SOIL EDUCATION AND PUBLIC AWARENESS

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Summary

The importance of soil in shaping life, including human civilization, is hard to exaggerate. Soil properties determine to a large extent how much food will be available in a region, where cities can be built, and whether or not living there is sustainable in the long term. Despite these realities, the importance of understanding soil is not immediately obvious to many people.

In biosciences, soil is a small part of the Earth's mass, varying from a few cm to a few
meters in thickness, depending on the specific definition of "soil" used. Past civilizations have risen based partly on the productivity of soil in producing an excess of food, allowing human effort to focus on government, industry, artistic and military pursuits. Recent human experience has largely forgotten that essential human tie to the land, though it is just as important now as it was thousands of years ago.

The current ignorance of soil appears to be reinforced by Society norms. If allowed, human consideration of distinct properties associated with soil formation starts at a very early age. Unfortunately, self-education about soil usually ends in childhood. We might probably avoid many of the problems we have with degradation of soil resources if an early interest in soil were allowed to develop and continue throughout a human's lifetime. In this chapter, we discuss the origins of soil education, the importance of soil to humanity, how education about soil is conducted in different parts of the world, the necessity for increased public awareness of soil's critical role in our lives, and how we might better improve soil education and public awareness through a more concerted effort to educate about soil, and a removal of current negative views of soil.

1. Introduction

Perhaps the most emphatic words ever penned by a soil scientist were those of C.C. Nikiforoff, who proclaimed soil as: *the excited skin of the earth*. Children understand the magic of soil, and many childhoods are spent studying the varying properties of soil; unfortunately, these studies are often abandoned with the loss of childhood. Anyone that has ever studied soil for any time realizes how appropriate a dynamic definition is, as soil harbors far more biodiversity than the aboveground portion of any ecosystem, and typically contains the bulk of the organic matter and nutrients as well.

Soil is often called *the hidden half of the land* because it is so difficult to study, and in the process of study, soil nearly always must be disturbed to such an extent that further study of the same soil material is difficult or impossible. However, an understanding of the soil is perhaps more important than an understanding of any other part of a terrestrial ecosystem, whether that be crops for agriculture, trees, or native species in an uncultivated land, because those organisms generally rely on soil to provide necessary resources.

It has been pointed out that several ancient civilizations, including the rise and fall of civilizations in Europe, Asia and the Americas, were based on the destruction of their previously fertile and productive soil resources by increasingly high demand due to increased population pressures (Hyams, 1976; Hillel, 1992; Montgomery, 2008).

It seems a paradox that we often do not understand and appreciate what we depend on so much, and clearly few things are more important to society than soil. D.H. Yaalon (2000) paraphrased Leonardo Di Vinci well in the journal Nature with the quote "why do we know more about distant celestial objects than we do about the ground beneath our feet?" We rely on soil for much of what we need in our daily lives, but few people understand soil's role in the production of food, fiber, shelter, and other vital items, its importance in human health, and other ways that soil benefits us. For instance, nearly all of our food, with the exception of the small amount produced from the ocean,
aquaculture and hydroponics, is produced by growing plants in soil. The same is true of much of our fiber, including the raw plant and animal materials for textiles, and we rely heavily on wood products for housing.

Our modern society also increasingly relies on the use of plants grown in soil to produce energy, particularly to produce biomass fuels for transportation, and will likely use biomass more as a raw material in place of petroleum in the future. Modern considerations of soil properties for a particular use range greatly, from suitability for wildlife habitat, to ability to produce food and fiber, to direct use for creating materials such as ceramics, and use in art (i.e. as pigments). A huge variety of items useful to human society can be extracted from soil, ranging from nutrient minerals to pharmaceuticals (see also: Soils, Food Security and Human Health)

Although informal consideration of soil and passing down of soil knowledge has likely existed as long as humans (after all, humans have always walked on soil), formal education regarding soils almost certainly developed with agriculture.

2. History of the Written Record of Soil

Perhaps the oldest written records from humans are cave paintings. In the Chauvet and Lascaux caves in southern France, early artists mixed charcoal and soil of different colors with animal fat or saliva to create a crude paint, spread on the walls of the caves (Lester, 1998). Though no cave depictions to date show any attempt at communicating soil information, the early artists almost certainly used soil properties like color, texture and adhesion for their cave drawings, and may have passed that knowledge on to apprentice artists.

As early as 5000 BC, ancient Egyptians associated the high productivity of fields in the Nile valley with the deposits of fertile black silt along the river during its annual floods. Ancient Egyptians clearly distinguished between the fertile valley soils, called "kemet" or "black earth", and the "deshret" or "red earth" of the surrounding desert. The continued success of Egyptian agriculture relied on a steady supply of soil being eroded out of the highlands of what is now Ethiopia. It was the responsibility of Khnum, the god of the First Cataract, to make sure that the annual flooding was of the right duration and height, so that the proper amount of silt would be deposited to ensure good fertility and harvest, and with the harvest ensure the prosperity of Egypt.

China is an ancient agricultural country with a long written history. According to legend, the Chinese began to cultivate soil more than 6000 years ago. There is also a long written history of soil classification according to uses and capabilities. In the Spring and Autumn Warring States period, scholars have found some records about soil classification in books, such as "Yugong", "Zhouli", and "Guanzi", which describe early soil classification methods, perhaps the earliest formal soil classification in the world. Ancient Chinese classified soil according to soil diagnostic horizons and their properties, including soil fertility, texture and structure. Classification was almost entirely oriented towards the practical uses of soils.

The book "Yugong" was written during the Xia dynasty, and divided the nation into
states that included Ji, Gong, Xu, Yang, Jing, Yu, Liang and Yong. The book recorded wide scale soil distribution for the first time in ancient China. The system included soil fertility, color, texture, water holding capacity and supported vegetation in a classification index, and divided the Chinese nation into different types, which included white soil, black fertile soil, red clay and loam soil, mud soil, green black soil, yellow soil, saline soil, black and hard soil, and clay soil. Every soil type classified was subdivided into three grades and nine levels. Based on soil types, land taxes were calculated and assessed, a very practical use of soil information. This classification method based on color and texture has a strong current scientific validity and is still used. Apparently, this was the first formal attempt at wide-scale soil classification in the world.

In China, formal agricultural education in managing soils might have begun as much as 4000 years ago near the town of Yangling, Shaanxi Province. However, as is so often the case, actual history vs. legend also clouds the picture. The legend says that Houji, the first official in charge of agriculture during the Yao and Shun periods, introduced varieties of grain to people and taught them how to cultivate and grow crops. Currently, Houji, legend or fact, continues to educate people about agriculture at Northwestern Agricultural University where his statue stands at the entrance to the campus near a national soils museum.

Unfortunately, little written material was recorded during the time period when Houji was supposed to have been educating Chinese citizens, and some of the details of the legend, such as his birth, seem to have been designed to compare him to Buddha, at least in the opinions of some authors that have written about Houji (Yang and An, 2005). However, no one can argue the love for and importance of Houji in the modern hearts and minds of Chinese agriculturists.

More than 3100 years ago, in the Zhou dynasty during the Warring States Period, the Chinese nation was intensely focused on soil, and the very important book Zhouli was published, in which it recorded the agricultural performances of different soils, especially detailing research works on land use planning and soil classification. This book was a further development of the much older Yugong.

Zhouli determined that agriculture, forestry and animal husbandry should be combined together according to natural conditions, and recycling of organic materials should be undertaken to sustain soil, practices that have been borne out in modern times to be essential to avoid soil degradation.

Zhouli defined five soil type areas, such as mountain forest, damp, hill, stream terrace and plain. It emphasized that nine crops, which included glutinous broom corn, millet, barnyard millet, rice, hemp, flax, should be planted according to soil suitability. In terms of soil fertility, it classified soil as three grades that were focused on the soil diagnostic characters of color and texture, dividing soil fertility into high, medium and low. These nine soil types could be improved by utilizing nine different fertilizers, the first formal procedures for specific fertilizer recommendations according to soil properties documented in the world.
The book of Lu's Spring and Autumn Analects, written in 239 BC, wrote that soil fertility could be increased or degraded by different practices. It illustrated that poor soil fertility was often increased by human tillage activities. These impacts were further documented and a Ming dynasty book "Nongshuo", which was composed by Yilong Ma, emphasized the relation between deep tillage and root system development, how the application of fertilizer enhanced fertility, and how properly managed soils could sustain higher plant densities and per-area productivities.

In 1742, in the book "Shoushitongkao", which was published officially and nationally, problems of soil suitability and sustainability were discussed. Clearly, China has a long history of soil classification, utilization and management, and the propensity for the Chinese to record their history allows us to read it in much greater detail than for many other cultures. Much of what was discovered and documented is in current use today, though the Chinese, as many other human societies, didn't necessarily know the mechanistic reasons why certain practices worked. Most early soil research emphasized a practical focus on what worked, rather than a scientific and mechanistic understanding of why it worked.

Agricultural facts and legends are sometimes difficult to separate even in relatively modern times. For instance, the English agronomist Jethro Tull is commonly credited with inventing the moldboard plow as well as the seed drill about 1601. Seed drills allow seeds to be sown in the soil much more quickly and efficiently than manual methods. However, it is probably true that Tull actually refined an invention of the Sumerians, who utilized seed drills as early as 1500 BC. It might also be noted in Figure 1 that tilling the soil with implements drawn by animals was evident in ancient Egypt. Chinese agriculture places seed drills to about the same period.

Figure 1. Ancient Egyptian plowing. Image from a tomb at Beni Hasan, ca. 1900 BC.

Camillo Torello invented and patented a seed drill with the Venetian Senate in 1566, possibly after seeing a Chinese drawing or product. It is very important to note that the authors of this article have utilized information that they were able to acquire, and many cultures may claim to have "invented" a particular item when it is likely to have been developed by parallel or earlier cultures to one extent or another, and perfected over time.
Tull also educated farmers and wrote about using horses and a horse-drawn hoe for weed control. In this way, Jethro Tull by writing and publishing his ideas, contributed a great deal to the development of modern agriculture from a soil management perspective, and British writing preserved that record. For instance, George Washington, the first U.S. president, utilized Tull's "horse-hoeing", or deep plowing of soil, with crops planted in rows so that the cultivating implements could pass between, and wrote about the success of this system in his diaries.

A scientific and mechanistic understanding of soil came by applying basic science to the study of soil properties. Many soil scientists consider the birth of modern soil science to begin about 1875 with the emergence of the Russian soil scientist V. Dokuchaiev. His substantial contributions to soil science were initiated in Russia and Ukraine because of the presence in the semiarid and steppe regions of black soils which were highly enriched by organic compounds. Dokuchaiev literally put soils on the map in introducing geographical variations in soil type that could be explained not only by geological factors (i.e. parent material), but also to climatic and topographic factors, and the time needed for soil formation (pedogenesis) to operate. These principles of Dokuchaiev were later utilized by Hans Jenny (1941) in developing his famous "five factors of soil formation", i.e. parent material, topography, climate, organisms and time (see also: History, Philosophy and Sociology of Soil Science).

After the creation of the USSR the government had first to solve the problem of supplying the new empire with food in order to achieve industrial development. The urban population improved communications and industrial infrastructure, while the rural population provided food. The USSR was built on the principle of self-dependence which resulted in the creation of the specialized faculties in universities and the numerous specialized colleges. The study of soil science as a recognized discipline flourished.

The scientific study of soil and understanding of soil properties related to plant growth can be traced to the German chemist Justin von Liebig, and the publication in 1841 of "Organic Chemistry and its Application to Agriculture and Physiology".

There are many labels associated with the use of soil and the advance of modern agriculture that can be attributed to Liebig, but perhaps the most important educational contributions were to devise modern laboratory-oriented teaching methods for the study of soil chemistry. Liebig is sometimes called the "father of the fertilizer industry" because of his discovery of nitrogen as a primary plant nutrient, and the "Law of the Minimum" that is still used in basic soil teaching to understand the contribution of each essential nutrient element on the growth of crops. Other scientists followed up on Liebig's work and contributed greatly to the foundation of modern soil science, but Liebig was the first to make the strong connection between chemistry and soil that continues through today.

3. Soil as a Subject of Scientific Study

It is now possible to study soil at ages ranging from pre-kindergarten to college graduate and post-graduate levels. The scientific study of soil is sometimes done as a
pure science without any particular thought towards practical uses. However, in most cases, soil is studied either as a contributing component to a larger system (i.e. as part of a terrestrial ecosystem such as a forest or wetland), or as a basic element in a larger renewable resources network (i.e. a production system for food or fiber).

One of the results of Liebig's research was demonstrating that nutrients could be added into soil to increase plant growth, and that in theory soil could be eliminated entirely as part of the food production system. In this context Sir Francis Bacon published the book “Sylva Sylvarum” in 1627 with detail on the methodology for this "solution culture". The method was developed in more detail in the mid 1800's, though only a relatively small amount of food was ever produced in that way. Other scientists have further promoted solution or soilless culture, and gave it a new name "hydroponics".

One definite benefit of research done on soilless agriculture was the recognition that scientific methods similar to those used in chemistry could be utilized to improve soil fertility and productivity, and that agriculture didn't need to be limited to the natural productivity of soil for crop production. More than anything else, it became clear that Liebig’s discovery of the role of nutrients could be applied to increase food production and improve agriculture. This is sometimes called the "modern agricultural revolution", and its basis was the application of scientific research principles to managing agricultural lands for increased production.

4. Current Education in Soil Science

Education, whether formal or informal, is key to developing an understanding of any subject. Developing a basic understanding of some of the most important physical properties of soils is relatively easy by simple observation, since soils of different properties (texture for example) can be handled, manipulated, utilized under different conditions, and then the soil response under similar conditions can also be predicted to be similar. For instance, if a child uses soil on the beach to build a sand castle, it quickly finds that when finer types of soil are used to line a moat around the castle, water will stay in the moat longer. In this way, it learns that finer soils have lower infiltration rates than coarser soils. Children are natural experimenters and often learn a great deal about soil through this type of experimentation. The problem is that as they grow up they are quickly taught to stop this particular type of experimentation. Learning then often becomes more formal.

For instance, the first author of this paper uses direct observation to teach undergraduate and graduate students in a "soils and land use" class the basic physical properties of soils. These students come from highly varied backgrounds, including many who are not science majors. Students in this class often comment that "they feel like kids again" during the required handling of soil, and some students even clearly exhibit the same humor and joy at handling soil that they likely experienced as children. These positive feelings may have been ingrained in human nature over the millennia where learning about soil resulted in a higher potential for survival, reproductive success, and successful raising of children through agriculture. In addition, these feelings may be a primary reason why working with soil in an informal way is such an enjoyable act for most people that can get past the stigma that modern society gives soil (i.e. dirty, filthy,
dirt-poor, etc.).

Activities that involve working with soil are known to be therapeutic for a variety of human illnesses. For instance, the American Horticultural Therapy Association (http://www.ahta.org) recognizes that horticultural therapy, which includes tilling and working in soil, can help with a variety of mental illnesses. In the 1800’s, Dr. Benjamin Rush, considered to be the "Father of American Psychiatry", wrote about how garden settings held curative effects for people with mental illnesses. Various types of agricultural therapy were used to treat war veterans in the 1940’s and 1950’s. Currently, horticultural therapy is well-recognized as a viable treatment for a variety of people with health problems.

It is clearly impossible to consider all of the potential informal and formal ways in which soil education is delivered, so we will consider just a few methods including formal and informal school education, informal methods, and online and other means of delivering informal education on soils. In addition, online education in various disciplines is advancing rapidly. We will consider some online material in this chapter, but realize that our brief consideration will rapidly become obsolete.

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**Biographical Sketches**

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