HISTORY, PHILOSOPHY, AND SOCIOLOGY OF SOIL SCIENCES

Eric C. Brevik
Dickinson State University, Dickinson, ND, United States of America

Alfred E. Hartemink
ISRIC - World Soil Information, P.O. Box 353, 6700 AJ Wageningen, The Netherlands

Keywords: soil science, history, philosophy, sociology

Contents

Summary

Soils knowledge dates to the earliest known practice of agriculture about 11,000 BP. Civilizations all around the world showed various levels of soil knowledge by the 4th century AD, including irrigation, the use of terraces to control erosion, various ways of improving soil fertility, and ways to create productive artificial soils. However, these early civilizations did not take soils knowledge to the level of a true science. Early soils knowledge was based on observations of nature; experiments to test theories were not conducted. Advances in soils knowledge were made and famous scientific names such as Francis Bacon, Robert Boyle, and Leonardo da Vinci worked on soils issues through the Middle Ages. However, soil science did not become a true science in its own right until the 19th century with the development of genetic soil science, led by Vasilii V. Dokuchaev. In the 20th century, soil science moved beyond its agricultural roots. Soils information is now used in residential development and the planning of highways, campgrounds, building foundations, septic systems, wildlife management, environmental planning and management, and many other applications; soils have become an important component in all forms of land use evaluation. However, soil science today is at a crossroads. Whether it continues to stand alone as a separate, distinct scientific field or is absorbed into related fields such as crop science, geology, and geography is one of the biggest questions facing soil science in the 21st century.

The study of soils involves sharing of knowledge with other scientists and society at large. This is done primarily by publication of research results in books, journals, and other outlets. Soils research is supported by universities, government agencies, and

private entities. One of the major sociological issues soil scientists must address is the generally negative perception the general public has historically had of soil.

1. Introduction

The history of soil research has largely been a history of soil use related to agriculture. This has had a profound impact on how soils have been studied, classified, and perceived by societies. While the agricultural use of soils is extremely important, soil knowledge is also important for non-agricultural purposes, including construction, environmental work, community planning, taxation, and many others. Soil is a complex material that serves as the foundation to construction projects, is intimately tied into changes in global climate, is an integral component in the environmental management of our planet, provides us with raw materials, and from which medicines have been developed, to name but a few. In short, there is much more to soil than most people realize. This chapter will give a brief explanation of how human soils knowledge has evolved over time, and how that has altered the way we use soil knowledge.

In 1970, Lakatos paraphrased Kant as such: “philosophy of science without history of science is empty; history of science without philosophy of science is blind.” This chapter will also explore some of the more notable 20th century philosophers of science, their ideas about how science works, and look at some brief examples of how soil science may fit into their theories.

Science is a social undertaking practiced by a community of scientists for the benefit of society. The composition of the scientific community and the perceptions of society concerning the topic of study influences the way that science is carried out and the effectiveness by which knowledge is gained and passed on. The natural topic being studied, in this case soils, also exert their own influence on human society and this paper will briefly explore some of these sociological issues as well.

2. Early Soils Knowledge

Agriculture was the first systematic use of soils by humans. The move to sedentary agriculture likely represented one of the first times that humans considered soil properties, be it directly or indirectly, in decisions on land use. The earliest known evidence of agricultural practices comes from a site near the modern village of Jarmo in Iraq, where implements for harvesting and tilling were found dating back to 11,000 BP. It is likely that people used a trial and error approach in determining where to farm, and agricultural settlements were established in places where the soils were suitable and favorable for crop growth. Evidence of irrigation has also been found in southern Iraq dating back to 9,500 BC, showing early efforts to manage and adapt soils for human needs.

In western societies the Middle Ages (5th to 14th Centuries AD) represented a period of repression for science and a neglect of soils knowledge that had been gained by the Greeks and Romans. This neglect was due to the strong dominance of religion in western life and the absence of a thriving science community. Of course, local soils knowledge existed in the Middle Ages, and in some parts of the world where religion had less influence it was expanded. It is only in the Renaissance and the subsequent development of the natural sciences that the scientific study of natural resources, including the soil, started in the western world.

2.1. The Middle East

The area between the Tigris and Euphrates Rivers in Iraq became home to the ancient civilizations of Mesopotamia. Southern Mesopotamia was ruled by the Sumerians from about 5,000 to 1,700 BC. Then the Babylonians gained dominance from their northern Mesopotamia base until about 1,000 BC. The people of Mesopotamia recognized differences in soils and adjusted their cropping patterns based on differences observed in soil fertility.

Mesopotamia had an advanced system of irrigation canals under both the Sumerians and the Babylonians. Irrigation was also intimately linked to the demise of the Mesopotamian civilizations. Political power in Mesopotamia shifted from the Sumerians to the Babylonians when the soils of Sumer became too saline for crop growth because of salts in the irrigation water and rising saline groundwater. Babylonian rule failed as canals filled with silt eroded off the surrounding hills. The Babylonians had removed timber from the hills to build their cities and grazed their sheep and goats on the hills. Increased erosion rates led to the deposition of as much as four m of sediment in Babylonian fields.

In approximately 1400 BC the Bible depicted Moses as understanding that fertile soil was essential to the well-being of his people. Numbers 13:18-20 (New International Version) reports on the charge Moses gave to the men he sent to explore Canaan. Moses says to them *"See what the land is like and whether the people who live there are strong or weak, few or many. What kind of land do they live in ? Is it good or bad ?...How is the soil ? Is it fertile or poor ? Are there trees on it or not ? Do your best to bring back some of the fruit of the land."* Moses specifically instructed his men to evaluate the fertility of the soil, showing recognition of the importance of the soil in agricultural production.

During the Middle Ages, Islamic-based societies had formed and spread from the Arabian Peninsula and were among the world's leaders in science, mathematics, and technology. This included the agricultural sciences. Earlier works from civilizations such as the Greeks, Romans, Chinese, and Indians were known to Muslim scientists, who studied, combined, and built upon these earlier works. A hallmark of Middle Ages Muslim governments was the development and support of extensive networks of irrigation canals. Advanced mathematics contributed greatly to the engineering of these irrigation systems. Muslim agronomists were also adept at identifying soils suitable to the crops being grown. Libraries in major Muslim cities typically contained numerous agricultural works, and the Muslim scholar Cordoba developed an agricultural calendar in the 10th century that listed, among other items, monthly tasks related to the preparation of soil for agriculture. Soil fertility was maintained through the use of manure, and it was recognized that different crops had different soil fertility requirements.

2.2. Europe and North Africa

The Ancient Greek philosopher-scientists developed a clear understanding of soils, recognizing differences between soils by the second millennium BC. They have been credited with creating the first recorded works that show knowledge of soil properties. The philosopher Xenophon recognized that life started and ended in the soil. Hesiod wrote of different types of plows that were developed to work different soils, and Aristotle and Plato linked soil to the giving of life by comparing it to a woman or mother. Greek philosophers also developed a concept of the soil profile and recognized that the soil supplies nutrition to plants. Theophrastus wrote what was probably the first agronomic work, including a classification for soils. The Greeks were quite successful at choosing crops suitable for soils found in their colonies around the Mediterranean and had literature devoted to soil management practices.

Despite their advanced knowledge of soil at an early age, the Greeks did not conduct experimental study of the soil. The Greeks were excellent observers of nature, but they did not test theories. As with the Babylonians before them, soil erosion became a serious problem in ancient Greece and the Greek agriculturists never developed techniques to combat soil erosion.

The agricultural knowledge of the Romans was developed under the influence of the Greeks. Italy had been colonized by Greece and produced grains under the Greek system for several centuries before the rise of the Roman Empire. Therefore, Roman knowledge of agriculture and soils can be seen as an extension of Greek knowledge.

The first period of Roman soils knowledge was during the 2nd century BC and was dominated by Cato, who advocated the use of manure and green manure as amendments to improve the soil. In particular, the use of green manure was a step further than Greek ideas concerning soil fertility, and Cato made the first recorded reference to what we now know as compost. The Romans also began terracing their fields to reduce soil erosion.

Varro ushered in the second period of Roman soils knowledge during the 1st century BC, and re-introduced works from Greek authors such as Theophrastus to the Roman literature. Varro proclaimed farming to be a science. He considered soils as one of two important components of farming and developed a classification system for the soils of Italy. He also advocated methods for the improvement of soil fertility. By the third period of Roman soil knowledge, scientists such as Pliny the Elder were arguing that soil fertility declined under cropping and that soil fertility could never be replenished. While Columella and Strabo offered opposing views, Roman ideas of soils and soil fertility as a whole took a step back.

By the 2nd Century AD, Roman science began to decline and the biggest contribution made at that time was in the recording of soils knowledge gained to that point, allowing it to be passed on to future workers. Given that the Roman Empire completely encircled the Mediterranean Sea, Roman ideas on soil science probably had a profound influence on soil science throughout the Mediterranean at that time. Other Mediterranean civilizations were tied to the soil, but did not develop the same level of understanding of the soil as the Greeks and Romans.

Long before the Greek or Roman Empires rose to prominence, the Egyptians developed an organized civilization around the Nile River that lasted from about 3300 BC to 332 BC. The Egyptian civilization was based on irrigation and the fertility of their agricultural soils was naturally maintained through frequent flooding of the Nile River, which led to deposition of rich silt. The Egyptians had a cultivated agriculture and they understood preparing soil before sowing. They also understood that the Nile floods watered and fertilized the soils and the floods removed accumulations of salts.

The Phoenicians, who were at their height from about 1200-800 BC, were the first to construct bench terraces on steep slopes in Lebanon and Syria. They practiced a cultivated, irrigated agriculture on these terraces, which showed an understanding of soil management to prevent erosion and thus allow for successful cropping.

Another early Mediterranean civilization was based out of the city of Carthage in Tunisia. Eventually conquered by the Romans, the Carthaginians were excellent farmers with advanced cultivation and irrigation systems. However, erosion by wind and water eventually removed the topsoil around Carthage, and today the region can not support the populations it once did.

Agriculture-based groups also existed in more northerly parts of Europe in the pre-Roman era. The Celts in Britain cultivated fields across the slope to slow erosion, bench terraces have been used in modern day France that possibly date back to the Phoenicians, and cultivation began in Poland as early as 5,500 BC. In general, agricultural techniques were improved in Europe when the Romans arrived. Farther east, farming tribes lived along the Dniester River as early as the 4^{th} century BC and a clay jug with an agricultural calendar that dates to the 4^{th} century AD has been found.

These examples display some level of soil knowledge from an agricultural perspective, but nothing has been found in other parts of Europe and North Africa that would indicate knowledge as refined as that of the Greeks and Romans.

Following the decline of Rome in 410 AD, Roman culture shifted to Byzantium in Turkey. Many Roman manuscripts, including agricultural manuscripts, were moved to Byzantium and the scientific ideas developed by the Roman Empire were preserved and advanced over the next 1000 years by the Byzantines. A 10^{th} century AD agricultural encyclopedia showed Byzantine soils knowledge. It includes works by Roman soils specialists, but several new Byzantine authors are also represented. It includes a description of the soils of the Byzantine Empire, discussions of which crops were most appropriate for different soils, and ways to evaluate the quality of the soil.

Agriculture declined in Europe following the fall of the Roman Empire, a decline that included both the area of land under cultivation and the yields obtained during crop growth. Brief periods of renewed interest occurred in the 8^{th} and 9^{th} centuries AD, but real agricultural improvement did not take place until the 11^{th} century. Draining of marshlands, fertilization of the soil with manure and marl, and use of a plow that turned over the upper layer of the soil all helped to increase agricultural yields; manure was in fact a highly valued commodity. Cultivated lands on steep slopes were returned to forest as early as the 10th century AD in an effort to reduce soil erosion.

2.3. Asia

In Asia humans were also learning about soils. Farmers worked sand and manure into the soils of the Amu Darya delta, found in present day Uzbekistan along the south shores of the Aral Sea, to improve fertility and other soil properties as early as 4,000 years ago. In India, Neolithic (3rd to 2nd centuries BC) farming communities were found in areas with fertile *black regur* soils (Vertisols) on the Deccan Plateau. Writings from the 4th century AD mention irrigation of fields and fines or penalties for those who allowed breaches in the irrigation system. These farming communities expanded at an early date to include the fertile floodplains of major rivers like the Ganges.

Land in China was drained and ameliorated as early as the 23rd century BC, agricultural literature existed by the 14th century BC, and a farming calendar was documented in the 2nd century BC. Chinese accounts tell of Count Hui dividing soils according to their quality and location in the 2nd century BC. The earliest records of soil conservation in China date to 956 BC, and Fan Sheng-chih wrote of soil properties and of optimal times for tillage in the 1st century BC. Early agriculture in China centered on the fertile floodplain of the Huang He, or Yellow River.

Southeast Asia was a region in which soils knowledge expanded during the Middle Ages. Chinese government documents from this period separated soils into 12 categories based on the crops they were most suited to and regulated the time of working the fields. In each community an individual was responsible to look after fertilizers and soil fertility. Terracing of farm fields in China for erosion control can be documented as early as the 7th century AD.

The decrees of Chinese emperors showed a strong appreciation for soils. Emperor Hinn included soil quality in the determination of land taxes in 1115. Emperor Ming ordered that all lands be divided based on their location and soils in 1387, and land surveys including soils information were made for large portions of the country.

Japanese agriculture was influenced by the Chinese until the 9th century AD, after which the Japanese halted immigration and moved away from Chinese influence. The lack of good land led the Japanese to place a high value on fertile soil. Several forms of soil fertility maintenance including manure, green manure, the growth of legumes, and crop rotations were used. Terraces were used on steep slopes and land surveys were common. Artificial soils were created on terraces on steep land where natural soils were poor. Because of the lack of good agricultural land the Japanese developed a reverence for soil.

In India irrigation, fertilization through manure application, fallow periods to restore fertility and selection of crops based on soils were widely used by the 14th century AD.

2.4. The Americas

Farming existed in Mexico by the 5th century BC, and included terracing and irrigation techniques. In Mexico, the Maya farmed flat valley lands with readily available water, and commonly used artificial soil made of aquatic plants, clay from lake or river bottoms, marl, manure, and a system that required some knowledge of soil properties. In Peru, the Inca developed bench terraces on mountain slopes, filled the area behind the terraces with non-soil material to within about a meter, then filling the final meter with fertile soils carried up from bottomland areas. The Aztec, Inca, and Maya all also farmed areas of fertile soils derived from volcanic ash, and the Aztec had a system of soil classification (Table 1). These various agricultural techniques succeeded in supporting some large cities such as Teotihuacan, which had approximately 125,000 inhabitants at its height.

Terra preta (dark earth) soils are found throughout the Amazon River basin in South America. These soils have carbon levels that can be up to 70 times greater than in the surrounding soils. While research into just how these soils formed is still ongoing, they are believe to be related to long-term human management by past indigenous people. They most likely formed when organic material was added to the soils though burning and mulching. Some of the terra preta may even become self-regenerating when biologic activity in them reaches a certain threshold.

3. Soils in the Scientific Revolution

The 15th century marked the beginning of the Renaissance in Europe, a period when science and scientific thinking began to develop and grow. There are a number of significant events that occurred in the study of soils during this period. Soil science was not a distinct scientific field but many of the phenomena that occur in the soil such as the supply of plant nutrients and changes in soil over time were being investigated. Some new scientific methods were being applied to the study of soils and Europe's scientists were also rediscovering earlier works by the Greeks, Romans, and others.

Soil Name	Distinguishing Properties	Summary of the Aztec Description
Tetlalli	Stony or gravelly texture	Found in gravelly or rocky mountainous settings, dries deeply but productive when moist. Probably broken into subclasses based on
Xalalli	Sandy texture	degree of stoniness.
Tezoquitl	Clayey texture	Low fertility, not valued as an agricultural soil. Firm, gummy, and sticky, dark in color. Broken
Teuhtlalli	Loess derived	into subclasses based on sand and silt content.
Tepetate	Formed in volcanic material	Earth that swirls up. Soft rock - earth of a hard but friable consistence. Divided into sandy, clayey, and
Tlalcoztli	Yellow color	clayey-sandy subclasses.
Tepetlalli or ximmilli	Found on mountain slopes	Good, fertile, esteemed soil. A dry, ashen, clayey-sandy soil valued for
Tepetlixpa	Found on hillslopes	cropping of maize, amaranth, beans, and fruit

Quauhtlalli	Woodland soil	trees.
		No good description has been found.
Tollalli	Reedy soil	Composed of rotten wood and leaves, black or
		yellow in color, prized for the cultivation of
Tlazollalli	Humus	wheat and maize.
Atoctli	Alluvial soil	Soil created from the rotting of reeds, produces
		a fertile soil.
		Humus that turns into soil, a fertile soil.
Techiauitl	Good water holding	Soft, porous, fertile soil that is food-producing.
	capacity	Subdivided based on texture. This term is still
		used by local farmers.
Chiauhtlalli	Wet soil	Soil that does not dry out quickly when it gets
		wet.
	Impermeable	
	Irrigated land	Soil that is always wet even though it is not
Nantlalli		irrigated, food-producing in years of low
Atlalli	House land	rainfall.
	Urinated land	Water does not soak in, it ponds on the surface.
	Salty land	A field or garden that can be successfully
Callalli		irrigated, fertile soils desired for maize and bean
Axixtlalli		production
		Fertile soil formed where a house once stood.
		Land ruined by human activities.
		Salty, bitter, corrosive land that is unwanted or
Tequixquitlalli		undesirable. This term is still used by local
		farmers.

Table 1. Examples of terms used in Aztec soil classification. Compiled from Williams,2006(in Warkentin, 2006).

-
-
-

Bibliography

Aldrich, M.L. (1979). American State Geological Surveys, 1820-1845. In C.J. Schneer (ed). *Two Hundred Years of Geology in America*. University Press of New England, Hanover, New Hampshire. pp. 133-143. [Contains information on soils work done by early American geological surveys.]

Ben-David, J., and T.A. Sullivan. (1975). Sociology of Science. *Annual Review of Sociology* 1: 203-222.

[Gives an overview of the sociology of science with examples.]

Feller, C., Brown, G.G., Blanchart, E., Deleporte, P. and Chernyanskii, S.S. (2003). Charles Darwin, Earthworms, and the Natural Sciences: Various Lessons from Past to Future. Agriculture, *Ecosystems and Environment* 99: 29-49. [A review of Darwin's contributions to soil biology.]

Feller, C.L.,. Thuriès, L.J.-M, Manlay, R-J., Robin, P. and Frossard, E. (2003). “The Principles of Rational Agriculture” by Albrecht Daniel Thaer (1752-1828). An Approach to the Sustainability of Cropping Systems at the Beginning of the 19th Century. *Journal of Plant Nutrition and Soil Science* 166: 687-698. [A review of Thaer's contributions to soil science.]

Helms, D., Effland, A.B.W. and Durana, P.J. (eds.) (2002). *Profiles in the History of the U.S. Soil Survey*. Iowa State University Press, Ames, Iowa. [A review of the history of soil survey in the United States, including early survey leaders and the soil geomorphology projects.]

Idrisi, Z. (2005). *The Muslim Agricultural Revolution and its Influence on Europe*. Foundation for Science Technology and Civilisation. Manchester, United Kingdom. 19 p. [A review of Muslim contributions to agriculture in the Middle Ages.]

Krupenikov, I.A. (1992). *History of Soil Science, From its Inception to the Present*. Amerind Publishing Co., New Delhi, India. 352 p. [An in-depth review of soil science history from the Soviet perspective.]

Kuhn, T.S. (1970). *The Structure of Scientific Revolutions*, 2nd Ed. The University of Chicago Press, Chicago, Illinois. [Kuhn’s most famous work, provides in-depth explanation of his ideas concerning the way that science advances.]

Lakatos, I. (1969). Criticism and the Methodology of Scientific Research Programmes. *Proceedings of the Aristotelian Society* 69: 149-186. [Compares the approaches of Kuhn and Popper to the philosophy of science, and offers a strengthening of Popper’s idea of falsification in science that addresses criticism of falsification by Kuhn.]

Lakatos, I. (1970). History of Science and its Rational Reconstructions. *Boston Studies in the Philosophy of Science* 8: 91-136. [Provides an explanation of why they studies of the history of science and philosophy of science are intimately interlinked.]

Meyer, L.D. and Moldenhauer, W.C. (1985). Soil Erosion by Water: The Research Experience. *Agricultural History* 59: 192-204. [Review of the history of soil erosion by water studies.]

Popper, K. (2002). *Popper: Conjectures and Refutations, the Growth of Scientific Knowledge*. Routledge Classics. Routledge, London. [A collection of essays by Popper that explain his ideas concerning the philosophy of science.]

Simonson, R.W. (1989). *Historical Highlights of Soil Survey and Soil Classification with Emphasis on the United States, 1899-1970*. International Soil Reference and Information Centre Technical Paper 18. Wageningen, The Netherlands. 83 p. [An overview of the history of soil survey and classification from the American perspective.]

Simonson, R.W. (1997). Early Teaching in USA of Dokuchaiev Factors of Soil Formation. *Soil Science Society of America Journal* 61: 11-16. [A report of the earliest known teachings of Dokuchaev's ideas in American universities.]

Troeh, F.R., J.A. Hobbs, and R.L. Donahue. (2004). *Soil and Water Conservation for Productivity and Environmental Protection*, 4th Edition. Prentice Hall, Upper Saddle River, NJ. [Provides a historical overview of soil and water conservation around the world.]

Van Baren, H., Hartemink, A.E. and Tinker, P.B. (2000). 75 years of The International Society of Soil Science. *Geoderma* 96: 1-18. [Gives the history of the ISSS.]

Warkentin, B.P. (ed). (2006). *Footprints in the Soil: People and Ideas in Soil History*. Elsevier, Amsterdam. [Provides a look at the history of soil science, interrelationships between soil science and allied fields, and some sociological issues in soil science.]

Relevant Websites

https://www.soils.org/committee/S205.1/ *Homepage for the Commission on the History, Philosophy, and Sociology of Soil Science of the Soil Science Society of America.*

http://www.iuss.org/division4/commission4_5.htm *Homepage of Division 4.5 History, Philosophy, and Sociology of Soil Science of the International Union of Soil Sciences.*

http://agriculturalhistory.ualr.edu/ *Homepage of the Agricultural History Society.*

http://www.hssonline.org/ *Homepage of the History of Science Society.*

Biographical Sketches

Eric C. Brevik is an Associate Professor of Geology and Soils at Dickinson State University, North Dakota, USA. Dr. Brevik earned his BS and MA degrees in Geology from the University of North Dakota and his PhD in Soil Science at Iowa State University. He has taught courses in soil science and geology at Valdosta State University (Georgia, USA) and Dickinson State University since 2001. His research interests include carbon sequestration by soil, soil health and productivity, soil science history, soils and society, and the integration of geological and soils information. Dr. Brevik is active professionally, having published over 130 peer-reviewed articles, abstracts, and other publications. Dr. Brevik is also active both in the United States and internationally in researching the historical and sociological aspects of soil science. He served as the vice chair and then the chair for the Soil Science Society of America's Council for the History, Philosophy, and Sociology of Soil Science from 2004-2006 and currently serves as the webmaster for the same group. Dr. Brevik is also the newsletter editor for the International Union of Soil Sciences Council for the History, Philosophy, and Sociology of Soil Science, and he helped organize and chaired a session on the History of Soil Science in Developing Countries at the 2006 World Congress of Soil Science in Philadelphia, Pennsylvania, USA.

Alfred E. Hartemink is a soil scientist at ISRIC – World Soil Information in Wageningen, The Netherlands. He holds a MSc degree from Wageningen University and a PhD from Reading University. Over the past 20 years, he has worked on the application of soil science knowledge to real-work problems such as food production, nitrogen leaching, and sustainable land management. He has worked in Congo, Kenya, Tanzania, Indonesia, Papua New Guinea and Australia. Currently, he leads a large international project that aims to make a new digital soil map of the world: *GlobalSoilMap.net* funded by the Bill&Melinda Gates foundation. He is the Deputy Secretary General of the International Union of Soil Sciences and has over 170 publications including 8 books. Alfred Hartemink is joint editor-in-chief of *Geoderma* – a Global Journal of Soil Science.