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Instituto Internacional de Agricultura Tropical (IITA)

Soil sampling and sample preparation

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Research Guide
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IITA Research Guide 2

Soil sampling and sample preparation

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IITA Research Guides

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Soil sampling and sample preparation

Objectives. This guide is intended to enable you to:

- explain the nature of soil variation;
- determine the number of samples required;
- take soil samples according to four sampling plans;
- prevent sampling errors;
- conduct sub-sampling and composite sampling;
- take soil samples and prepare samples for analysis.

Study materials

- Samples or photographs (color slides) of soil profiles,
- Photographs of topographic variation.
- Soil samples.
- Sampling tools.
- Sample preparation tools.

Practicals

- Demonstrate soil variation in the field.
- Practice soil sampling according to sections 3 to 6.
- Calculate number of samples required.
- Make composite samples.
- Take soil samples and prepare them for analysis.

Questions

- 1 Why is obtaining a representative sample not easy?
- 2 What is often the fault of incorrect laboratory data?
- 3 Why do soil sampling methods vary?
- 4 What factors cause variation among soils?
- 5 What is the effect of vegetation on soil variation?
- 6 On what condition does intensity of soil sampling depend?
- 7 What instructions does the first step in soil sampling include?
- 8 What are the four types of sampling plans?
- 9 On what parameters does the number of samples required depend?
- 10 Describe judgment sampling.
- 11 Where is random sampling needed?
- 12 What are the steps in simple random sampling?
- 13 Why should you sample farms or fields according to soil areas?
- 14 What does "stratified sampling" mean?
- 15 Why is systematic sampling popular?
- 16 Under what conditions is systematic sampling inefficient?
- 17 How can you overcome sampling errors in systematic sampling?
- 18 How can you eliminate selection errors?
- 19 Describe sub-sampling and composite sampling.
- 20 Describe the steps of sample preparation.

Soil sampling and sample preparation

- 1 Nature of soil variation**
- 2 Number of samples required**
- 3 Judgment sampling**
- 4 Simple random sampling**
- 5 Stratified random sampling**
- 6 Systematic sampling**
- 7 Sources of error**
- 8 Sub-sampling and composite sampling**
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Abstract. The approach to soil sampling depends on the reasons for soil analysis. Soil is not a homogeneous mass. Plant life, topography, agronomic practices, etc. affect the uniformity of a soil. The accuracy of the soil analysis data depends on the accuracy with which the soil samples are taken.

1 Nature of soil variation

The starting point of a soil analysis is obtaining a representative soil sample. Obtaining this sample is not simple because soil is not just a neatly mixed variety of minerals, deposited in a uniform manner, but a complex living media of a very heterogeneous nature.

Soil analysis is only as good as the soil sample used. When laboratory data is criticized, the fault has often occurred at the sample gathering stage.

Soil sampling methods vary depending on the reasons for the analyses:

- For analysis of soil fertility, the sample might be extracted from a depth comparable to the rooting zone.
- For soil classification for mapping purposes, soils should be mapped and described according to their texture, color and the thickness of each layer or horizon.
- For non-agricultural purposes, parameters such as compaction, bearing capacity, shearing strength and infiltration are examined.

Soil is never homogeneous. Heterogeneity exist even among soils that are classified as belonging to the same unit. It is important to consult reference material on the subject and become familiar with a specific soil series before attempting to take a sample.

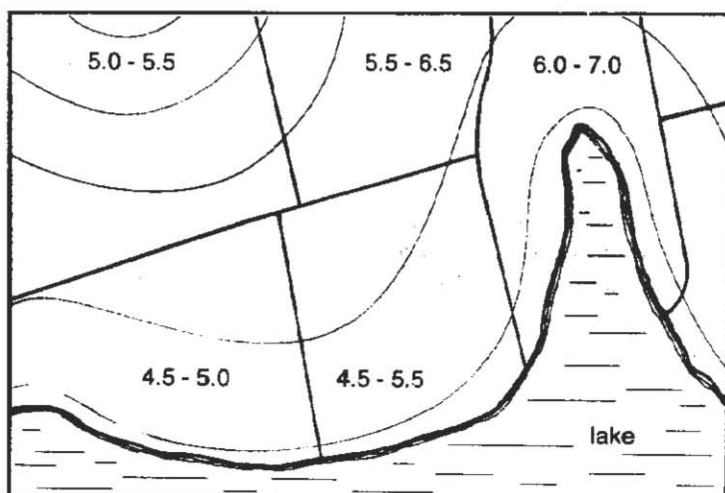
Many factors may cause variations among soils. Some more influential factors are:

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- vegetation,
 - topography,
 - cropping and tillage practices.

Vegetation. The type of plant life which covers a certain area of land can exert its influence in several ways. Changes in soil composition can occur when plant residue is incorporated into the soil. This is often the case after harvesting. Also, the structure of the soil is affected. The crop canopy and rooting system protect the soil from rain damage and severe temperatures, and make soil less susceptible to erosion and leaching.

Topography. Good top soil is often eroded from hilltops and ridges and can be found deposited, along with clay, in the lower areas. Figure 1 shows the influence of topography and cropping practices on soil acidity (pH). Each field has been planted with a particular crop for several years.

Figure 1. Soil acidity (pH) of different fields.



Cropping and tillage practices. The distribution of soil nutrients, and thereby the composition of soils, vary among those that are heavily tilled and those that are worked only slightly or not at all. As a result, samples from fields with different cultivation practices are to be taken from different depths.

Regardless of which factors have been most instrumental in causing variation in soils, whether variations are caused by vegetation, topography, cropping, tillage, or a combination of all four, they influence the intensity with which a soil must be sampled. The more heterogeneous the soils which make up a sample population, the more intense the sampling must be in order to obtain a given accuracy.

The first step in gathering soil samples is to make a detailed plan of the sampling technique used. This should include proper instructions on:

- the depth of sampling the soil;
- the amount of sample required;
- the number of samples required for a given accuracy.

There are four types of sampling plans:

- judgment sampling - Section 3,
- simple random sampling - Section 4,
- stratified random sampling - Section 5,
- systematic sampling - Section 6.

2 Number of samples required

It is often important to take a statistically correct number of samples representing the area surveyed. To test for a particular quantifiable soil characteristic, determine the number of samples required by estimating the mean (\bar{Y}) and the variance ($V(\bar{Y})$) of the mean, given by the following equation:

$$\bar{Y} = \Sigma y_i / n$$

$$V(\bar{Y}) = \Sigma (y_i - \bar{Y})^2 / n(n-1) = s^2 / n$$

where y_i is the value observed for the sampling unit and n is the number of sample units in the sample. If more than 10 % of the population is included in the sample, an adjustment has to be made in the estimate of the variance of the mean. s is the standard deviation.

Confidence limits (L) may now be expressed by the following relationship:

$$L = \bar{Y} \pm t_a(s^2 / n)^{1/2}$$

t_a = student's t distribution with $n-1$ degrees of freedom at the a probability level, and s^2/n is as previously defined.

If an estimate of the variance or standard deviation is available, or if the variance can be calculated from the population, then it is possible to decide the number of samples required to give a certain accuracy. The equation used to determine the number of samples needed within a specified limit or accuracy is:

$$n = t_a^2 \times s^2 / D^2$$

where D = specified limit (accuracy).

Example: How many samples do you need from a field to estimate its mean potassium status within ± 5 ppm (D) at 95 % probability.

Assume that 10 preliminary core samples were taken and analyzed for exchangeable K:

sample core	ppm K	$y_i - \bar{y}$	$(y_i - \bar{y})^2$
1	59	2	4
2	47	-10	100
3	58	1	1
4	80	23	529
5	57	0	0
6	62	5	25
7	52	-5	25
8	50	-7	49
9	47	-10	100
10	58	1	1
$\bar{y} = 57$		$\Sigma = 834$	

t_a for $n - 1$ ($= 9$) d.f. $= 2.262$; (see t-table in statistics books).

$$s^2 = \sum (y_i - \bar{Y})^2 / (n - 1) = 834 / 9 = 92.7$$

$$D^2 = 5^2 = 25$$

$$n = t_a^2 \times s^2 / D = (2.262)^2 \times 92.7 / 25 = 18.9$$

Result: You need 19 (18.9) samples to estimate the mean potassium status within ± 5 ppm (D) at 95 % probability.

The 95 % confidence limits (L) can now be calculated as follows:

$$L = 57 \pm 2.262 (92.7 / 10)^{1/2} = 57 \pm 6.9$$

With 95 % confidence, we can say that the true mean potassium status of the field lies between 50.1 and 63.9 ppm K.

3 Judgment sampling

Researchers, scientists, or farm managers may be called in when a crop shows a certain growing pattern or when surface differences are observed for a soil. For example, differences may occur in soil color which may be the result of many factors. The researcher judges the color differences: e.g. he may judge a particular shade of color to be typical for a sample at certain sites. Then from these sites, samples are drawn. The accuracy of these samples depends totally on the judgment of the researcher – which may or may not be good.

Some persons, in order to include as many extremes as possible, commit the error of over sampling. Probably less desirable is the person who takes the opposite approach, excluding the extremes and ending up with a sample which is not representative. In either case, the judgment of the sampler determines the accuracy of the results.

In certain situations, sample choices based on judgment are accurate enough. For example, if small sites are involved and no estimate of accuracy is needed, judgment sampling might be satisfactory. As the sample site becomes larger, and the selection of representative samples becomes more difficult and time consuming, judgment sampling is inaccurate and other sampling methods must be used.

4 Simple random sampling

Simple random sampling is a more precise method of taking soil samples and is less biased by the sampler than judgment sampling. Judgment sampling is used where soil or cropping differences are noticeable and where the focus of the survey is only on one particular area of the field. Random sampling is needed where the soil differences are not immediately noticeable by color, texture, etc. and selection of representative samples becomes more difficult.

Simple random sampling could be used, for example, to take a soil sample in a small experimental plot where high accuracy is needed. In this case, sampler bias must be eliminated as much as possible for the sample to be representative of the entire plot.

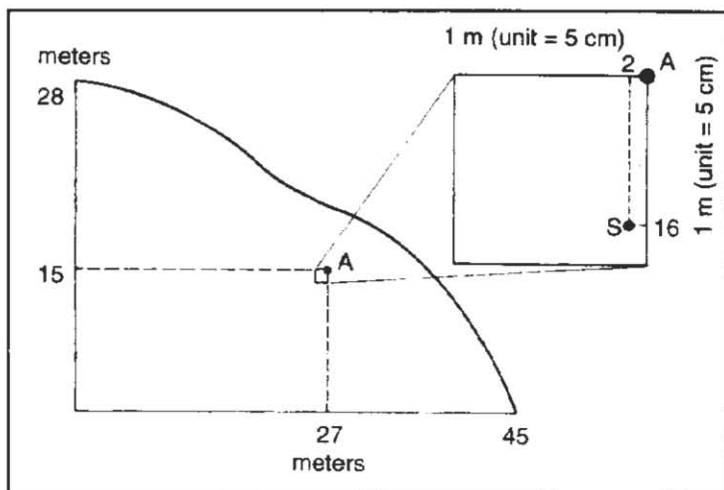
Following are the steps needed to take a random soil sample:

- Obtain a map or sketch of the area to be sampled.
- Decide upon a scale for the sketch: if it is a large field, you may decide that 1 cm equals 100 m; if a small field, 1 cm could equal 1 m. (Use any convenient unit of measurement such as feet, paces, yards, etc. if preferred).
- Select a corner of this map and draw two lines connected at one point at right angles to each other (Figure 2). They do not need to be equal in length. Each will extend from the point at which they meet to the farthest point at the edge of the field. The important thing is to cover as much of the field as possible using two lines joined at one end. These lines are usually called the "axes".

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- Using the map scale units you decided on, determine the length of the two axes. (Example: one axis is 28 cm and the other is 45 cm, corresponding to 28 m and 45 m in the field).
 - Number slips of paper from 1 to the highest number of units on either of the two axes (Example: numbers 1 to 45). Place the numbers in a box and shake well.
 - Draw any one number between 1 and 45 from the box at random without looking (for example 27). Return the number to the box and draw a second number between 1 and 28 (for example 15).
 - Plot the point of the first number on its axes and the other number on the other axes. These two points are called "coordinates".
 - Plot the point where the coordinates intersect in the field (Point A in Figure 2). This is the *approximate* location where the sample will be taken.
 - Draw two new axes parallel to the first, at right angles, starting from the point you just marked (see enlarged insert in Figure 2).
 - Roughly measure the width of your sampling device. (Example: if you are using an auger, the auger might have a diameter of 5 cm).
 - Divide the unit of measurement you decided on for the field by the diameter of the sampling device. (Example: We chose 1 m, which is 100 cm; $100 \text{ cm} / 5 \text{ cm} = 20$).
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- Put slips of paper numbered 1 to the number you just calculated into a box and shake. (Example: papers numbered 1 to 20).
- Draw two slips of paper. These are your new coordinates. (Example: 2 and 16).
- Find the spot in the field that corresponds to the intersection of the coordinates (point S). This is where you take your sample (Figure 2).
- Using the field units chosen, measure out in the field what you have plotted on paper, and take the sample with your sampling device.

Figure 2. Random sampling.

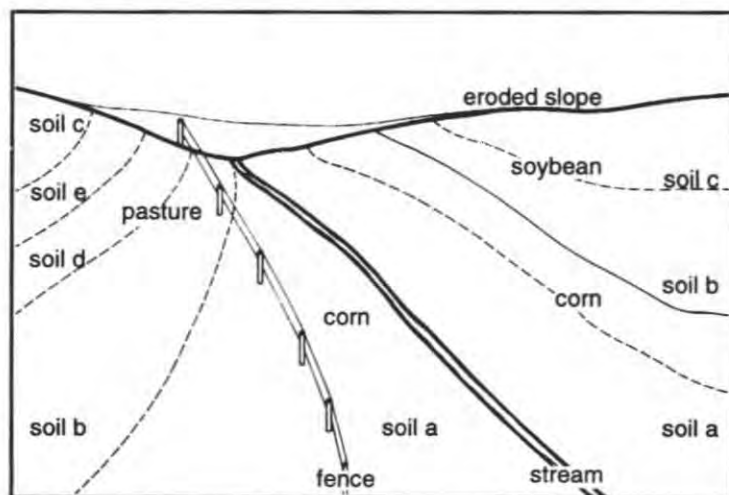


5 Stratified random sampling

Farms or fields should be sampled according to soil areas. Different histories of crop management require separate samples even on the same soil. Eroded areas or other poor yielding spots must be sampled and evaluated separately. Samples have to be taken from each soil and crop sequence (Figure 3).

When stratified random sampling is used, the population, i.e. a field or plot, is divided into sub-populations (strata). For example, the strata may be a ridge, a slope, a low area or a level area. A simple random sample is taken from each strata.

Figure 3. Stratification of soils (Smith 1976, modified).



The scientist or researcher prefers this sampling method for two reasons:

- to make a statement about the sub-population,
- to increase the accuracy of estimates over the entire population.

Since the sampler selects stratified random sampling for its accuracy, stratification must eliminate some variations caused by any sampling errors. In general, accuracy increases as stratification becomes more well-defined.

To estimate the sampling error of a stratum, sample at least two units. If the stratum is kept small enough, a good estimate of error can be obtained.

One final point to keep in mind when applying this sampling technique is that the stratum is sampled in proportion to the total. If it is 20 % of the total, then the number of sampling units to take from the stratum should be 20 %.

6 Systematic sampling

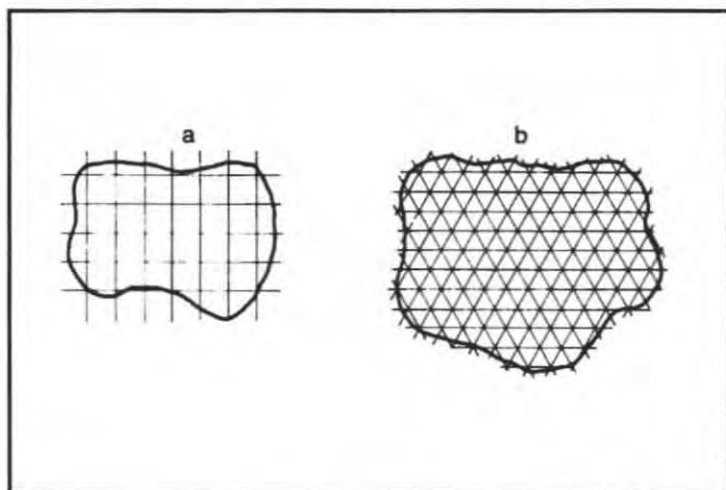
Systematic sampling is popular because it is accurate and relatively easy to use.

Systematic samples are taken from sites that are equidistant from each other, either in one or two dimensions, forming a grid. Select the first unit at random. Take the following samples at uniform intervals.

Figure 4a consists of a grid formed when two sets of equidistant parallel lines are intersected at right angles to each other.

Figure 4b consists of equidistant, parallel lines, set at 60 degree angles. Triangles are formed by drawing horizontal lines through the intersections.

Figure 4. Grid patterns for systematic sampling.



Although the systematic grid pattern usually allows more accurate sampling, under certain conditions, it is inefficient. Madow (1944) found this to be the case when a fertility gradient existed, either along the rows or columns of a field. For this reason, systematic designs cannot be applied to fields having a slope or drainage problem without first considering the form of population distribution.

The main problem of systematic sampling is how to estimate sample error. There are several approaches:

- 1 Assume that the population was in random order before the systematic sample was drawn. Estimate the sample error in the same way as the simple random sample.
- 2 Block or stratify the sample, assuming that variations among units within a block are sample variations. Estimate the sample error as with the stratified random sample.
- 3 Take a number of separate, systematic samples, drawn at random from all possible systematic samples of the same type. Calculate the mean and treat as a simple random sample.

7 Sources of error

In the process of gathering soil samples for use in laboratory investigation, errors can occur at several stages:

- sampling errors,
- selection errors,
- measurement errors.

Sampling errors. Sampling errors cannot be eliminated entirely. Since sampling means to take a part, errors can be reduced by careful selection.

Selection errors. Selection errors can occur when a sampler, eager to do a good job, over-samples the borders of a field. Sampling in rocky areas can also cause error. The errors often cancel each other. Otherwise the sampler may employ the two-step procedure of the simple random sampling which is designed to eliminate selection errors.

Measurement errors. These types of errors arise in various circumstances:

- When the measurement taken is not the true value of the unit. One example is the *random error*. A random error takes place when cores of soil are mistakenly assigned constant weights, even though they are variable.
- As a result of variations in analytical techniques. Fortunately, random errors of measurement tend to cancel each other as the sample size becomes larger.
- Bias errors arise either because tare weights are ignored or because of an offset calibration of the appropriate curve.

8 Sub-sampling and composite sampling

Sub-sampling. In many soil investigations, sub-sampling or multi-stage sampling is advantageous. To subsample, first divide a sample unit into small portions. Then choose a second sample from these portions and measure it according to the characteristics under consideration. This method of sampling, frequently used when bulk density cores are taken, saves both time and money.

Composite sampling. When conducting laboratory analysis, using a composite sample instead of individual samples saves time and money. To obtain composite samples, first take a number of field samples of equal amount sufficient to represent the population. Then mix them to form one composite. Laboratory analyses is done on this composite or a subsample of it.

9 Sampling tools and sample preparation

A sampling tool should be:

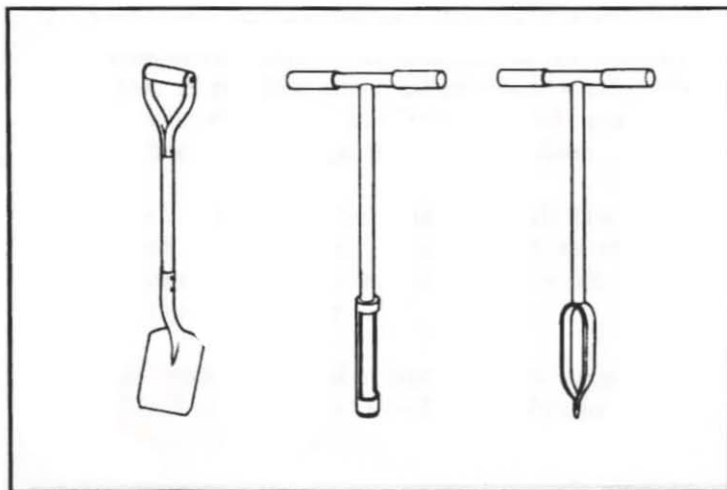
- uncontaminated,
- approximately uniform in cross section to the desired depth,
- provide reproducible sampling units.

Tapered cores or slices may bias the analysis result if systematic variations with depth are significant.

Commonly used sampling tools are (Figure 5):

- blades: trowel, spade, shovel, spoon, knife, cutlass;
- tubes: open-sided and plain cylinders;
- augers: wood-bit, post-hole, sheathed auger.

Figure 5. Blade, tube, and auger (left to right).



For comparison over periods of time, take soil samples at approximately the same time of the year (e.g. before planting). When making comparisons, consider other factors like weather conditions, crops, treatments, seasonal fluctuations.

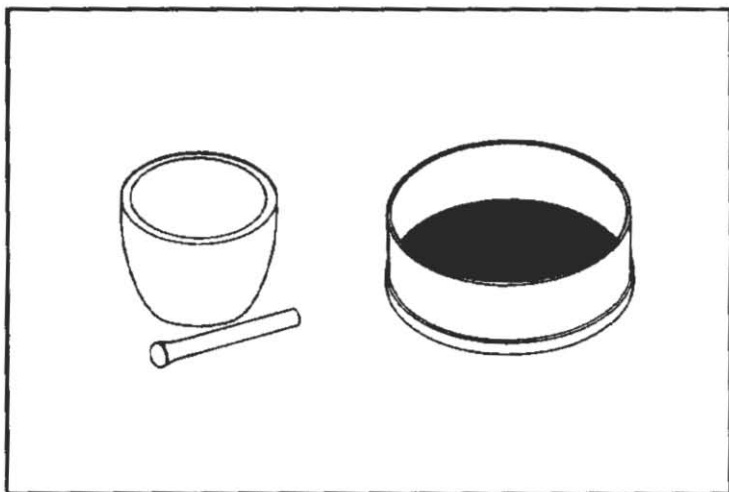
Select sampling depth according to the purpose of sampling. For soil fertility evaluations in annual crops, sample at a depth of 0 to 15 or 0 to 20 cm. For perennial crops (e.g. trees), take deeper samples since tree roots often grow deep into the soil.

Soil samples usually need preparation before laboratory analysis:

- *Air-drying.* Crush large soil clods to facilitate drying. Do not dry at high temperature. During air-drying, avoid contamination (i.e. from dust, gases, rain, etc.). Air-drying usually takes one week.
- *Crushing.* Crush the sample in a mortar using a rubber or porcelain-capped pestle (Figure 6). The mortar is usually made from porcelain.
- *Pulverizing.* Not all samples require pulverizing. The sub-sampling error is a function of the ratio between the average weight of the largest particles and the weight of the subsample. If the subsample being analyzed is small (i.e. for total nitrogen and organic carbon analysis), the sample has to be pulverized to a fine powder (less than 0.5 mm).

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- **Sieving.** Sieve the soil through a 2 mm sieve made of brass, stainless steel, or plastic. Use plastic sieves when micro-nutrients are to be analyzed.
 - **Mixing and storage.** Mix samples thoroughly, then store in clean closed containers (i.e. polyethylene bags or bottles). Label the containers.

Figure 6. Mortar, pestle, sieve.



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11 Suggestions for trainers

If you use this Research Guide in training:

Generally:

- Distribute handouts (including this Research Guide) to trainees one or several days before your presentation, or distribute them at the end of the presentation.
- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listen to you.
- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (and this Research Guide) contain all relevant information.
- Keep your training activities practical. Reduce theory to the minimum that is necessary to understand the practical exercises.
- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, etc.). Allow consultation of handouts and books during examinations.
- Promote interaction of trainees. Allow questions, but do not deviate from the subject.
- Respect the time allotted.

Specifically:

- Before presenting your subject, ask participants about objectives and difficulties of soil sampling (5 minutes).
- Present and discuss the content of this Research Guide. Have soil samples, tools and implements at hand. Use slides or overhead transparencies for the illustrations.
- Conduct practicals according to the suggestions on page 3 in small groups, 3 to 4 participants per group. Design a different practical for each group. If practicals have the same duration, you can "rotate" the groups through the practicals. Assign a resource person to each group.



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The International Institute of Tropical Agriculture (IITA) is an international agricultural research center in the Consultative Group on International Agricultural Research (CGIAR), which is an association of about 50 countries, international and regional organizations, and private foundations. IITA seeks to increase agricultural production in a sustainable way, in order to improve the nutritional status and well-being of people in tropical sub-Saharan Africa. To achieve this goal, IITA conducts research and training, provides information, collects and exchanges germplasm, and encourages transfer of technology, in partnership with African national agricultural research and development programs.

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