COLLAGE OF AGRICULTURE AND NATURAL RESORCES, DEPARTMENT OF PLANT SCIENCES

SOIL SCIENCE PROGRAM (MSc)

Soil Survey and Land Evaluation

SOSC 5322

PREPARED BY
MEKONNEN ASRAT (PhD)

DEBRE MARKOS
2019

<u>Course outline for Soil Survey and Land Evaluation (SoSc5322)</u>

Chapter 1. Definition and objective of soil survey

1.1. What is soil survey
1.2. Objective of soil survey
1.3. The beneficiaries of soil survey

Chapter 2. Principles, procedures, soil survey types and common terminologies of soil survey

2.1. Principles of soil survey
2.2. Procedures to be followed in soil survey
2.3. Soil survey types
2.4. Definitions of common terminologies used in soil survey
- Landscape properties
- Soil characteristics

Chapter 3. Soil mapping

3.1. Definitions of common terminologies used in soil mapping
-Soil Map Units
-Scale
3.2. Different soil mapping types

Chapter 4. Non-FAO land evaluation methods

4.1. Non-FAO land classification method
4.2. USDA land capability classification
- Definitions of land *capability un* and capability unit
-Soil profile characteristics for the method
4.3. Assumptions of the method
4.4. Classifying evaluation units
4.5. International adoptions
4.6. Parametric system for evaluation
- Additive system
- Multiplication systems
- Interpretation
4.7. Scheme of the classification method
4.8. Land capability classification for potential use
4.9. Procedure of the method
4.10. Recommended land use and conservation practices for different capability classes
4.11. Limitations of the method
4.12. Relation to FAO evaluation method

Chapter 5. FAO land evaluation method

5.1. Definitions of the common terminologies used in land evaluation
Land use
Land cover
Land use planning
Land utilization
Land characteristics
Land quality
Land use requirements
Major kind of land uses
Land suitability class suitability class and sub class
5.2. Statistical modeling
5.3. Yield estimation -Principal components in yield prediction
5.4. Principles of the method
5.5. Soil erosion survey
5.6. Suitability order, class, sub-class and unit
5.7. Definition of land classes
5.8. Rating
5.9. Classifying evaluation units for agricultural land
5.10. Evaluation of land for forestry
5.11. Evaluation for non-agricultural uses

Chapter 6. Land evaluation for irrigation usage

Chapter 7. Land classification in Ethiopian context

Chapter 1

Definition and objective of soil survey

1.1. What is soil and soil survey?

The term land generally includes such natural resources as soil, mineral deposits, climate, water supply, location in relation to markets and transportation, vegetative cover, and structures such as buildings and terraces. **Land** comprises the physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use. It includes the results of past and present human activities. Land is a renewable resource if it is handled properly, but in actual condition it is **c**ontinuously degraded and become scarce due to its higher demand and becoming non-renewable. Land is not same everywhere depending on its location, soil genesis and land use.

The soil an important is component land. Soils are complex and variable. Soil's chemical and physical properties differ from one location to another on both large and small scales. Certain soil differences have a great influence on the suitability of the soil for specific uses; other properties may be more important for other uses. For example, the contents of various plant nutrients are a concern where plants are to be grown, but physical properties like texture and permeability are more important when soil is used to build a road or a dam.

Soil survey is a branch of soil science which involves the identification of the different types of soil in a given landscape and the location of their distribution to scale on a map. In addition, soil survey provides information on the quality of the land in terms of its response to management and manipulation. From this definition, it is clear that soil classification is a branch of soil survey and the unit of classification is the taxonomic unit or mapping unit or pedon. A taxonomic class depicts the properties of a soil profile as given in the profile description and analyses.

Soil resources surveying is deal with natural resources survey and information gathering required in interpretation of soil characteristics for land evaluation. Soil survey required soil characteristics that collected from the field and laboratory analysis. Soil surveys are an inventory of soil resources constituting soil characteristics data that may affect land use types. They are not a definitive, accurate picture of the spatial relationship of all soils and soil attributes. According to USDA definition soil survey is the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of soils on a map, and makes predictions about the behavior of soils.

On the other hand, a soil survey describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and makes predictions about the behavior of soils. The different use of the soils and how the response of the management affects them are considered in designing and carrying out the survey. The information collected in a soil survey helps in the development of land use plans and evaluates and predicts the effects of land use on the environment. Thus, it describes soils characteristics and classifying according to standard system of the given area.

1.2. Objective of soil survey

The tasks of soil survey are soil description, classification, analysis and mapping. For practical purpose, soil survey's data are numerous, more accurate and useful predictions of land performance to be made for specific purpose than could have been made otherwise, i.e. the absence of location specific information about soils.

Soil survey study soils on the landscapes where they occur, delineate soil areas on maps, and describe their characteristics. Collect and recorded information that required for classifying the soils to evaluate their suitability for various uses. Soil surveys provide sound full information for land management of farms and ranches. Soil survey is helpful in providing the full information to implement precision agriculture; a modern method of management through subdivides fields into small management units and applies variable rates of seed, fertilizer, pesticides and soil amendments.

Soil surveys are also used as a guide for mechanizing cultivation in developing countries, for identifying areas of nutritional deficiencies and toxicities for animals and people, for proper disposal of wastes, and for general land development. The information collected in a soil survey helps for the development of land use plans and evaluations and predicts the effects of land use on the environment.

Soil is described as a natural body consisting of layers or horizons of mineral and/or organic constituents of variable thickness, which differ from the parent material in their morphological, physical and chemical, and mineralogical properties and biological characteristics. This implies that: it has a map unit made up of pedons which are comparatively similar in terms of horizon sequences, soil properties and parent material e.g. soil series, a taxonomic unit, mapping of physical, chemical, biological; and morphological properties of soils.

Soil survey reports (texts and maps) are valuable as a scientific basis for land use planning. Such plans should be made on a sustainable basis so that the land will be productive in the future as well as at present. The concepts of prime and unique agricultural lands were developed to preserve productive soil for essential food, feed, and fiber crops. Such areas are delimited only with the help of a soil survey. Town and county planning and zoning agencies are now using soil surveys as a basis for their ordinances and orders. Construction projects that result in major soil disturbances now require environmental impact statements. Soil factors are essential in the preparation of environmental impact statements.

The main practical purpose of correlation is to allow efficient technology transfer**,** i.e. experiences in one area to be applied to another area. Some soils with similar properties occur over wide geographic area, even discontinuous area, with some local modifications, it may applied in other areas of the same soils.

1.3. The beneficiaries of soil survey

Soil survey data are helpful for make decision on land use and management of various development organization (agents) such as farmer, forester, engineer, planner, and others. Soil surveys must know their consumers: the consumer is a person or organization who needs information to know something about soil properties. These consumers are

- Land managers: such as farmers, ranchers, foresters, and plantation managers. This group decides what to do with each land area, i.e. what do to use it for, and under what management system. Since arable farming is the kind of land use to which soils survey is most directed, farmers would be the min users. In case of foresters, they need soils suitable for tree species, input costs (establishment & maintenance of roads), output (timbers).
- Advisors of land managers: extension workers. Advisory staff has the task of carrying experience from one farm to another and of introducing new techniques, derived from research. The soil series is the most convenient unit for this purpose, and the advisory service progressively builds up a body of management experiences linked to series.
- Service industries related to land use/private investors**:** e.g. agricultural credit agencies, banks, investment groups (if their investment will be productive)
- Land user planners: rural, suburban, peri-urban, and urban. (Prohibits, advises, or facilitates certain kinds of land use in different areas). This may involve the allocation of each part of the farm to a major kind of land use (rotational arable, permanent pasture, forest lot, etc.) and the incorporation of soil conservation measures. It is also used in land capability classification (LCC) and land suitability evaluation. Planners want to change existing land uses to other beneficial uses: grazing to forestry; arable to urban; forestry to arable, etc. There is a need to then to assess the suitability of the soils/land for the intended purposes.
- Taxation authorities**:** Land tax on its productive potential.
- Environmental managers: who use the soil as an element of landscape ecology
- Researchers**:**
  - ✓ For various land uses and management strategies, e.g. agricultural experiments; fertilizer responses; disease resistance; they expect the soil units respond differently to management
  - ✓ For various natural and human processes: hydrologists, geographers, etc
- Development organization**:** In developing countries, the primary call for soil surveys comes from the agencies responsible for rural development. These include international organization (FAO), national and regional governments of the countries concerned.
- Engineers: They need soil information for foundation of road and building, disposal of sewage and other wastes including toxic materials. Engineering tests may include: shear and compressive strength, plasticity, shrink-swell characteristics, corrosivity to steel and concrete.

Therefore soil survey results can be applied in three ways:

1. Planning and management of farming, ranching and forestry
2. Engineering and related purposes
3. Evaluating the suitability of the land for alternative uses during regional and urban planning

In developing countries, soil survey has much to do in many ways:

1. **Resource inventory and project location**-in understanding nature and extent of resources, identification of promising areas for specific projects Ex. Resettlement
2. **Project feasibility:** a feasibility survey is one considered before decision is made to invest on a cost project (mostly at semi-detailed survey). This is designed for two functions:
   - **Hazard avoidance:** prevention of human disasters, flooding, crop failure through drought or diseases, salinization brought by irrigation. Avoidance is achieved either by taking appropriate measures to counteract the hazard or by not using the most seriously affected land
   - **Guidance on suitability:** reefers to blocking out of land into irrigated, rain fed arable, pasture, forestry, water catchment nd as other uses as appropriate
3. **Project planning**. At this stage in development the decision to go ahead with a project has been taken, its boundaries are more or less fixed, and planning needs are concerned with the layout of physical infrastructure, e.g. roads, canals, farm or other management units, supply centers or soil conservation works. Further soil surveys at the detailed scale may be necessary for all area.
4. **Management**. Here a project is already under way and a management problem has been encountered, such as salinization, poor yields over part of the area, or drainage problems. Detailed or intensive special purpose soil survey of selected areas will be necessary.

Chapter 2

Principles, procedures, types and common terminologies of soil survey

2.1. Principles of a soil survey

There are a number of general considerations to soil surveys and their applications, directly partly at those who commission or make use of such surveys and partly at those who execute them

- Soil survey must have an objectives or aims: e.g. provide general multipurpose data, specific data for irrigation, update information, etc. ***A soil survey must have an objective.*** The objective or aim of soil survey must be defined before the commencement of the survey. It may be wide ranging or it may be narrow and specific. The survey is utilitarian (it is mapped for one or more purposes). Points to be reconsidered are:
  - Determine the pattern of the soil cover
  - Divide this pattern into relatively homogenous units
  - Map the distributions of the units, enabling to predict soil properties of certain area
  - Characterize the mapped units in such a way that useful statements can be made about their land use potential and response to change in management

This is not a simple process of mapping task but a complicated process as:

- Each soil property changes gradually in both vertical and horizontal directions

- Change in one property will not necessarily change the other property, so that identical delineations in the landscape becomes difficult
- Boundaries are transitional and intergrades are common
  - ❖ Plot the boundaries of the soils on a map
    - Different kinds of soils must be separated on a map
    - Geographical location of each soils that is interesting for the land use be known
    - Each soil type its distribution is located on the map

A mapping unit is a geographical unit of certain area of land within which the greater proportion is occupied by the taxonomic class after which it is named. For example, if about 85% of the soil within a mapping unit is occupied by a soil property is Ibadan series.

Soil survey is designed to make predict and mapping soil properties. But this is not the only desirable end or activity.

- The result expressed in map and reports are complementary. The products of a soil survey include both a map and a report. The amount of information that can be printed in the face of a map is limited and must be amplified by data given in the survey memoir or report. Soil map shows soils: but maps produced by soil survey are soil map, landscape, geology map, etc. Soil- landscape map is a soil map as long as it consists of description of properties of soils. Land resources do not consist of soils alone: It consists of climate, geomorphology, geology, etc.

The report is more than just an amplified legend; it contains in addition background material on other environmental factors, information on land potential and probable responses to various alternatives forms of management, and sometimes also land use and management recommendations. One report may serve for several map sheets.

- **A soil survey is not the sole basis for decisions on land use and management**; it is only an aid. This principle applies also within the broader context of land evaluation surveys. Decisions on land management are invariably influenced by economic considerations, social and institutional factors, often by existing legal land rights and political constraints. Even within the more limited sphere of the physical environment, the soil is only one factor; thus slope angle frequently has a dominant influence on the choice between arable and non-arable use, and climate is the main determinant in choice of crops. To view the soil, or the physical environment as a whole, as the controlling influence on land use is a one-eyed attitude. Rather, the findings of soil and land evaluation surveys are of a conditional nature: if such a course of action is taken, certain results will ensue, or certain measures will be needed to prevent adverse consequences.
- **Mapping a soil for high accuracy with little effort**. Soil survey is a slow business and the information obtained depends on the effort expended. The boundaries between soil mapping units are complex and not always visible by eye, whilst the mapped units themselves are by no means homogeneous. Modest levels of predictive accuracy are obtainable relatively cheaply, but there are

thresholds of accuracy that can only be crossed by intensive and time-consuming survey and analysis. These levels of accuracy, and the scales and intensities of survey necessary to achieve them, are discussed in detail later. And must be cost effective.

- Produce one soil classification that meets the needs of all users. The criteria employed in a classification should be those that are significant for the purpose for which it is intended. Even within the limits of arable use, different criteria are significant for different crops; thus, for example, sorghum is more sensitive to subsoil drainage impedance than maize, whilst rubber has lower nutrient requirements than has oil palm. For other kinds of use, such as road foundations, the significant criteria are quite different; many good agricultural soils have poor foundation properties. No single soil classification can be devised that will meet all the varied needs of different kinds of land use. Soil survey must serve the society as a whole and can be made for scientific purposes.
- Grade land uniquely from 'best' to 'poorest' quality. This situation arises from the previous aspect. Not only are soil and other land requirements specific to each use, but what is better for one use may be poorer for another. Some extreme examples are leveled; poorly drained land is unsuitable for most crops but favorable for swamp rice, whilst Vertisols that are excellent for growing cotton make appalling road foundations. Grain crops generally give better returns on soils of medium to heavy texture, root crops and groundnuts on lighter textures, whilst some crops have very specific requirements (e.g. tea requires available aluminum). The practice of grading land into a single ranking, such as is done in land capability classification, contains many tacit assumptions and is only valid for certain generalized purposes.
- Produce, by soil survey alone, accurate estimates of crop yields. Broad estimates of ranges of crop yields, and other levels of production, can and should be obtained in the course of soil surveys for project feasibility studies, and in planning situations involving choice between alternative competitions, and crop productions estimates that all such estimates have a substantial range of error, of the order of $\pm$33%; are highly dependent on levels of inputs and standards of management, which thus need to be described carefully; and can only be obtained if field survey activities are directed specifically towards this end.

Tell the user of the land what to do. Soil surveys and land evaluation studies can only provide information relevant to certain aspects of land management decisions. These frequently take the form that, if such a course of action is taken, certain consequences will follow. In land management decisions, these considerations will be taken into account, along with others derived from, for example, economics, social custom or political necessity. However, to suppose that soil surveys provide a full and infallible guide to the many and complex decisions involved in land use planning and management is to invite disappointment. It is demand driven, not for scientific purposes, Hence methods and products of survey can be specified according to demand & budget

2.2. Procedures to be followed in soil survey

Well designed (planned) soil survey is result cost effective result, thus to achieve this the following steps should be carried out

1. **Needs assessment**: Who needs the survey and why?

   Need to know who need soil information. Determine the type of information required and their extent of detailed output. There are two types of soil surveying

   - ✓ Specific purpose: one application, short term period of publicity
   - ✓ General-purpose: many publications, long term period of publicity

   If the survey is for land evaluation or land use planning, we need to know the size of decision area; **minimum decision area** (MDA).

   Purpose dictates the categorical detail of the map legend, choice of map scale and survey scale, for instance the surveying for irrigation project the rate of infiltration, leaching requirements and salt accumulation information are required.

2. **Planning or terms of reference**: based on the scale, type of map units, intensity of observations, schedule, personnel, etc. Some points to be reconsidered during this phase are:

   - Anticipated users & uses of the soil survey
   - Scale of the survey/base map: scale directly related to the cost, the intensity of observations, publication scale, and degree of detail and the smaller the area to be shown. An appropriate scale is required considering the intricacy of the soil pattern. **A field scale more than 2.5X** the publication scale is likely to lead to wasted effort in surveying boundaries to a degree of detail that can not be represented on the final map.
   - Determine soil map units

The soil survey data used for land evaluation or land use planning, we need to know the **size of decision** area; minimum decision area (MDA). The area of delineation on the ground (MDA) determined by scale of a soil map (Table 1)

Table 1. Minimum-size delineation values on actual ground scale for a number of map scale (minimum-size delineation for all published maps being 0.4 cm^2)

Map scale	MDA (ha)	Type of survey
1: 5 000 000	100, 750	Reconnaissance (groups, major groups or physiographic assemblages)
1: 1 000 000	4 030	Reconnaissance (groups, major groups, or physiographic assemblages
1: 500 000	1008	Reconnaissance (groups, major groups, or physiographic assemblages
1: 250 000	252	Reconnaissance (groups, major groups, or physiographic assemblages
1: 200 000	161	Reconnaissance (groups, major groups, or physiographic assemblages
1: 100 000	40.3	Semi-detail survey (series & association of series)
1: 50 000	10.1	Semi-detail survey(series & association of series)
1: 25 000	2.52	Detail survey (phases of series)
1: 20 000	1.51	Detail survey (phases of series)
1: 10 000	0.40	Detail survey (phases of series)

Determine the categorical detail map, the choice of soil mapping phase, map scale and survey scale, for instance the surveying for the irrigation project the rate of infiltration, leaching requirements, salt accumulation information are required.

- Type of map units-, whether all delineations are to be visited, transects, or other quality control methods. Location and Intensity of observations: number of detailed/ rapid soil observations Density of observations must increase with the publication scale; if a map is to be at a large scale it must be on a high density of observations. The relationships between cost, time and density of observations are straightforward; the relationship between the density of observations and the accuracy of mapping depends on the nature of the soil pattern, its external expression/complexity of the landform and the ability of the surveyor. In locating observations whether to use free or rigid survey or a combination of these, factors affecting include:
  - ✓ Form & scale of published map
  - ✓ Contents of report: map unit descriptions
  - ✓ Kinds of interpretations to be included in the report; The interpretative aspect of soil survey is not an office exercise but requires filed activities directed specifically towards this end. These may include, for example, visits to experimental stations, field trial sites, forestry growth plots and to ordinary farmers, assembling information on crop yields, management problems, etc., and observing the soil to which those records and experience refer. In some special-purpose surveys these activities may come into the research phase, preceding routine soil mapping.
  - ✓ How scientific quality is to be ensured: field and office review procedures
  - ✓ Personnel, logistics (vehicles, access, …)
  - ✓ Schedule, checkpoints, along the way
  - ✓ Budget

✓ **Variations between surveyors** necessarily occurred in terms of site selection, profile description, soil classification, and delimitation of mapping units.

Research: Existing information (soils, geology, climate, vegetation, geomorphology, land use, etc.). Collect all relevant information on the study area.

- ✓ Cartographic: especially a reliable base map
- ✓ Thematic: anything affects soil formation, e.g. geology, geomorphology, vegetation, land use
- ✓ Theoretical: soil formation, geomorphology

3. **Pre-mapping**: Preliminary API, selection of sample areas, detailed mapping in sample areas, decision on legend categories. The purpose of this step is to understand the soil pattern and to establish a mapping legend for the routine mapping stage.

- Preliminary API: tentative geopedological legend
- Selection of sample areas
- Detailed mapping in sample areas

- ✓ Generally at 2X mapping scale (i.e. areas are magnified 4X)
- ✓ Uses more detailed legend, allows estimating map unit composition
- ✓ Idea is to understand typical soil landscapes
- ✓ Can make block diagrams and cross-sections of landscapes

- Decision on legend categories: which classification system to be used, nature of mapping legend, and details of mapping
- Develop a field key

4. **Field mapping:** Complete coverage of survey area, additional sampling.
   - This is a complete coverage of survey area using the field key, additional sampling.
   - API lines may be adjusted
   - API units may be combined or split based on soils actually found
   - Extrapolation to similar API units, not every unit is visited, but the landscape correspondence must be checked
   - Data organization in the field: survey is a set of scientific observations; and an interpretation of these observations into a coherent theory of pedogenesis and soil geography, hence
   - ✓ We must keep accurate and complete field notes
   - ✓ Standard forms to record observations; standard terminology
   - ✓ Have exact location (1) GPS, (2) airphoto (3) topomap
   - ✓ Standard numbering scheme
   - ✓ Be a good observer in the field; clearly distinguish between observation and interpretation
   - ✓ Note correlations with land use for the land evaluation phase
5. **Quality control**: including correlation. A major problem of mapping is quality control and correlation
   - Quality control: is the work done correctly?
   - Correlation: are terms and concepts used consistently?
   - Progress reviews
     - Final review: adjust legend if necessary
6. **Cartography**: transfer to geometrically correct base, map publication. This involves:
   - Transfer to geometrically-correct base
   - Map publications
7. **Interpretation for land evaluation**
   - According to the terms of reference
   - May consist of tables, graphs most used by clients
   - May consist many interpretations using the legend categories of a soil map
8. **Reporting:** descriptive legend, interpretative tables, classification and correlation
   - Descriptive legend

- Interpretative tables
- Soil classification and correlation

9. **Soil geographic database**, including GIS layers
   - It done as an integral part of the mapping and reporting.
10. **Publicity**: An unpublicized soil survey is a waste of time and money. From the beginning of the project it should be decided how to disseminate the results.
    - Standard channels: government offices, libraries, extension offices
    - Schools, producer's co-operatives, professional associations (e.g. soil science society)

2.3. Soil survey types

The aim of soil survey is to show the geographical distribution of soils. Soil survey types can be categorized based on the following ways

1. Purpose of survey
2. Regularity of observation
3. Based on scale of mapping

1. Classification based on the purpose of survey- based on the purpose of survey there are two types of survey. These are general purpose and special purpose survey.

A. General purpose soil survey: it provides the basic data for interpretations for various kinds of uses, present and future, including that currently we cannot anticipated. This commonly found in the national survey of each country, e.g. the USDA, FMAWR. The information may not be needed at the time of survey but such a survey is done for record purpose. It may be done for adding information on the already existing inventory of soil data.

Advantages:

i. Reused and interpretable for many purposes
ii. Collects several properties/characteristics
iii. Landscape classification
iv. Soils are natural bodies (soil morphology), with the same sequence of horizons developed on similar parent material, under similar external conditions (i.e. essence of soil series)
v. Shows pedological map
vi. Can serve as for further interpretation (land evaluation) as it contains topography, geology, climate and socio-economic of the survey area
vii. Sufficient characteristics of each mapping unit

Disadvantages:

i. Not ideal for any purpose (do not serve all purposes equally)
ii. No anticipate of future use
iii. Obsolete after some years and re-survey may be necessary
iv. Costly, more expensive

v. Needs highly trained man power

B. Special purpose soil survey - surveying is done for specific (particular) purpose and surveying of single soil characteristics depending on time of management, (limited in applicable time. for a few time) and the limits between predefined classes of these characteristics are mapped The map unit limits are applicable to a use e.g. survey for irrigation or survey for citrus plantation, map of soil salinity for of infiltration rates

Advantages:

i. Concentrate on specific properties of interest on mapping

ii. Mapping is more rapid and can be done with less skilled mapping manpower

iii. Cheap to make it.

Disadvantages:

i. No record of properties that are vital for others, (commercial sugar cane vs. arable farming)

ii. Completely useless for other objectives;

iii. Problem of defining boundaries, no landscape characterization

iv. No concept of natural body

2. **Based on the regularity of observations**, three kinds of surveys have been distinguished: - free survey, rigid grid and flexible grid.

A. F**ree survey**, there is no rigid pattern of observation. The surveyor uses the field features such as change in vegetation, topography, slope and even change in sound to movement to observe soil and to locate soil boundaries. Most modern soil survey involving on wide area ($\geq$ 5000 ha), adopted this type of survey methodology. This method creating area class maps where the surveyor is free to choose sample points in order to systematically confirm a mental model of the soil-landscape relationships, draw boundaries, and determine map unit compositions.

- Starts with detailed physiographic air photo interpretation
- All boundaries are verified and possibly modified by field investigation
- Surveyor walks most of the landscape, usually in traverses across concerning on problem areas
- Surveyor's judgment and experiences are important
- Requires the greatest skill and experience to interpolate and extrapolate from observations to best judge where the next observation should be
- Some areas may have very few observations, if they fit exactly to the mental model (i.e. the soil pattern can easily be predicted), others (problem areas) may be sampled in detail
- In areas with poor correlation of geomorphology to soils, the field observation themselves are used to locate the boundaries.
- Enough observations to obtain a fairly good estimate of internal variability.
- Biases as dictated by the surveyor experience and judgment

B. **Rigid grid survey,** examinations of the soil are done at regular and pre-determined interval. It is normally used when detailed information is required, e.g. mapping the soil of a research station or mapping for irrigation. Usually, the points of observation are at the intersection of the two regularly placed vertical and horizontal lines.

- A systematic sampling is designed, taking into account expected range of spatial auto correlation
- Sample points are located in the field and characterized
- Standard statistical and geo-statistical methods are used to estimate variability
- Large scale map (>1: 50 000)
- Grid survey may be a waste of time, but gives better maps in complex areas

C. Flexible grid survey method is a compromise between the free and rigid grid methods of survey. In this system of survey, the number of observation is fixed but the locations of the observation points are not pre-determined. It may be systematic or non-systematic

Systematic survey- the first observation point is randomly determined on the base map (top-map) and then after observations made every specified meter systematically. In boundary delineations, variability of soil characteristics as conditioned by external factors (geomorphology, geology, vegetation and climate) will be considered during the survey. It is very similar to grid survey.

Non-systematic survey- boundaries are determined from other maps such as geology and physiography. Widely spaced field checks are used to determine typical soils properties, No estimate of internal variability and widely used in small scale maps (<1;500, 000), not considered as real maps but sketches

3. **<u>Based on the scale of mapping</u>**, there are seven kinds:- compilation, integrated survey, exploratory survey, reconnaissance survey, semi-detailed survey, detailed survey and intensive survey (Table 5- 7)

A. Compilation: These are soil maps produced by abstraction from other soil surveys. And where they exist they are filled by inferences. The scale is usually at 1: 100,000 or smaller. Many national soil maps of many countries are produced in this way. It provides the small scale map information about soils distribution of certain area, in compound map units.

B. Integrated survey: It is also known as land system survey. It is based on mapping of the total physical environment and in fact landforms are mapping unit. Soils are important component but their properties usually not defined in the mapping unit. The scale is 1: 250,000 or smaller. It provides small scale map information about soils distribution of certain area, in compound map units.

C. Exploratory survey: Exploratory surveys are not proper survey. They are usually rapid road traverse made to provide modicum information about the area that are otherwise unknown. Scale of exploratory survey varies from 1: 2,000,000 to 1,500,000. It provides the small scale map information about soils distribution of certain area, in compound map units.

D. Reconnaissance survey: These are mostly based on remote sensing especially Area Photo Imagery (API). They are the smallest scale of survey where the whole area is still covered. The scale is usually

1:250,000 although smaller scales have been used. It provides the small scale map information about soils distribution of certain area, in compound map units.

E. Semi-Detailed survey: In a semi-detailed survey, surveying based on a combination of remote sensing and field work. Mapping units are usually soil association. Scale of mapping varies from 150,000 to 100,000. It provides the medium scale map information about soils distribution of certain area, in compound or simple map units.

F. Detailed survey: Detailed surveys are executed through field examination with predetermined numbers of observation points and or spacing. These kinds of surveys are usually employed for small area and for special purposes. Scale of observation varies between 1: 10,000 and 1: 25,000. Mapping unit are usually soil series. It provides the large scale map information about soils distribution of certain area, in simple map units.

G. Intensive survey: Intensive survey rigid grid approach, i.e. number of observation and spacing of observation are pre-determined. Mapping units are soil series and phase of soil series. Scale of mapping varies from 1: 1,000 to 1: 10,000 or even larger. It provides the large scale map information about soils distribution of certain area, in simple map units.

Moreover, each surveying type can be categorized based map scale also as indicated on table 4 map. These map scales are relative to the area being shown.

- **Large scale:** a given area is represented by a large map (sheet of paper). This shows an area on separate sheets or on a large paper that can not be seen in few glances. It needs more paper and shows all features of interest.
- **Small scale**: a given area is represented by a small map (sheet of paper). This shows a large area on a small piece of paper/map and can be seen at a glance. It needs less paper and does not show all features of interest. However, some authors use an absolute scale definition of large and small, depending on the map theme and intended use, such as given below.

Table 4. Map scale ranges for different categories

Map type	Scale	Intended use
Large scale	1: 2 500 – 1: 25 000	Shows all features of interest
Medium scale	1: 50 000 – 1: 150 000	Shows many features of interest in detail, there is some generalisation, the map is directly useful but it is understood that some finer features are not shown
Small scale	<1: 250 000	Almost all features of interest are generalised, the map gives an overview only and is not directly useful

Conversion factors

Units: meters (m), centimetres (cm), millimetres (mm), kilometres (km), hectares (ha)

Linear measure: 1m ~ 100 cm ~ 1000mm; 1km~ 1000m

Area measure: 1ha ~ 10 000 m^2; 1km^2 ~ 100ha ~ 1 000 000 m^2

When discussing scale and delineation size, we must always be clear whether we are referring to ground and **map** distances and areas. For example, ground meters (g) and map meters (m)

Linear map scale

The map scale is the **ratio of map distance to ground distance**, both linear measures, and measured in the same units; it is dimensionless and always written as a scale ratio with unit numerator.

Scale ratio: Map distance: ground distance; e.g. 1: 10 000 ~ 1cm on the map ~ 10 000 cm on the ground ~ 100m on the ground.

The scale of map can be expressed in

A. **Representative Fraction (RF)**: the scale ratio as fraction (1:10 000) ~ 0.00001), mathematically it is dimensionless.
B. **Scale number (SN)**: 1cm to 2 km
C. **Graphic scale**: Represented in the form of a segmented graphic scale.

They are usually experimental station surveys. It provides the information about the distribution of soils in certain area in simple map units. Minimum-size delineation values on actual ground scale for a number of map scale (minimum-size delineation for all published maps being 0.4 cm^2). Minimum delineation area (MDA) on the ground is determined by scale of a soil map (Table 5 and 6).

Table 5. Survey type with minimum delineation area

Map scale	MDA (ha)	Type of survey
1: 5 000 000	100, 750	Reconnaissance (groups, major groups, or physiographic assemblages)
1: 1 000 000	4 030	Reconnaissance (groups, major groups, or physiographic assemblages
1: 500 000	1008	Reconnaissance (groups, major groups, or physiographic assemblages
1: 250 000	252	Reconnaissance (groups, major groups, or physiographic assemblages
1: 200 000	161	Reconnaissance (groups, major groups, or physiographic assemblages
1: 100 000	40.3	Semi-detail survey (series & association of series)
1: 50 000	10.1	Semi-detail survey(series & association of series)
1: 25 000	2.52	Detail survey (phases of series)
1: 20 000	1.51	Detail survey (phases of series)
1: 10 000	0.40	Detail survey (phases of series)

2.4. Definitions of common terminologies in soil survey

Soil characteristics: are observable or measurable soil parameters in the field or laboratory, or can be analyzed using microscope technique. (e.g. characteristics such as color, texture, structure, features of biological activity, arrangement of voids, and pedogenic concentrations (mottles, cutans, nodules, etc.) as well as analytical determinations) pH, particle size distribution, CEC, Bases, amount and nature of soluble alts, etc).

Landscape properties- the topographic properties in relation to slope gradient, slope length, slope curvature, regularity of knolls and depressions, its surface water features, etc. The “soil-landscape” is more than soil and it is more than landscape, it is the complex interaction of the two. The term “soil-landscape” refers to the combination of soil and landscape properties within a given geographic location.

Mapping Unit: A mapping unit is a geographical unit (area of land) its greater proportion occupied by the same taxonomic class. For example, if 85% of the specific area of the land within a mapping unit occupied by the property of Ibadan series, Ibadan series map is mapping unit.

Land use: it is describing human uses of land, or immediate actions modifying or converting land cover. Land use is the intended employment and management strategy placed on the land cover by human agents, or land managers to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging, and mining among many others.

Land cover: it is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement. Land-use change is the proximate cause of land-cover change. The driving forces to this activity could be economic, technological, demographic, scenic and or other factors. Hence, Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales.

Planning is the process of allocating resources, including time, capital, and labor, in the face of limited resources, in the short, medium or long term, in order to produce maximum *benefits* to a defined group. Although individuals plan for the future, by 'planning' in the context of land evaluation we understand some form of collective activity, where the overall good of a group or society is considered.

Land use planning is the process of allocating land and resources to suitable uses. The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whiles at the same time conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. It is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land-use options. Its purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future. The driving force in planning is the need for change, the need for improved management or the need for a quite different pattern of land use dictated by changing circumstances.

Land evaluation (**land use planning**) - interpretative land classification, it is a decision to a change in the use of a land depending on its economic terms (e.g. not returnable investment, etc), physical resources (land degradation, conservation) and social or political benefits. **Land evaluation is** concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be of value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

Chapter 3

Soil mapping

Soil map units are named by one taxonomic class. Soil map units describe soil pedons as they exist on the landscape. A map unit named by one taxonomic class is a consociation. Descriptions of such a map unit contain a paragraph that gives other taxa included within their delineations. The problem of map unit inclusions results from the use of artificial taxa, soil series, to name natural soil landscape units. Soil map unit inclusions may be similar or dissimilar and limiting or non limiting. Similar inclusions are soils that share limits of diagnostic criteria and have similar management requirements. The map scale determines as to how the map can be used. Detailed maps of large scales are useful for a broad overview of an area. Soil maps are made using satellite imagery, aerial photographs or traditional methods such as walking across the land, digging holes and observing pedon characteristics. The number of observations made by the soil surveyor determines the map's level of detail. Maps are a form of geographic data.

Before making a soil survey, it must be clear on what soil map is and how this concept relates to the broader idea of land, which often included in soil surveying. A practical soil map almost always includes non-soil areas and even, in soil areas, non-soil-land characteristics. Thus the debate on what is soil is has implications for a soil survey.

The first step in making a soil map is to define the units to be mapped. A soil survey attempts to delineate areas that behave differently or will respond differently to some specified management. The mapping units serve as a basis for predicting soil behavior. In **general-purpose surveys**, soils are mapped according to their morphology on the hypothesis that soils which look and feel alike will behave similarly and those that appear different will respond differently in many circumstances. If the purpose of the survey is narrowly specific and the soil properties relevant to that purpose are known, these properties can be mapped directly.

A map unit of an area-class map is a set of delineations, all supported to have the same properties except for their geographic position. These terms are relative to a specific classification system or list of soil properties and their diagnostic limits. That is, a homogenous map unit of a categorically general map may be the same as a compound map unit of a categorically-detailed map. The map legend is the list of categories or map units shown by an area–class or point-class map. In other words, it is the information content of the map. The categorical detail map refers to the internal composition of the map unit. The basic distinction:

Most surveys produce maps showing the geographical distribution of soil classes or properties. These maps are of several types. The area class-polygon map is the most common in soil survey, but the others can be better solutions in some cases. There are two kinds of soil information - geographic data and point data. Both types are needed if soils are to be used properly. Geographic data is available as soil maps and they portray the arrangement of soils on the landscape as seen by the soil surveyor. Geographic information includes the distribution of soils on the landscape, current land use and potential uses. Soil map units describe soil pedons as they exist on the landscape. The map scale determines as to how the map can be used. Detailed maps of large scales are useful for a broad overview of an area. Soil maps are made using satellite imagery, aerial photographs or traditional methods such as walking across the land, digging holes and observing pedon characteristics. The number of observations made by the soil surveyor determines the map's level of detail. Computerized storage, retrieval and interpretation of geographic data eliminate the laborious task of drawing maps.

1. Point soil maps: Maps where the actual sample points are shown, along with their class or one or more properties. Direct representation of what was actually sampled, Not all area is covered, No model of spatial variability is implied
2. Area-class polygon (chloropleth soil map) soil maps: The survey area is divided into polygons by precise boundary lines, each polygon being labeled with a class name, and each class in turn being described in a legend. Almost all soil maps are of this type. Easily be represented by vector GIS model. Maps conform to Discrete Model of Spatial Variation (DMSV). Variation across the landscape can be partitioned by sharp boundaries into relatively homogenous areas. Imposes a hierarchical division of the mapped area into m classes, and then into individual delineation. Each delineation belongs exactly to one legend class.
3. Continuous-field maps made by interpolation: commonly presented by isolines or on a fine grid (raster GIS model). Show the inferred continuos distribution of a soil property. Made by interpolation from point observations. With some methods of interpolation, both the property value and variance can be shown on separate maps. Conform to the continuos model of spatial pattern variation (CMSV). No sharp boundaries, all variation across the landscape is considered to be continuous.
4. Continuous field made by direct observation over the whole field: There is actually a measurement made at every point (in practice, a small area). Are commonly presented as a grid map (raster GIS model). Show measured continuous distribution of a soil property. Conform to the CMSV. Currently, much interest in precision farming. Method also used in other fields-elevation, vegetation index

The ultimate goal of a soil survey is to produce a soil map. Soil maps as other maps contain information. Map with legend and descriptions it provides information about soil characteristics and properties.

Soil properties: are combinations (“assemblages” of soil characteristics which are known to occur in soils and which reconsidered to be indicative of present or past soil-forming processes (e.g. vertic properties, which are a combination of heavy texture, smectitic mineralogy, slickensides, hard consistence when dry, sticky when wet and swelling when wet).

It is indeed a predictive tool; the aim is to indicate the nature and properties of soils at one or more points or areas. A soil map is designed to answer specific where and what type questions and any user of the results should beware of the associated errors.

The potential importance of a soil map depends on the ability of the map-reader to extract information from the map. The soil map is a representation of survey data, which is intrinsically and a discrete and already interpreted form from experienced practitioner.

Soil survey employs observations and sampling at discrete points yet requires spatial interpolation and extrapolation from these points using knowledge of landscape processes. Several factors influence the legibility and understanding of any thematic map:

- The number of areas outlined (polygons)
- The choice of colors and patterns used to represent these areas
- Supporting locational detail
- Quality of cartography and map layout
- Simplicity of the classification and legend

5.5. Map units

A map unit of an area-class map is a set of delineations, all supported to have the same properties except for their geographic position. These terms are relative to a specific classification system or list of soil properties and their diagnostic limits. That is, a homogenous map unit of a categorically general map may be the same as a compound map unit of a categorically-detailed map. The map legend is the list of categories or map units shown by an area–class or point-class map. In other words, it is the information content of the map. The categorical detail map refers to the internal composition of the map unit. The basic distinction:

1. **Homogenous-** within each delineation map unit it has the same characteristics, thus given the same name at the level of the classification and the map unit. For purposes of interpretation of land evaluation, the homogenous map unit has the same values of all land characteristics over all its extent. **Land characteristic values** are typically measured in ranges, and in homogenous map units, these ranges cover all the variability in the map unit. The LC values are not identical, but they are in reasonably narrow ranges. These homogenious map unit also catagorized in to two based on detailed mapping , these are consociation and undifferentiated group

   1.1. **Consociation-** delineated areas are dominated by a single soil taxon and similar soils

   All five of the following conditions must be met for the map unit to be called consociation

   1. At least 50% of the area of the consociation is classified in the named taxon (typically phase of series or family) or taxadjunct in every delineation of the map unit. Such as if the map unit says Alemayan loamy sand series, 0-2% slopes, at least 50% of the pedons must classify in the Alemayan series, they must have a loamy sand topsoil, and have slopes between 0% and 2%. This ensures that we do not group similar soils that occur in different geograpHical areas into one map unit and call it consociation.
   2. At least 75% of the area of the consociation is classified in the named taxon or in a similar taxon, again in every delineation of the map unit. Note that the concept of similar taxon is established by the classification system and by the detail of the interpretation. Note that this

total of 75% must in general have ≥ 50% of the named taxon, because of rule (1), and the rest is then made up by similar inclusions, for a total of ≥ 75%. If they are e.g. 60% of the named taxon, then the similar inclusions must be ≥ 15%.

3. As a result of (2), no more than 25% of the area can be dissimilar inclusions, even if non-limiting.
4. No more than 15% of the area can be dissimilar limiting inclusions. That is up to 15% of the area of the delineation could be an unusable for a particular land use, and the delineation is still called homogenous.
5. No single dissimilar limiting inclusion can exceed 10% of the area. This implies that the small areas of strongly contrasting soils should be of different types. If one strongly contrasting soil occupies >10% of the area, it should be recognised in the map unit name, and the map unit must be **compound**. One way out of this is to indicate the dissimilar limiting inclusions by **spot** symbols; then those areas do not count for the purpose of these rules.

Naming consociations: Consociations are named for the dominant taxon, at any categorical level, using the plural.

1.2. Undifferentiated group- Suppose we have similar soils occurring in different geographical areas. We may have several soils that interpret the same for all anticipated land uses. The correlator might want to simplify the map legend by joining several fairly small legend categories that would separately, be inclusions into one legend category. This is possible by the use of **undifferentiated groups.** This is not homogeneous in composition, because different delineations have different soils; however, it is homogenous with respect to interpretations.

The undifferentiated group has its main criteria:

A. The use potential and management methods for the named components are essentially the same;
B. The components do not occur together in a consistent pattern in each delineation

If the map unit fails one of these criteria, it is a compound map unit. Also they must meet homogeneity criteria, similar to those for the consociation.

Naming undifferentiated group- it named by the constituents, using the word and e.g. Alemayan and Hameresa silt loam series.

2. **Compound-** Within each delineations, there are significant areas of more than one contrasting class of soil, so that the different locations in the map unit may classify as different soils. This kind of map unit is made up of two or more homogenous constituents. Besides due tothe following three situations

A. When the map scale is too small to show constituents that otherwise could be mapped, and
B. When the constituents can not be separated at any realistic map scale

C. When there is no enough sampling to establish whether (1) or (2) applies, but it is known that more than one contrasting soil occurs in the map unit.

Compound map also catagorized into different soil map units occur based on pattern on the landscape. This does not mean that the surveyor can map them at the mapping scale, only that the pattern is known.

2.1..**Unassociated soils:** In the case where the components of a map unit do **not all occur in every delineation**, or if we do **not** even know if the soils **always occur together**, and in addition the components do **not have similar interpretations**, thus it use the map unit of unassociated soils.

This implies that the map user may find any or all of the named soils in any delineations and that the different soils will have different properties and management

Naming unassociated soils- in delineations of the map unit, using the conjunction '**or**', adding soils to the map unit name until the homogeneity criteria are met, using all named soils to meet them. Ex. Alemayan or Hameressa soil series/

2.2. Associations

If the major (contrasting) soils and their pattern is known, and **this pattern is similar in every delineation of the map unit**, we then divide into those map units which could be mapped as homogenous map units at reasonable scales (these are the **associations**). And those where the soil pattern is so intricate that they could not be so mapped (these are the **complexes**).

Associations: components can be mapped separately at large scale. Compound map units of two or more soils that could be separately mapped as consociations at scales of 1:24 000 or larger.

Thus associations are map units at a give scale, where contrasting soils or land types occurs in **regular, predictable and mappable patterns** at some practical large scale. In addition, all components must occur in approximately the same proportions in all delineation of the map unit. **Mappable** mean it refferes its external features (such as geomorphology, vegetation, land use, surface properties and topography …) easly for delineation.

Associations are very often used for soil maps at semi-detailed or smaller scales, and for generalizations of larger scale maps.

Naming associations- it named by their major soils (enough to meet the homogeneity criteria for a consociation, but the soils taken together), the names separated by a hyphen (-) and with the word association. Once the component is listed in the association name, it is no longer an inclusion. Ex. Alemayan-Hameressa loamy sands, 0-2% slopes, association. Soils are named in order of area covered within the map unit, including with each soil any similar inclusions.

2.3.Complexes: an association only because the components can not be separately mapped since

- All components must occur in approximately the same proportions in all delineations of the map unit; otherwise this could be **unassociated** soils
- Components must be **contrasting**, otherwise they could be grouped together in a **consociation**

Complexes: Components could not be mapped at a large scale.

Naming of complexes- it named by their major soils (enough to meet the homogeneity criteria for a consociation, but the soils taken together), the names separated by a hyphen ('-') and with the word 'complex'. Example. Vertisol-Cambisol-Luvisol complexes

5.6.User requirements from soil maps

Users of soil maps vary in their requirements, skill levels and expectations. Many users are not versed in soil science or soil survey complexities and often do not understand the type and level of information that the map has to offer. Users expect

- Accuracy and reliability of information at any scale
- Information that is useable for different purposes and situations
- Clarity
- An attractive presentation
- Availability at a reasonable cost
- Information presented is the best available and the most comprehensive

However, no one soil survey or set of maps can satisfy all these requirements, as for example:

- A grazer may want to have a small scale map (1:250 000) to give an indication of variation in the type of country
- intensive crop farmer will require, as detailed map as possible of variations in pH, water holding capacity, surface structure, depth, organic matter, and nutrient availability in soils
- the land valuer wants to know what is good soil and what is poor soil

Information provided by soil maps

Soil maps are information kits, which are the result of specialist skills, expert knowledge, and painstaking toil. The two dimensional soil maps represent the three-dimensional soil pattern and provide the following information. It is however abstract and complex requiring great care in interpretation.

- Spatial pattern of soil types
- Spatial pattern of soil attributes (if mapped)
- Soil types draped over topography map with GIS give better model of soil landscape
- GIS enhances attribute mapping

Five ranges of scale, or levels of intensity, are recognized for soil surveys and maps (soil survey of Canada) corresponding to intensity. In addition, there are maps produced by compilation at scales similar to the exploratory (Table 7).

❖ ***Exploratory surveys (intensity level 5*).** These are conducted to provide a bit of soil information about otherwise unknown regions.
  - They are carried out by road and track or helicopter traverses without attempting uniform coverage, with maps produced at scales between 1:500 000 and 1:5000000.
  - This method of survey was used to fill some empty areas for the FAO Soil map of the world.
  - Surveys based on satellite imagery with low-intensity ground checking also fall into this type.

Compilations are syntheses based on pre-existing soil maps at various scales, filled in by inference where there are gaps in coverage. The legend should include a diagram showing coverage by scale and reliability. The FAO-Unesco Soil map of the world (1970-80) is of this type, as are the national soil maps of most countries. Scales are usually 1:1000000 or smaller and mapping units are the higher categories of an international or national soil classification. Owing to the low and variable reliability, such maps cannot be used for practical planning. Their purposes include display, national atlases, teaching, answering inquiries from international organizations and as a general orientation or background for soil surveyors.

❖ **Reconnaissance surveys (level 4).** Such surveys achieve a uniform coverage of the survey area at a small scale, most commonly at 1:250 000. Mapping units are mostly based on landform-soil units or land systems and much use is made of air photo-interpretation and/or satellite imagery. Geographic soil association or sets of similar profiles have been adopted where there has been a substantial field mapping effort, but in some landscape it is not meaningful to map soils as such at this scale. A few countries now possess complete coverage at reconnaissance scale.

- General information on natural resources and their distribution is a necessary first step in planning future land development.
- Results are expressed in purely physical (i.e. non-economic) terms with a relatively long life.
- Ethiopian soil-geomorphology map 1:1000000 and 1: 2000000

❖ **Semi-detailed surveys (level 3**). Semi-detailed surveys, typically at 1:50 000, are the smallest scale at which soil series can be mapped, although some associations will nearly always be necessary.

- Air photo-interpretation and field survey both contribute significantly but substantially more time spent on fieldwork.
- In developing countries, this is a good scale for feasibility surveys of arable or multipurpose land development projects.
- It provides the information necessary to allocate land to its major uses (arable, tree crops, pasture, forestry, etc), and the areas under these uses give the basis for economic analysis.
- 1:50 000 is not an adequate working scale for project design and management.
- For agricultural advisory purposes, the problem of this scale is that field boundaries cannot be shown.

❖ **Detailed surveys (level 2).** These cover both the 1:25000 and 1:10000 scales.

- Air photographs have substantial value but the bulk of survey effort is in the field.
- The usual mapping units are soil series, phases and other closely defined units.
- This is the ideal scale for agricultural advisory work. The framer and the adviser can see the farm, field by field, at a manageable size, and the soil units mapped are for the most part of a size and kind that are practicable to use in management.
- It is also a good scale for detailed planning of development projects, it is indispensable for irrigation projects, and it is useful in some management and peri-urban surveys.
- Why, then, with all these advantages, is this scale range not universally employed? The answer is the rather slow rate of progress and hence considerable cost. There is no way around this cost; to do a proper job of mapping requires that amount of field effort.

❖ **Intensive surveys (level 1.).** Intensive surveys are at scales larger than 1:10000.

- Besides soil series and pHases, maps of individual soil properties can usefully be produced.
- Owing to the very high cost per unit survey of area, this scale shows detail information on soils and environment of the mapping units, and is recommended for high value land.
- The high value of land in the urban and urban fringe zone, coupled with the varied and specialized uses to which it is put, may justify intensive surveys.
- Agricultural experiment stations should be surveyed on this scale, and some enterprising farmers have commissioned intensive surveys when new crops or management practice, e.g. supplementary irrigation, are projected.
- It is appropriate wherever there is to be a large capital investment in high-value crops or new techniques, whether by government agencies or on privately owned farms.

Table 6. Observation density and time requirements* associated with different intensities of soil survey

Examples of purpose	Scale	Average density of observations 0.5 per cm^2 of map	Rate of progress per 22 day month	Approximate time required for different activities (days per month)				Report preparation (weeks)
				Basic survey	Representative profile description and sampling	Field tests and laboratory	Office	
Implementation of land Reclamation or irrigation Projects; management Problems; urban and Industrial developments	1:5000 1:10000	2 per ha 1 per 2 ha	250 – 500 ha 450 – 800 ha	8	2	8	4	6 – 12+
General –and special Purpose project Planning, irrigation and Urban fringe surveys	1:20000 1:25000	1 per 8 ha 1 per 12.5 ha	1000 – 15000 ha	12	2	5	3	6 – 12
General-purpose Project feasibility and Regional land use Planning	1:50000	1 per 50 ha	30 – 100 km^2	16	3	-	3	4 – 8
Resource inventory Project location	1:100000 1:250000	1 per 2 km^2 1 per 13.5 km^2	150 – 500 km^2	16	3	-	3	2 - 5

*In addition to the time requirement indicated here, 10 to 30% should be added for contingencies such as bad weather and difficult access general purpose regional mapping the areas of more complex soil pattern

Table 7. Soil map scale or levels of intensity for soil surveys

Kind of survey of map and level of intensity	Scales Range Typical	Area represented by $1cm^2$ on map	Mean distance between field observations at 1per cm^2	Mapping units	Examples of purposes
Exploratory surveys and compilations; level 5	1:1000000 and smaller	100 km^2 and less	--	Taxonomic soil classes of high categories, e.g. brown earth luvisols, mollisols, sols ferrugineux	Display, national atlases, teaching background for survey preparation
Reconnaissance: level 4	1:500000 1:250000 to 1:120000	6.25 km^2	2.5km	Land systems or other landform-soil units, combining great soil groups	Resource inventory at national or regional levels; national land use planning, tentative project location
Semi-detailed; level 3	1:100000 1:50000 to 1:30000	25ha	500m	Associations, series; landform-soil units combining associations and series	Project feasibility studies; regional land use planning
Detailed level 2	1:25000 1:25000 to 1:20000 1:10000 1:10000	6.25 ha 5ha 1ha	250m 200m 100m	Series, phases of series, some associations and complexes	Agricultural advisory work, project planning, irrigation surveys, some management and peri-urban surveys
Intensive level 1	larger than 1:10000	0.25 ha	50m	Series, phases of series individual soil properties	Management, peri-urban and urban soil surveys, in variably special-purpose

5.6. Reducing and enlarging a polygon map

5.6.1. Reducing a polygon map

The cartograpHic result of a mechanical reduction in map size (i.e. a decrease in scale) is to each delineation smaller, in accordance to the square of the ratio of scales. The Minmum Legible Area (MLA) is increased correspondingly, i.e. proportionally to the reduction in scale. The reduction ratio (RR) is defined as the ratio of the two linear scale numbers:

$$\mathbf{RR: SN_{new}/SN_{original}}$$

Ex. If a map is originally compiled on a 1:50 000 base and then reduced to 1:100 000, the linear scale is reduced by 2x, and RR~ 100 000/ 50 000 ~ 2. Therefore, the area scale is reduced 2^2 ~ 4x. The MLA increases from 10 ha to 40 ha.

In case of soil maps, there is no purely cartographic solution. We must mechanically throw out illegible polygons and assign their area to the surrounding or adjacent polygon. In case of islands, they must be absorbed by their surrounding polygons.

But what about a small polygon that borders on several larger polygons? Or a group of larger polygons that together would be >MLD at the new scale? The **landscapepattern** at the new, smaller, scale must be analysed?

Even in case of islands the remaining large polygon has a different composition, i.e. different proportion of soils. The remaining map units must be re-examined, re-described and **possiblyre-named** in light of their new composition.

Note that the **GIS can perform a mechanical generalisation**, e.g. by eliminating polygons that are too small and merging them with their largest neighbor. But that is purely cartograpHic, and we must consider the categorical implications.

5.6.2. Enlarging polygon map to a larger scale

In this case a map is printed at a larger scale than the source documents. Since we can never add information, the larger scale map is misleading, because the MLD at this larger scale were in fact not mapped. Also, boundary lines look smooth; they may in fact be more detailed at the larger scale, but they were not mapped. It is very rarely justified to print a map at a larger scale than its original source.

Soil Map Units

The individual soil map units are almost all named as phases of soil series, although phases of a class at a higher categorical level are used on some generalized maps. Also, a few miscellaneous units are used for non-soil areas such as bare rock or gravel bars and for drastically disturbed sites such as mine spoils and made land in and around cities and developments. Some areas are mapped as rough broken land or as intermixed soil series too small in area to show separately.

Phases are used to specify information that is not considered in Soil Taxonomy but has practical significance. Phases specify the soil series plus slope range, erosion status, degree of stoniness, or some other property that affects the use and management of the land even though it does not change the classification of the soil. A soil surveyor draws boundaries on the map to separate the soil map units defined in the local mapping legend. The map units approximate as nearly as possible the taxonomic units known as polypedons. A symbol is placed in each soil area to designate the type of polypedon plus phase designations such as slope and erosion classes.

Polypedons are composed of contiguous pedons of the same soil series. One soil series is differentiated from another by properties inherent in the constituent *pedons* (in Greek, *pedon* = ground). Each pedon represents an individual unit of soil large enough to grow a representative plant. By definition, soil pedons have a minimum surface area of 1 m2 and may be larger (up to 10 m2) if necessary to adequately represent the soil. They are characterized by the color, texture, structure, porosity (permeability), consistence of structural units (peds or clods), pH, concretions, clay coatings, organic matter, and root abundance of each horizon and the depth to bedrock or other root-restricting layer. Polypedon field descriptions also record the vegetation, surface drainage, slope class, erosion class, parent materials, stoniness, and land use (Soil Survey Staff, 1993). The field descriptions are supplemented by laboratory analyses of soil samples taken from selected sites.

SOIL MAP UNIT INTERPRETATIONS

Soil maps and soil descriptions need to be interpreted to make them useful; in fact, they need to be interpreted in several ways to suit the needs of different users. Modern reports include interpretations for agronomic, engineering, and sanitation uses. Interpretations for horticulture, forestry, and rangeland are included where these uses are important. When the mapping units are used according to the limitations specified, the soils will remain productive, nonpolluting, and useful. Examples of soil map unit interpretations are included in the following sections.

Chapter 3

Non-FAO land evaluation methods

A tract of land is defined geographically as a specific area of the earth’s surface: its characteristics embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area, including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of the past and present human activity to the extent that these attributes exert a significant influence on present and present human activity to the extent that these attributes exert a significant influence on present and future uses of land by man. Hence, land is not the same as soils. Other groups of physical properties also influence the nature and usefulness of land.

Land evaluation is then the assessment of land when used for a specified use e.g. for agricultural, engineering, etc. Therefore, the characteristics of land are evaluated for their suitability against intended use. There are direct and indirect methods of land evaluation/planning.

Direct land evaluation

This involves the performance evaluation of land directly by a trial, such as growing a crop or building a length of a pipeline, to see what happens. This, but:

- Applicable only to the specific trial for that particular site,
- Are often extrapolated to apply to the whole of a natural environment unit or specifically to a soil-map unit

Definition of Land-use planning

Land characteristics are single attributes of land that can be measured or estimated, e.g. mean annual rainfall, slope (%), soil texture etc

Land quality is a complex attribute of land that can be assessed using land characteristics, acts in distinct manner in its influence on the suitability of land for a specific kind of use. Example:- - Rooting condition, nutrient retention, nutrient availability and land preparation can be assessed or estimated using its soil depth, CEC, slope