion problems from the intervention (e.g. biofuel production, conversion of marginal lands to forest land, pasture or cropping, conversion of agro-pastoral areas to intensive cropping or ranching).

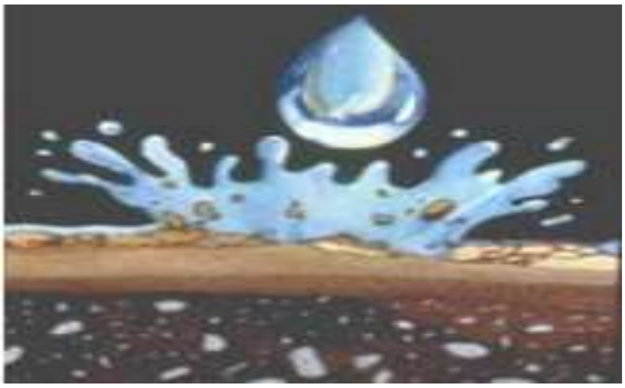
D. a baseline for subsequent monitoring of the status of erosion features by repeating the given observations and measurements on a specified time period, for a given area i.e. to monitor continued degradation in a "non-intervention" scenario (control) compared to an area with interventions that lead to reduced erosion, prevention of erosion, or restoration of eroded lands.

7.1. Erosion Hot Spot Areas

Those parts of an area that are seriously affected are called **"hot spots".** Visible erosion features, such as rills, gullies & concentrated accumulations, often indicate **hot spots.**

Types of water erosion

- **Splash or raindrop erosion**: Raindrops impacting the soil surface disperse and splash the soil, displacing particles from their original position. Splash erosion is caused by the bombardment of soil surface by impacting raindrops. Splash erosion occurs when a raindrop hits the ground and detaches soil particles from their original aggregates with its kinetic energy. On level surface, these detached particles are grouped in a symmetric circular fashion around the point where the drop has its impact. On a slope more soil material move in the downhill direction, which is the beginning of the actual process of soil transport. Other important impact of raindrop is, that the detached particles lead to sealing of the soil surface (ie.colloidal materials which tend to plug soil) and hence to lower infiltration and increased surface runoff.



- **Sheet erosion:** if a rainfall exceeds the infiltration capacity of the soil, water starts flowing in thin, more or less even or discontinuous film over the ground (surface runoff.) Those soil particles, which are detached by splash, can be transported now. The runoff itself can also scour the soil but much lower than that of splash.

- **Rill erosion:** down slope, the flow will be concentrated into small depression, which is called rills. Having more mass and velocity than sheet flow erosivity increases and the rills are cut dipper in the soil.

➢ Even further downhill rills can grow together forming **gullies** which are bigger, deeper and wider than rills developing into gullies. (Note.) The distinction between splash and sheet erosion is theoretical and that both processes are working together.

Gully formation

– Gully formation can result from overland flow and from seepage flow and surface collapse from piping, road building etc.
– Gully erosion is proceeded by complex of processes where by the removal of soil is characterized by large incised channels in the landscape. The gully formation process may include:
    - Scour by concentrated runoff,
    - Dispersion in subsoil around seepage channels, followed by tunnel formation;
    - Collapse of overlaying soil into the tunnel and surface gully flow.
    - Then Head ward erosion
    - gully widening and deepening

Note: The water erosion includes sheet and rill erosion, gully erosion, tunneling and landslides. Sheet and rill erosion is the most important erosion form in all zones and altitudinal belts of the Ethiopian highlands

➢ **Tunnel Erosion**

Tunnel erosion, also known as pipe erosion, is the underground soil erosion and is common in arid and semiarid lands. Soils with highly erodible and sodic B horizons but stable A horizons are prone to tunnel erosion. Runoff in channels, natural cracks, and animal burrows initiates tunnels by infiltrating into and moving thorough dispersible subsoil layers. The surface of tunnel erosion-affected soils is often stabilized by roots (e.g., grass) intermixed with soil while the subsoil is relatively loose and easily erodible. Presence of water seepage, lateral flow, and interflow is a sign of tunnel erosion. The tunnels or cavities expand to the point where they no longer support the surface weight and collapse forming potholes and gullies. Tunnel erosion changes the geomorphic and hydrologic characteristics of the affected areas.

Reclamation procedures include deep ripping, contouring, re-vegetation with proper fertilization and liming, repacking and consolidation of soil surface, diversion of concentrated runoff, and reduction of runoff ponding. Re-vegetation must include trees and deep rooted grass species to increase water absorption.

- **Stream bank Erosion**

It refers to the collapse of banks along streams, creeks, and rivers due to the erosive power of runoff from uplands fields. Pedestals with fresh vertical cuts along streams are the result of stream bank erosion. Intensive cultivation, grazing, and traffic along streams, and absence of riparian buffers and grass filter strips accelerate stream bank erosion. Planting grasses (e.g., native and tall grass species) and trees, establishing engineering structures (e.g., tiles, gabions), mulching stream borders with rocks and woody materials, geo-textile fencing, and intercepting/diverting runoff are measures to control stream bank erosion.

Name: ________________________ Date: _______________

- **Short Answer Questions**

Self-Check -7	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Define **erosion Hot Spot Areas**. (3points)
2. List the types of water erosion. (2points)
3. Mention at least 3 outputs of the soil erosion assessment. (10points)

Note: **Satisfactory rating >7.5 points** **Unsatisfactory - below 7.5 points**

Answer Sheet

Score = ___________

Rating: ____________

Information Sheet-8	Area delineation

8.0. Area delineation

Delineating the area to be assessed and measured for soil erosion in consultation with the community.

Procedures

- ✓ Demarcate bounds of the area to be assessed & measured to indicate the physical boundaries of erosion damage area (hotspot area).
- ✓ **Delineation can be conducted**
  - o **Topographic map sheets**:- the technique is slow and does not provide very accurate information
  - o Better delineation can be done with **aerial photographs** (scale larger than 1:15 000) using stereoscopes
  - o **Filed mapping using GPS**
  - o **Digital Elevation models** and use of **GIS softwares** to delimit the watershed boundary.

The **conventional method** of delineation of area to be assessed & measured requires a topographic map.

- o To start the divide
  - ▪ We should start from the location of the chosen stream cross- section,
  - ▪ Then we draw a line away from the left bank or the right bank always maintaining an angle of 90° to the contour lines.
  - ▪ We continue the line until it is generally above the headwaters of the stream network.
  - ▪ Finally we return to the starting point and we trace the divide from the other bank,
  - ▪ Eventually connecting it with the first line

Fig: conventional method of delineation of area to be assessed & measured using a topographic map.

Before and during delineation of the area to be assessed & measured the following activities should be conducted:

Public Education

- ✓ A series of public awareness campaigns were organized with the officials to educate all the key stakeholders; chiefs, elders, rural development committee, etc.

The campaign will be organized to meet the following specific objectives:

- ✓ To educate the people that, the boundary of area to be assessed & measured needs to be clearly defined in the field for easy identification;
- ✓ To provide credible documents, including co-ordinates, with a detailed description of the boundary, for which the chiefs' will give their firm undertaking to accept its location;
- ✓ To gain appreciation for the benefits that the existence of clear boundaries would bring to the present and future generations and the need to maintain them;
- ✓ To convince the concerned population by word and proof that, it is futile to shift or destroy boundary markers of any kind or quality;
- ✓ Materials such as Site layouts, photomaps and every information that were necessary for the education will be obtained from relevant agencies such as the district offices and recognized bodies including the chiefs, elders and caretakers.

Field work

In the execution of the project, laborers will be hired from the adjoining communities as a gesture. This is to give employment to the communities so as to get them to develop interest in the project, and also to make the knowledge of the existence of the boundary pillars known to them.

a. **Reconnaissance survey** of the boundaries will be undertaken with the approval of the chiefs, elders and opinion leaders. This is one of the most important aspects of any survey and must always be undertaken before any angles or lengths are measured. With the assistance of the chiefs' representatives, elders and opinion leaders from interested parties one should arrived at a common boundary.
   - o The process is run to meet the acceptance of the paramount chiefs
   - o The two types of boundary identified during the reconnaissance survey are:
     - ✓ Imaginary line herein referred to as Defined boundary and
     - ✓ Natural feature such as river, stream, and Forest Edge.

   The boundaries are identified by the representatives from the adjoining paramount stools. Once the adjoining paramount stools have agreed upon the common boundary, a survey station was selected and the preparatory demarcation work begun. The reconnaissance survey of the boundary which was carried out involved putting in pegs at some selected stations at intervals ranging between 0-1km based on the nature of the boundary as indicated by the adjoining paramount stools. The surveying team made it a point to be always on the field with the Adjoining Paramount Stools.

b. **Field Observations:** two teams, comprising six and eight people will be created. Each team is made up of a representative of the chiefs from the proposed area owning the adjoining lands. The first team will be trained by a technical team to use Geographic Positioning System (GPS) equipment and surveying techniques. The second team will be used as an advance party in clearing the boundary

Name: ______________________________ Date: __________________

- **Short Answer Questions**

Self-Check -8	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Describe the **conventional method** of delineation of area to be assessed & measured. (3points)

2. What are the two types of boundary identified during the reconnaissance survey (2points)

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet-9	Identifying the state, extent and severity of erosion in a delineated area

9.0. Identifying the state, extent and severity of erosion in a delineated area

9.1. Field observations of erosion– type, state, extent and severity

How to select observation sites

The following process is foreseen to identify areas for the required erosion observations and measurements in order to understand cause, type, extent, severity, etc. and, in turn, enable to propose and plan improved land management or rehabilitation actions:

1) conduct if possible a "desktop" study of the intended study areas using any available maps and remote sensing images ((topographic and cadastral maps, Google Earth®, air photos, satellite imagery, digital elevation models -DEM, soil/ geology maps, etc.) and previous studies and reports to elucidate any major erosion features, their place in the landscape (land unit, slope) and their association with recognizable land uses in the area, etc.

2) seek out representative sites in the various land use types (LUT) in the area under consideration (e.g. cropping land, forest, pasture or fodder producing land, orchard, vegetable production, etc); and

3) be led by locals who live or work in the area (i.e. land users, farmers, herders, forestry workers, state farm managers, etc. as a follow up to the Community Focus Group Discussion) to those areas that they believe are most degraded, or on which they are most dependent (e.g. for food production, forest replanting, winter pasture re-growth, etc.) or previously eroded areas that have been effectively restored through effective management measures.

It is important to collect information on timescales of relevance to soil formation and erosion processes in order to understand the impact of the different erosion types/ processes and particularly the capacity to repair or diminish their impact.

- Sheet wash may be an annual event or more frequent occurrence;
- rills may form after a series of heavy rainfall events on ploughed land;
- gullies and ravines are most commonly the effect of several seasons or years of water concentration that result in deep incisions;
- landslides and mudflows are often rare events but these more serious erosion types are more likely to occur on certain soil types and sedimentary materials.

Repair strategies, therefore must be prepared and designed for relevant timescales. For example, rills may be readily ploughed out and can be prevented by appropriate vegetation cover and soil and water management practices but gullies will require years to reclaim by installing physical barriers (e.g. gabions and check dams) and through vegetation enrichment with suitable trees, shrubs and grasses.

The “secondary data” from maps, images and reports can be validated and updated in the study area using the observations and measurements outlined below. This on-site ground truthing should be backed up by interviews/ discussions with land users/other knowledgeable persons to cross-reference the observed types, extent and severity of erosion features with recent and historic land practices and weather observations; rainfall periodicity and intensities for water erosion and wind intensity for wind erosion features. This should provide good understanding of the processes, timescales and causes that have resulted in the currently observed erosion features.

Describing soil erosion on the community sketch map – initial observation Step1

As described earlier, the community sketch map that is prepared with land users as part of the community focus group discussion should highlight major visible features in the area to be evaluated, in terms of terrain, land use, soils / geology, water resources, their relative proportion of the total land area; degradation features, including soil erosion (sheet erosion, rills, gullies) and causes (overgrazing, intensive cropping, wetland encroachment, etc.) and existing conservation / sustainable land management measures and their effects (negative and positive) on land productivity. If the sketch map has not clearly indicated erosion features or if more specific information is required for a selected study area, a few community members can be asked to reassess these issues and highlight if and where erosion by water or wind is a significant factor and the main causes.

Once the main erosion features are drawn on the “**community sketch map**”, each soil erosion area can be qualified in terms of four descriptors: **type, state, extent and severity.** Each of these is defined below to the extent possible (though wider application of the tools and feedback is envisaged to lead to better definition of the classes and terms).

On the community sketch map (Figure X), which reflects the landscape view showed on Photo below, discussion with locals led to delineation and description of the main erosion features, other relevant information (vegetation, main land uses, slopes, villages, roads, streams, etc) and location (latitude, longitude, elevation and north point) of the observation point using a GPS unit.

Photo x: Example of a “distant view” of an area of land to be investigated for erosion features (just north of Dushanbe, Tajikistan)

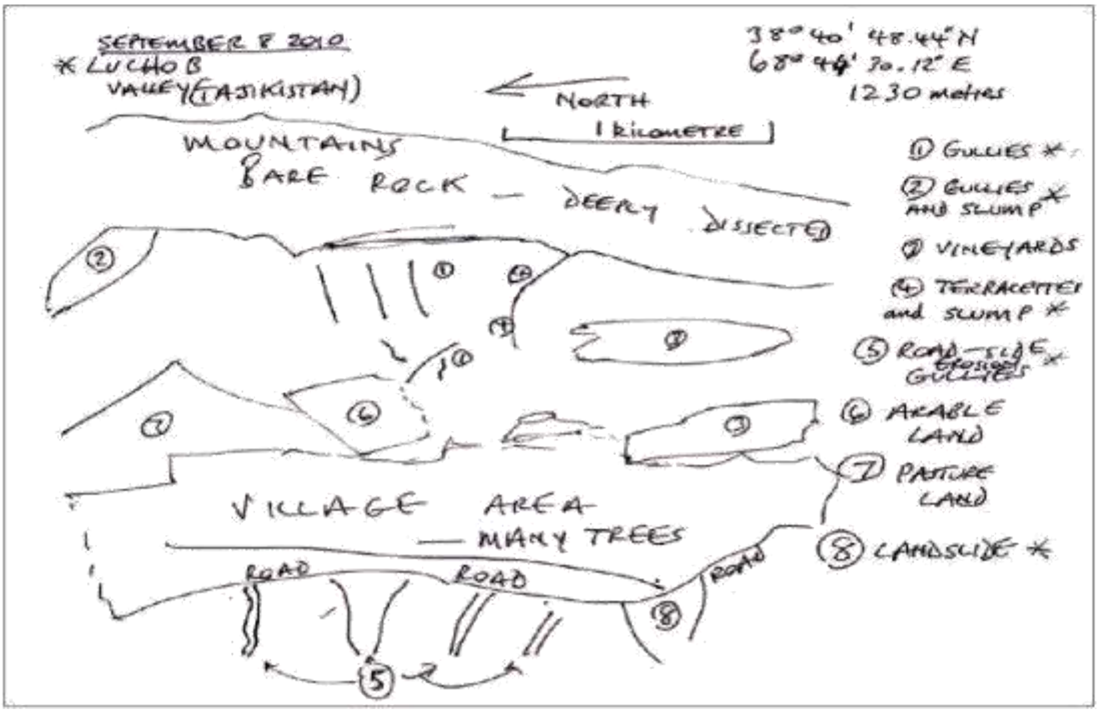


Figure x “Community map” sketched on-site, overlooking the area in Photo x

Erosion Type Step, 2: Erosion types are specified progressing from those that are the least evident to those that are most evident i.e. from (rain) splash and sheet wash, to rills, to gullies, to ravines and landslides and other mass movements. It is important to specify that “type”, as used in this guide, describes the physical nature of an erosion feature and indicates the boundaries that determine when one erosion type becomes another (e.g. When does a rill become a gully?). This will ensure more commonality of erosion type definition, hence replicability between users and geographic areas.

TABLE X: Types of soil erosion-definitions, indicators and boundaries

Type of soil erosion & Score	Code	Definition	Indicators (How to recognize
Splash (1)	SP	Raindrop impact displaces soil particles vertically and downslope	Soil particles on lower parts of plants and/or a compacted (or dispersed) soil surface crust
Sheet wash/ Sheet (2)	S	Erosion of the top layer /sheet of the soil as differentiated from linear erosion (rill, gully, ravine)	Gravel/stones protruding from soil surface; root exposure; loss of darker topsoil horizon; subsoil exposure
Rill (2)	R	Irregular, downslope, linear channels, shallow (up to 0.3 m deep and wide)	Shallow, commonly long channels running downslope
Gully (4)	G	Irregular, V-shaped, steep-sided, linear channel formed in loose material, deep (0.3 – 2.0 m deep) formed by water erosion	Deep, pronounced channels
Ravine (4)	A	As in the definition for “gully” but very deep and wide (> 2m deep and wide)	Very deep and wide, pronounced channels
Landslide (4)	L	Sudden downslope movement of a concentrated mass of soil and rock, mainly under influence of gravity, triggered by water saturation or earthquakes (sometimes termed mass movement)	Almost vertical sides; rounded head (gully has narrow or sharp head)
Slumping (2)	SL	Slow, irregular, downward progression or of a thin (< 1m) layer of soil, due to water saturation, but possibly in combination with freezing-thawing	Rounded scar; irregular, uneven, downslope surface
Rotational slumping (3)	RS	A form of mass movement where rock and soil move downwards along a concave face. The rock or soil rotates backwards as it moves in a rotational slip. They always have a concave sliding plane and multiple scars (while slides have relatively straight shear	Series of irregular scars and wide cracks

Type of soil erosion & Score	Code	Definition	Indicators (How to recognize
Tunnel (3)	TU	Sometimes hidden, sub-surface holes and tunnels that can break-through to form surface gullies	Often hidden but may break through the soil surface as potholes and gullies
Roadside erosion (2 or 3)	RE	Erosion (mostly gullies) caused by concentrated water flow over the impervious road surface; cutting back into the road and causing damage to roads or erosion downslope. Score depends on gully or tunnel intensity	Erosion features below the point where water runs off the road
Stream bank erosion (2 or 3)	SE	Undercutting of streambank by running water. Score depends on gully or tunnel intensity	Fresh cuts in banks; exposed tree roots; collapsed structures
Wind erosion (Variable)	WE	Detachment and transport of soil particles by wind. Score difficult as the features observed are almost always "effects" of wind erosion: dunes, scouring of vegetation, posts, etc	Scouring on windward side or deposits at leeward side of obstacles. Sand dunes (stable or moving)

Erosion State: STEP 3: For each erosion type, one of four classes below is used to describe the level of activity:

(i) **active– erosion feature** is increasing in size or extent;

(ii) **Partly stabilized**– between active and stable;

(iii) **stable**– it is either an historic (relic) feature from past climate and land use, or a more recent erosion feature for which recent anthropogenic interventions (e.g. contour bunds or change in land management) have slowed or stopped the erosion process;

(iv)**Decreasing**– where recent anthropogenic interventions have begun to reverse the erosion process i.e. rock, sediment and vegetation filling of gullies, leading to stabilization and increased soil organic matter and plant growth

Erosion Extent, STEP4: Estimation is made of the spatial extent of each erosion type. The intent is less to measure actual areas, in hectares or square metres (though some may choose to do this) and more to provide a good estimate of the area under consideration that is affected by the erosion types recorded. As such, it is considered that extent (used in this way) implies the proportion of a stated area that is affected by the recorded erosion type. The five terms used to define extent are:

- negligible (0-2% of the area under study)
- localized (3-15% of the area)
- moderate (16-30% of the area)
- widespread (typically 31-50% of the area)

Note that the class "**widespread**" is intentionally maximized at 50% of the area under consideration. This reflects that each erosion type is classed individually, so it is possible (in one area) that there is, for example, sheet wash, terracettes and gullies, with localized

(10%), widespread (50%) and moderate extent (20%) respectively – showing that 80% of the area is eroded but by these three different erosion types.

There are various ways to record extent.

1. The areas affected by the specified erosion types can be drawn on a "community map" as in Figure 2.
2. Where available, the erosion features can be either located or drawn onto available maps (topographic, soil, etc), aerial photos, orthophotos, satellite images, Google Earth® images, etc.
3. If required for detailed study, a theodolite or dumpy level can be used for accurate mapping and geo-placement of recorded erosion features; though this requires a high level skill set with related expense and time considerations.

Erosion Severity, STEP 5: Severity in terms of soil erosion is often defined as the "degree of the effect of the (specified) erosion type". A more pragmatic definition is the rate or "average amount of soil that is moved by water or wind", expressed as units of mass/ area/time (Leys, 2010). Based on this definition, a field usable estimate of erosion severity is made using five classes, recognizing that the mass of soil loss will rarely be known (particularly with historic erosion features) (Leys, 2010). Over time with wider usage, these classes may be better defined and perhaps oriented to specific geographic areas.

- **low–** minimal erosion types evident; most commonly splash or rill erosion
- **moderate**– evidence of erosion but eroded sediment remains within the area under study
- **high**– evidence that sediment is being exported off site
- **severe**– sediment is exported off site and surface lowering < 0.1 m
- **extreme**– sediment exported off site and surface lowering > 0.1 m.

An important consideration is that certain erosion types, by their nature, will never be described as of "low" or "moderate" severity. The most obvious examples (from Table 26) are gully, ravine, landslide, tunnelling – all of which immediately fall into the severe and extreme classes as the erosion feature is >0.1 m deep. Nonetheless, it is important to bear in mind that insidious sheet or rill erosion, that is continuous throughout rainy seasons and year by year over large areas, may be equally or more serious to widely spaced gully erosion in terms of total soil loss and impacts, especially in shallow soils.

9.2. Field scoring method for soil erosion features

A simple scoring system is presented for the erosion types present and recorded in a study area. This scoring system has been substantially adapted from a first version developed and tested by the LADA team in Tunisia as part of an earlier version of the LADA-Local manual (FAO 2010). As such the scoring aims to provide a quantitative judgment of erosion and to allocate an erosion class. The aim is to provide a basis for inter-comparisons of erosion status and trends that may vary between land uses, management practices, topography, etc. and over time.

The scoring system is based on the classifications of type, state, extent and severity as defined above. Each of the classes in these four sets of descriptors will be allocated a score and the sum of the scores (for any one area, however defined) will allow the allocation of an erosion class (Table Z).

Important is that this scoring system is taken and used for what it is: a simple methodology of better quantifying erosion degradation for a given area. There are several, recognized problems with the scoring system, some of which will be covered here, so users should be aware of these in interpreting the cumulative scores obtained and the resultant allocation of an erosion class :

- The allocation of the score classes to the erosion types (Table Y) is somewhat arbitrary. The concept is that either end of the scale (1 and 4) is readily ascribed. In most circumstances splash erosion is a minor feature (score = 1), whereas gully, ravine, landslide, tunnel erosion are considered very serious landscape features as they cannot be readily repaired (score = 4). Between the two extremes, the current score allocations are based on the author's experience and may change with time and wider use of this system

- As discussed above, certain erosion types, by their very nature, will never be describable as of "low" or "moderate" severity. The most obvious examples (from Table 26) are gully, ravine, landslide and tunnel – all of which fall into the severe and extreme classes, as the erosion features are >0.1 m deep. So, not only do these erosion types score “4” for type, they also immediately score “3” or “4” for severity (rate).

- If several types of erosion are found in the area under investigation, the current system scores each type separately, and then sums the individual scores to give a composite score. The basis for this summation approach is both that each of the types of land degradation is inter-related, and their presence in one area has an additive, negative effect on land productivity. This composite scoring system may change in the future with time and wider use of this system.

Table Z gives the final erosion class for any one erosion type in a study area, arrived at by summing the score value of each of the four categories of type, state, extent and severity. Where more than one erosion type exists in

Table Y: **Scores for the individual descriptors of a) state, b) extent and c) severity of the soil erosion types**

State	score	Extent	score	Severity	score
				extreme	**4**
active	**3**	widespread	**3**	severe	**3**
partly stabilised	**2**	moderate	**2**	high	**3**
stable	**1**	localised	**1**	moderate	**2**
decreasing	**0**	negligible	**0**	low	**1**

Table Z: **Erosion classes**

Erosion class :	negligible or decreasing	low /weak	moderate	severe	very severe
Score :	0-1	2-5	7-10	10-12	13 +

One area, the class values of Table Z are added together for each erosion type – to give a composite score. It is evident that in situations where two or more erosion types are present in an area, the erosion class will almost always be «severe » (i.e. a score of >13).

The erosion classes are derived by adding -up the individual scores for each of type, state, extent and severity of Tables x and Y).

Worked examples of scoring erosion features

Five examples will be given, based on the descriptors mentioned above, the individual scores in Table Y and the classes of the summed scores in Table Z.

- ✓ Example 1 presents the scores for the incidence of gully erosion (score 4) that is active (score 3), widespread in extent (score 3) with extreme severity as the soil loss in eroding areas is over 1 m deep (score 4). The total (summed) score = 14. So, the overall erosion class is very severe.
- ✓ Example 2 is one of rill erosion (score 2) that is partly stabilized (score 2), localized in extent (score 1) with moderate severity (score 2). The total (summed) score = 7.So, the overall erosion class is moderate.
- ✓ Example 3 is one of ravine erosion (score 4) that is decreasing in state (score 0), moderate in extent (score 2) with severe severity (score 3). The total (summed) score = 9.So, the overall erosion class is moderate.
- ✓ Example 4 scores an area that has two erosion types: (i) splash (score 1) that is active (score 3) localized in extent (score 1) with low severity (score 1); Total score = 6; and (ii) land slide (score 4) that is stable (score 1), localised in extent (score 1) with extreme severity (score 4); total = 10; The total (summed) score = 16. So, the overall erosion class is very severe.
- ✓ Example 5 scores an area that has three erosion types: (i) sheet wash(score 2) that is active (score 3) localized in extent (score 1) with moderate severity (score 2); Total score = 8; (ii) terracettes (score 2) that are active (score 3), localised in extent (score 1) with moderate severity (score 2); total = 8; and gullies(4) that are partly stabilized (2), localized (1) and extreme (4); total = 11. The total (summed) score = 27.So, the overall erosion class is very severe.

Note that, though the between-examples scoring gives some basis for comparisons of the impact of the erosion features, it is complex to definitively compare scores between such physically different types of erosion, as rills and gullies. A whole landscape may be covered in rills, and the resulting soil loss may be very large with important implications on soil depth and fertility, but a few large ravines in the same unit area would give quite different management problems (e.g. access for timber removal, thinning of stands and the cutting of roads that impair general access) and will require major, expensive interventions to repair and conserve.

Additionally, although generally scored low the cumulative effects of sheet and rill erosion should not be underestimated, particularly as they strip away the all important surface soil layers that are generally richer in organic matter and nutrients from plant residues, litter accumulation and vegetative growth.

Field measurements of erosion features to quantify rates and amount of soil loss as shown in section of 9.3 this Learning guide. This section provides field techniques to measure soil erosion features with the aim of gaining more quantified data on rates of soil erosion. Such quantification would be valuable if soil erosion is identified as being a major degradation process in the study area and to understand the implications in terms of rate and quantity of soil loss, effects on productivity and off site implications in terms of nutrient and sediment load of water resources, siltation of valley bottoms/floodplains and wetlands, etc. However, it is an optional tool for the local level assessment according to the importance of erosion and the time and budget of the assessment team.

Of the 13 erosion types in Table X, only 3 erosion types - rill, gully and ravine - lend themselves to a direct, rapid and simple method of field determination of amount soil loss (9.3). Rates and quantities of soil loss from the other erosion types listed in Table X can be estimated indirectly by measuring the effects of erosion.

9.3 Measurements of soil erosion (direct and indirect)

A. Direct measurement of erosion

1. Measurement of rill erosion

The estimate of the soil loss through rill erosion is based on measuring the space volume from which the soil has been eroded, to arrive at the mass of soil now missing from the rill. The measurement of soil loss from rills assumes that the depression forms a regular geometric shape that is estimated to be triangular, semi-circular or rectangular in cross-sections, as determined by field observation.

To calculate the quantity of soil lost, measurement is made of the depth, width and length of the rill. It is important to collect a number of measurements of both the width and depth of any one rill and of many rills in the study area to get an average cross-sectional area.

The average catchment area for the rills in any one area must also be estimated, i.e. the area of land that contributes material to the rill. If it is known how long it has taken for the rill to form (if, for example the land was last cultivated two months or two years ago, or has only recently been cleared of forest) then an annual rate of soil loss can be estimated.

Note, that the combination of the averaging of many field measurements, and the estimation of the cross-sectional shape of the rills (in any one area) to be predominantly triangular, semicircular or rectangular causes the soil loss calculation to be only an estimate of the actual soil loss.

Method: Using the average measurements of width and depth, calculate the average cross-sectional area of the rill, using the formula for the appropriate cross-section:

- ☞ Triangle = ½ horizontal width x depth
- ☞ Semi-circle (1.57 x width x depth)
- ☞ Rectangle (width x depth).

Worked example:

a. For an area where the average dimensions of many measured rills is:

Width = 0.12 m, depth = 0.042 m,

b. The average cross-sectional area of the rills in a study area, assuming a triangular cross-section is:

½ * 0.12 * 0.042 = 0.00252 m2

c. Assuming the average rill length in the study area was 2.5 m, the volume of soil lost from an average rill is:

0.00252 * 2.5 m = 0.0063 m3

d. The volume of soil lost, from the estimated catchment area (here 12 m2) is converted to a volume per square metre :

0.0063 / 12 = 0.000525 m3 / m2

e. The volume per square metre is converted to tonnes per hectare, using an estimated soil bulk density value of 1.3 t/ m3
0.000525 * 1.3 * 10,000 = 6.9 t/ha

Hence in this worked example, 6.9 tonnes / ha have been lost in rill erosion, alone.

2. Measurement of gully and ravine erosion

Gullies and ravines have the same, general shape of a flat floor and sloping sides, hence the bottom of these features (the floor) is less wide than the top (parallel to the soil surface). Such a shape is best estimated as that of a trapezium[14] (Fig. M). Calculation of soil loss, therefore, is generally similar to rills, except with a different cross-sectional shape. As with rills, the measurement of the dimensions of the gullies and ravines gives an estimate of the amount of soil displaced from the area

To calculate the quantity of soil lost from a gully or ravine, measurement is made of the depth, width at lip (the top of the feature) and base, as well as the length of the feature. Equipment used to collect these measurements will vary between operators, but could be a laser-based rangefinder (expensive) for large gullies and ravines, or a 30 to 100 m tape for smaller features. It is important to collect a number of measurements of both the width and depth along any one feature and also of many gullies in the study area to achieve a representative sample. An annual rate of soil loss from gullies and ravines is more feasible than from rills, as the former are more or less permanent features of the landscape.

Information on soil loss over time can be achieved in various ways, including repeated visits (particularly if permanent monitoring stakes can be installed as reference points), and time series of aerial photographs and/or satellite imagery. Even with such methods over a known time period, the annual rate of soil loss is “at best’ an estimate due to such factors as:

(i) different rates of soil loss will occur as the gully/ravine deepens and different layers of soil are exposed;

(ii) rainfall totals and periodicity will vary annually, particularly the incidence of rain with vegetative state around the gully or ravine;

(iii) change in forest density with time (both growth and thinning/clearing phases) will influence erosion rates;

(iv) tunneling may also occur on the sides of the gullies and ravines, greatly exacerbating soil loss in some years.

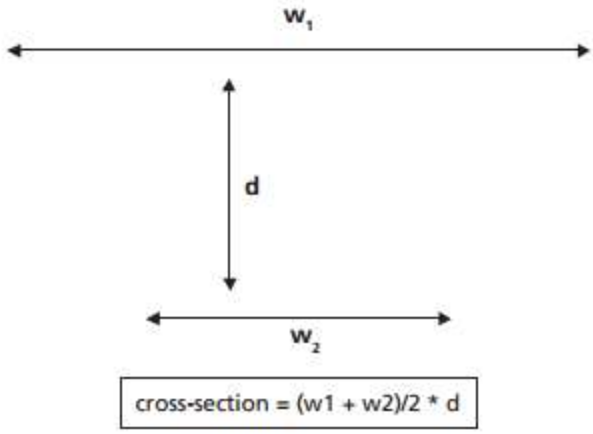


FIGURE **Calculation of the cross-section of the trapezoid shape of gullies/ ravines**

Fig M:Gully dimension measurement

Method: Using the average measurements of width at lip and width at base, and depth, calculate the average cross-sectional area of the gully or ravine (considering the cross-sectional shape is trapezoid; Fig. M), using the formula:

(width at lip (m) + width at base (m) / 2) * depth (m)

Worked example:

For an area where the average dimensions of many measured gullies or ravines is :width at lip = 10.2 m, width at base = 4.8 m, depth = 2.0

a. The average cross-sectional area of the rills in a study area, assuming a trapezoidal cross-section (Figure 16) is :((10.2 + 4.8)/2) * 2.0 = 15 m2

b. Assuming the average gully or ravine length in the study area is 200 m, the volume of soil lost from an average gully or ravine is:15 * 200 m = 3000 m3

c. The volume of soil lost, from the estimated catchment area (here 1 km2) is converted to a volume per square meter :

3000 / 1,000,000 = 0.003 m3 / m2

d. The volume per square meter is converted to tonnes per hectare, using an estimated soil bulk density value of 1.3 t/ m3:

0.003 * 1.3 * 10,000 = 39 t/ha

Hence, in this worked example, 39 tonnes / ha have been lost in gully or ravine erosion.

B. Indirect measurements of erosion

Indirect measurements of soil erosion rely on features observed and measured in the field that demonstrate the « **effects** » of soil erosion. In total, seven erosion proxies will be presented here: plant/tree root exposure; fence post and similar structures' base exposure; tree mounds; pedestals; solution notches and rock colouration; armour layer; and soil build up against a barrier. The erosion types that most commonly lead to these erosion effects are splash, sheet wash and wind erosion (Table X).

PHOTO 20 **Tree root exposure, Vietnam (source Stocking)**

PHOTO 21 **Tree root exposure by erosion (Library on soil erosion processes UNEP/FAO)**

PHOTO 22 **Exposed aerial roots of maize, Brazil**

With all but the last of these indicators (soil build up against a barrier), the general mode of measuring soil loss from erosion is to measure the current (eroded) soil level against the evident location of the original (or at least a recently previous) topsoil level. Particularly in terms of measuring soil loss against living objects such as trees or plants, if the planting date is known then an estimate of annual soil loss is possible. The same is also true if the date of installing fences, poles, walls, houses, etc. are known.

In measuring soil build up against a barrier the reverse is measured, i.e. the accumulation of eroded sediments behind a physical barrier such as a hedge or fence. The depth of this deposited soil is measured relative to the current top soil level. The amount of soil loss can only be estimated if the area contributing eroded material and the area of deposition can be determined.

3. Plant / tree root exposure

The removal of soil particles by water or wind can lead to the exposure of the roots of trees, and other plants as erosion lowers the overall soil level. Close inspection of the lower portion of the tree trunk or plant stem may reveal a mark indicating the level of the original soil surface.By measuring the vertical difference (with a ruler) between this mark and the present soil surface, an estimate can be made as to how much soil has been lost.(see Photos 20 and 21) In the case of lateral roots away from the tree trunk, the upper surface of the most exposed roots is usually taken as the former soil surface. For forests and perennial crops, the soil loss estimate would cover the period from when the crop/tree was planted. In areas of degraded natural vegetation (scrubby forest and bush land), it may not be so easy to relate the measured soil loss to a particular number of years. In the case of an annual crop an estimate of soil loss in one growing season can be estimated.

Care is needed as some roots give a deceptive impression of soil loss such as the aerial roots of maize plants (see Photo 22)

As with measurements of erosion features (above) several examples of exposed tree / plant roots need to be measured and averaged, to improve the site-representativeness of the measurements. Additionally, the data should also be cross-checked with other erosion indicators (as below) to determine, whether the estimated soil loss is realistic.There are several cautionary notes that with common sense will ensure greater validity of the data collected

- Differences in root exposure may reflect different erosion processes (e.g. rain-splash and sheet wash) occurring in the same field.
- Roots and stems may act as an obstacle to runoff and may cause channeling of erosive water flows, thus increasing the soil loss around the obstacle, or it may slow down the surface flow, allowing deposition to occur. Likewise roots and stems may trap and allow the accumulation of windblown material. Therefore extrapolated soil losses, calculated solely by reference to plant/tree root exposure, may be either over- or under-stated.
- Some plants have a tendency to lift themselves out of the ground as they grow, thereby giving a spurious impression of high soil loss. This effect is often indicated in

stony soils, especially where larger platy fragments occur. Look for evidence in the alignment of stones as tree growth may force a rearrangement of stones so that they become tilted, with the raised end nearest to the trunk.

- Tree roots may expand in diameter as the tree grows, so roots running parallel to the soil surface may rise to/above soil level, giving the impression of more erosion than actual.

Method: Using the average of the measurements of the height difference between the top of the exposed tree/ plant roots or stem and the current soil surface.

Worked example:

a. For an area where the average depth of soil loss is :5.88 mm

b. This drop in soil level is converted to tonnes per hectare, using an estimated soil bulk density value of 13 t/ha:

$$5.88 * 13 = 99.23 \text{ t/ha}$$

c. If the average age of the plants or tree where the soil level change was measured was 4 years, then the estimated annual soil loss is:

$$99.23 / 4 = 24.8 \text{ t/ha/yr}$$

Hence in this worked example, ~25 tonnes / ha year have been lost to soil erosion.

4. Fence post (and similar structures') base exposure.Similar to plant / tree exposure, the exposure of the bases of anthropogenic structures such as fence posts, house and bridge foundations, telegraph poles, etc. can provide indicators of soil loss, principally, again, from splash, sheet and wind erosion.

The measurement strategy depends on the object used for establishing the original ground level. For fence posts and poles this can be established by determining the height of the exposed part of the post/pole and/or the length buried into the ground. Often standard post/pole lengths are used in any one area. If not, it is necessary to determine a typical value by measuring the above ground length of posts in those sites that appear to have been least affected by soil erosion.

The distance between the new ground surface and the point on the post that would originally have been at ground level can be measured using a ruler. In some instances erosion may remove soil equivalent to the depth of the below ground portion of the post in which case, providing it is certain that the post was not broken and that no part remains below ground, a minimum rate of erosion can be estimated. In other cases, the post may be entirely free of the soil but held in position by taut wire and hence the full extent of erosion can be determined.

Cautionary notes with interpretation of these measurements include the following.

- The age of the structure (fence installation, house and bridge construction, etc.) is required to present data on an annual soil loss basis.
- Any of these anthropogenic structures can actively promote erosion or sedimentation and may act differently, depending on rainfall amounts, intensity and periodicity, as well as wind direction and strength in the case of wind erosion.
- It will be important to have close discussions with locals to better ascertain the weather modalities since the structure was put in place.

Method and calculations: as per the plant / tree root exposure example above.

5. Tree mound

In contrast to the above two indices, the use of tree mounds to provide measures of soil loss depends on the umbrella- and raindrop energy- absorbing properties of tree canopies. This often causes the soil under a tree canopy to be at a higher level than the soil in the surrounding area, as it has been protected from raindrop impact and subsequent splash and sheet erosion.

The difference in height between the soil surface under the tree and in the surrounding area provides an indicator of the amount of soil loss that has occurred during the life of the tree (tree age gained from forest records or by talking to locals). It is recommended that such measurements are recorded for a range of trees of different size and age in the study area as there is large variation in the capacity of the canopies of different species to protect the underlying soil, and some varieties may be leafless during the peak rainy season, for example. (see Photo 23).Cautionary notes with interpreting soil loss data, based on tree mounds include the following.

- Mounds around the base of trees, shrubs and other plants may have been caused by factors other than erosion, e.g. termite mounds or sediment (water and wind) and tree litter build up against the tree trunks.
- -Some trees may lift the soil around them as they grow, thus giving natural mounds

and an appearance of higher levels of soil loss than actual.

- Tree canopy size and density changes as the tree grows, hence the tree mound will not be at a constant height above the level of the surrounding soil. Thus, it is important to take measurements at different points from the edge of the mound towards the tree trunk.

Method and calculations: as per the plant / tree root exposure example above.

PHOTO 23 **Tree mounds (Stocking and Murnaghan, 2001)**

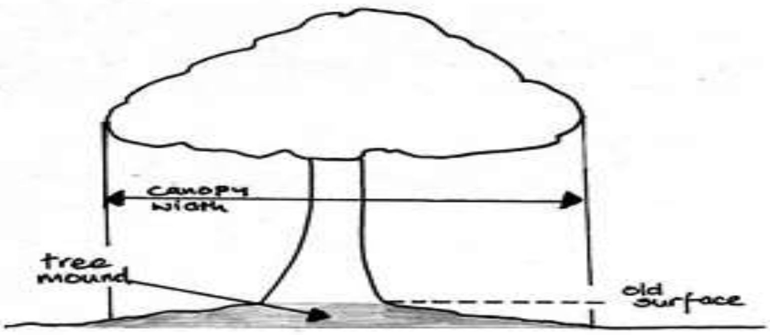


FIGURE 18 **Sketch of tree mound (Stocking and Murnaghan, 2001)**

6. Pedestals

A pedestal is a column of soil standing out from the general eroded surface, protected by a cap of resistant material (such as a stone or root). Bunch grasses can also protect the soil immediately under them (comparable to tree canopies and tree mounds, above) and give a pedestal-like feature. Care is required, however, in interpreting these latter observations.

Pedestals are caused by differential rain splash erosion, which dislodges soil particles surrounding the pedestal but not under the resistant capping material that absorbs the energy of the raindrops (Figure 18). (Note: Pedestals can be artificially simulated by using bottle tops pressed into the soil. Pedestals are created, as the bottle top protects the soil beneath from erosion, whereas the surrounding soil is exposed. They give a ready indicator to monitor surfaces where erosion rates are very large due to high intensity rainfall).

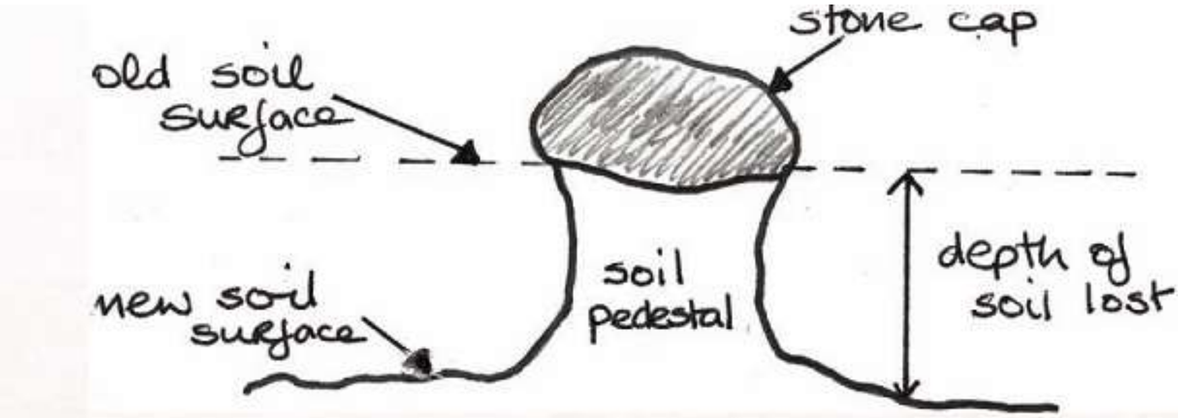


FIGURE 19 **Sketch of a soil pedestal capped by a stone (Stocking and Murnaghan, 2001)**

Measurement of pedestals is done using a ruler and it is important that a number of measurements are taken in the study area, even to the extent of dividing up the area and averaging pedestal height in each of the subdivisions, seeking across-site variability. Assuming that the cap was at the surface when erosion started, the measurement should be from the base of the stone or other capping material to the base of the pedestal, where it meets the general soil surface around. This measurement represents the soil loss since the soil was last disturbed (through forest clearing or cultivation). Therefore, by knowing the timing of the disturbance, it is possible to estimate an annual rate of soil loss.

Cautionary notes with pedestal height measurement and interpretation of data include the following.

- Pedestals often form under trees or crops where intercepted rainfall falls to the ground as a larger drop. If this is the only location in which pedestals are found they would provide an unreliable estimate of the level of soil loss for a larger area.
- Measurement of pedestals in association with clumps of vegetation should be avoided as the vegetation can accumulate soil.
- Capping stones may have originally been buried in the soil and are now exposed with an underlying pedestal; hence the pedestal height will underestimate erosion.

Localised redistribution of material eroded from under the stone requires accounting for local accumulation, hence needs to be subtracted from the calculated soil loss.

Method and calculations :as per the plant / tree root exposure example above.

7. Solution notches and rock colouration

Solution notches are indentations found on rocks that indicate historic soil levels (Fig. 5). They arise because of chemical reactions between the soil, air and the rock and particularly mark the level of past topsoils that due to their greater organic matter content (hence humic acids) etched a notch at the air/soil interface

The definition is extended here to include stone or rock discoloration, that again may indicate historic soil levels, where the soil (now eroded) discolored the rock, so leaving evidence of earlier soil levels. Solution notches are most likely to occur on limestone and calcareous rocks as they are more susceptible to acid organic chemicals, see Photo 24. The solution notch also coincides with an obvious change from the stained (iron oxide and humus materials) to the original grey rock colour, above.

Measurement is made of the distance from the notch or colour change to the current soil level, using a ruler, to give an indication of how much soil has been eroded. It is important that a number of measurements are taken in the study area. One difficulty with soil notches is determining the time over which soil loss has occurred, though calibration with other soil loss indicators (e.g. tree trunks of known age) to estimate a rate of soil loss.

Method and calculations: as per the plant / tree root exposure example above.

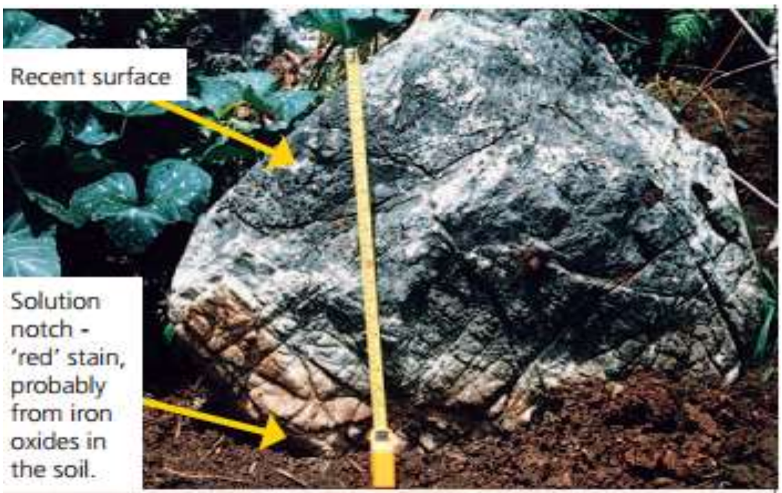


PHOTO 24 **A solution notch on a limestone rock (Stocking and Murnaghan, 2001)**

8. Armour layer

An armour layer is the concentration, on the soil surface, of coarser soil particles that would ordinarily be randomly distributed throughout the topsoil (Figure 20).The concentration of coarse material in the armour layer is interpreted as indicating that finer soil particles have been selectively removed by the energy of wind or water, leaving behind the coarser particles. The armour layer can be measured by digging a small hole to reveal the depth of the coarse top layer. Several measurements at different places in the field should be made in order to calculate the average depth of the armour layer. The approximate proportion of stones/coarse particles in the topsoil below the armour layer is judged by taking a handful of topsoil from below the armour layer and separating the coarse particles from the rest of the soil. In the palm of the hand, an estimate is made of the percentage of coarse particles in the original soil. Again, this estimation should be repeated at different points in the field. The depth of the armour layer is then compared to the amount of topsoil that would have contained that quantity of coarse material. The amount of finer soil particles that have been lost through erosion can then be estimated. See Photo 25.

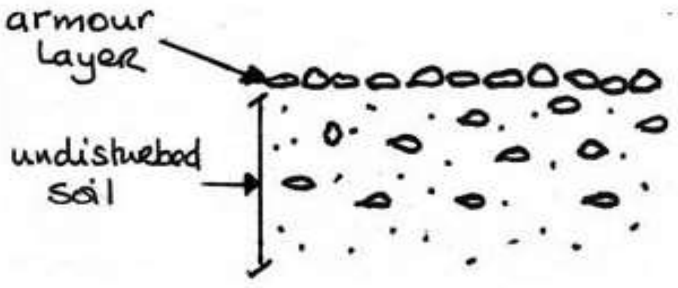


FIGURE 20 **Diagram of an armour layer**


PHOTO 25 **Removal of a portion of an armour layer. (Stocking and Murnaghan, 2001)**

Cautionary notes with interpretation of the measurement of armour layers are many.

- Stones on the surface may arise for other reasons, such as the exhumation of a concentration of stones in the subsurface soil by animals or frost action.
- Accurate measurement (to mm tolerance) of the thickness of the armour layer is critical, as for every 1 mm, the equivalent soil loss is 13 t/ha (assuming an average bulk density of1.3g/cm3).
- As well as erosion processes, repeated shallow tilling of the soil may concentrate more stones near the surface. Where this happens, the erosion rate will be exaggerated, unless the percentage concentration of stones in the original soil is based on an estimate well below the (tilled) topsoil.

Method: Using the average of the measurements (mm) of the thickness of the armour layer.

Worked example:

a. Convert the average soil loss (1mm) to equivalent in metres:

1.0 * 0.001 = 0.001 m

b. Calculate the depth of soil required to generate the 0.001 m of armour layer, where the proportion of coarse material in the topsoil was determined as 20% on average (i.e. a 1:5

ratio)

0.001 * 20% (= 1/5th) = 0.005 m

c. Calculate the depth (m) soil lost :0.005 – 0.001 = 0.004 m

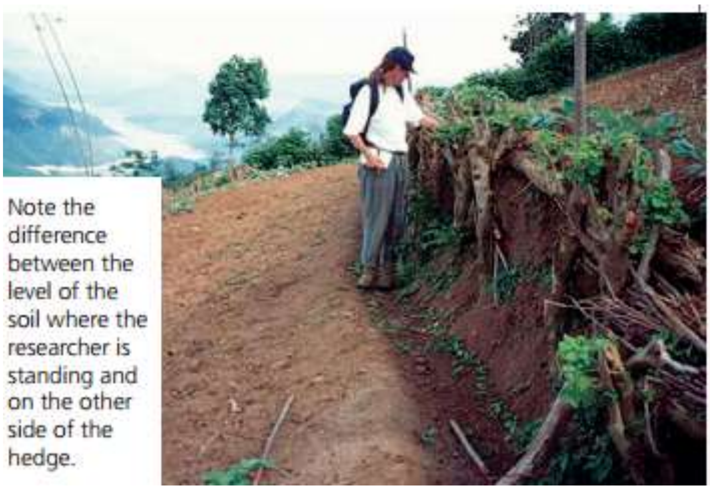
d. This drop in soil level is converted to tonnes per hectare, using an estimated soil bulk density value of 1.3g/cm3(or 1.3 t/m3), where 1 mm of soil loss is equivalent to 13 t/ha, so 1m soil loss would be equivalent to 13,000 t/ha 0.004 * 13,000 = 52 t/ha

Hence in this worked example, 52 tonnes / ha have been lost to soil erosion.

9. Soil / sand build-up against a barrier

The build-up of eroded material against a barrier is a measure of the movement of soil across an area of interest rather than loss from that area. In this case, the eroded materials are halted by an obstruction, and the materials deposited against the obstruction as the water slows (see Photo 26). The result is a build-up of sediment against the barrier.

Method: The volume of soil trapped behind the barrier can be calculated by measuring the depth of the soil deposited and the area over which it is deposited. Where the build up is against a continuous barrier such as a fence or hedge the measurement will give an approximation of soil loss from the field. A visual examination of the area close to the barrier will indicate how far the deposition extends into the field.



Note the difference between the level of the soil where the researcher is standing and on the other side of the hedge.

This distance (Length) should be measured at a number of points. The depth of the soil accumulated against the barrier can be determined by examining the soil level against the barrier on the other side from the accumulation. In order to calculate the amount of soil accumulated a linear slope is assumed and the « wedge » of soil behind the barrier is regarded as a triangle.

Estimating soil erosion: The amount of soil accumulated behind a barrier represents a build-up over time. The annual rate of soil loss from a hillside can be arrived at by dividing the quantity of accumulated soil by the number of years that a barrier has been in existence.

Cautionary notes with interpretation of the measurement of accumulations behind barriers are many:

- There is a danger that because of soil erosion on the lower side the soil level next to the barrier will have been lowered.
- The depth of the accumulation of soil behind the barrier is not constant. Rather the depth of accumulated soil becomes thinner (less deep) with distance away (up slope) from the barriers.
- The calculations do not differentiate between sediment that results from in-field erosion and sediment that results from erosion further upslope and outside the immediate field, which may lead to an overestimation of the soil loss per field.
- Not all materials transported in runoff will be deposited at a barrier. The speed, volume and direction of runoff all influence the level of deposition.
- Therefore, the estimated soil loss may be understated by the amount of soil carried beyond the barrier.
- Forest clearing may increase the soil depth behind barriers, particularly where conservation techniques such as terracing have been introduced to lessen the effect of slope. If the slope was convex before the barrier was constructed, the estimate of soil loss will be understated as it assumes a linear slope.
- The soil level below the barrier may not be the original soil level. As evident in Figure 26, excavation and leveling of the area immediately below the fence has occurred for road building.

Method: Using the average measurements of depth of the deposit at a barrier of 7 metres length, and the length of the accumulation up slope of the barrier of 0.945 m, the average cross-sectional area of deposit (considering it is triangular) is calculated using the formula:

The average cross-sectional area of deposit (A)= Depth at barrier (m) * (horizontal length (m) / 2)

Worked example:

For an accumulation against a barrier that has:

Depth at barrier = 0.16 m, length of accumulation = 0.945 m

a. The average cross-sectional area of the deposit behind the fence, assuming a triangular cross-section is :

$(½ * 0.16) * 0.945 = 0.07560$ m2

b. For a barrier that is 7 m in length, the volume of soil accumulated behind the barrier is:

$0.07560 * 7$ m $= 0.5292$ m3

c. The volume of soil lost, from the estimated catchment area (here 70 m2) is converted to a volume per square meter :

$0.5292 / 70 = 0.00756$ m3 / m2

d. The volume per square meter is converted to tonnes per hectare, using a estimated soil bulk density value of 1.3 t/ m3:

$0.00756 * 1.3 * 10{,}000 = 98.3$ t/ha

e. If the barrier is known to have been constructed three years before the measurements were collected, the annual soil loss as represented by the soil accumulated behind the barrier is:

$98.3 / 3 = 33$ t/ha/yr

Hence in this worked example, 33 tonnes / ha /year have been lost from this site and accumulated behind the barrier.

10. Enrichment ratio

Indicator: Comparison between the higher levels of nutrients to be found in the areas where the fines are deposited, and the nutrients in the area from which they have been eroded, is referred to as the enrichment ratio.

Process: Wind and water erosion can selectively remove the finer soil particles and lighter organic matter, both of which contain relatively higher levels of nutrients than the coarser mineral deposits left behind. The effect of this selective erosion process is to progressively reduce the inherent fertility of the remaining soil. When the finer particles are deposited downstream or downwind then they will enrich the location in which they settle. This may just be a local redistribution within the same field, for instance where sediments are trapped by cross slope barriers or against field boundaries, or transported further and accumulate in drains, valley floors, local reservoirs and ultimately the sea.

Method: This type of erosion is normally assessed by measuring the quantity of nutrients found in the deposited sediment and comparing this to the quantity in the original soil from which the material was eroded. For the purposes of making a quick field assessment the proportions of finer soil particles can be used as a proxy measure, as these are closely related to nutrient levels and in themselves are also good variables for assessment of enrichment.

This involves taking equal quantities of soil from the eroded and the depositional locations, and visually observing them in the palm of the hand so as to estimate the proportion of coarse material to fine material in both samples. This should be repeated a number of times.

Estimating the redistribution of fines also known as the enrichment ratio. The average percentage of fine materials in both the enriched soil and the eroded soil should then be calculated. The enrichment ratio is the ratio comparing the percentage of fine particles in the enriched soil, to the percentage of fine particles in the eroded soil. It should also be possible to quickly identify by hand texturing the different samples whether the selective removal and subsequent deposition of fines is taking place within a field. A field form is provided in Table 29 for recording measurements.

Potential for Error

1) The technique for assessing the enrichment ratio requires considerable field experience because estimation of proportions of soil particle sizes is difficult. The novice field assessor is best advised to accompany an experienced person.

2) As the selective removal of fines is a natural process care must be exercised to ensure that the observed trends relate to the land management practices and not to features inherited from prior conditions. For example, ant hills, termite mounds and earthworm casts often contain higher proportions of finer material than the topsoil. Because erosion of these structures may result in the redistribution of this finer material down slope, any observed increase in fines may have little to do with existing land management practices.

3) Estimates undertaken solely by visual inspection of fine particles are very approximate. If possible, laboratory determination of macronutrient (Total
N, P or K) content or of organic matter should be done to corroborate findings.
This is particularly the case for clayey materials.

4) The enrichment ratio can be understated where not all the eroded material is deposited in the site where the enriched soil is identified. The finest particles may have been carried away completely from the site.

5) Understatement of the seriousness of erosion may also occur where deposition from upslope occurs on the eroded soil, thus masking the full extent of finer materials lost.

Similarly, the enrichment ratio may be overstated where run-on to the site from further upslope increases the level of fine particles in runoff thus contributing to the enriched soil.

Erosion measurement intensity, frequency and reporting

In terms of advising on the intensity, frequency and reporting protocols for observations and measurements of erosion features in dry lands, it is difficult to be prescriptive due to the variety of circumstances where these data will be collected. In particular, timescales of erosion vary greatly depending on climate, soil type, slope and current vegetative cover. Accordingly, observations and measures to record the various degrees of effect and the intensity and frequency required to capture erosion correctly will vary widely.

There is, however, the over-riding consideration in terms of recording dryland erosion of establishing protocols of "**benchmarking and monitoring**". With this, the first **observations and data** collected act as **the baseline** for all subsequent observations and measurements, to record continuing **degradation or improvements** with **time**. Critical is to apply the same set of observations and measures (detailed above) to provide a true "**change with time**" evaluation.

As stated earlier, monitoring considers both non-intervention scenarios (where the erosion is allowed to continue) as well as interventionist scenarios, where some physical or vegetative barrier is created to begin to mitigate the negative impact of the observed erosion.

Frequency of monitoring observations is commonly different between the two scenarios.
Non-intervention scenarios are commonly monitored on a fixed interval basis that is governed by the intensity of the erosion process; annually in active erosion situations or sensitive watershed/crop land scenarios and perhaps every 5 or 10 years where erosion is less active and widespread. **Intervention scenarios** are monitored as required to capture the effect of the intervention; commonly more observations soon after implementing the intervention, then less often with time once the improvement trend is captured.

Intensity of observations considers the number of observations to be conducted at one time in an area of interest. Again, a prescriptive approach is impossible due to the many situations that may be experienced. However, the observation and measurement protocols given above provide many “**entry levels**” to the type and intensity of observations that could be conducted on any one occasion.

Worked example

TABLE 29 **Field form - Enrichment ratio**

Site:
Date:

Measurement	**% of fine particles in eroded soil:** i.e. soil remaining in-field	**% of fine particles in enriched soil:** i.e. soil caught downslope and deposited
1	20	28
2	25	25
3	15	30
4	22	30
5	20	35
6	20	35
7	22	35
8	19	25
9	20	30
10	20	28
11	18	28
12	20	32
13	18	30
14	22	32
15	22	28
16	20	28
17	18	26
18	20	30
19	20	35
20	19	30
Sum	400.00	600.00
Average*	ERODED = 20.00%	ENRICHED = 30.00%

NB: To obtain an average divide the sum of all the measurements by the number of measurements made.

Calculations:
(1) Calculate the ratio of fine materials in the eroded soil to fine materials in the enriched soil

ENRICHED	30%	÷	ERODED	20%	=	ENRICHMENT RATIO	1.50

At the simplest level, a “**community map**” could be sketched rapidly for short time intervals, then the time sequence of sketches compared to investigate the more active or widespread areas and types of erosion features, for closer investigation. The next level is to solely describe and class the erosion features present in an area of interest, using Tables mentioned earlier above

Lastly, the measurements of soil loss take the longest time, so tend to be used less often and less intensively. Intensity of observations is also governed by the types of erosion features that occur in a study area. For example, if there are only 5 to 10 gullies in a given LUT, then the tendency would be to describe and measure all of these in some detail, even installing fixed measuring posts to exactly measure soil loss and gully encroachment. At the other end of the scale, in a heavily degraded, recently cleared, steeply sloping land in the monsoon season there may be all of sheet wash, rills, gullies and landslides.

Most often human resources are inadequate to comprehensively describe and record so many types that are changing so rapidly. Photography and community sketches would be the best approach as these can be subsequently analyzed to capture the rapidly changing situation.

It is important to identify relationships between the various erosion types recorded and current or recent management activities that contributed to the type, state, extent and severity of the erosion. Such linkages will provide a more proactive consideration of soil erosion with consideration of the potential to repair or diminish the recorded erosion, lessen the chance of its re-occurrence and, particularly in areas being newly opened up for production, to initiate from the outset improved management strategies to avoid or minimize erosion.

This section aims to provide **a field usable and scientifically robust** set of methods for describing the various types of erosion, scoring the degree of negative impact of each type and estimating the quantities of soil lost. **The results** should then be considered together with other **type of degradation** (of soil properties, vegetation and water quality and water resources) to assess impacts on **productivity, other ecosystem service**s and **resilience**.

Wind Erosion

Wind erosion, also known as eolian erosion, is a dynamic process by which soil particles are detached and displaced by the erosive forces of the wind. Wind erosion occurs when the force of wind exceeds the threshold level of soil's resistance to erosion. Geological, anthropogenic, and climatic processes control the rate and magnitude of wind erosion. Abrupt fluctuations in weather patterns trigger severe wind storms. Wind erosion is the result of complex interactions among wind intensity, precipitation, surface roughness, soil texture and aggregation, agricultural activities, vegetation cover, and field size. Plowed soils with low organic matter content and those intensively grazed and trampled upon are the most susceptible to erosion. About 50% of the dust clouds result from deforestation and agricultural activities (Gomes et al., 2003).

Process

Wind detaches and transports soil particles. Transported particles are deposited at some distance from the source as a result of an abrupt change in wind carrying capacity. The three dominant processes of wind erosion, similar to those of water erosion, are: detachment, transport, and deposition. The mechanics and modes of soil particle movement are complex. Deposition of suspended particles depends on their size and follows the Stoke's Law. Large particles settle down first followed by particles of decreasing size. Smaller particles remain suspended forming the atmospheric dust.

The three pathways of particle transport are suspension, saltation, and surface creep. The mode of transport of soil particles during wind erosion is governed by the particle size. Small particles (<0.1 mm) from pulverized soils are preferentially transported in suspension, medium-sized particles (0.1–0.5 mm) in saltation, and large particles (0.5–2 mm) by surface creeping. Because of abrasion, rebounding, and rebouncing effects, saltating and creeping particles can be broken into smaller particles and be transported in suspension. Saltation, suspension, and surface creep are not separate but interactive and simultaneous processes of transport. The size of moving particle with wind decreases with increase in height above the soil surface.

Processes of Wind Erosion

Detachment

- Primary and secondary soil particles are detached by the erosive forces of the wind.
- Particles collide, abrade, and break into smaller particles.
- Detachment and movement of soil particles depends on the wind threshold velocity.
- Threshold velocity is the minimum amount of velocity needed to move soil particles.
- Detachment occurs when soil is dry and bare.
- The detaching capacity of wind is a function of friction velocity and size of erodible particles.
- Dry aggregates made up of fine particles are harder to detach than those of coarse particles with weak contact points.

Transport

- Particle transport is a function of wind velocity, surface roughness, particle size, and percent of detached particles.
- Well-aggregated and moist or wet soils are unaffected by wind erosion regardless of particle size and wind velocity.
- Turbulence and gusts produce different range of wind velocities above the soil surface with variable particle carrying capacity.
- Transport capacity increases rapidly from the windward edge of eroded and bare soil.
- The total soil removal is equal to the fifth power of the friction velocity.

Deposition

- Soil deposition occurs when the gravitational force is greater than the upward forces of wind holding the soil particles in air.
- Any obstacle (e.g., windbreaks) that causes a sudden decrease in wind velocity promotes deposition.
- Rain during wind storms also contributes to deposition.
- Change in soil conditions from dry to wet also captures saltating and creeping soil particles.
- Vegetation intercepts floating particles, which adhere to leaves and branches and deposit in the soil surface with rain.
- Transported loess material is accumulated in piles or dunes on the leeward side of the field.

Fig.Three main processes of wind erosion

Processes of Soil Transport

Suspension

- Small soil particles are transported in suspension in the air as dust or haze, and they are too small to overcome the upward current of the windstream.
- Soil particles float and remain scattered in air until the upward wind force drops below the threshold level of the weight of the suspended particles.
- Soil particles deposit on the soil surface when their weight surpasses the declining upward wind force or when it rains.

Saltation

- Soil particles with 0.1 to 0.5 mm in diameter move downwind by bouncing and saltating along the soil surface.
- Particles can jump as high as 1 m, depending on their size, wind velocity, and surface roughness.
- Coarse particles are lifted no more than 1 cm.
- Velocity of soil particles is half or one-third the wind velocity.
- During saltation, particles abrade and become suspended.

Surface Creep

- Soil particles with diameters between 0.5 and 2 mm creep or roll along the soil surface due to their large size.
- Creeping particles may also collide with larger and non-creeping particles (e.g., pebbles).
- By consecutive abrasion, creeping particles with decreasing size can be transported by saltation.
- Surface creep transport accounts for about 1/3 of wind erosion.

Fig. Processes of soil transport during wind erosion

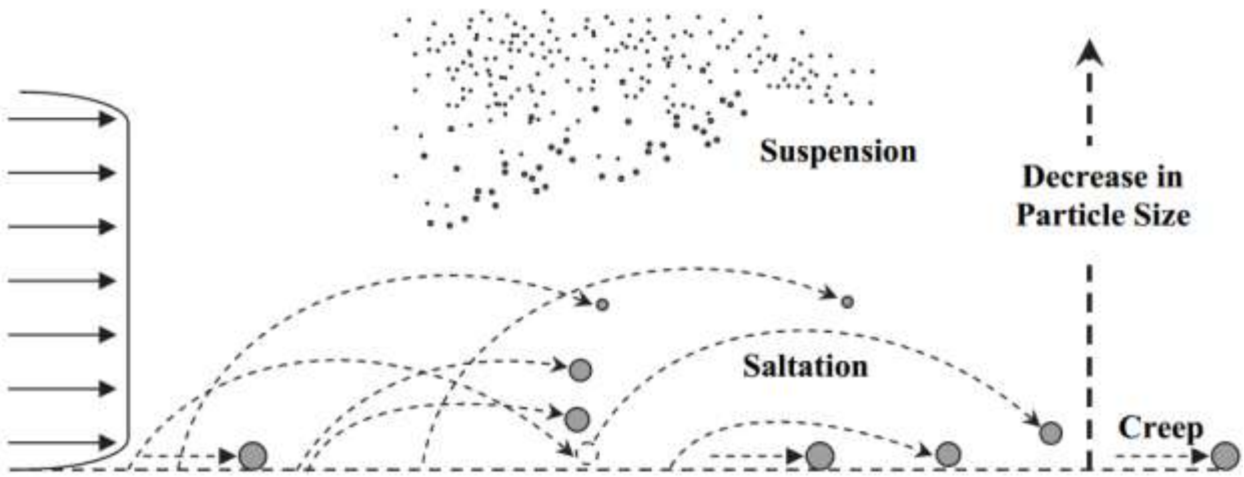


Fig. Modes of soil particle transport by wind during erosion

Wind erosion is the result of a combination of many factors associated with climate, soil, land surface, and management conditions (Table below). Wind velocity, soil surface water content, surface vegetative cover, surface roughness (e.g., ridge height), aggregate stability, field length, rock volume fraction, and soil texture are the most sensitive parameters influencing wind erosion (Feng and Sharratt, 2005).

There are two opposing forces that take place during soil erosion (Fig below). The force of wind which tends to move everything away faces an opposing front, which is the natural resistance of the soil that offsets the wind energy until the threshold level of resistance is overcome by the wind force at which point erosion is set in motion. For example, high winds increases soil transport, whereas well-aggregated soils decrease the availability of loose particles for erosion. The net effect of the opposing forces determines the rate of soil erosion. The wind is a moving force whereas the forces of soil resistance are stationary.

Table Four interactive factors affecting wind erosion dynamics

Climate	Land Surface Properties	Soil Properties	Land Use and Management
• Wind speed, duration, direction, and turbulence • Wind shear velocity • Precipitation and temperature • Radiation and evaporation • Air humidity, viscosity, and pressure • Freezing and thawing	• Field slope • Length, width, and orientation of the field • Terrain roughness • Non-erodible materials (e.g., rocks, stones) • Residue orientation (e.g., flat, standing)	• Particle size distribution and particle density • Aggregate size distribution • Aggregate stability, strength, and density • Water content • Bulk density and crusting • Soil organic matter content • $CaCO_3$ concentration	• Residue management • Type of land use (e.g, forest, rangeland, and pasture) • Type of cultivation (e.g., no-till, plow till, rotations) • Fallow or bare soil • Afforestation or windbreaks

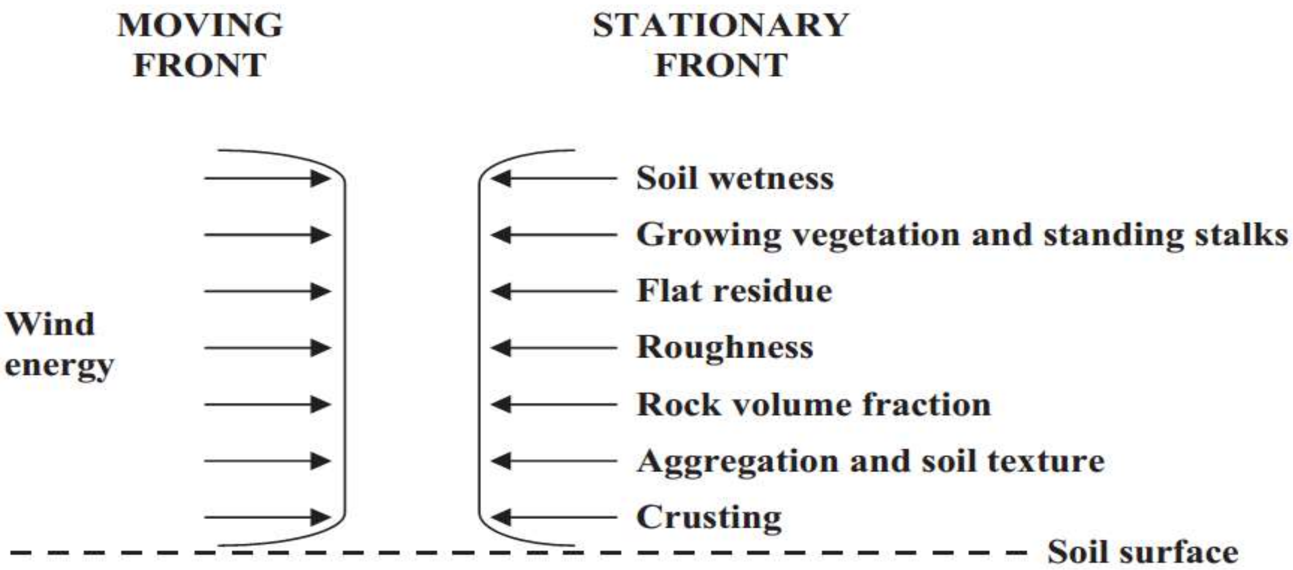


Fig. Forces defining the rate of wind erosion (After Fryrear et al., 1998)

Name: ___________________________ Date: ________________

➢ **Short Answer Questions**

Self-Check -9	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What are the 3 methods/techniques used to assess and measure soil erosion? (3points)
2. What are the visual indicators of soil erosion?(5points)
3. Which modes of soil particle transport large amount of soil particles by wind during wind erosion?(5points)

Note: **Satisfactory rating >7.5 points** **Unsatisfactory - below 7.5 points**

Answer Sheet

Score = ____________

Rating: ______________

Information Sheet -10	Erosion assessment and measurement techniques

Apply Erosion Assessment and Measurement standard Techniques

Assessment of current erosion damage (ACED) is carried out in three steps after erosive storms, starting with the visible erosion features. **The first step** is to measure the volume of the erosion features & the land management unit where they occur, in so- called damaged **area.** Erosion damage may occur particularly on cultivated field or other areas that are partly left without vegetation cover. erosion features can often be linked to causes located on the damaged field itself, e.g. on steep slopes with high runoff velocity, in depression & on long slopes with high runoff concentration , on silt soils & on soils with low organic matter with high erodibility, on fields which are plowed up & down slope, etc.

The second step is to investigate the upslope area in view of its contribution to the features. The sources of runoff may be found outside the area with actual erosion damage, i.e. above or upslope of the damaged area. Commonly, runoff is created on areas of low infiltration, such as the sealed surfaces of settlements, roads, footpaths & animal tracks. Interestingly, also grass & bush- lands, which have a much better infiltration, can produce considerable run on if overland flow from these areas is not well drained. It is one of the most dangerous sources of erosion down slope. Where does run on enter the damaged field, & where is it generated (along roads, small depressions or catchments, etc)? The relevant answer to this questions can only be found if the mapping staff is in the field during a rainfall event.

The third step is to document the subsequent impact of the erosion features on the down slope area. Damaged areas can easily create consequent damage on the areas down slope. For example, the eroded material accumulates & buries plant & seedlings, or blocks roads & pollutes settlements. Field border erosion (gully) is a commonly observed phenomenon in humid areas where field have to be drained. These gullies may also extend & destroy infrastructure such as roads or villages. Eventually , sediment that reaches the river can affect water quality & may lead to sedimentation of irrigation dams ,while increased runoff can cause flooding or flash floods , a danger for downstream settlements

Rills as an indicator of considerable topsoil loss & long distance transportation often occur in slope depressions, alternating with accumulations on concave foot slopes (in the fore ground). In this example, the very low vegetation cover shortly after germination has fostered the erosion process. However, the rill originates almost at the upper field border, which means that the conditions of the damaged field alone, such as vegetation cover, slope, soil, etc., cannot be the only reason for the rill.

A frequent observed phenomenon is gullies that develop parallel to roads, particularly when the road is crossing aslope depression or valley. The factor contributing to that incident is manifold. The road itself & the village area compacted surface that does not permit infiltration. Such sealed area is a source of tremendous overland flow. People & animals use the area adjacent also contributes to the concentration of overland flow. Were the trees planted to stop gully erosion, or has the gully below developed because of the plantation (keeping in mind that densely planted eucalyptus trees? & uncontrolled grazing & collecting firewood prevents the establishment of ground cover)?

Assessment of Current Erosion Damage (ACED)

ACED was developed for two purposes.

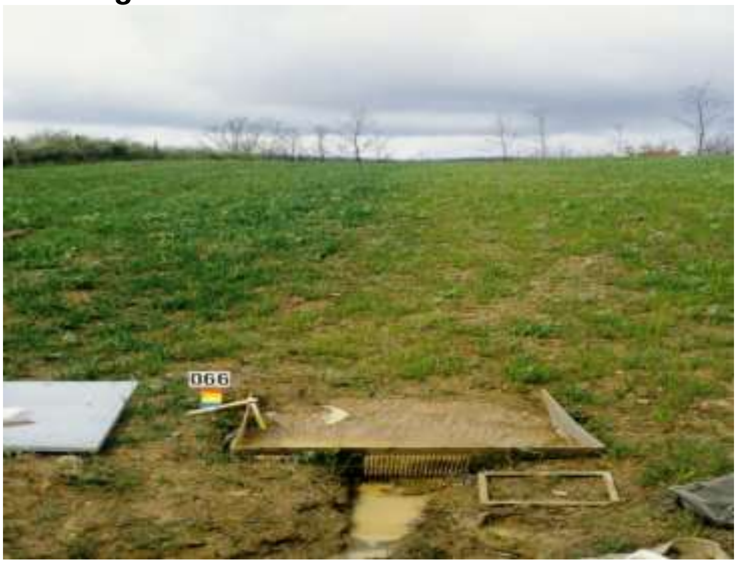
- ✓ To supplement existing erosion measurement levels such as test plots & rivers gauges stations.
- ✓ To provide practitioners with a more cost- effective tool to assess soil erosion & draw conclusion about implementations of SWC.

Levels of Soil Erosion Measurement

1. **Hot spots: Damage mapping**

2. **Field: Testplot measurement**

3. **Field: Sediment trough / flume**



4. **Watershed: River station**

Erosion assessment and measurement techniques may include, but not limited to:

- **Universal Soil Loss Equation (USLE) model:**

Soil erosion is influenced by many different variables. The essence of USLE is to isolate each variable and reduce its effect to **a number** so that when the numbers are multiplied together the answer is **amount of soil loss**. The equation is used to **predict soil loss** and helps to choose agricultural or soil conservation practices.

Erosion processes do not normally affect all areas of a landscape equally. It is also not technically possible, socially sounding and economically feasible to conserve all soil erosion areas at once. Predicting the location of excessive erosion hazard is therefore relevant to make successful erosion control, properly manage degraded lands, and improve the wellbeing and development of people. Soil erosion models are commonly used to achieve these goals. The absence of appropriate erosion assessment model for tropical and subtropical countries forced many researchers to rely on USLE or other soil loss assessment models developed for temperate countries. These models, however, can be adapted to the existing local condition and erosion hazard assessment of tropical and sub tropical countries (Hurni, 1985a). In the developing countries, shortage of data limits the application of data intensive research models. However, the compatibility of the USLE model help in estimating soil loss rate, identify hotspots of soil degradation and priority of land management in a wide range of areas enables researchers to apply the model. The model can be used to calculate the soil loss rate of the catchments based on the product of six different data sets: rainfall intensity (R), soil erodibility (K), slope length and angle (LS), land use/cover (C) and land management (P) factors. Once the data of these erosion factors are available, the average annual soil loss rates (A), based on USLE, can be calculated as shown in Equation:

The equation is presented in the form:

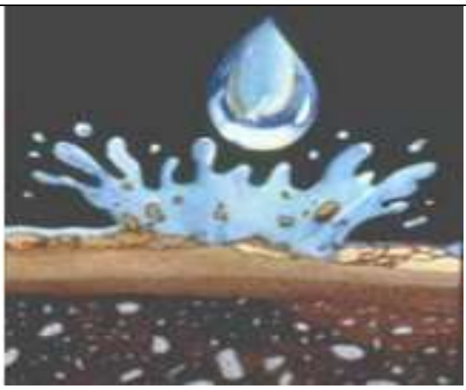
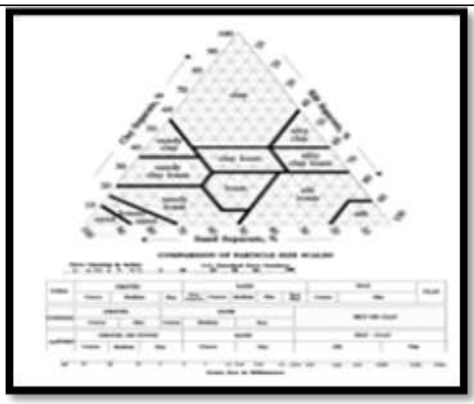
$$A=R*K*L*S*C*P$$

- ☞ A=soil loss in tons/ha/year.
- ☞ R=the rain fall erosivity index; number indicating erosivity of rain.
  - Measures the erosive forces of rainfall to detach and transport soil particles in a given.
- ☞ K=soil erodibility factor: a number, which reflects the liability of a soil to erosion.
  - Refers to the inherent soil susceptibility to the forces of erosion by rainfall.
- ☞ L=the slop length factor: gives the ratio of soil loss from the length of the field for which erosion is to be predicted.
- ☞ S=slope (gradient) factor: the soil loss on the site concerned with its specified slope gradient.
- ☞ C= Land cover/crop management factor; the soil loss on the site concerned with various crops.
  - Different land use/cover patterns have various degree of soil protection against soil erosion. Land use/land cover pattern with better vegetation cover has lower C value and low degree of soil erosion hazard and vice versa. By intercepting rainfall drops and reducing velocity of runoff, plant cover protects the soil against erosion.

- ☞ P= Management/conservation practice factor; it is the relation of soil on the site concerned, to the soil loss on a standard plot under fallow.

Despite the simplicity and usefulness of the equation, its application for Ethiopian condition for the time being is limited. Since the equation is developed in USA and even it was adapted to Ethiopian conditions which differs enormously from USA that the values are not directly transferable.

Table: Each site factor that influences erosion (i.e., variable in the Revised USLE) is described below.

Variable in the RUSLE		**Description**
Rainfall/ Climate (R)		• Climate, and particularly rainfall intensity and duration are directly related to erosion: ○ Droplet size is important from the aspect of splash erosion ○ Other considerations include: storm patterns, types of vegetation native to the area, vegetation morphology and growth characteristics, and average annual soil temperatures
Soil Erodibility (K)		Soil erodibility is the propensity for soil particles to become detached by actions of water or wind. The K factor: • Is a function of soil texture, organic matter content, soil structure and permeability • Is expressed as numerical values in USDA/NRCS tables

<table>
<tr>
<td>Flow Path Length and Slope (LS)</td>
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The degree to which length and slope (LS Factor) play in erosion can be calculated using USDA/NRCS charts.
Slope Length: distance along flow path to a point where deposition is first likely to occur
Slope Steepness: ratio of horizontal distance to vertical rise (e.g., 3:1 slope); percentage (e.g., 33% slope); or degrees (18 degree slope)
In general:

The effect of flow path length is not as great as effect of slope steepness
Long uninterupted slopes and especially long steep slopes (2:1 horizontal: vertical or greater) should not be constructed
Long slopes should be shortened by creating contour diversions or benches every 25 feet.
A convex slope shape increases runoff and magnifies slope erosion
A concave slope shape enhances infiltration and reduces erosion

Aspect or orientation of slope is important with respect to:

Vegetation establishment
Moisture content

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<tr>
<td>Cover</td>
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<td>
The rate of erosion is related to the amount of permanent or temporary cover. The functions of cover are to:

Reduce rainfall impact on soil
Reduce surface water velocities
Enhance infiltration
Filter sediment in surface runoff
Retain soil particles in place and reinforce soil structure
Promote permanent vegetation establishment

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</table>

Conservation Practices (P)		Conservation practices are controllable, imaginative, experience driven, and interactive factors such as slope roughening perpendicular to the direction of runoff. For the most part, they can: • Enhance the factors of cover and soil texture • Mitigate the influence of rainfall and runoff • Modify velocity flow path length and steepness

Universal Soil Loss Equation adapted for Ethiopia (H. Hurni)

SOURCE: WISCHMEIER AND SMITH, 1978

ADAPTIONS: R CORRELATION: HURNI, 1985
K VALUES: FROM BONO AND SEILER, 1983, 1984: AND WEIGEL, 1985
S EXTRAPOLATION: HURNI, 1982

EQUATION: A = R * K * L * S * C * P (TONS PER HA PER YR)

1. R: RAINFALL EROSIVITY

ANNUAL RAINFALL (MM)	100	200	400	800	1200	1600	2000	2400
ANNUAL FACTOR R	48	104	217	441	666	890	1115	1340

2. K: SOIL ERODIBILITY

SOIL COLOUR	BLACK	BROWN	RED	YELLOW
FACTOR K	0.15	0.20	0.25	0.30

3. L: SLOPE LENGTH

LENGTH (M)	5	10	20	40	80	160	240	320
FACTOR L	0.5	0.7	1.0	1.4	1.9	2.7	3.2	3.8

4. S: SLOPE GRADIENT

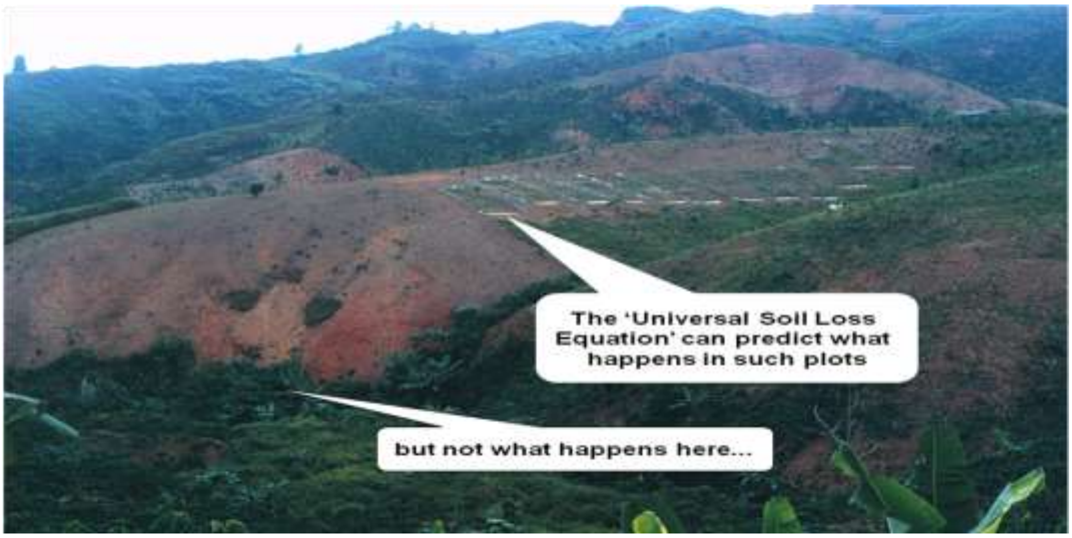
SLOPE (%)	5	10	15	20	30	40	50	60
FACTOR S	0.4	1.0	1.6	2.2	3.0	3.8	4.3	4.8

5. C: LAND COVER

DENSE FOREST:	0.001	DENSE GRASS:	0.01
OTHER FOREST:	SEE GRASS	DEGRADED GRASS:	0.05
BADLANDS HARD:	0.05	FALLOW HARD:	0.05
BADLANDS SOFT:	0.40	FALLOW PLOUGHED:	0.60
SORGHUM, MAIZE:	0.10	ETHIOPIAN TEF:	0.25
CEREALS, PULSES:	0.15	CONTINUOUS FALLOW:	1.00

6. P: MANAGEMENT FACTOR

PLOUGHING UP AND DOWN:	1.00	PLOUGHING ON CONTOUR:	0.90
STRIP CROPPING:	0.80	INTERCROPPING:	0.80
APPLYING MULCH:	0.60	DENSE INTERCROPPING:	0.70
STONE COVER 80%:	0.50		
STONE COVER 40%:	0.80		



- **Rill and gully measurement techniques**

Gullies and ravines/rill/ have the same, general shape of a flat floor and sloping sides, hence the bottom of these features (the floor) is less wide than the top (parallel to the soil surface). Such a shape is best estimated as that of a trapezium[14] (Fig. Z). Calculation of soil loss, therefore, is generally similar to rills, except with a different cross-sectional shape. As with rills, the measurement of the dimensions of the gullies and ravines gives an estimate of the amount of soil displaced from the area

To calculate the quantity of soil lost from a gully or ravine, measurement is made of the depth, width at lip (the top of the feature) and base, as well as the length of the feature. Equipment used to collect these measurements will vary between operators, but could be a laser-based rangefinder (expensive) for large gullies and ravines, or a 30 to 100 m tape for smaller features. It is important to collect a number of measurements of both the width and depth along any one feature and also of many gullies in the study area to achieve a representative sample. An annual rate of soil loss from gullies and ravines is more feasible than from rills, as the former are more or less permanent features of the landscape.

Catchment's characteristics based on the vegetation, soil type, and slope condition to find out runoff /rill/gully generating characteristics.

Dimensions Rill and gully: Decide the top width or top and bottom width; depth and length. The dimension must provide sufficient capacity to confine at the peak runoff from a storm with a certain return period (ten-year).

Grading:_Rill and gully drains always be graded in the longitudinal direction of the slope. Therefore, slope angle and slop length is also additional factors considered in measurement.

- Generally, larger values of slope-length exponent are associated with increasing of concentrated flow and rill erosion. Hence, the amount of erosion would normally be expected to increase with slope length and steepness which enhance the velocity and volume of surface runoff.

Method: Using the average measurements of width at lip and width at base, and depth, calculate the average cross-sectional area of the gully or ravine (considering the cross-sectional shape is trapezoid; Fig. Z), using the formula:

Volume of soil lost =(width at lip (m) + width at base (m) / 2) * depth (m)

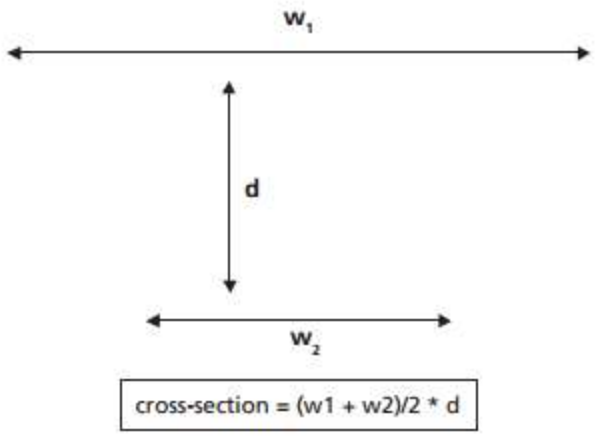
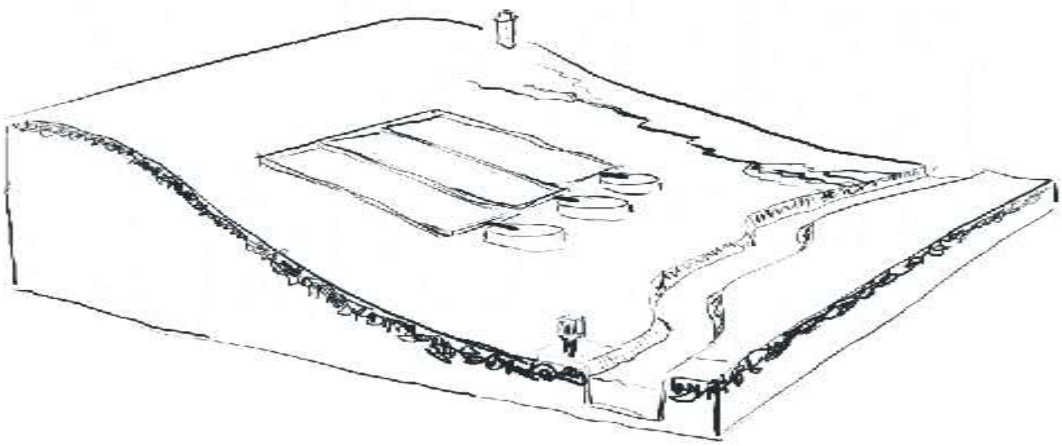


FIGURE **Calculation of the cross-section of the trapezoid shape of gullies/ ravines**

NOTE! When the above procedures and guides you can calculate the dimensions of rill/gully. Using tables from various soil conservation textbooks. Remember that different books have their own methods of calculation of the rill/gully size and may give you different results.

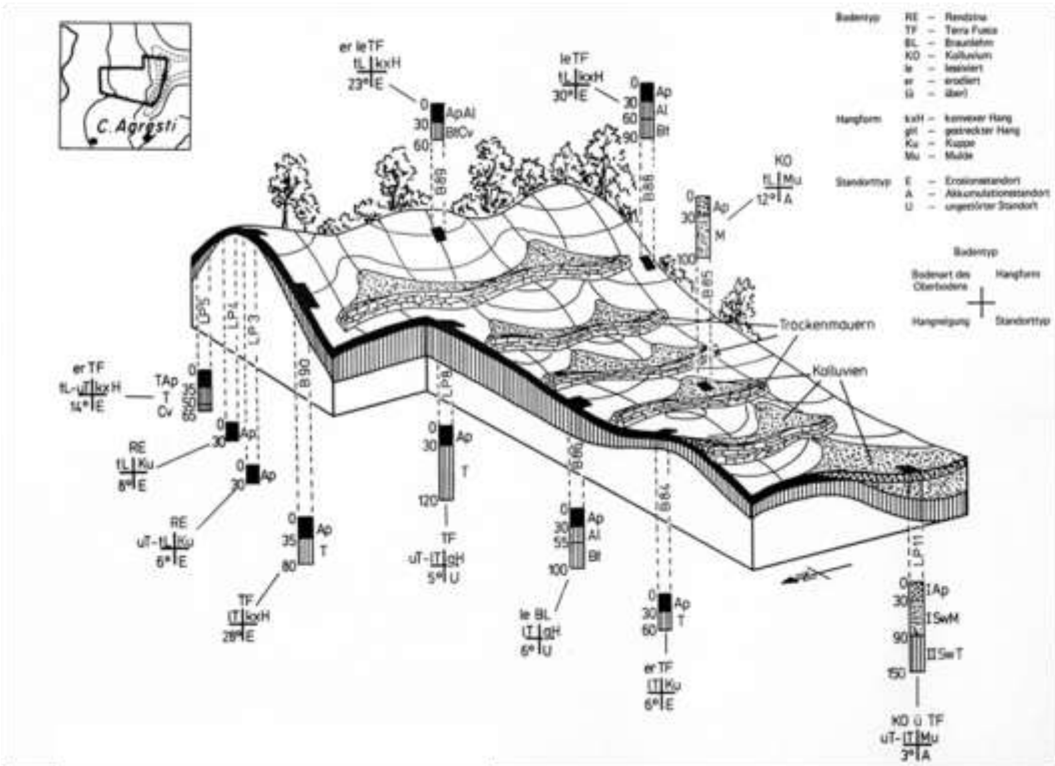
Classification of gullies depending on the age or development.		
Characteristic process	**Name**	**Control feasibility**
Scour in surface	Incipient gully or rill	high
Head ward erosion	Yong gully	low
Widening and flattening	Mature gully	moderate
Stabilization, new soil formation	Old gully	very high

➢ **Land profile change**

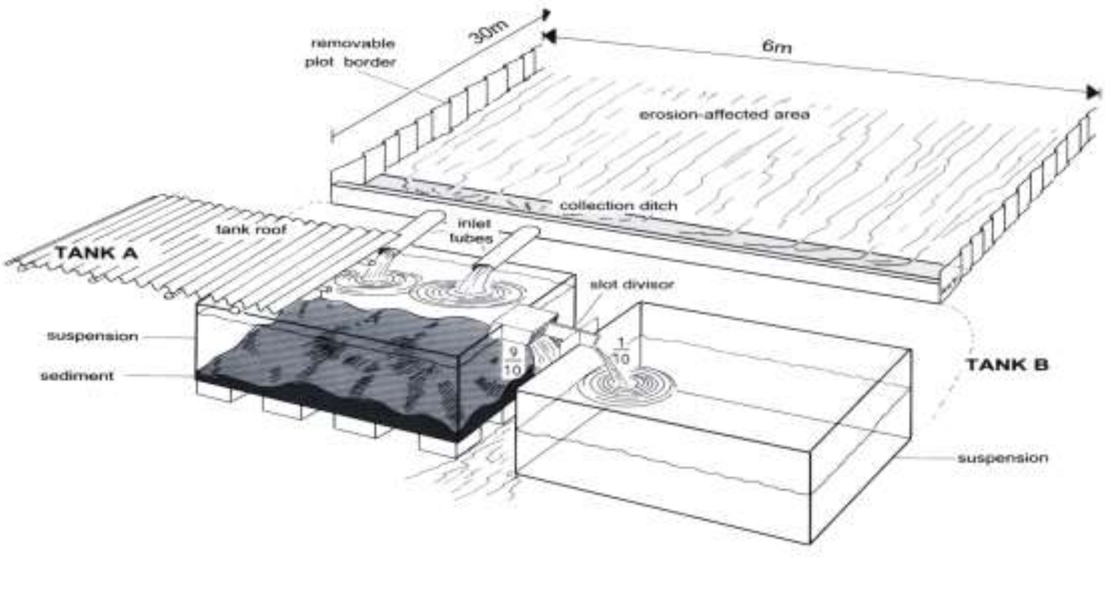


Land profile change

Soil Profile Mapping: Indicator of Cumulative Soil Degradation



- ➢ **Runoff plot method**
- o **Test Plot Data**
  - ✓ Test plot measurement (t/ha) suggests a certain representativeness' for a large areas, the "average rates & conditions "of erosion. This is because plot conditions are controlled & influencing factors such as soil types, slop angle, vegetation types few in number & rather homogeneous. Thus, test plot measurement simulates an aerial element, and is theoretically replicable at any location in the catchment with the same conditions.
  - ✓ The rill mapping represents the critical location of a field with "extreme "erosion, while the test plots represent an "average" erosion value.



To compare mapping & plot results, it thus appears appropriate to use the unit "mm top soil loss" instead of t/ha. The latter unit would give the wrong impression that also rill mapping results imply area coverage, which is not always the case.

➢**Measuring deposition in retention (soil and water conservation) structures, and measuring sediments in stream flow.**

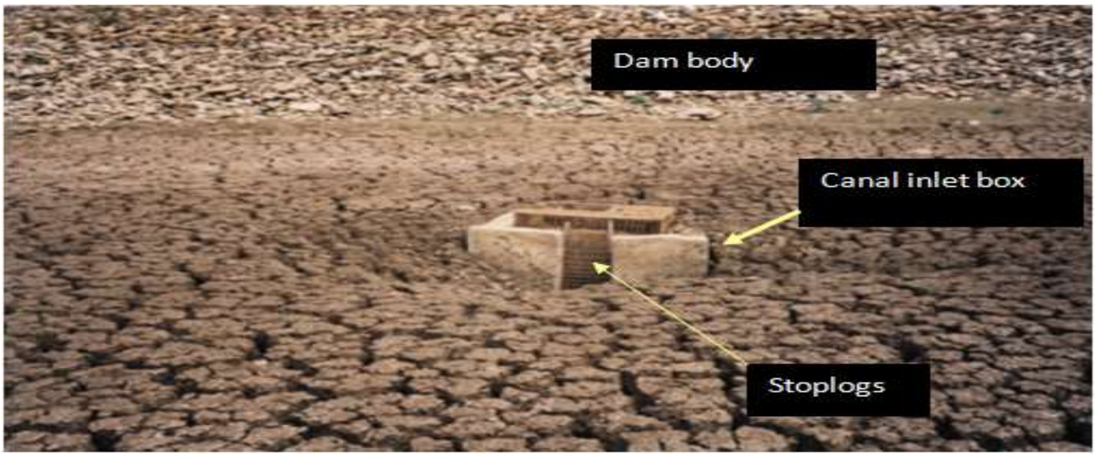
The main source of sediment yield measured in the river bed itself. However, since it is not possible to estimate the extent to which single source contributes, the entire catchment to be the area of actual damage.

Sediment yield studies

- Sediment yield is the net result of erosion and deposition processes. It is defined as the total sediment outflow from a catchment, measurable at a point of a reference and for a specified period of time. It can be expressed in absolute terms (e.g. t y-1) or in area specific terms (e.g. t ha y-1) Accurate estimation of sediment yield makes it possible to adapt the dimensions of planned constructions so that the actual lifetime of a reservoir or pond can meet the requirements.
- Sediment yield can be monitored using various techniques:
    1. Simultaneously monitoring the suspended sediment load and the water discharge,
    2. Measuring total eroded soil and deposited sediment volumes in small catchments and
    3. Measuring sediment volumes in ponds, lakes or reservoirs.
- An intensive program of sediment sampling enables the detail record of variations in sediment concentrations to be constructed, since the long-term sediment yield may be evaluated by combing the concentration record with the continuous record of stream discharge.
- Sediment yields can be measured by computing from stream discharges and sediment concentration.
- Information on sediment yield at the outlet of the river basin provides information on the rate of erosion and soil loss in a watershed upstream.

- Measurement of sediment yield at a single outlet can provide information on average rates of soil erosion within the basin. Large no of plots or similar measurements have to be made to derive an equivalent average.
  - Continuous impounding in reservoirs act as excellent sediment traps and successive reservoir surveys can be compared to determine the sediment volume accumulated during the survey interval. These surveys are necessary to get more realistic data estimate regarding the rate of siltation and to provide more reliable criteria for studying the implication of annual loss of storage over a definite period of time with a particular reference to reduction of intended benefits in the form of irrigation potential. Sediment volume in reservoirs can be used to reconstruct sediment yield values for large- areas. Especially in developing countries, this technique can be very helpful in establishing large data set on sediment delivery, as there are often no resources for expensive monitoring. However, measurement during peak flood discharge is not required.
  - Sediment yields can be computed from measured stream discharges and sediment concentration.

Sedimentation: Dam construction prior to catchment conservation leads to failure of the irrigation and hydropower intervention due to siltation problems earlier than the expected life of these developments.



The sediment yield of the respective catchment (river gauge) is included to show the amount of soil really lost from the catchment. Careful comparation of these three levels of measurement during extreme storms reveals a different in soil movement of about one order of magnitude between each level. However, soil loss may also vary considerably. the amount of soil lost due to rill erosion , which is frequently above 100mm, may also jump to more than 1000mm if the constellation of factors changes . The first three examples were measured under low vegetation cover; the last example shows a situation under high vegetation cover. The latter reveals again that high cover does not prevent soil loss during extreme events.

Name: ___________________________ Date: ________________

➢ **Short Answer Questions**

Self-Check -10	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Mention at least 3 standard erosion assessment and measurement techniques? (3points)

2. What is the limitation of USLE? (2points)

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ____________

Rating: ____________

Information Sheet-11	Analyzing gathered data

The **analysis of the qualitative and quantitative information** on soil erosion can be subsequently related to the community map and other land use and topographic maps of the study area to understand wider implications of soil erosion in the landscape.

Analyzing the gathered data

- ✓ Examine gathered data in detail in order to understand it better or draw conclusions from it
- ✓ Separation of gathered data into its constituents in order to find out what it contains, to examine individual parts, or to study the structure of the whole data
- ✓ assess, describe, or explain gathered data, usually through careful consideration or investigation
- ✓ Analyze & interpret the gathered site/soil erosion/ data into useful information for positive interventions. In doing so now days many soft- wares are developed & exist on the market to aid the analysis, so choose appropriate software to be used.
- ✓ Interpretations may be in the form of percentage, average, graph, etc

Name: _________________________ Date: _______________

- **Short Answer Questions**

Self-Check -11	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Why analyzing & interpreting the gathered site/soil erosion/ data into useful information? (3points)

2. List forms of Interpretations (2points)

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ___________
Rating: ____________

Information Sheet-12	Carrying out assessments

12. Carrying out assessments

Carrying out assessments or evaluation throughout the whole assessment activities. Monitoring and evaluation of whole assessment works/activities helps us weather the goal set in plan will be achieved or not.

Purposes of Monitoring and Evaluation

- Ensuring planned results are achieved
- Improving and support management
- Generating shared understanding
- Generating new knowledge and support learning
- Building the capacity of those involved
- Motivating stakeholders
- Ensuring accountability
- Fostering public and political support

A. Monitoring

Erosion assessment & measurement monitoring is the process of (1) tracking the implementation of erosion assessment & measurement plan decisions (implementation monitoring) and (2) collecting data/information necessary to evaluate the effectiveness erosion assessment & measurement plan decisions (effectiveness monitoring)

- ☞ **Implementation monitoring** is the process of tracking and documenting the implementation (or the progress toward implementation) of erosion assessment & measurement plan decisions. This should be done at least annually and should be documented in the form of a tracking log or report. The report must be available for public review (one way to accomplish this is an annual planning update which can be sent to those who participated in the planning process or have expressed an interest in receiving the report). The report should describe management actions proposed or undertaken to implement erosion assessment & measurement plan decisions and can form the basis for annual budget documents. In subsequent years, reports should document which management actions were completed and what further actions are needed to continue implementing erosion assessment &

measurement plan decisions.

- ☞ **Effectiveness monitoring** is the process of collecting data and information in order to determine whether or not desired outcomes (expressed as goals and objectives in the erosion assessment & measurement plan) are being met (or progress is being made toward meeting them) as the allowable uses and management actions are being implemented. A monitoring strategy must be developed as part of the erosion assessment & measurement plan that identifies indicators of change, acceptable thresholds, methodologies, protocols, and timeframes that will be used to evaluate and determine whether or not desired outcomes are being achieved.

The monitoring process should collect information in the most cost-effective manner and may involve sampling or remote sensing. Monitoring could be so costly as to be prohibitive if it is not carefully and reasonably designed. Therefore, it is not necessary or desirable to monitor every management action or direction. Unnecessary detail and unacceptable costs can be avoided by focusing on key monitoring questions and proper sampling methods. The level and intensity of monitoring will vary, depending on the sensitivity of the resource or area and the scope of the proposed management activity.

B. Evaluation

Evaluation is the process of reviewing the erosion assessment & measurement plan and the periodic plan monitoring reports to determine whether the erosion assessment & measurement plan decisions and the **National Environmental Policy Act (NEPA)** analysis are still valid and whether the plan is being implemented. Erosion assessment & measurement plan are evaluated to determine if:

(1) decisions remain relevant to current issues,

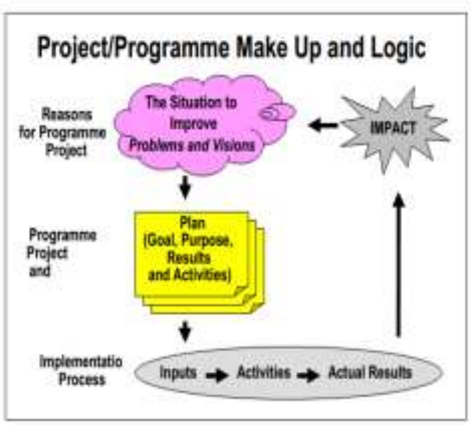
(2) decisions are effective in achieving (or making progress toward achieving) desired outcomes,

(3) any decisions need to be revised,

(4) any decisions need to be dropped from further consideration, and

(5) any areas require new decisions

In making these determinations, the evaluation should consider whether mitigation measures are satisfactory, whether there are significant changes in the related plans of other entities, and whether there is new data of significance to the plan.



Name: ________________________ Date: _______________

- **Short Answer Questions**

Self-Check -12	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What are the purpose of monitoring and evaluation? (3points)
2. ___________is the process of reviewing the erosion assessment & measurement plan and the periodic plan monitoring reports to determine whether the erosion assessment & measurement plan decisions and the National Environmental Policy Act (NEPA) analysis are still valid and whether the plan is being implemented. (2points)
   A. Evaluation B. Monitoring C. Effectiveness monitoring D. Implementation monitoring

Note: **Satisfactory rating >2.5 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ___________

Rating: ____________

Operation Sheet 01	Assessing Erosion Hot Spot Areas

This part of the learning guide in your possession contains lessons about assessment of erosion hot spot areas. Therefore, based on the information provided assess erosion hot spot areas -

Objectives

- ✓ To assess erosion hot spot areas

Procedures:

- ➢ Make necessary arrangements
- ➢ Prepare simple data collection sheet and checklist
- ➢ Collect basic information about specific site
- ➢ Contact with the people and organizations to be affected by erosion
- ➢ Make preliminary observation of the area
- ➢ Record relevant evidences of erosion
- ➢ Identify following OHS procedures
- ➢ Delineate the area to be assessed & measured in consultation with the community
- ➢ Identify the extent & severity of erosion in a delineated area (Erosion Hot Spot Areas) using, first, visual indicators of erosion
- ➢ Apply Erosion Assessment and Measurement standard Techniques particularly USLE
- ➢ Analyze the gathered data
- ➢ Present your outcome in appropriate reporting format

Operation Sheet 02	Measurement of gully and ravine erosion

This part of the learning guide in your possession contains lessons about gully measurement. Therefore, based on the information provided assess gully measurement -

Objectives

- ✓ To measure gully erosion

Procedures:

For an area where the average dimensions of many measured gullies or ravines estimate soil loss in ton/ha/yr using the following steps:

1. Measure the average cross-sectional area (width at lip = ____ m, width at base = _____ m, depth = _____m of the gully/rill in a study area, assuming a trapezoidal cross-section
2. Measure the gully length in the study area, and then compute the volume of soil lost from an average gully or ravine.
3. Delineate and determine the catchment area of the gully
4. Convert volume of soil lost in step 2 to a volume per catchment area (square meter).
5. Estimate soil bulk density value of the area using oven dry method in your local soil laboratory or use secondary data of the area available.
6. Convert the volume per square meter soil lost in step 4 to tonnes per hectare
7. Interview the indigenous people about the age of the gully in year(s).
8. Convert tonnes per hectare by dividing by the age of the gully to tonnes per hectare per year (t/ha/yr)

Hint: Using the average measurements of width at lip and width at base, and depth, calculate the average cross-sectional area of the gully or ravine (considering the cross-sectional shape is trapezoid); using the formula:

(width at lip (m) + width at base (m) / 2) * depth (m)

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions:

1. You are required to perform any of the following:

   1.1. Request your trainer to arrange for you to join a survey team of erosion assessment and measurement Make sure you assess and measure an area using appropriate techniques.

   1.2. Request a set of erosion assessment and measurement, then perform the following tasks in front of your trainer–

   - Undertake soil erosion assessment and measurement using Field scoring method.
   - Undertake gully erosion measurement

2. Request your trainer for evaluation and feedback

List of Reference Materials

1- BOOKS

Mitiku, H., Herweg, K., Stillhardt, B., 2006 *Sustainable Land Management – A New Approach to Soil and Water Conservation in Ethiopia*. Mekelle, Ethiopia: Land Resources Management and Environmental Protection Department, Mekelle University; Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern, and Swiss National Centre of Competence in Research (NCCR) North-South. 269 pp.

MOARD. 2010. *Sustainable Land Management-* Sustainable Land Management Project (SLMP), Natural Resources Management Sector, Ministry of Agriculture and Rural Development of the Federal Democratic Republic of Ethiopia. Indigenous and introduced technologies to be scaled up in the various agro-ecological and farming practices of Ethiopia.321pp.

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Liniger, H.P., R. Mekdaschi Studer, C. Hauert and M. Gurtner. 2011. Sustainable Land Management in Practice – Guidelines and best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).

Humberto Blanco and Rattan Lal.2008. Principles of Soil Conservation and Management. Current address:Kansas State University Western Agricultural Research Center-Hays 1232 240th Avenue Hays, KS 67 601 USA; The Ohio State University 2021 Coffey Road Columbus OH 43210 422B Kottman Hall USA.

R. P. C. Morgan. 2005. *SOIL EROSION AND CONSERVATION* .3rd ed. published by Blackwell Publishing Ltd. ISBN 1-4051-1781-8 (pbk. : alk. paper): A catalogue record 2004009787.