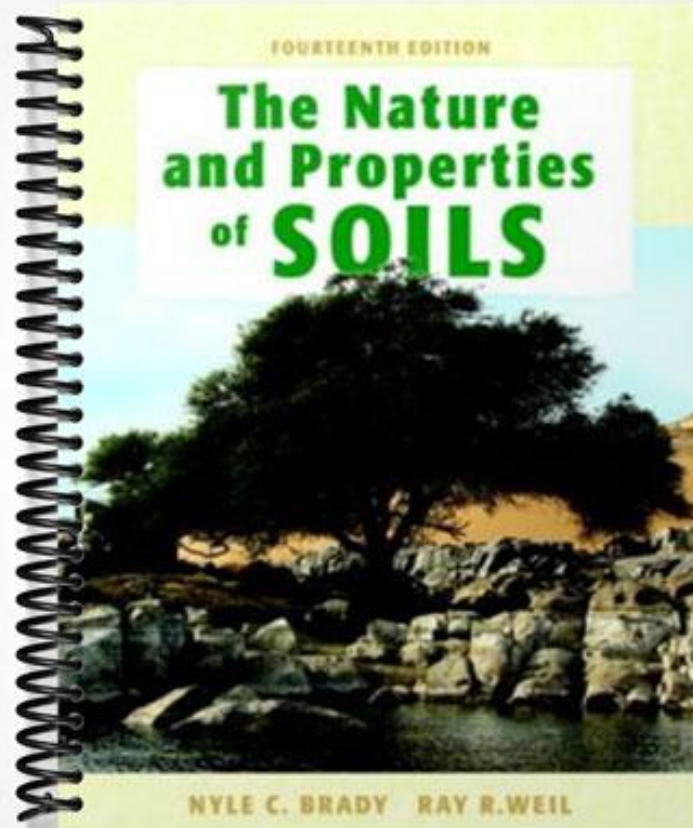


SOLUTIONS MANUAL



Instructor's Manual
with Test Item File
to accompany

The Nature and Properties of Soils

Fourteenth Edition

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PREFACE

This **Instructor's Manual** is designed to make it easier to teach soil science classes using the fourteenth edition of the textbook, **The Nature and Properties of Soils**. The manual brings four basic resources to the instructor:

- 1) A concise, three to five page summary of the main concepts from each chapter in the textbook.
- 2) Concise model answers to the study questions found at the end of each chapter.
- 3) A bank of about 40 test questions and answers for each chapter of the textbook, some 825 questions in all. These questions are in a format suitable for machine scoring in large classes. About half of the questions are in a multiple choice format and half in a true-false format. A CD with these questions is also provided as an aid in constructing exams and assignments.
- 4) A CD-ROM disk containing downloadable image files for most of the Figures and Tables in the textbook. These can be easily inserted into presentation software in order to make overhead transparencies, slides or computer presentation for the classroom.

Teaching a college level course in the fundamentals of soil science can be one of the most rewarding and satisfying experiences available to the professional educator and scientist. For most students, enrolling in such a course will mark the first time that they have given much thought to soils. In our experience, most students are unaware of the fascinating world that will be opened to them when they learn to truly see the soils around them. For many, the course in soil science will represent their first real opportunity to see practical applications of the principles learned in their basic chemistry, biology, and physics courses. A course in soil science offers an unparalleled opportunity to help students integrate the many concepts and skills they have collected during their years of education. Furthermore, students soon realize that soil science concepts, learned well, will reward them many times over in on-the-job situations. Inspired teaching of soil science will reward the instructor with the light of wonder and discovery in students' eyes.

I prepared this **Instructor's Manual** to accompany our textbook in order that you, the instructor, may be able to spend less time reviewing the material, writing exam questions, and preparing lecture visual aids. Perhaps you will thus have more time to interact with students and help them master, in an integrated way, the broad subject of soil science.

I hope that you find both this **Instructor's Manual** and the fourteenth edition of the textbook, **The Nature and Properties of Soils**, to be valuable tools in your teaching activities. Please let us know what you think. I have tried to make these books as up-to-date, accurate, comprehensive, and comprehensible as possible. I would gladly welcome your suggestions for improvement in future editions of the manual and the textbook. If you find an error, would like to suggest material for inclusion or deletion, or are aware of particularly useful illustrations for basic concepts, I would like to hear from you. Please fax, E-mail, or write to me at the following address:

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Chapter 1. The Soils Around Us

Overview

Roles of Soil

Soils play critical roles in many of the environmental challenges facing the world. Soils are essential for life on earth. People may not realize it, but they are becoming ever more dependent on the **ecological functions** of soil. Soil plays six key roles in the ecosystem: (1) supporting **plant growth**, (2) largely controlling the **flow of water** through the hydrologic cycle, (3) **recycling waste** products of society and nature, (4) modifying the composition and properties of the atmosphere (5) **providing habitat** for an enormous diversity of organisms, and (6) functioning in built environments as **construction material** and support for building foundations.

Medium for Plant Growth

Most plants depend on the soil for a suitable medium for growth. Soils provide at least six factors for plant growth: (1) physical **support**, (2) **aeration** for roots, (3) **moisture** supply and storage, (4) moderation of root zone and near-ground air **temperature**, (5) an environment relatively free of **phytotoxins**, and (6) 13 of the 17 **essential nutrient** elements. Usually animals and people obtain their mineral nutrients indirectly from the soil via consumption of plant materials, however for various reasons, **geophagy**- intentional eating of soils-is practiced by millions of people around the world for

The Pedosphere Concept

The importance of soil as a natural body derives in large part from its roles as an **interface** between the worlds of rock (the **lithosphere**), air (the **atmosphere**), water (the **hydrosphere**), and living things (the **biosphere**). Environments where all four of these worlds interact are often the most complex and productive on Earth. The soil, or **pedosphere**, is an example of such an environment.

Soil as A Natural Body

A soil is a three-dimensional natural body that exists in the **landscape**, much as a mountain or river does. The soil forms in the upper part of the regolith. Soil horizons develop as horizontal layers of the regolith become differentiated and a soil profile is formed, typically with O, A, E, B, and C master horizons. **Organic matter** is added to the surface, clay and salts are translocated, and parent material weathers into new soil material. In the process, topsoil becomes quite different from the subsoil. The nature of the soil at all depths in the profile - from as shallow as the upper 1 cm, to as deep as 5 or 10 meters - can be important for making wise land management decisions.

Soil: The Interface of Air, Minerals, Water and Life

An ideal soil in good condition for plant growth would have a volume composition of about 50% solid (about 45% mineral and 5% organic matter) and 50% pore space (about half filled with air and half with water).

Mineral (Inorganic) Constituents of Soils

Mineral soil particles come in all sizes and are grouped by size into coarse fragments (>2 mm), sand (2-.05 mm), silt (.05-.002 mm) and clay (<0.002). Clay differs, not only in size, but also in mineral make-up, from the sand and silt. Clay consists of both primary and secondary minerals. Soil structure describes the manner in which soil particles are grouped together.

Soil Organic Matter

Soil organic matter generally accounts for only 1 to 6% of a soil's dry weight, but greatly influences nearly all soil properties and uses. The soil organic matter includes living macro and micro organisms that make up the biomass portion. Humus is the portion that is well decomposed, colloidal,

and relatively resistant to further microbial attack.

Soil Water: A Dynamic Solution

Water in the soil is different from the water encountered in everyday life, for two reasons: (1) the liquid properties of soil water are modified by the attraction between water molecules and soil particles and (2) the water in the soil is never pure, but always has a tremendous variety of substances dissolved in it. The soil solution contains, among other solutes, most of the elements essential for plant growth. Eighteen elements (Table 1.1 lists both the **micronutrient** and the **macronutrients**) are now considered to be essential to plant growth (nickel was recently recognized as such), and all but C, H, and O are supplied to plants from the soil solution. The pH of the soil solution may range from very strongly acid (<4) to very strongly alkaline (pH>10), but most soils have pH values between 5 and 8.

Soil Air: A Changing Mixture of Gases

Soil air is different from atmospheric air because **carbon dioxide** is produced and **oxygen** is used up by soil organisms. Soil air is generally several times more concentrated in carbon dioxide than is atmospheric air. The exchange of gases with the atmosphere is of critical importance to plants.

Interaction of Four Components to Supply Plant Nutrients

Mineral weathering and organic matter decomposition release nutrient elements from unavailable storage forms to more available **adsorbed** or **dissolved** forms. The great bulk of most soil nutrients is present in unavailable forms stored in the solid framework of the soil.

Nutrient Uptake by Plant Roots

Soluble nutrients reach plant roots from the bulk soil by root interception, mass flow, and diffusion. Nutrients are taken up into the root by a biologically **active carrier mechanism** that transports nutrient ions across cell membranes.

Soil Quality, degradation and Resilience

Continued growth of the human population forces us to produce more food from the same or smaller area of land. Intensified agriculture on the best soils may help spare land for wildlife habitat and other uses, but only if soil quality can be maintained. **Soil quality** is a measure of the ability of a soil to carry out ecological functions, such as plant growth, water supply, and nutrient recycling. Soil quality reflects a combination of *chemical, physical, and biological* properties. Soil erosion, salt accumulation, nutrient depletion and organic matter depletion are some of the processes by which poor management can lead to **soil degradation**. Some soils are more **resilient** than other as evidenced by their ability to recover their quality more rapidly after such disturbances.

Model Answers to Study Questions

- See Section 1.1 and Figure 1.1.
 - Need to transform solar energy into food energy over huge areas of the Earth's surface.
 - Society's increased appreciation of and continued dependency on the services of natural soil-based ecosystems for water, wildlife, natural cycles and recreation.
 - Increasing replacement of petroleum by soil-grown plant products as feedstocks for chemical industry (e.g. soy bean based inks).
 - Increasing replacement of finite fossil fuels with renewable plant-based biofuels (e.g. ethanol).
- See Section 1.9.

A *soil* is an organized, three dimensional body that is a component of a landscape. Mere *soil* is some material from such a body that can be moved around by a shovel or bulldozer.
- See Section 1.1-1.2

Six soil roles or functions: (1) medium for plant growth; (2) regulator of water supplies; (3) recycler of nutrients and carbon; (4) modifier of the atmosphere; (5) habitat for soil organisms; (6) engineering medium. Examples of interactions between these roles: Plant cover (*medium for plant growth*) enhances infiltration of rainwater (*regulator of water supplies*); an abundance of soil organisms (*habitat for soil organisms*) enhances the release of nutrients (*recycler of nutrients*) by the decay of plant residues.
- See Box 1.3.

Individual experiences. Examples: observing erosion at a construction site; washing "grit" from a batch of fresh spinach; watering house plants; planting a tree; observing earthworms on the sidewalk after a rain; eating almost any food that contains nutrients from the soil in which it was grown.
- See Section 1.12.

Approximate percentages after compaction: air (10%), Water (30%), mineral (54%), organic (6%).
 Approximate percentages on a weight (mass) basis: air (0%), mineral (80%), water (18%), organic (2%) from the following approximate calculation:

Component	Volume, cm ³ A	Density, g/cm ³ B	Mass, g C=A x B	Fraction of total mass
air	25	0	0	0
water	25	1.0	25	25/135.5 =0.18
mineral	45	2.65	108	108/135.5=0.80
organic	5	0.5	2.5	2.5/135.5=0.02
total	100	-	135.5	1.00

- See Section 1.17 and Figure 1.25.

Most of the soil's nutrient "assets" are in complex and very slowly available mineral and organic forms (analogous to long term investments), but these release smaller amounts of nutrients into somewhat more available colloid fraction, which in turn help keep up the supply of adsorbed or exchangeable nutrients on colloid surfaces, which in turn resupply the nutrient content of the soil solution (analogous to pocket cash).

7. See columns 2 and 3 in Table 1.1.
Plants derive these essential (or quasi-essential) elements mainly from the soil: N, P, K, S, Ca, Mg, Si, Na, Fe, Mn, B, Zn, Cu, Cl, Co, Mo, Ni.
8. See Section 1.2 and Appendix B, page 923.
No, plants also take up elements which are not essential to the plant's growth. Examples are silica and sodium (not essential for some plants), selenium, vanadium, lead, etc. Some of these are nutrients for animals eating the plants, others (such as lead) are not, but are of concern because of their potential for animal toxicity.
9. See glossary for definitions.
10. See Section 1.19.
Some soil degrading processes: erosion, salt accumulation (salinization), nutrient depletion, and chemical pollution.
11. See Section 1.9
Pedologists study soils as natural bodies in the landscape without a particular land use in mind. Pedology is therefore closely related to surficial geology. The edaphological approach to soils aims at understanding the soil system as it relates to the suitability of the soil as a medium for plant growth. Edaphology is therefore a kind of ecology.

Multiple Choice Questions

(Circle the single best answer for each question.)

- Most of the different nutrients essential for growth are supplied to plants directly from the _____.
A. rain water B. soil solution C. atmosphere
D. cosmic radiation E. humus
- In a load of 10 cubic meters of topsoil, approximately how cubic meters of the volume would be solid material?
A. 1 B. 2.5 C. 4 D. 5 E. 7.5
- Which of the following is (are) essential plant nutrients?
A. Cu B. Al C. Sr D. Pb E. all of the above
- Which of the following is considered to be a plant macronutrient?
A. N B. P C. S D. Ca E. all of the above
- Soil occupies the _____ part of the regolith.
A. upper B. lower C. younger D. both B and C
- The lithosphere is made up of _____.
A. air B. rock C. water
D. plants and animals E. all of the above
- The layers of contrasting material found when one digs a hole in the ground are called _____.
A. pseudoliths B. regoliths C. pedons
D. horizons E. soil structure
- A soil profile consists of _____.
A. the sum of chemical and physical data known about a soil
B. the way a soil "feels"
C. the spatial boundaries of a particular soil
D. the set of layers seen in a vertical cross section of a soil
E. the general outline of a soil or group of soils when viewed from the side
- "Topsoil" is generally equivalent to which soil horizon?
A. A B. B C. C D. D E. E
- "Subsoil" is generally equivalent to which soil horizon?
A. A B. B C. C D. D E. E
- In a typical mineral soil in optimal condition for plant growth, approximately what percentage of the pore space would be filled with water and what percentage filled with air?
A. 10% water and 90% air B. 90% water and 10% air
C. 25% water and 25% air D. 50% water and 50% air
E. 25% water and 75% air
- The amount of different sizes of mineral particles in a soil defines the soil _____.
A. structure B. texture C. pore space
D. solution E. profile
- The water in the soil typically differs from pure water because the soil water _____.

- A. contains organic compounds
 - B. contains mineral nutrients
 - C. is restrained in its flow by attraction to particle surfaces
 - D. all of the above
 - E. none of the above
14. Compared to silt, clay-sized soil particles are characterized by _____.
- A. greater attraction for water
 - B. greater proportion of primary minerals
 - C. less tendency to form hard clods when dry
 - D. less capacity to hold nutrients in plant-available forms
15. Which of the following pH values represents a neutral condition?
- A. 1.0 B. 5.0 C. 6.0 D. 7.0 E. 10
16. Which of the following pH values represents the most acid condition?
- A. 1.0 B. 10.0 C. 7.0 D. 100 E. 5.55
17. Most (usually 80% or more) of soil potassium and calcium can be found in the form of _____.
- A. dissolved substances
 - B. structural components of minerals
 - C. exchangeable ions
 - D. organic compounds
18. Increasing the organic matter content of a soil is likely to _____.
- A. have no effect on water holding capacity
 - B. increase the soil's water holding capacity
 - C. decrease the soil's water holding capacity
19. Hydroxyl ion concentrations are greatest in a soil solution with a pH value of _____.
- A. 0.1 B. 4.0 C. 5.0 D. 6.5
20. In a given soil, the horizon with the highest organic matter content is generally the _____ horizon.
- A. E B. C C. D D. B E. A
21. Information about conditions at 2 to 4 meters deep in a soil is usually most helpful for understanding_____.
- A. how best to design a building foundation
 - B. the diversity of animal life in the soil.
 - C. the proper classification of the soil.
 - D. fertility requirements of most crops

True or False Questions
(Write T or F after each question.)

22. Except for some kinds of foods, modern industry has made human dependence on soils a thing of the past.
23. Most of the water in our rivers and lakes has come in contact with and has been affected by soils.
24. Soil air usually has a higher carbon dioxide content than the air in the atmosphere.
25. Plants can be grown without any soil.
26. Hydroponics will likely be a key element in enabling the world to feed and clothe its increasing human population in the next few decades.
27. Practices that tend to increase the amount of organic matter in soils would be expected to reduce the global greenhouse effect.
28. Soil, like concrete and steel, is a standard construction material. Its properties are well characterized and predictable so that standard building foundation designs can be used uniformly at all building sites of a given topography.
29. Although subsoil is more difficult to obtain, it is generally equally as good as topsoil for landscaping purposes.
30. Subsoil is typically equivalent to the O horizon.
31. The mineral particles in soil consist of sand, silt, and clay.
32. Where organic matter constitutes only 1 or 2 percent of the soil by weight, it has only negligible influence on soil properties.
33. The dark brown and black humus found in many soils does not mix well with clay minerals so there is very little contact between these two soil components.
34. Soil horizons, like alluvial sediments, generally have a horizontal orientation, regardless of the slope of the land.
35. A, B, C, and E horizons can be found in any true soil.
36. For any soil in which it is present, the C horizon is the parent material for the B horizon.
37. While many organisms depend on the soil for nutrients and water, only a few very specialized organisms live in the soil itself.
38. If supplied with a suitable nutrient solution, plants can grow normally without any soil at all.
39. Natural soils (as opposed to modern farm soils) can recycle organic compounds, but not inorganic elements.
40. Most of the water flowing in rivers passed through a soil profile or over soil surfaces before reaching the river.

41. Most, if not all, of the nutrient supply stored in a fertile soil is in forms readily available to plants.

42. In humid regions most rainwater that soaks into the soil and is not used by plants eventually flows into rivers and streams.

Chapter 1 Answers

1. A
2. D
3. A
4. E
5. A
6. B
7. D
8. D
9. A
10. B
11. D
12. B
13. D
14. A

- 15. D
- 16. A
- 17. B
- 18. B
- 19. D
- 20. E
- 21. A
- 22. F
- 23. T
- 24. T
- 25. T
- 26. F
- 27. T
- 28. F

- 29. F
- 30. F
- 31. T
- 32. F
- 33. F
- 34. F
- 35. F
- 36. F
- 37. F
- 38. T
- 39. F
- 40. T
- 41. F
- 42. T