Soil and Civilization

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Many persons think of the soil as a lifeless, residual layer, which has somehow accumulated over a long period of time and which merely holds a supply of things necessary for plant growth. Far from being a lifeless zone, it is a changing and developing body teeming with life. We know that soils become adjusted to conditions of climate, landform, and vegetation and will change internally when those controlling conditions change.

Soil has been inextricably associated with plant life and higher animals on the earth. Although soil has mainly been studied as a place to grow plants it is perhaps the most important natural resource which we have. Soil gives us the food of life, it conserves our water resources, it supports much of our housing, provides us with airports and road bases and many of our minerals, and conceals much of our industrial and domestic waste. When badly handled or misunderstood it gives us our dustbowls, fills our hydro dams with silt, erodes and slips and destroys our homes.

Soils occur on the earth's surface mainly in climatically controlled zones. In areas where the soil parent materials have been recently renewed by glacial, volcanic or fluvial action, fertile soils occur today. Each year the Nile floods and brings its bounty of plant nutrients, while in Indonesia and on the slopes of Vesuvius, recent volcanic ash gives rise to fertile soils. In areas such as Canada and Northern Europe where the last glacial period exposed fresh mineral rock materials, fertile soils are

found.

On the other hand, in old geologically stable continents such as Australia, Africa and India the soil materials have been strongly weathered for geologic periods and deprived of most of their plant nutrients; in these areas human and plant deficiency diseases are common. It is a grim stroke of ill luck that most developing countries already harassed by internal domestic problems have their economic problems compounded by poor soils.

Deep clay deposits in Ontario and other parts of Canada may change their consistency suddenly from the solid to the liquid and slide out, causing tragic loss of life. Such a "quick clay" slide occurred in 1971 in St. Jean Vianney in Quebec and claimed many lives. The ramifications of freeze and thaw and permafrost are major economic considerations in Canada.

Modern agriculture is virtually dependent on herbicides, pesticides and the use of artificial fertilizers. The long term effects of these on the soils and on the environment are not fully understood but some of the results are ominous. The effects of pollution of rainfall, most commonly by SO_2 forming H_2SO_4, have been shown to be far-reaching in some areas. The role of DDT in soils has been well documented.

The soil has long been used as one of the major materials for disposal of industrial and domestic waste. The role soil plays in the breakdown of these materials and the ensuing water cycle is a vital one. What the long term effect on the deep-rooting plant will be is not fully known.

The soils' ability to decompose organic animal and human wastes is quite unbelievable but it is nevertheless limited with respect to time. It is known that humble worms can pass through their bodies 15 tons of dry earth per acre per year. This is a startling figure and means that an acre is completely processed to a depth of eight inches each 60 years. Earthworms' cats may weigh as much as 16,000 pounds per acre.

SOIL PROPERTIES

A soil has distinctive, physical, chemical and biological qualities which set it off from the infertile substratum. The soil is composed of mineral and organic particles and has distinctive layers or horizons. Soil matter is made of substances existing in three states: solid, liquid and gaseous. Weathering of the rocks produces inorganic particles that give the soil the main part of its weight and volume. These fragments range from gravel and sand to tiny colloidal particles too small to be seen in

the optical microscope. Organic matter produced by the breakdown of plant and animal life is disseminated through the upper horizons of the soil as colloidal-size materials. The soil is the habitat of millions of small animals called macroorganisms and a host of varieties of microorganisms such as bacteria, enzymes, viruses, etc.

Soil has the property of base exchange: that is, the electrical binding of plant nutrients to the tiny soil colloids which carry an electric charge. This property and photosynthesis are probably the two most important natural phenomena enabling life to exist on our planet.

The term "soil profile" denotes the arrangement of the soil into layerlike horizons of differing colour, texture and consistency. Basically there are three parts to the soil profile. The surface horizon is the zone of humus accumulation and soils which are high in organic matter are usually black to very dark brown. With decreasing organic matter the horizons become lighter in colour. Reds and yellows are common colours in soils and are the result of small quantities of iron and the state of hydration of iron: goethite is yellow and hematite is red. Pale blue and gray colours indicate the presence of iron in the reduced ferrous form common to waterlogged and wet environments.

Soil texture, a major characteristic of the soil, refers to the particle sizes composing the soil. The primary particles of the soil are classified as sand, silt or clay and the relative amounts of these in a soil sample denote its texture; sand, loam or clay.

ORIGIN OF SOILS

Many types of processes and influences, known as soil formers, act together to develop a soil. The principle soil formers are climate, topography, parent material, biology, time and man. These factors, acting in different ways at each site on the earth's surface, have produced zones of characteristic soil profiles in the earth. The presence of these zones was first discovered by a Russian civil servant, V.V. Dokuchaev, who made regular trips from St. Petersburg to Crimea. Owing to linguistic and communication difficulties, his concepts did not reach the West until many years after his death in 1909.

In humid climatic regimes, rainfall and other surface water will enter the soil, pass through the entire soil profile and enter the drainage systems. The soil profile will be leached and distinctive horizons produced. By convention the zone in the soil profile which is strongly leached

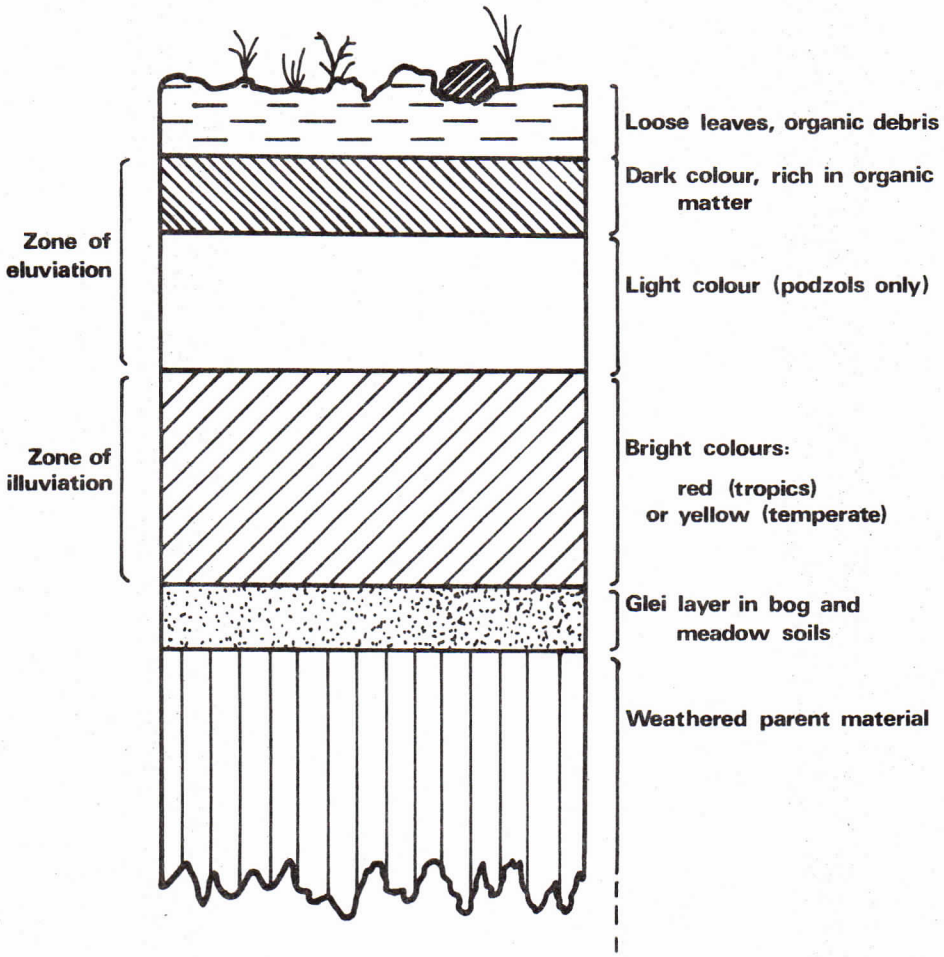

FIGURE 1. IDEALISED SOIL PROFILE

is called the A horizon or the eluvial zone, and that zone in which some of the materials leached from A are accumulated by various processes is called the illuvial zone, or B horizon. The A horizon is only slightly darkened by organic material (humus). The B horizon is the subsoil or parent material. In wet areas, soil profiles are generally light coloured with well defined rust-coloured mottles: this is called glei and gleization.

DISTRIBUTION OF SOILS

Soils occur throughout the world in zones which are first and foremost a function of climate. Soil zones run north-south in U.S.S.R. and east-west in U.S.A. owing to differing distribution of climatic zones. As one ascends a high mountain the climatic effects are similar to moving laterally from one zone to another. The generalised classification of soils shown in Table 1 is a useful guide.

TABLE 1: GENERALISED CLASSIFICATION OF SOILS

REGION	CLIMATE	SOIL GROUP
Humid forests	(1) Mild temperatures	PODZOL
	(2) Equatorial and subtropical	LATERITIC
Grasslands	(1) Mild humid climate	CHERNOZEM
	(2) Dry and hot	GRUMUSOL
Cold zones		TUNDRA
Wet zones		BOG, MEADOW
Arid regions	(1) Saline	SALINE, CALCAREOUS

The Podzolization process dominates in climates generally polewards of 40° latitude with a cool marine climate or with continental cold winters and adequate precipitation distributed throughout the year. Humic acids, produced from the abundant leaf mould and humus, leach the upper soil strongly of bases, iron and aluminium, leaving the characteristic gray soil composed largely of quartz. The materials carried out of the upper hori-

zons collect in the lower levels, forming iron, clay or base-rich horizons.

The Laterization process is in some respects the warm-climate relative of podzolization, taking place in hot, humid forest environments. The extreme weathering conditions break down all but the most resistant soil constituents. The iron oxides are precipitated in the soil profile and may form layers of up to 20% iron in the soil. This has been called laterite as it irreversibly hardens.

Some soft laterite occurs today in the Indian subcontinent where it is dug from the soil by hand, hardened in the sun and used for building materials. In those areas where climatic change to arid has occurred since Tertiary time the laterite occurs as a very hard layer in soils. It is commonly about 4 ft thick and although it constitutes a potential source of iron, it is not yet profitable to mine it as an ore. In some areas bauxite, the most common ore for aluminum, is formed instead of laterite.

The Calcification and Salinization processes occur in arid environments where rising capillary waters bring the products of soil mineral breakdown to the surface where they are precipitated out. The most common form is caliche - secondary calcium carbonate - which may occur as a continuous hard horizon. In some areas, salts of sodium, potassium and magnesium concentrate in the surface horizons and produce characteristic soil profiles.

Finally, the Gleization process occurs in areas which are dominated by high water tables, be they in cool or tropical regions. In cool regions organic matter may form a peaty surface horizon. In regions with constantly high water tables, minimum oxidation and mineral breakdown will occur and iron is maintained in the virtually colourless to pale blue-green ferrous state. However, in sites where the water table fluctuates so that reduction and oxidation conditions alternate, reddish to yellowish-red spots are formed around suitable oxidising centres such as root holes, worm holes, etc. These spots are called mottles and the patchwork of reddish and yellowish-red mottles set in a blue-gray background is said to be mottled, while the term glei refers strictly to the unoxidised profile.

SOIL EROSION

Man has generally been exploitive in his use of soils. In early times, and even now in many parts of the developing world, man has practised a system of shifting agriculture whereby an area of forest is felled and cultivated and the accumulated nutrients used up in a few years (may range from one to six) by the native cultivator. The forest is then set to

fallow again and a new piece of forest is felled and burned. This cycle was usually of about 25 years duration but with new population pressures this cycle has been dangerously shortened in many areas. Agricultural practices in the New World were aimed (during the nineteenth and early parts of this century) at the complete exploitation of the soil resources. This was probably dramatised with the occurrences of the "dustbowl" conditions in U.S.A. and Canada, but man was almost equally destructive in Australia, New Zealand, South America and South Africa. In Mesopotamia, at least ten civilizations rose and fell during the period of Babylon-Nineveh. The mighty Nebuchadnezzar built the greatest city-state and empire the world had seen. Trees were cut down so extensively that forested slopes have never been replaced even to this day: cedars were imported from Lebanon when timber supplies ran out. Evidence indicates that soil erosion tipped the balance for the survival of many of these civilizations. When the practices of good soil husbandry were neglected, the silting of canals so vital to a continuance of the society occurred rapidly.

In the Negev desert the city-state empire of the Nabateans ruled from the second century BC. to the rise of the Arabs. Petra was their unofficial capital. It is estimated that many of the cities using conserving methods of soil and water use supported more than 10,000 people. When the state of Israel took over the Negev in 1948, there were less than 4,000 nomadic bedouins in the whole area. This state had prevailed since the rise of the Arabs about 750 A.D.

When the soil nutrient reserves are exploited to such a degree that the organic matter content is severely reduced, soil loses its natural aggregation properties and tends to erode easily. This condition, together with socioeconomic conditions in the early part of this century, led to the dustbowl conditions of the 1920's. The same kind of conditions may also obtain under conditions of native agriculture and many agricultural systems in Africa are quite exploitive.

I should also draw attention to the potentially erosive nature of Arctic soils. We have learned to our surprise how quickly these soils may erode along and in connection with pipeline construction. Considerable care should be exercised in the siting of such operations.

FUTURE PERSPECTIVES

This is the age of the doompreachers. The spectre of world starvation within the next generation is projected as a fact, if not a reality. The food supply problem for future generations arises from the question of

how to live within one's ecological means without being forced to do so by naked hunger. It would be irresponsible for me to suggest that we should not take heed for the future, but it is my conviction that at the present time serious technical limitations to feeding the world's population at 3000 calories a day are not in sight. The cold hard fact of life is that farming virtually throughout the so-called Western world is the non-U occupation and bankruptcy stares many farmers in the face. Knowhow and capital are by far the greatest limiting factors for agricultural production today. If the Russians cared more about practical agricultural production than the tenets of Marxism, they could be exporting wheat instead of importing. Need I remind you that until the 1950's Viet Nam was one of the "rice baskets" of Asia? I nourish no doubt that New Zealand, much of South America, Europe, the U.S.A. and Canada could increase their production many times in a very short period if the economic stimulus was present. It may not need more than the cost of one day of the Viet Nam war to finance a substantial increase in food production research.

Having now made this statement, how can I defend my premise that we must take heed for the future? Land is our most precious continuing resource. As resource fuels, wood, charcoal and coal have come and almost gone - oil will soon be on the way out and atomic energy is helping us now. However, the soil must go on forever. Existing agricultural land will be reduced as demands for urban and industrial demands increase - our Niagara area is a sad example of this. The best land must be held in trust for the coming generations as they will certainly need it. Between 1882 and 1952 the total land area of the world occupied by permanent buildings increased from 0.87 billion to 1.6 billion hectares. This will be much higher if by the year 2000, 81% of the population of developed countries and 43% of the developing countries are living in urban areas. It is thus vital that urban development is planned and directed so that good land is maintained and that building and development are situated so as to jeopardize as little as possible the future world food production.

Many modern ills such as the use of artificial fertilizers, heavy machinery and pesticides are poisoning the soils. I do not worry about the fertilizers but I am certain that far-reaching changes in laws restricting the use of pesticides must soon be established in spite of the fact that it appears that heavy dressings of these are necessary to produce crops. Biological control will certainly be found for many pests, and new cultural and biological controls for weeds are on the threshold. Plant breeding will probably be the most exciting agricultural research field of the immediate future. Great advances have been made locally in rice and wheat production in tropical regions, but when financial incentive stimulates, I

am certain we will see even greater strides in plant breeding in temperate regions. Instead of thinking only of yield increase, perhaps it is more relevant to think of decrease in maturing time. In Norway 56-day barley is the basis of their modern and enterprising agriculture. Why not a 60-day wheat for the same region?

Finally, may I remind you that soil is still one of our major resources and that in spite of the green revolution and the depressed conditions of Canadian and much of world agriculture, a goodly percentage of humanity dies prematurely of hunger each year. We must conserve these resources to the best of our ability so that the humble soil is preserved for future generations and the best use is made of it both for this and succeeding generations.

REFERENCES

There is an increasing variety of reference works available on soil science. There are books with a traditional soils/agriculture alignment but now there is an increasing number of books on the study of soil as a natural historic body.

One of the classical works by a "grand old man" of soil science is *Soil Conditions and Plant Growth* by Sir John Russell (Longmans, Green & Co., 9th Edition, 1954) which ran eight editions in his lifetime and has now been revised by his son twice.

The Nature and Properties of Soils (H.O. Buckman and N.C. Brady, 1969) is excellently written and is of interest to all readers in spite of its strong agricultural bias. It is used as a course reference at this university.

Introductory texts with a general appeal include:

Strahler, A., *Physical Geography* (N.Y., John Wiley and Sons, Inc., 1969). Chapters 19 and 20 give an excellent concise introduction to the nature and distribution of soils.

Bridges, E.M., *World Soils* (Cambridge Univ. Press, 1970). Paperback. Excellent value, used as text at Queen's.

Origin, Classification and Use of Ontario Soils. Available free from Ontario Department of Agriculture and Food or very cheaply from Queen's Technical Supplies. This is a first class study of the soils, geomorphology and late Pleistocene history of Ontario.

There are many worthwhile chapters on soils and the environment in

a number of recent publications.

Committee on Resources and Man, *Resources and Man*, National Academy of Sciences/National Research Council (W.H. Freeman and Co., San Francisco, 1969). The resource potential of soil with respect to food and minerals.

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