Spotlight on…

Soils: understanding the world beneath our feet

Eefje Smit, Paul Strehlenert and Laura Grassi

Teachers at an EELLSS training event in Barcelona in November 2016 learn how to perform and teach soil assessment. Photo: © Paul Strehlenert.

Introduction

Soil. We find it everywhere. In every urban or rural area an entire world exists beneath our feet. Why, then, when this world is so easily accessible, is soil so hard to find in the curriculum? Although 'soil' appears in the key stage 3 National Curriculum Programme of Study for geography in England, it still begs the question: what, if anything, is actually taught in relation to this topic? Soil science is a discipline concerned with a material that has unique features and behaviours (Churchman, 2010). Part of this is the multidisciplinary character of soil. Soil is not only relevant to natural science (physics, chemistry, biology), but also to geography, social sciences, art and history (Bryce, 2015). In both secondary and higher education the topic of soil and soil science is not tied to one specific subject. As we might expect, however, there is a remarkable distinction between academic soil science and what gets taught about soil in secondary schools. In secondary education soil is connected to geography, chemistry and biology, but none of these subjects really 'owns' the topic outright, and in geography 'soil' is often limited to soil classification or soil erosion. In the academic world soil science is mainly related to agriculture; however, as Philip points out, 'the content of soil science is uneasily placed between natural science on the one hand and the world of professional practice on the other' (1991, p. 91). In recent past decades academic soil science has changed rapidly, with an increase in the number of projects and publications, and an overall growing demand for soil science expertise (Hartemink and McBratney, 2008). But, where does all this leave soil in education?

An international initiative

In 2015, which happened to be the International Year of Soil, a partnership of educators and soil scientists from seven European countries was founded and funded through Erasmus+. The European Experiential Learning Laboratory on Soil Science (EELLSS) partnership (see website) discussed strategies to teach soil in a way that acknowledges the multidisciplinary character of the

subject. More fundamentally, the question arose of what we should teach regarding soil in secondary schools. For instance, what topics within soil science relate to so-called 'wicked' problems and issues such as climate change (Rittel and Webber, 1973)? Ten school projects were carried out in seven countries, all of which related to soils in a broad perspective. Below, the authors – who represent three of the EELLSS partners – explain why we should teach soil in secondary education and, more specifically, *what* we should teach regarding soil.

Why is it so important to teach soil science?

Soil is an indispensable resource for human life on Earth; among other things, soil allows us to grow crops, provides the oxygen for plants, hosts vast biodiversity, fosters essential ecosystem services and conserves the history of former geological eras. In addition, soil plays a crucial role in food security, climate change adaptation and mitigation, and poverty alleviation. Yet, soil is ultimately finite and exhaustible.

Changes in soil functions caused by soil degradation affect food security both directly and indirectly. The state of soil has an impact on crop yields and can be considered one of the main factors for stagnating productivity (Bindraban *et al*. cited in Vargas Rojas *et al*., 2016). Worldwide, an estimated 33% of soils suffer from degradation (FAO, 2015), and each hour 11 hectares of soil are 'sealed' (built upon). On top of this, 50,000km^2 (or 24 billion tons) of fertile topsoil is lost, mainly by erosion, every year. Even so, while food security is an issue that national and international organisations such as the Food and Agriculture Organization (FAO) are tackling, the fundamental role of soils in providing healthy and nutritious food is often overlooked (Godfray *et al*., 2010; Vargas Rojas *et al*., 2016). Due to its important role in the hydrological and carbon cycle, soil is a major factor in the global climate system. Thus, soil is considered the largest carbon pool after the oceans. It is estimated that in the European Union (EU) around 75 billion tonnes of carbon is stored in soil (European Commission, 2008). To put this into perspective, in 2006 the total carbon emission in the EU amounted to approximately 1.5 billion tonnes (EEA, 2008, 2017). However, as is the case with food security, in relation to climate change, the importance of soil is often overlooked. For example, the 2015 Paris International Climate Change conference focused mainly on the reduction of greenhouse gases, but the role of carbon dioxide (CO_2) captured in soil and the release of it by unsustainable land use was never mentioned.

Moreover, the degradation and erosion of soil violates peoples' human rights – another factor that is often overlooked:

- with the pollution of soil, the right to live in a clean and safe environment is not respected
- the erosion of soil and the absence of soil fertility leads to people being unable to access food and nutrition, and
- the appropriation of land for commercial uses such as mining, monoculture and urbanisation often involves the invasion of peoples' 'peaceful enjoyment of property' in that it deprives local communities of the opportunity to support themselves (Equality and Human Rights Commission, n.d.).

It is in the light of these breaches of human rights that the Global Soil Partnership (established by members of the FAO in 2012) maintains that sustainable soil management requires the adaptation of legal frameworks that enforce the implementation of good practice for the protection of soil by landowners and major stakeholders (Vargas Rojas *et al*., 2016).

In summary, although soil is crucial for human life, the general public, decision-makers and even scientists are not always aware of the basic interconnections outlined above. We argue, therefore, that the general understanding of soil can be seen as an iceberg – with only one-tenth visible and the rest submerged. At the very top of the 'soil-berg' we see soil as simply dirt beneath our feet, while the other nine-tenths – i.e. the importance of soil to human life – remains largely invisible. This situation presents a huge challenge for scientists, teachers and schools who are teaching about soil as an ecosystem.

The EELLSS partnership stresses that the indisputable importance of soil must not reside exclusively in legal frameworks, or in scientific and research institutions. An effective transfer of such knowledge and expertise to school students and their parents, civil society, stakeholders and local governments is necessary. A 2012 study in the UK has shown that a knowledge and understanding of soil science is among the top 10 of most needed skills in a nationwide skills-gap analysis (NERC, 2012). We may conclude that encouragement is needed to supply the soil scientists and policy makers of the future and that this might be done if we invest more in teaching about soils.

Soils: understanding the world beneath our feet

Achieving a deeper understanding of soil

As mentioned above, when it comes to soil most people only know about the top 10%. The challenge for educators is to raise awareness of the submerged part – namely the importance of soil for human life on Earth. Furthermore, since soil problems are often 'wicked problems', a multi-disciplinary approach is imperative to get a message across (Rittel and Webber, 1973). We are also aware that educators need a plan for progression of the topic over the years, and require the tools to do so; tools that include appropriate teaching models (Treagust, 2002). This begs the question: on what topics related to soil should we focus in secondary education?

If we take Bruner's concept of a spiral curriculum, where the level of abstraction is increased over the years (Bruner, 1960), we suggest a foundation knowledge of soils can be laid down in primary schools. Children need to be aware of our relationship with soil and of the ecosystem services provided by healthy soils. In the primary years, teachers can discuss the general state of soils and the fact that soils are non-renewable resources with pupils. For pupils to understand why soil is non-renewable, primary teachers need basic models that illustrate the regeneration time of soils, and simple explanations of how soil is lost by erosion, sealing, contamination, and so on. Within the EELLSS partnership, a straightforward, but effective, practice was carried out: Latvian primary pupils tested the effect of organic fertiliser in their school gardens. Such close-to-home experiments as these can help younger pupils to understand the importance of sound soil management.

When investigating soils, practical elements such as fieldwork are essential for students to develop in-depth understanding. Photo: © Paul Strehlenert.

In the lower secondary years, students should gain a deeper understanding of the importance of sustainable soil management to accommodate, for example, the growing world population. At this point, the degree of specificity can increase. Rather than focusing on details such as calcification and nomenclature (as is commonplace) the study of soils should benefit from a systemic approach. Students could gain a deeper understanding of the role of soils within the hydrological or carbon cycle, although establishing the general principles in describing soils and related processes is beneficial. For instance, the composition of a 'typical' soil can be described as 45% minerals, 25% air, 25% water and 5% organic matter (Jones *et al.*, 2012). This oversimplified yet useful model can provide the starting point for discussions that would lead to greater insights. Here questions such as 'what would happen if you take the air out of the mix?' and 'how is soil included in the carbon cycle?' are highly relevant. In another EELLSS-related project, students from a Dutch partner school designed a plan to convert a municipal forest property into a food forest. They were required to investigate the soil properties on site and relate the resulting information to suitable edible plants. A concern for soils needs to emerge from investigations into agriculture or forestry, and thus students can cover a wide range of important soil issues. Topics such as the effect of commercial artificial fertilisers, a loss of biodiversity, effects on ecosystem services, and the resulting contamination and/or compaction of soils can all be attained through examples and straightforward soil experiments.

In upper secondary education the same soil-related content is relevant, but here enquiries and projects can be more open. At this level, using a systemic approach is even more important because it allows students to dig deeper into the significance of organic materials in soils, the connection between the organic materials in the soil and levels of CO_2 in the atmosphere, the amount of biodiversity in an area and the immense complexity of soil chemistry. Practical elements, such as fieldwork, are essential for students to develop an in-depth understanding of both science and geography, because such an approach helps them explore the connection between theory and the real world (Lambert and Reiss, 2014).

Soils provide endless possibilities for research projects with a scientific component; the added benefit is that often students can carry out field-based experiments close to the school or within the school grounds with relatively low outlay for materials. As part of the EELLSS project, for instance, Swedish students carried out research on the level of copper contamination in soil in former boat-yards. They expected to find higher copper concentrations in these yards than elsewhere, due to the amount of copper-containing impregnates used for boat maintenance. The students used spectrophotometry to gather enough evidence to adopt this hypothesis; and they needed to employ their understanding of chemical analyses plus their geographical and mathematical knowledge to reach this conclusion.

The complete 'soil-berg'

If we want young people to develop a deeper understanding of a range of contemporary issues, such as climate change or food security, we argue that a deeper systemic understanding of soil is necessary. As the examples outlined above demonstrate, there are numerous possibilities for fieldwork close to the school and it is relatively easy to set up soils experiments with the materials available in school chemistry laboratories. An understanding of the challenging ecological issues of today's world starts, we believe, with an investigation of the world beneath our feet: the world of soils.

References

Bruner, J.S. (1960) *The Process of Education*. London: Harvard University Press.

Bryce, A. (2015) 'Soils in schools: embedding soil science in STEM', *Teaching Science*, 6, 3, pp. 14–25.

Churchman, G.J. (2010) 'The philosophical status of soil science', *Geoderma*, 157, 3–4, pp. 214–21.

European Commission (2008) 'Review of existing information on the interrelations between soil and climate change'. *CLIMSOIL Final Report to the European Commission*. Available at http://ec.europa.eu/environment/archives/soil/pdf/climsoil_report_dec_2008.pdf (last accessed 11/10/2017).

European Environment Agency (2008) *National Emissions Reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism.* Copenhagen: European Environment Agency. Available at www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-2 (last accessed 1/11/2017).

EEA (2017) *Soil and Climate Change*. Available at www.eea.europa.eu/themes/soil/climate/soil-and-climate-change (last accessed 11/10/2017).

EHRC (n.d.) *Human Rights.* Available at www.equalityhumanrights.com/en/human-rights (last accessed 1/11/2017).

European Experiential Learning Laboratory on Soil Science (EELLSS) partnership website: EELLSS.eu (last accessed 1/11/2017).

Food and Agriculture Organization (FAO) (2015) 'Soils are endangered, but the degradation can be rolled back', *News report*. Available at www.fao.org/news/story/en/item/357059/icode/ (last accessed 11/10/2017).

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. (2010) 'Food security: the challenge of feeding 9 billion people', *Science*, 327, 5967, pp. 812–18.

Hartemink, A.E. and McBratney, A. (2008) 'A soil science renaissance', *Geoderma*, 148, 2, pp. 123–9.

Jones, A., Panagos, P., Barcelo, S., Bouraoui, F., Bosco, C., Dewitte, O., Gardi, C., Erhard, M., Hervás, J., Hiederer, R., Jeffery, S., Lükewille, A., Marmo, L., Montanarella, L., Olazábal, C., Petersen, J.-E., Penizek, V., Strassburger, T., Tóth, G., Van Den Eeckhaut, M., Van Liedekerke, M., Verheijen, F., Viestova, E. and Yigini, Y. (2012) *The State of Soil in Europe: A contribution of the JRC to the European Environment Agency's Environment State and Outlook Report – SOER 2010*. Luxembourg: Publications Office of the European Union.

Lambert, D. and Reiss, M.J. (2014) *The Place of Fieldwork in Geography and Science Qualifications*. London: IOE.

National Environment Research Council (NERC) (2012) *Most Wanted Postgraduate and Professional Skills Needed in the Environment Sector*. Swindon: NERC.

Philip, J.R. (1991) 'Soils, natural science, and models', *Soil Science*, 151, 1, pp. 91–8.

Rittel, H.W.J. and Webber, M.M. (1973) 'Dilemmas in a general theory of planning', *Policy Sciences*, 4, 2, pp. 155–69.

Treagust, D.F. (2002) 'Students' understanding of the role of scientific models in learning science', *International Journal of Science Education*, 24, 4, pp. 357–68.

Vargas Rojas, R., Caon, L., Achouri, M. and Maroulis, J. (2016) 'Healthy soils: a prerequisite for sustainable food security', *Environmental Earth Sciences*, 75, 3, article 180.

Eefje Smit is a geography teacher-educator at Fontys University of Applied Science, the Netherlands (email: e.smit@fontys.nl); Paul Strehlenert is a biology and chemistry teacher at Värmdo Gymnasium, Sweden (email: paulst@vgy.se); and Laura Grassi is a soil scientist at SOURCE International, Italy (email: laura@source-international.org).