INTRODUCTORY SOIL SCIENCE

A Study Guide and Laboratory Manual

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Preface

An introductory survey course by its very nature covers a broad spectrum of topics to adequately acquaint students with the diversity and significance of a general subject matter area such as soil science. It is the function of a good textbook to provide the background information on all the necessary topics. However, a major hurdle confronts the students in attempting to sift through and grasp the significance of the plethora of information encounted within the time frame of a single three or four credit course. Is is unrealistic to expect the student to divine what an instructor may judge to be most important to understand and remember from textbook assignments. Goals and objectives should be explicitly stated and used as a basis for measurement of achievement. One of the major purposes of this study guide then is to assist students in charting their way through the maze of material and to state the educational objectives in as clarion a manner as possible. Since, in many cases, understanding an idea is not fully achieved until one can use it quantitatively, occasions for quantitative manipulation of some of the concepts are provided. Finally, it is an aim of the guide to offer opportunities for self-discovery or first-hand experiencing of concepts discussed verbally. This is done through a series of laboratory exercises.

To make the breadth of subject matter manageable, it is subdivided into ten units each of which considers a limited and closely related set of concepts that are usually aligned to a subdiscipline within soil science such as soil physics or soil microbiology. Each of the units is organized using a common topic sequence. In some units topics are found unnecessary and are thus omitted. Following is a list of the topics in the sequence found in each unit and a description of their content and purpose:

Introduction A brief discussion of the nature of the subject matter, its relation to other units and, if appropriate, the particular concepts that will be emphasized.

Outline An organized listing of the ideas to be discussed in approximately the sequence presented; this should assist the student in organizing and recording his notes; readings from the assigned text may be conveniently listed in this section opposite the pertinent outline topic.

Illustrations A compilation of visual aid material that can be used by the instructor in his presentation; inclusion in the guide enables the student to concentrate his attention on the

lecture since it is not necessary to attempt a rapid, usually incomplete or inaccurate, reproduction of an illustration for later perusal and study.

Educational Objectives The specific and measurable goals or things a person should be able to do when the unit has been completed; these are the guidelines useful in determining what the instructor deems important; they are also very helpful in reviewing or testing ones retention and comprehension of the subject matter; quizzes and examinations should be designed to measure the degree of achievement of these objectives.

Information Sources Relevant readings from texts or reference books; presented on two levels, introductory and advanced; these are mainly to provide sources that may present the same material in a somewhat different manner or that gives a more in-depth presentation.

Key Words and Phrases Vocabulary pertinent to the subject matter that one should know and be able to use; no definitions are included since most introductory texts contain a glossary of soil science terms.

Practice Problems Problems pertaining to the subject matter of the unit that provide practice in the quantitative manipulation of some of the concepts; examples with step by step solutions are included to illustrate the logic involved in problem solving; an answer set to the practice problems is given to allow self checking of one's progress.

Study Questions Questions that offer a means of self-testing and determining if the educational objectives have been achieved; answers to these questions are not included but should be readily found within the study guide, in lecture notes, or in text reading assignments.

Laboratory Exercises Provides a means to experience first-hand many of the concepts or procedures encountered only in a verbal manner; questions sets concerning the laboratory work or applications of the concepts are included in most cases.

These guidelines and self-learning aids are intended to minimize the "cost/benefit" ratio. Cost in this context means the time devoted to study and benefit the degree of achievement of the educational objectives. You are fervently urged to use them to your advantage.

L. J. JOHNSON

Acknowledgments

Rarely, if ever, is a manuscript the work solely of one individual and this case is no exception. The opportunity for preparation of this study guide was made possible by a grant from the University Division of Instructional Services, The Pennsylvania State University, for the improvement of an introductory soil science course, Agronomy 001. Donald W. Johnson, who represented UDIS on the improvement project advisory committee, provided invaluable guidance and advise throughout the life of the project. James Canelos, a graduate assistant from UDIS associated with the project from its beginning, was a great inspirational help and motivator who maintained excellent liaison between the author and the various sections within UDIS. His enthusiasm, interest, and eagerness to help in any way was a key factor in the auspicious inception of the project and its timely progress throughout the year. An example of his varied contributions is the installation of a new projection screen in 112 Buckhout, the usual lecture room for Agronomy 001. This was the result largely of Jim's efforts. Richard Rosenfeld very graciously coordinated the production of the art work. All the illustrations, graphs, and diagrams are the work of George Lavanish the artist associated with the project. His forbearance in transforming crudely drawn drafts into a quality product are sincerely appreciated. Through the creative effort of Francis M. Dwyer, who constructed the questionnaires, an informative evaluation of the newly prepared instructional material was made possible. The tolerance and good will in filling out questionnaires, and the frank evaluations by the Fall 1976 and Spring 1977 students in Agronomy 001 are commended. The influence of A. C. Richer throughout the study guide, but particularly in the laboratory exercises would be very obvious to any of his former students of which the author is one. Typing of the manuscript from handwritten copy was accomplished by the preseverance and devotion of Christine King, Judy Adams, and Tammy Leathers. Alsc recognized are the members of the faculty advisory committee for the project, Ernest L. Bergman, George L. Hargrove, Roger Pennock, and James L. Starling.

Contents

Unit 1

Prelude to Soils

1.0 Introduction

Soil it is but dirt it is not! Whatever the name used, soil has, whether we know it or not, a real impact on our lives as individuals and collectively as a society. Land, with its resources of flora, fauna, water, minerals, and soil, is the foundation on which nations and civilizations are based. It is abused and misused at our peril. All of our necessities and many of the amenities of life are inextricably linked with land and soil. Husband it, care for it, use it wisely, so that you and the generations to follow may reap its benefits.

Land, with its soil, is used for many different human purposes: (1) as building sites for homes, roads, shopping centers, schools, factories, (2) for forests, parks, and recreation, (3) as the ultimate repository for most of our solid and liquid wastes, and (4) for the growing of our food and fiber. Allocation of land resources to various competing uses has been a topic of increasing interest in the recent past and will continue to be into the indefinite future, on a local, state, and national level. *Finite* earth has been discovered and is entering our consciousness.

Although nonagricultural land use will be recognized where appropriate, our paramount interest in land and soil will be as an agricultural resource—a medium for plant growth. External to the plant itself (the plant's ecology) there may be defined six factors that control its growth and development: (1) light energy, (2) heat energy, (3) air, (4) water, (5) nutrients, and (6) mechanical support. Soil is the supplier of the last two and is involved in all except light. Another important aspect, sometimes included as a seventh factor, is the absence of *adverse* environmental conditions—insects, disease, weeds, foot traffic, air pollution, etc. The subsequent development of the subject matter about soil will be modulated by the concept presented above.

Land and soil are not synonomous, interchangeable terms, although they are often used in this manner. Land is a general term, including within its meaning, not only soil, but also all the living organisms and water bodies within or on it, the air above, and the rocks below. Soil is a narrower concept, which is composed of that part of the land surface that is a loose, unconsolidated material and in which plants grow (refer to the glossary in your text for a more specific definition).

1.0 Outline

1.1 Orientation
- 1.11 Necessary mental attitude
- 1.12 Scientific orientation—common element in many courses
- 1.13 Plants—common interest of diverse group
- 1.14 Brief historical review

1.2 Course description
- 1.21 Mechanical organization
- 1.22 Subject matter content
- 1.23 Subject matter organization

1.3 Soil-plant system
- 1.31 Plant system; ecological factors (6 or 7)
- 1.32 Soil system; physical components
- 1.33 Soil-plant connection; root system

1.4 Definitions and boundary conditions
- 1.41 Land and soil; dirt
- 1.42 Definitions of soil
- 1.43 The soil and a soil
- 1.44 Mineral and organic soil

Plants Growth Requirements

1. Light
2. Heat
3. Air; O_2 and CO_2
4. Water
5. Nutrients (17)
6. Mechanical support

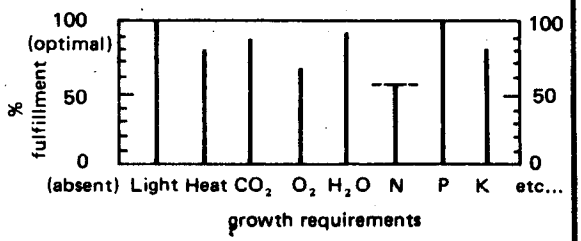
---

7. Absence of adverse conditions

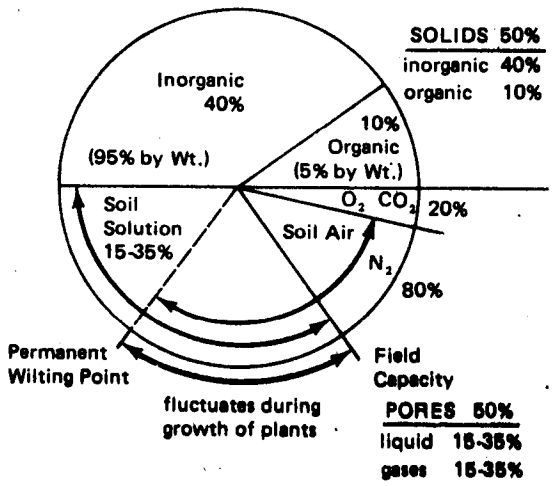
REQUIREMENTS FOR 150 BU/ACRE OF CORN (GRAIN, STOVER, AND ROOTS)

	Approximate lbs per acre	Supplied or Represented by
H_2O	$6.45\text{-}8.25 \times 10^6$	29-36 inches of rain
O_2	10,200	
C	7800 C or 28,500 CO_2	Carbon in 6 tons of coal
N	310	675 lbs urea
P	52	115 lbs triple super
K	205	340 lbs KCl
Ca	58	150 lbs gd. limestone
S	33	33 lbs sulfur
Mg	50	515 lbs epsom salt
Fe	3	15 lbs iron sulfate
Mn	0.45	1.3 lbs manganese sulfate
B	0.10	1.0 lbs borax
Zn	tr.	
Cu	tr.	
Mo	tr.	

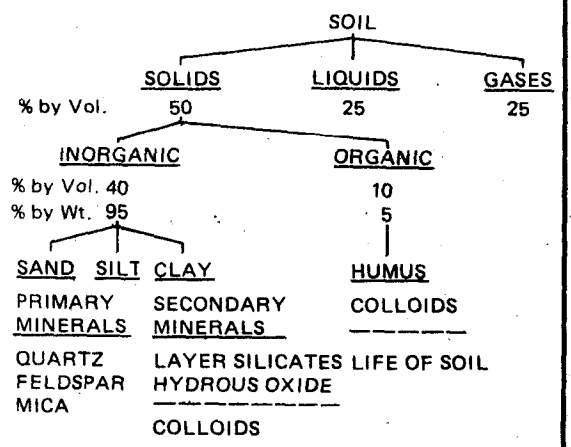
Law of the Minimum



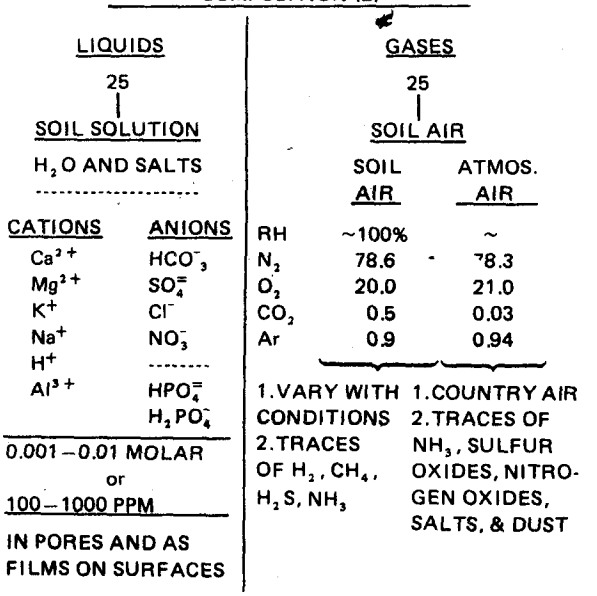
APPROXIMATE COMPOSITION OF A SURFACE SOIL (by volume)



TYPICAL TOPSOIL – APPROXIMATE COMPOSITION



TYPICAL TOPSOIL – APPROXIMATE COMPOSITION (2)

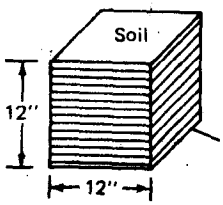


SOIL – ROOT SYSTEM

Rye plant in 1 ft.³ soil for 4 months

	length – miles	surface area – ft.²
ROOTS	385	2550
ROOT HAIRS	6600	4320

M = ~ 7000 or 1.0% of surface area in 1.0 ft.³ of soil

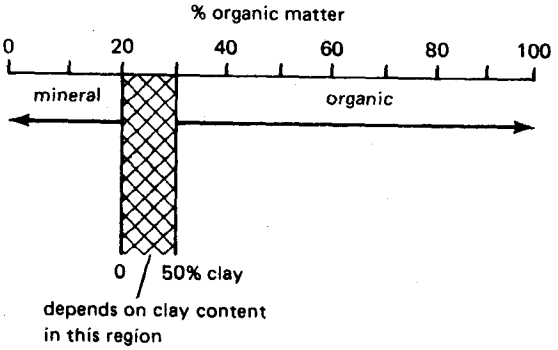


7000 slices

$\frac{12''}{7000}$ = ~ 0.002" or 0.005 cm or 50 μm

furthest distance of root surface from soil

MINERAL OR ORGANIC SOIL



1.0 Educational Objectives

On completion of this unit, the student should be able to complete the following:

1.1 Write a brief paragraph on the place of soil within our socioeconomic system, and its possible role in the rise and fall of past civilizations.

1.2 Distinguish between land and soil, by enumerating the factors involved in each and define soil from a practical (edaphological) and theoretical (pedological) point of view.

1.3 List the ecological factors determining plant growth, indicating the controlling influence and the role of soil in each.

1.4 Identify the physical phases composing a soil, indicating the amount present by volume, and give a brief description of the materials found in each.

1.5 Describe the physical nature of the soil-root system.

1.6 Define how soils are distinguished one from another and name some properties useful for this purpose.

1.0 Information Sources

1.1 Introductory and General

1.11 Brady, N. C. The Nature and Properites of Soils. 8th Ed. Macmillan Publishing Co., Inc., New York. 1974. Chapters 1 and 2. pp. 19-30.

1.12 Dale, T. and V. G. Carter. Topsoil and Civilization. 2nd Ed. University of Oklahoma Press, Norman, Oklahoma. 1974.

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1.18 Thompson, L. M. and F. R. Troeh. Soils and Soil Fertility. 4th Ed. McGraw-Hill Book Company, New York. 1978. Chapter 1.

1.19 Townsend, W. N. An Introduction to the Scientific Study of the Soil. 5th Ed. St. Martin's Press, New York. 1973. Chapter 1.

1.0 Key Words and Phrases

plant growth requirements
law of the minimum
soil
land
soil horizon
O, A, B, C-horizons
soil profile
solum
parent material
topsoil
subsoil
mineral soil
organic soil
soil monolith
soil series

1.0 Study Questions

1.1 Historical perspective

1.11 What is a land-oriented explanation for the development and long-term survival of civilizations in the Nile and Indus Vallies and the Mesopotamia area?
1.12 Why have civilizations in other areas not persisted for periods longer than 30 to 70 generations (800-2000 years)?
1.13 What has been the history of land use on the North American continent after occupation by nonnatives?

1.2 General Orientation

1.21 What ecological requirements must be fulfilled to sustain plant growth? Give the source of, an example of, and/or the reason for the requirement.
1.22 Explain the meaning of the "law of the minimum". Who originated this idea?
1.23 Briefly describe the physical situation of the root-soil system.
1.24 Define the term, *soil horizon*, and give examples of the main types. What is a soil profile?
1.25 Into what physical components may a soil be subdivided? What proportion by volume do each occupy? Name the constituents found in each. How does soil air differ from atmospheric air?
1.26 How can you distinguish between topsoil and subsoil? Organic and mineral soil? Land and soil? Define soil.

1.0 Laboratory Exercises

The soil, a generally-occurring body of unconsolidated, mineral and organic matter at the earth's surface, may be subdivided into innumerable individual, distinct bodies, any one of which may be called a soil. Recognition of a unique, individual soil body is made possible by examining and describing the morphological properties of its soil *profile*. A profile is a sequence of soil *horizons*—layers of soil essentially parallel to the soil surface,

that differ in properties – that are observed when a section of soil, vertical to the soil surface, is exposed upon excavation. The kinds of horizons found, and their properties, are thus used to define a soil. Some common physical characteristics used in describing a soil profile are *color*, *texture* (particle size), *structure* (particle arrangement), and *thickness* of each horizon. These individual soil bodies are called soil *series* and, for purposes of identification, are assigned names which usually originate from a nearby geographic locality where the soil series was first discovered. The Gatesburg soil series, for example, is named after the small village of Gatesburg, located in Centre County, a few miles southeast of State College, Pennsylvania.

The main horizon types are identified by the letters *O*, *A*, *B*, and *C*. *O* represents organic layers, *A* the topsoil, *B* the subsoil, and *C* the parent material. Use of the term *parent* implies that A and B were originally the same as *C* in appearance and properties but, over time, soil-forming processes have changed the parent material into the *A* and *B* horizons. *Solum* (true soil) is used in reference to the combination of the *A* + *B* since they are the horizons that are truly developed through soil formation.

In the exercise that follows, several examples of soil profiles are to be examined, using soil monoliths, to observe the appearance of soil horizons, profiles, and series.

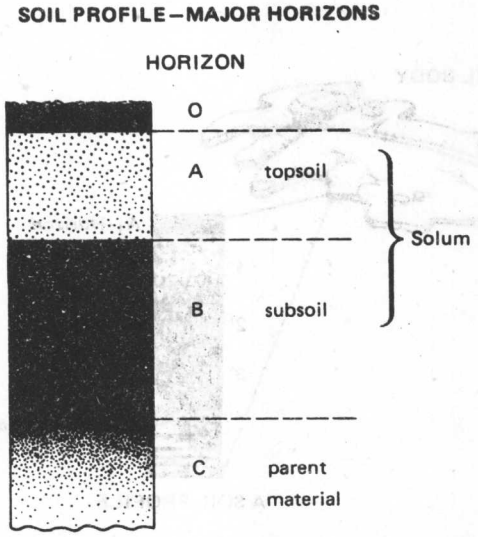

Figure 1.1 Main horizon types in a soil profile

Exercise 1.11 Examination of soil monoliths.

Monoliths are thin, vertical sections of a soil profile that have been mounted on a board by the use of plastic cement. They provide a convenient means of observing and comparing different soil series without going into the field. It should be emphasized that a soil cannot wholly be transported into the laboratory. A soil is a three-dimensional body, occupying some niche in the landscape, Figure 1.2, that gives it such properties as depth, slope, and aspect that are not transportable. A monolith is only part of a soil which just provides a sample of all or part of the soil horizons.

Material

1. Soil monoliths
2. DATA SHEETS and pencil or pen
3. Acute powers of observation

Procedure

1. Carefully examine the assigned soil monoliths.
2. Describe the nature of the profile by drawing in the major horizon boundaries and recording properties of each horizon—color, texture and thickness. Use the DATA SHEET.
3. In the field, the soil is liberally handled in the process of description. Unfortunately, this is not possible with monoliths. Therefore, only observable properties can be truly described. However, some of the field-determined properties are included on the brief compilation accompanying each monolith and may be used in making your description.
4. From the description provided with each monolith, find and list the series name, parent type material, topographic position in the landscape, and geographic locality where sampled.

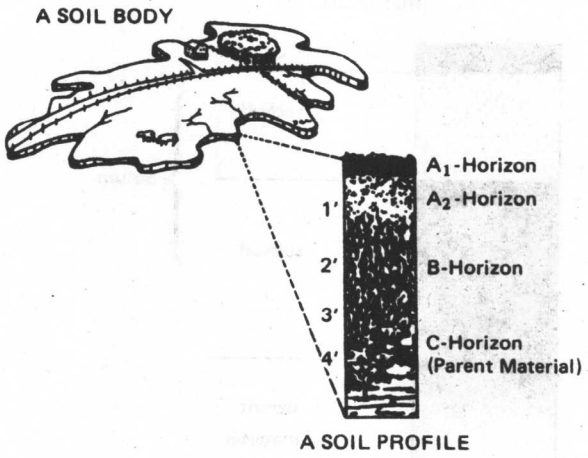

Figure 1.2 Illustration of a soil as a three-dimensional body within a landscape

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