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.

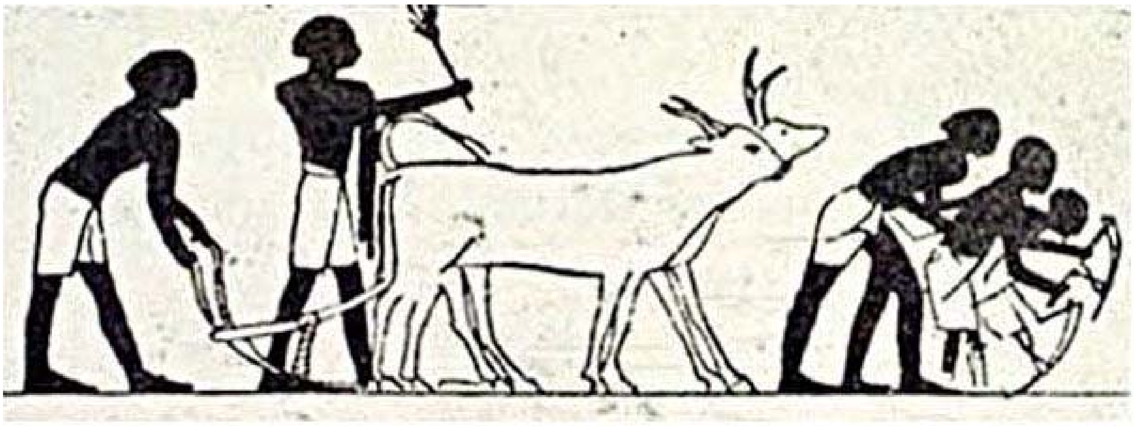

Figure 1. Ancient Egyptian plowing. Image from a tomb at Beni Hasan, ca. 1900 BC.

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.

4.1. Kindergarten through Secondary School (K-12 Education)

We are unaware of any schools that formally teach soils through the use of a soils course in the same way that many colleges do. Properties, uses and importance of soils are often introduced in other coursework, particularly agriculture, horticulture, biology and increasingly environmental sciences. In the realm of "Advanced Placement" (AP) courses taught according to US College Board standards, environmental science is among the fastest growing of the AP courses. Students can get college credit for AP coursework provided they are able to achieve adequate scores on AP exams.

The College Board AP Environmental Science exam, for instance, includes a number of questions directly about or related to soils, particularly in terms of soils as a component of the natural environment. The College Board considers "Soil and Soil Dynamics" as one of four subtopics in the major topic of "Earth Systems and Resources" that comprise 10-15% of AP Environmental Science courses and exams. Soil as a basic resource is also considered in topics such as "Ecosystem Structure", "Agriculture", "Urban Land Development", and dozens of other topics. These are specific topics of College Board, but other organizations offer similar courses and exams.

The U.S. National Academies of Science have a "National Committee for Soil Science" which helps to develop educational materials on soils and to elevate consideration of soil and soil problems in the consciousness of Society and Science. Much of the educational material is aimed at children. The U.S. National Science Foundation has also used soil to develop "inquiry-based science" material for experiential learning for elementary school students. The module for the second grade (7-8 year olds) uses soil as the material with which to ask and answer questions about a variety of subjects.

In Russia, soil education is an important part of the elementary and secondary curriculum. The fourth year of school includes a course in natural history that typically includes structure and function of soil, including practical and laboratory classes. By high school, soil education has dropped off substantially in comparison to disciples such as biology, biochemistry and genetics.

Though whole courses are rare, it is thus quite common for students in K-12 schools to have formal and informal teaching in soils. The varied physical properties of soil, as well as the large amount of variation in those properties, make soil an excellent subject for introducing children to ideas of formulating and testing hypotheses.

4.2. Higher Education

Many major university and some smaller schools of higher education currently offer at least one formal course in soil science. College level introductory soil science typically covers a wide variety of soil science topics, from basic concepts of soil such as the soil profile, to specific applications of soil principles in agriculture and other fields. Since many major universities have always offered agricultural studies as one of their main priorities (i.e. land-grant universities in the United States), the majority of students taking soil courses have been in some field of agriculture, including agronomy, crops, range and forestry.

With the relatively recent transformation of agriculture from a labor-intensive to a technology, chemical, and machine-intensive industry (often called the "agricultural revolution"), the proportion of students studying soils that will subsequently be employed in agricultural production compared to other fields has greatly decreased. In reality, freeing much of the human population from the need to produce food is a pre-requisite that allows other arts and sciences to flourish. Increasingly, students have a desire to learn about soils not from the standpoint of production of commodities such as crops, but with an emphasis on environmentally-oriented applications, such as:

- Understanding the soil's role in the natural environment;
- The soil in ecological restoration;
- The soil as a carbon sink;
- Soil pollution;
- Soil as an engineering and structural material; and
- The soil’s role in the supply of water and the regulation of rivers, lakes and groundwater.

Following an introductory course in soils, additional study often centers around a basic science, another field of study, or a solution to a problem related to soil. Notable and quite common courses include soil physics, soil chemistry, soil genesis, soil classification, soil biology and microbiology, forest soils, soils and land use, and soil fertility.

At a typical university, worldwide, the number of topics for possible courses has increased, and in many cases, additional requirements for graduation have been added. One response to the larger number of courses and additional requirements has been for some students to take additional coursework that extends the amount of time to graduation. However, many institutions of higher learning have restricted enrollments and if students were required to attend the same college for additional time, this would likely restrict enrollment further.

In order to accommodate increased demands for additional coursework while still giving students some background, soils have sometimes been integrated with other disciplines into a single course. Disciplines often taught together with soils in an introductory integrated course include hydrology, climate, fire science and often with ecology and environmental sciences as well.

Additional courses give additional opportunities for learning. However, a problem with the requirement of additional courses is that some state legislators have put limits on credit hours that can be required in a degree program. Pennsylvania is just one example. A number of programs have cut the credit hours of their core courses to accommodate such legislation. This makes it even more difficult to adequately address the ever increasing body of interdisciplinary knowledge.

4.3. Informal Education on Soils

Much learning about soils is informal, not only among subsistence farmers in developing countries, but also among recreational gardeners in developed countries. Recreational gardening is increasingly popular because of the joy of handing and working soil as much as the benefit of growing plants; and worldwide it includes a very large number of people. For instance, it is estimated that only 1-2% of the United States' population are farmers, but that a much greater percentage of Americans spend at least one day per year gardening, primarily as a recreational pursuit. The U.S. library of Congress, for instance, lists over 24,000 books in print with the word or derivation of the word "garden" in the title.

A typical hardware store in the United States, Australia and Europe will include literally thousands of products related to soil, including educational and instructional books that include information about soil related to plant requirements, implements for working soil, fertilizers to improve soil fertility, compost and soil amendments, and many other materials aimed at correcting, enhancing or replacing soil used in gardening. As a direct result of the economic crisis starting 2008 the interest in house gardening and producing vegetables in Europe has tremendously increased.

In China, the long history of high population density and occasional famine, along with the very early recording of history in writing has led to an integration of informal education on soil in the culture perhaps unlike anywhere else in the world. Even though China has sustained a high population density for several thousand years, China has remained relatively rural until recently (Xiaotong *et al*., 1992).

University education on soils in Russia and Ukraine almost always includes a required soil science course for students in biology. This soil science course is usually combined with microbiology with the aim of more complete understanding of biogeochemical cycles and the importance of soils in mankind life. In the old USSR, higher education was nearly always coupled with participation in cultivation and harvesting on collective farms, but that requirement has largely disappeared in modern Russian and Ukraine societies.

In the experience of the authors of this Encyclopedia entry, informal learning about soil is one of the main avenues whereby people learn about soil properties and uses, even if they previously attended a college where courses in soil are taught. The first author of this paper commonly teaches professionals with college degrees relatively informal "courses" on soils, usually oriented to specific needs of the audience. For instance, "students" as varied as elementary school, garden clubs, "Master Composters", "Master Wetland Stewards", and professional foresters are commonly taught informally either to introduce them to material they never learned during college or to refresh their previous learning and introduce material that can address specific needs that they may have.

Given the prevalence of the internet as a learning and resource tool, the potential of online soil information in formal and informal education is enormous.

4.4. Online Resources for Learning about Soils

4.4.1. General Information

Given the ease and speed with which information can be disseminated over the internet, information on soils is increasingly available to the public online. This entry cannot cover all of the currently-available public information, nor seek to determine the quality of all of it. Several high-quality sources of information on soils aimed primarily at the public or educators are highlighted.

If a viewer starts with the popular search engine "Google", and uses the word "soil", about 93,000,000 entries are generated. When one selects the definition of the word "soil", an interesting insight into the love/hate relationship between society and soil can readily be seen (see also: *Land Use,Land Cover and Soil Sciences*). For instance, the first part of the definition includes commonly-held technical definitions, such as that soil is "the top layer of the earth's surface", that soil "consists of rock, mineral particles and organic matter, etc."

However, the second definition of "soil" includes the word "soiled" and "soiling", and defines these as "to make dirty", "to disgrace or tarnish", "to corrupt or defile", and to "dirty with excrement". None of these commonly-held meanings for soil are utilized in the technical definitions of soil, but it is easy to understand the negative impact these common terms will have on the public view of soils as a subject worthy of study.

The very first entries in a Google search appear primarily designed to provide information for the general public. The first entry for the search directs us to the Wikipedia entry on soil (http://en.wikipedia.org/wiki/Soil), and is fairly accessible for a student, but would not likely be very understandable by children. The page is somewhat technical in nature, and probably of most interest to someone intending a further study of soil or a desire to integrate what he/she learns here into something else, such as a term paper. This may change as the entry is developed, but the 12 pages of the Wikipedia entries on soils include primarily a description, basic properties of soils, and a description of the five soil forming factors of Jenny (1941). Some uses and environmental problems are presented as well as numerous other links related to soil, for example references to some of the most basic and important soil publications.

The second link that pops up on Google is likely to be of much more interest to young children, but is also quite instructive on the importance and properties of soil. The soil link (school.discoveryeducation.com/schooladventures/soil/) brings one to a page that has three sections: (1) "Down and Dirty", (2) "Field Guide", and (3) "Soil Safari".

The first section "Down and Dirty" is an introduction to basic soil properties, including the soil profile, associated horizons, and the composition of soil. Links on the single page lead to a variety of other pages. This page would be a fairly good introductory source for the general public ranging from elementary school children to adults.

The "Field Guide" gives some striking pictures of soil organisms, including a range from greatly magnified microorganisms such as amoebas and bacteria through mites and nematodes to macrobiota such as night crawlers and moles. The third section "Soil Safari" is likely to be fun for everyone from children to adults, and introduces the concept of scale in soil quite visually. In this software, you enter a "transporter", kind of like a spaceship for travel through soil, and then move through soil seeing various important soil organisms and relationships. The transporter ranges in scale from 0.003-300 mm, and what you can see depends on the scale of your own size.

One can easily imagine a video game that could interest and educate a large range of the public from children to adults based on current popular video games. Soil education is best served with numerous field trips to observe it in a natural setting. Much could be done by integrating geographic information already available with additional information about soils. However, the vast majority of online information about soil available to the public appears to be of an entertaining nature with a fairly limited depth, or fairly technical in nature and primarily interesting to someone already trying to learn about soils.

4.4.2. More Specific Information

In terms of a compendium of soils information with additional links, the Netherlands International Institute for Geo-Information Science and Earth Observation (ITC), has compiled a series of web pages titled "A compendium of online soil survey information" aimed at bringing all online soil survey information together in one site (http://www.itc.nl/~rossiter/research/rsrch_ss.html). This is certainly an ambitious project, and most similar projects might soon become overwhelming, but is probably as good a starting place as any if one wants to view soil information. Fortunately, the compendium is well-designed, and appears to be regularly updated. Many of the pages accessed by links from other sites appear to be badly dated, and sometimes do not lead to other web pages at all.

The ITC site is certainly interesting for someone who already has a basic knowledge of soils, although much of the information might be inaccessible to the general public. Fortunately, for a dedicated person, links to general educational soil information rapidly appear. Perhaps it would be good to change the page to allow people of different ages and interest to access sites more appropriate by changing the page to group links by age level.

In Britain, the Soil Association (http://www.soilassociation.org/) includes a large variety of soil information aimed primarily at promoting sustainable organic farming. Though the Soil Association itself seems to be mainly about promoting organic agriculture, the pages of the Soil Association's web site are loaded with soils information, though not entirely information about soil. Anyone interested in gardening will likely find this site interesting, and it is different than many gardening sites in that most of the information is oriented toward improving soil as a means of gardening success.

The British Broadcasting Company (BBC) has a series of science lessons aimed at children, grouped by two-year age ranges from years 5-11, and including resources for teachers. The lessons on rocks and soils at http://www.bbc.co.uk/schools/scienceclips/ for ages 7-8 shows how interactive online education could work in teaching about soils. The lesson is fun, educational, but over far too quickly. A web site at http://www.teachersdomain.org/ asset/ ess05_int_soils/ includes descriptions and basic properties of soils distributed around the world. However, it also leaves the reader wanting more information about soils, with no such additional access provided through this site.

One of the most ambitious soil education projects is soil-net, located at http://www.soil-net.com/. The site is clearly aimed at children, with interactive information and soil information "Easter Eggs" that the viewer can find by moving the pointer across the screen. Soil-net is divided into an Introduction, "Global Cycles", "Soil Functions", "Soils on Earth", "Threats to Soils", "Future Concerns", "What Else", "Case Studies", "Activities and Downloads", and "Teachers and Parents" sections. A "Did You Know?" section keeps changing with interesting soil facts. For instance, one says "The moon doesn't have soil as Earth does. Although there are minerals there is no organic structure nor water, only rock dust". Another says "one teaspoon of good earth holds more creatures than there are people on the whole earth". Such ingenuity in design can keep a young mind focused on learning about soil, and this site clearly has a lot of readership throughout the world.

The U.S. Bureau of Land Management has a site "Just for Kids: Soil Biological Communities" located at http://www.blm.gov/nstc/soil/Kids/index.html. The site is divided into "Home", "Soil Importance", "Incredible Journey", "Amazing Facts", "Fun Activities", "Explore Your Mind", "Adopt a Soil Critter", "Want to Learn More" and "Kids Gallery", all of which are rich in interesting information about soil, particularly for young people, but also providing links to more technical information.

The Regional Environmental Center for Central and Eastern Europe has an online soil lesson at http://greenpack.rec.org/soil/index.shtml. This lesson goes into: why soil is important, basic soil functions, problems and threats to the soil, impacts of war on soils, and finishes with "what people can do" to protect soil for the future.

The Field Museum (http://www.fieldmuseum.org) has a very hands-on series of lessons for children called "underground adventure", with exercises in soil texture, temperature, compaction, percolation, factors that affect soil use, and soil biodiversity. The site is located at http://www.fieldmuseum.org/UndergroundAdventure/kidzone/soil_properties.shtml.

4.4.3. Information about Soils in the United States

The U.S. National Resources Conservation Service, formerly called the "Soil

Conservation Service" has a series of lessons on soil importance and properties at their web site at: http://soils.usda.gov/ education/. The site includes sections as follows:

- Soil, which includes definitions of soil and soil survey, information on careers, some basics on soil formation and classification, soil science glossary, and regulations for moving soils;
- Key Messages, which includes ten key messages to understanding soils;
- State Soils, which includes information on distribution and properties of official soils of each state in the United States, and shows the variation in soil properties in a large country such as the U.S.;
- Water Movement in Soil, which includes a movie showing how water moves in all directions within soil and factors controlling water movement;
- The Twelve Orders of (U.S.) Soil Taxonomy poster;
- Links for students and teachers, divided into (a) Grades K-6, (b) Grades 7-12, and (c) College level;
- A link to the exhibit "Dig It! The Secrets of Soil", which is sponsored and located at the Smithsonian National Museum of Natural History and created with the help of the Soil Science Society of America;
- A site for NCSS (National Council of Soil Scientists) for training and job aids;
- A link to the USDA Web Soil Survey with online soil maps and data for most of the U.S.;
- And an online photo gallery, with natural resource and conservation related photos from across the United States.

The Smithsonian Institution is the premier U.S. national museum, but it has been pointed out many times that the Smithsonian has almost no information about soils in its exhibits. This deficiency was corrected in July, 2008 with the opening of "Dig-It!", a joint Smithsonian/Soil Science Society of America approach including both a static and a traveling exhibit. The non-traveling exhibit is located in the National Museum of Natural History, with five basic themes: (1) Soils are Living, (2) Soils are Varied, (3) Soils Change Over Time , (4) Soils Link the Earth’s Land, Air, and Water and (5) Soils are Resources : Renewable, but Subject to Misuse and Overuse. Much of the information in the exhibit can also be accessed by either of the following websites, http://www.sites.si.edu/soils/ or https://www.soils.org/Smithsonian/. Most of the message of the exhibit can also be learned from the online information.

4.4.4. Information about Soils of China

Perhaps the most ambitious project aimed at compiling soil information is the Chinese National Soil Museum located at Northwest Agricultural University in Yangling, China. The museum does not have a web site, but information about the museum can be found at: http://www.360cities.net/ image/shanxisheng-yangling-3.

The museum has soils exhibits on three floors and is very interesting, particularly to a person already interested in soils; it includes nearly everything a student would learn in a basic course on soils. The focus is on soils in China's past, present and future, but much of the material presented is universal in nature, and repeated in the Smithsonian. Normally excellent English-language translations are provided beneath Chinese characters for all presentations. For instance, one area in the China Soil Museum explains that "Soil is Alive". The soil museum is little-known outside of Yangling, China, considered to be the birthplace of modern Chinese agriculture as explained earlier in this chapter.

4.4.5. Online Information about Soils in Brazil

In 2008, the IVth Soil Teaching Brazilian Symposium took place in Piracicaba in the Brazilian state of Sao Paulo, clearly demonstrating the Brazilian Society of Soil Science’s concern about gathering people that act, or have interest in acting, on formal and informal education on soils. The symposium's purpose was to increase the dissemination of soil's information through workshops, educational and scientific extension of experience on soil, and presentations through an online discussion board. This symposium was created primarily as a discussion forum at the college level, but its focus was later modified and amplified to also focus on basic soils.

As highlighted at the symposium, there is a large potential for soil's education currently untapped by teaching and research institutions, considering the major resources of people and infrastructure, that could bring additional soils knowledge to Brazilians. As recognition of the importance of soils becomes more widespread, it is only natural that soil science education increases in scope. The following are some ongoing projects at Brazilian universities that are developing teaching about soil in public schools.

The Project "Soil at School", at the Paraná Federal University (UFPR), started its activities in 2002 and has several goals, including soil expositions and soil-oriented visits to schools, courses and events, and production and publishing of soil information. This project has a web-site (www.escola.agrarias.ufpr.br), information can be viewed and downloaded, including the soils "experimentotech".

The exercise "Soils" from the Project "Scientific Education ABC – Hands on the Dough", from the São Paulo University Science Research Station, gives school teachers 15 activities in five teaching sequences, which approach soil learning in a linked manner. The suggested activities include:

- Soil in the landscape;
- Painting with soil samples;
- Testing soil water-holding capacity and movement through soil;
- Making physical objects (i.e. soil ribbons) for determining soil texture;
- Soil heating tests;
- Simulation of erosion; and
- Terrain cycles of soil.

Brazil also has a soil museum at the Federal University in the city of Santa Maria (UFSM) in the state of Rio Grande do Sul. The museum celebrated its 35th anniversary in 2008. According to a summary of activities, the museum has always been engaged in issues related to teaching about soils. The most recent innovation is the Rio Grande do Sul Virtual Soils Museum (www.ufsm.br/msrs), which turned out to be an efficient tool in meeting the museum's main goals: soils and environmental education.

A Soils and Environment Education Program was created at the Earth Science Museum in Viçosa Federal University (UFV) in 1993. The museum's stated purpose has the following objectives: 1) increase soil comprehension as an essential environment component, 2) educate people, individually and collectively, about how we degrade soil in various ways, 3) develop knowledge about the importance on soil conservation, and 4) spread general knowledge about soil. The program offers site visits, inter-disciplinary projects at schools, and produces information for teachers as well as written materials about soils.

The University Extension Program "Soil at School", developed by the Agriculture Superior School "Luiz de Queiros" (ESALQ) at the University of São Paulo was created in 2006, within its own unique space. The program includes demonstrations about different soil properties, from various rock samples as soil parent materials through demonstrating the impact of a rain drop on the soil surface. Soil demonstrations vary in nature, including static, dynamic and interactive displays. The program's main goal is to help educate teachers and students from elementary and middle schools, and that soil is an essential component of terrestrial ecosystems which we must understand and preserve, because our life depends on the ecological functions that soil facilitates. All of these initiatives indicate that soil education has been assuming a growing importance in Brazil, including from the support from the Brazilian Society of Soil Science and from major Brazilian universities.

4.5 Information Correlation and Transfer

One of the problems with soil education and public awareness of soil is that not all soil information is presented alike. For instance, engineers classify soil differently than soil scientists, and the definition of a particular word sometimes changes from system to system (i.e. the definition of "sand"). Perhaps the most widely used soil classification system is that of the World Food and Agricultural Organization (http://www.fao.org/), which includes 25 basic soil units. There are separate soil classification systems in many other countries, notably the US (http://soils.usda.gov/technical/ classification/), Canada (http://sis.agr.gc.ca/cansis/), Australia (http://www.clw.csiro.au/ aclep/asc/asc.htm), etc. Some resources are available to cross-reference the different systems, but there is a great deal of confusion even among professional soil scientists in this regard (see also: *Soil Geography and Classification*).

In Australia, a review by McKenzie *et al*. (2008) showed the clear need for standardization of online soil information within Australia, but also throughout the world. Because of the ease with which the public can get information online, it can be quite confusing when similar soil properties are defined with varying definitions and standards. This is particularly true of soil classification systems, which vary widely in different parts of the world. The online information system on soils is badly in need of a reference system that can allow the public to learn about soil information in one country, and be able to understand how the definitions and references may change as they move to another country, or even perhaps how they can vary within the same country (i.e. engineering vs. USDA soil classification in the United States).

5. Educational Materials currently being developed and Future Trends

Until fairly recent times, many people on earth had a direct close relationship with soil, because they were farmers. With increased urbanization the number of citizens increased and much of the connection to the land was lost. In modern times there is a new tendency for people to "come back to the land" in an effort to protect the environment. In the United States and other countries, early education aimed at conserving and sustaining soil for agriculture was developed primarily by governmental agencies. Current trends in public education on soils continue to focus on farmers and other agriculturists, but also include an increasing number of other members of the public, including urban planners, construction workers, ecologists, and anyone else whose profession includes some use of soil.

The profession of soil science is clearly in decline due to the lower numbers of farmers worldwide, but the need for protection and wise use of the soil resources is as urgent as ever. It seems clear that the public needs a new means of learning about soil. The "Dust Bowl" disaster (http://www.encyclomedia.com/video-the dust bowl disaster.html) in the United States during the 1930's started a strong response from the U.S. government, including the creation of the Soil Conservation Service (SCS; now Natural Resources Conservation Service; http://www.nrcs. usda.gov/). Documentaries produced included such films as "The Plow that Broke the Plains" in 1936, and "Rain for the Earth (1937). The SCS focused on developing improved conservation methods and educating farmers in the use of management techniques that would avoid such problems in the future.

In most developed countries of the world, the abundance of food and the smaller proportion of the population that works in agriculture has led much of the public to be apathetic about the need to understand soil and protect it by wise management. It is notable that the Societies that had soil most in their current thinking often suffered severe famine, and perhaps the current lack of famine in western countries has created complacent societies. The quote of George Santayana "*Those who do not remember history are condemned to repeat it*" reveals an obvious danger in a society that forgets to value the soil that feeds it.

The need for widespread public education and understanding of soils is generally agreed upon. Unfortunately, just as the need becomes greater because of widespread problems such as global warming, dwindling energy supplies, the need to feed an ever-growing human population on a shrinking agricultural land base, etc., the profession of soil science and the formal study of soil is declining. Most popular books currently in print are oriented toward the specific use of gardening. For instance, Amazon.com lists the title of the current most popular book (among all books) as "*Teaming with Microbes: A Gardener's Guide to the Soil Food Web",* and customer reviews indicate that almost all readers of the book are gardeners. However, no book on the subject of soil (or gardening) is listed in the top 200-selling books of all time, so soil remains a relatively obscure subject for most of the world's readers. Fortunately, many books on soil that are no longer in print and are old enough to be in the public domain can be downloaded in their entirety (http://www.soilandhealth.org/).

Unless love of soil can be developed in the same way that a love for other natural resources has been, particularly by the popularization of the plight of animals (i.e. Jacques Cousteau, Animal Planet, "Crocodile Hunter"), the public is unlikely to care a sufficient amount about the destruction of the Earth's soil resource, even though it might have a far greater negative impact than, for instance, the loss of endangered species. Most relatively current movies are fairly fact-filled, but appear to be unable to ignite the imaginations of most people the way that some popular media on animals does. For instance, media such as "Dirt TV" (http://extension.usu.edu/AITC/teachers/movies/dirt.html) are quite interesting in their popular approach and the excitement the actors show toward soil and "dirt".

However, most movies lack the ingredients that are likely to hold the attention of children and get the message of the importance of soil across in the same way that popular animal-based movies like "The Lion King", which combines an ecological message with a dynamic movie. It is the 18th most popular American film of all time. Of course, in Lion King, animals are personified in ways that misrepresent their actual behavior. The primary purpose of Lion King was to generate a profit for parent company Disney, but the inclusion of ecological principles probably will be retained by young viewers for their entire lives. Unfortunately, some of the ideas also generated (i.e. that hyenas are evil), are absolutely wrong and unacceptable in serious education about ecology.

Movies such as "An Inconvenient Truth" have definitely had significant impacts on the public, though the total number of people that have seen this movie is probably relatively small compared to the general population. However, at $46 million dollars in receipts, it is the highest grossing documentary film of all time, and clearly millions of people have viewed it. There is at least one upcoming movie with a soil theme based on William Bryant Logan's book "*Dirt, The Ecstatic Skin of the Earth*" (http://dirtthemovie.org/status) that will strive to entertain as well as educate, and possibly make a profit. "*Dirt: The Movie*" was shown at the Sundance Film Festival in January, 2008, and as of the time of writing this chapter, it isn't yet available for general viewing. Some of the clips from the movie are quite compelling, and the actors and people interviewed have clearly rehearsed for Hollywood-style impact.

Such films may be able to contribute a great deal to soil education and public awareness of soil since a much larger audience will likely view an entertaining film. Unfortunately, current movie titles that include the word "Soil" (34 on Amazon.com) are generally not about soil, and those that contain the word "dirt" (137 on Amazon.com) usually use the word in a derogatory way.

6. Raising Public Awareness of the Importance of Soil to Society

The importance of soil in shaping ecosystems and human civilization is hard to exaggerate, but since soil is hard to see and study, it often isn't considered at all. Numerous studies have shown that the availability of nutrients originating from soil limit the productivity of terrestrial ecosystems, and often limit the local availability of food. Past civilizations have risen when the fertility of the local soils allowed the production of food in excess of need, allowing human efforts to focus on government, industry, artistic and military pursuits.

Recent human experience has largely forgotten that essential tie to the land, though it is just as important now as it was thousands years ago. For instance, a recent survey of an Environmental Science class of about 700 students at the University of Washington showed only four students acknowledging their families had any direct role in producing food from land. These students are among a decreasing percentage (now less than 1%) of Americans living on farms. A similar situation occurs in Western Europe where farmers make up less than 2.5% of the population. Unfortunately, it is increasingly difficult to find students that gravitate toward the study of soil.

Interestingly and contrary to the general decline in soil-related professional activities, in the United States and other developed countries where people rarely worry about how they will get their next meal, "getting back to the land" is often a strong personal desire more than a necessity. Given that perhaps hundreds or even thousands of generations of humans would have benefited by developing and maintaining a knowledge of soil to benefit their agricultural work, we would expect that natural selection might have favored humans that developed a practical knowledge of soil as much as it might have benefited humans that developed more proficient hunting skills than their neighbors. However, much of this is speculation on the part of the authors of this chapter.

Given the universal reliance on soil for the production of food and fiber for so long in human history, the soil resource is clearly taken for granted by most people in the modern societies that soil has made possible. As mentioned before, nearly all advanced societies ultimately have relied on soil to produce the bulk of their food supply, but rarely has the focus of the scientific, artistic and governmental branches of these societies been on soil. Many science fiction works predicted the early demise of traditional soil-based agriculture in favor of hydroponics, or soilless agriculture, where chemicals are supplied in an available form through a "nutrient solution".

Hydroponic-based food production, for example, is demonstrated at Disney's Epcot Center near Orlando, Florida. When Disney opened the Center in 1982, the hydroponics exhibit predicted that much of the world's problems with food supply could be reduced by using the soil-less techniques demonstrated. Many of the predictions of Epcot have been borne out largely as predicted. In fact, it is said that the writings of science fiction are predictive of the future, but in almost all cases the predictions of science fiction writers relative to the production of food have not been borne out.

Other stories and books sometimes predicted a continued reliance on soil, though only as a source of raw organic material that could be reworked into almost any other required organic molecules, including food (i.e. "*The Brave New World*" by Aldous Huxley) by microorganisms engineered to do this work. Currently, many of the predicted systems are available, and could potentially be utilized to produce a substantial amount of food and raw materials if necessary, but at considerably higher cost than soil-based agriculture. Soilless agriculture produces a very small amount of our current food supply, usually only specialty and very high priced seasonal crops such as tomatoes, lettuce and cucumbers.

More common perhaps, is the production of "artificial" or "enhanced" soils for a variety of purposes. Soils cannot only be amended with chemical nutrients to increase their fertility, but also can they be amended to change their physical, chemical and biological properties. In modern soils literature these soils are often identified with the term “Technosols”.

7. Soil Science Education of Women and Minorities

A 1992 workshop in Rennes, France brought together soil scientists with the goal of facilitating conversation about soils research in developing countries. It concluded that soil science would best be benefited by a shift in focus “not just towards the physical, chemical and biological aspects, but also to those environmental, economic, social, legal, and technical aspects that affect soil use” (Bridges and Catizzone, 1996). This so-called “holisitic approach” is identified as an essential step in developing sustainable land management systems.

Perhaps as important as the suggested paradigm shift is the choice of the term “holistic” to describe it. The word itself is derived from the Greek *holos*, meaning whole, entire, or total. This illustrates a transcendence of traditional disciplinary boundaries, but also hints at a need for a diversity of background and experience in order for soil science itself to move successfully forward. Herrmann (2006) articulates this need for diversity more directly by stating that from the public and political perspective, all groups of people should be the target of soil education and awareness if its governing rules and laws are to be obeyed and respected. Thus, increasing the breadth of both the soil scientists and the public are important in its efficacy.

Professional soil science in Russia exemplifies some of what can be accomplished through such efforts. For varying socioeconomic and sociopolitical reasons the number of women in soil science surged in Russia in the 1950’s, 1970’s and 1990’s (Sycheva, 2006). As of 2006, there are more female than male soil scientists in Russia as a result of these surges. The gender distribution of soil scientists in the United States lags significantly behind the Russian example, and soil science professionals are experiencing a crisis in dwindling numbers perhaps as a result.

The primary professional society for soil scientists in the United States, the Soil Science Society of America (SSSA) has a membership, which as of 2006, saw 44% of its members over the age of 50 (Hartemink *et al.,* 2008). Further, nearly all of their members in that age bracket were men. Of those 30-50 years old, nearly 75% were male. It has not been until quite recently that the membership of the SSSA has begun to see gender equity (closest among their members in their 20’s).

Similarly, soil science education in the United States is going through a period of transition. Between 1992 and 2004 graduate student enrollment in the United States and Canada saw a 40% decrease (Baveye *et al.,* 2006). Despite this attrition, however, the proportion of female students increased across the graduate ranks, particularly at the

Ph.D. level. Similar trends have been observed in other countries. Likewise, the Master of Science degree programs in soil science in the Netherlands went from approximately 10% in 1980 to nearly 50% in 2005 (Hartemink *et al.,* 2008).

If, as we assert, increasing the diversity of both the soil scientists and the public is important in the efficacy of soil science education and public awareness, these trends among women in soil science are heartening. Far less attention, however, has been dedicated to similar trends of minorities in soil science. Further consideration of increasing the diversity of soil science beyond the great strides made in terms of gender equity will be key as the relationship between soil science and the public continues to evolve. This is certainly key in continuing to grow soils as a scientific discipline and, as Herrmann (2006) points out, in appealing to those that are directly affected by it – everyone.

8. Conclusions

For such an important resource on which humans rely so much for their food supply and other important renewable resources and environmental services, it appears that society has lost much of its previous direct and practical knowledge of soil. On the other hand, the realization that soil is a critical resource is widely acknowledged, and a fairly large amount of material about soil is now available through the internet and in published form, aimed at audiences from young children to higher education levels. Informing and educating the public about the importance and basic properties of soils is also part of more holistic materials published about ecosystems, where soil is not considered individually as a separate, but as part of a functioning ecosystem.

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Glossary

Biodiversity: The variation of life forms within a given ecosystem or larger unit, including the entire Earth. Biodiversity is often used as a measure of the health of biological systems. The biodiversity found on Earth today consists of many millions of distinct biological species, including the variation in function within species.

Holistic approach: Looking at the totality of form and function of a system that is much greater than the sum of its component parts. Often a system cannot be understood by the isolated examination of

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Biographical Sketches

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