Chapter 5 -- Soil Science

SUGGESTIONS FOR STUDYING ATOLL SOILS

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A. Objectives:

The purposes of studying the soil vary according to the aims of the investigator but recognition of alternate or subsidiary objectives may aid him in getting the most from his study. Common objectives -- which overlap to some extent -- are:

1. For knowledge of soils per se as natural bodies, their kinds and distribution and how these are affected by climate, geological materials, vegetation, topography and age.

2. There are obvious relationships between soil and vegetation. Very commonly the soil decidedly influences the distribution and competitive abilities of both macro- and microflora and of the fauna.

3. In a larger sense the soil is part of a comprehensive ecological view. Even in general terms, a "feeling" for the historical development of the land surface and soil, their response to natural processes and cataclysms, and the influences of both primitive and recent mankind provide a perspective or frame of reference for other investigation.

4. Agricultural development and, to a lesser extent, a detailed understanding of contemporary or paleoagriculture obviously depend on knowledge of soils.

5. The study of soils often has geological, hydrological and archeological implications. Soil texture, moisture relationships, profile age or inferred typhoon history are obvious examples. Indications of man's former activities are occasionally revealed as are some of the natural limitations on his use of land.

These objectives are stated in general terms. The significance of some aspects is greatly altered by the youthful nature of the atoll soils. From the meager reports all appear to be lithosols and regosols, their characteristics still dominated largely by parent material and time of development; none of them are mature soils in the usual sense of the term. For this reason the amateur student should be quick to lay aside his textbook generalities about soil profiles and development when they fail to fit field observations.

B. General methods of study:

There is a popular notion, unfortunately shared by too many naturalists, that the important and concealed properties of the soil are somehow revealed by means of a "soil test." It should be clearly understood that knowledge of the soil starts in the field; without comprehensive information on their natural occurrence, laboratory analysis of samples is at best limited in applicability and may be useless or misleading. Usually we are concerned with three general types of information:

1. Knowledge of the kind of profiles and their distribution: The kinds of profiles are distinguished by differences in parent material, drainage and degree of development. These usually involve description of soil texture, structure, color, depth, etc. Fortunately, in the simple environment of the atoll there are relatively few combinations of these factors.

(a) Parent materials, for the most part, are from corals, mollusks, calcareous algae, foraminifera, etc., usually in mixture. These are largely composed of calcium and magnesium carbonates with very small amounts of other materials. Their physical nature -- gravel, sand, etc., -- and consolidation, is important; identity of the class of organisms may be also inasmuch as it influences chemical compositions.

Phosphatic materials are usually readily recognized by their brown color. Such deposits are often cemented but loose sands also occur. Wave working and redeposition of such deposits or even local washing from them may influence surrounding areas and such admixture should be looked for. Guano deposits are of obvious significance.

The presence of other kinds of parent material is not probable but the possibility must be kept in mind. The occurrence of basalt fragments in the Rose Atoll reef presumably explains Lipman's analytical results of soil material from there and entirely vitiates his conclusions. Ships ballast, and soil transported for garden by colonials or natives -- as on Funafuti, Jaluit and elsewhere -- may locally influence the soil.*

(b) Soil drainage is in part inferred from topographic position, groundwater level, etc., and confirmed by profile examination. Because of their coarseness most atoll soils are well-drained and peats formed under conditions of extremely poor drainage are easily recognized. Between these, however, may be soils of progressively poorer drainage which cannot be characterized by any single feature. Water level, soil moisture content, character of the surface soil and deeper layers compared with those of obviously well-drained soils, etc., provide evidence for the classification of drainage levels.

(c) Degree of development is a relative term since most atoll soils are youthful. The horizons that can be distinguished are described as to sequence and character, that is, texture, depth, color, etc. Most well-drained atoll soils appear to be simple and shallow, consisting of a horizon of organic incorporation (A_1), say, 4 to 10 inches deep which passes through a more or less narrow transitional zone into relatively unaltered parent material (C horizon). The upper portion of the C may be slightly weathered and stained with organic matter and tongues of the A_1 may penetrate into it. Upon Arno atoll the depth, color and organic content of the A_1 usually increased in passing from the shores to the wide interiors; this sequence is related to both time of development and character of the vegetation.

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* Floating pumice

Particular attention should be given to evidence of erosion, deposition, buried horizons, etc., which may otherwise be misinterpreted. Buried profiles are relatively easy to distinguish for accumulation of an appreciable organic horizon is a surface phenomenon. Their occurrence at depth is obviously related to further deposition by storm waves, blow sand, etc. Soils receiving continual small surface additions as wind-blown or washed on sand, may develop a deep A_1 horizon fairly rapidly and to a degree simulate an older soil.

It should be borne in mind that many islands have been long inhabited and thus occasional profile anomalies caused by man's digging can be expected. On Arno the pits dug for sanding walks occasionally intersect former pits which were filled with rubbish before being closed; these now appear as extraordinarily deep A_1 horizons. Hog rooting can cause widespread disturbance of the upper few inches of the soil.

The character of the surface horizons, drainage level, salinity and texture (sandy or stony) largely determine the more obvious soil-plant relationships. These elements can be studied as separate variables or as properties associated with soil groups. For classification it will be found that most of the "normal" profiles can be referred to a few groups or soil types. Within each of these will be a certain amount of deviation about the "modal" or "type" profile and in fact some of the types may intergrade. Having fixed upon recognizable units these can be mapped to show distribution, or used to describe areas or study their relation to other features. Recurring associations of different soils (or soils and land types) which are hopelessly intermingled can be described and mapped as <u>complexes</u>. Thus, on Arno the stony land formed on the beach rampart could not be satisfactorily separated into units of different age and development although generally it became progressively more youthful towards the sea; accordingly, it was mapped simply as a stony land complex although this is admittedly unsatisfactory for vegetational studies.

2. <u>Other field observations</u>: These will vary with the purposes of the investigator. Presumably vegetation, plant development or agricultural use will be recorded as a matter of routine. Degree of rock weathering, soil fauna and extent of their activity, evidence of land clearing and trash burning, evidence of old house sites or disturbance and inferred land history are other observations that must be made on the spot. To some extent qualitative observations of soil moisture, such as depth of wetting or drying, unusual wetness, as at the capillary fringe, etc., may be useful although the coarse texture and uniform color of the lower horizons limits the accuracy of such determinations.

Depth of rooting and root distribution, particularly in relation to groundwater and its salinity appear to be very significant for vegetation. Fosberg and Cox suggest that groundwater salinity is probably the feature controlling development of the breadfruit. By way of contrast, coconut roots seem to readily penetrate from the soil upward into heaps of sodden decaying coconut husks on the surface. Root nodules and legumes may be inconspicuous, fragile or distant from the root crown so their absence should not be inferred from superficial observations.

As soils, special materials such as peat, phosphate and guano may have little genetic significance but increase the limited range of habitat variations over which a given species or vegetational type can be studied. Thus, coconut and pandanus may grow successfully on the low-humic, seemingly dry recent dunes as well as in the highly organic soils of the interior and in fresh water peats where there is no competition for moisture. Rock porosity and the presence of fissures must be considered when studying moisture relations of cobbly soils or those shallow over consolidated rock.

3. Analytical procedures and sampling:

(a) Field analytical techniques are limited to pH and soil or groundwater salinity. Determinations of nutrient availability, etc., by the usual field "kits" are eseentially meaningless. Soil moisture could be determined with reasonable accuracy by drying to an air-dry condition and weighing, but other physical analyses require specialized equipment or "briefing."

By using indicators pH can be determined easily in the field. Reaction probably has little general significance, since most soils are calcareous. Poorly drained soils, peats, and phosphatic soils should be tested in the field, however, since a wide range in pH is possible and, moreover, the reaction of peat samples may change materially upon drying.

The most rapid means of measuring salinity of the groundwater and soil extracts is with a conductivity bridge but the cost and possibility of instrument failure remote from repair facilities must be considered. Chloride titration with silver nitrate is an accurate method adaptable to field use. Fosberg's hydrometer method, with temperature correction, provides a rapid means of determining groundwater salinity in the field although of only moderate precision.

(b) It is unnecessary to mention the laboratory analyses here but the investigator would do well to make tentative arrangements for analysis of the samples before they are taken. Otherwise, he may have more or less than can be examined. As already implied, if the laboratory analyses are to be worthwhile the samples must be taken with reasonable care from well described profiles. In general, samples should be taken from a known depth but within recognized horizons, dried at air temperature without contamination, enclosed in tight durable containers and well labeled.

It is well to describe the profile thoroughly prior to sampling. The samples are taken as representative of horizons or portions of a horizon and usually are composites of several inches of depth, e.g. 0-6 inches, 6-11 inches, 14-20 inches, etc. Samples should be at least 100 grams in weight and 300 to 400 grams is preferable. In taking a sample from a given depth range equal amounts of soil must be taken from each part of the range if the sample is to be truly representative. The number of samples and width of the range can be modified to fit circumstances. Transitional zones should be excluded or sampled separately. With the simple profiles found on

Arno two to four samples per profile, often covering a six-inch range, were found adequate. Roots, stones, excess gravel, etc., are usually excluded when sampling since only the finer fraction (less than 2 mm.) is used for analysis. With very stony or gravelly soils some estimate should be made of the amount of the excluded matter, preferably by weighing, if analytical results are to be compared with other soils. Thus, 30% organic matter in the 2 mm. fraction of a very gravelly soil may be no more significant than 10 or 15% in a uniform sand.

The sample should be spread out and air-dried as soon as convenient; in long periods of wet weather gentle artificial heat may be necessary but this should be at a minimum. The most suitable container for field collection and shipment are small canvas bags made for the purpose. Paper bags disintegrate when wet and are likely to burst in shipment; however, extra-heavy 3 or 5 pound paper bags can be used double and tightly packed for shipping. Cylindrical, waxed cardboard icecream containers are satisfactory but are very bulky even when empty.

Samples for study of microorganisms must be taken and handled with a special regard for contamination.

All samples entering the country must pass through the USDA Division of Foreign Plants quarantine. If necessary samples may be shipped directly to the Inspection House, Bureau of Entomology and Plant Quarantine, Washington, D. C., enclosing list of samples and a copy of the covering letter; the originals of both should be sent to Dr. H. S. Dean of the above division and bureau. A much better procedure will be to write Dr. Dean and work out arrangements in advance of shipment; this will facilitate entry and delivery. If microbiological studies are intended this should be stated so the samples will not be fumigated.

C. Field procedure:

Possibly the primary intent of field work will be to recognize and define classes of soil so their relationship to each other and to other features may be observed. Classes, which may or may not correspond to soil types recognized elsewhere, are established by recognizing the modal profiles and a permissible range about each. The field procedure is thus somewhat as follows:

1. Know the general geography of the island being studied. Locate profile pits, topographic features and type lines on maps or sketches.

2. Observe the origin and geomorphology of the area studied, e.g. lagoon or sea beach origin, dune ridge, beach rampart, basin, etc.

3. Examine soil profiles in excavations.

(a) Before attempting serious description look at a number of profile exposures -- sand pits, wave-cut dunes, etc., and shovel holes -- for a general notion of the soils.

(b) Dig or, better, have dug a few to several profile pits to penetrate well into unaltered material. When in doubt, dig deeper.

(c) Describe these profiles in detail, preferably with a methodical recording of depth, texture, structure, color, etc., of each recognizable horizon.

(d) Tentatively establish classes and examine as many more profiles as necessary to clearly define their modal profiles and limits. This is less burdensome than may appear for the number of classes on an atoll will be few and some limits will be fixed sharply by the considerations of 2 above.

(e) Sample profiles representative of major soil types or otherwise significant profiles. These may be chosen to represent a sequence of development, drainage level, etc. If desired, map the types established under (d) for an accurate picture of soil distribution.

Despite the above it should be understood that step-by-step instructions for studying soils have the same limited usefulness as they would for, say, making love. In both instances there is a high degree of individual variation and, in any event, if intuition or previous experience is lacking, the case is probably hopeless.

D. Miscellaneous:

1. The USDA Soil Survey Manual currently in press sould be referred to for definition of terms and units.

2. The tools and equipment for the study of soils in the field are simple:

a. A soil auger may be useful occasionally but a shovel or spade of some sort is essential; a long bladed tiling spade is useful since a slice will expose the entire upper profile.

b. With the pH kit should be included dilute hydrochloric acid and extra supplies of acid and indicators.

c. Containers for samples.

d. For intensive field work a set of Munsell soil color charts is useful but for most purposes accurate color determinations can be made on the dried samples upon arrival at the laboratory.

e. Additional equipment is necessary for moisture or salinity determinations.

f. Paper on which to spread samples for air-drying, labels, wrapping materials, etc.