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Shelter, clothing, and fuel: Often overlooked links between soils, ecosystem services, and human health

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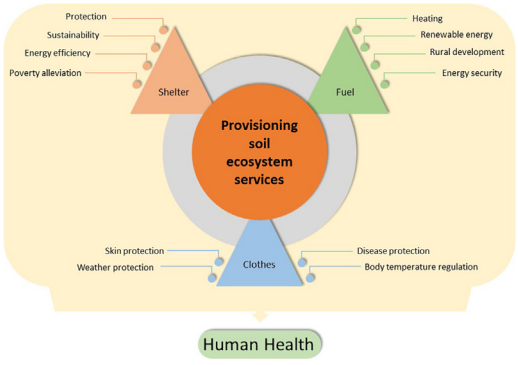
HIGHLIGHTS

- Shelter, clothing, and fuel are important to human health.
- These are ecosystem services that can be supplied by soil.
- They have been overlooked in soil and human health studies.
- Modern methods of obtaining these are energy and resource intensive.
- Sustainable practices can supply these from soil in an environmentally responsible way.

GRAPHICAL ABSTRACT



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ABSTRACT

There are clear connections between ecosystem services (ES) and human health, as well as between soils and human health. However, studies to date have not investigated links between soil ES and human health. Viewing the relationship between soils and human health through the ES lens reveals that soil ES such as the provisioning of shelter, clothing, and fuel have been overlooked in the soil and human health literature. Shelter is important to human health because it provides protection against inclement weather, temperature extremes, and other potential threats. Clothing provides a more consistent micro-environment around the skin and also provides protection from ultraviolet radiation and some parasites. Fuel allows us to warm shelters, providing refuge from cold temperatures, and cook food, which reduces disease. The materials supplied by soils in support of these functions are often done so in a more environmentally responsible way than is the case with many modern building and clothing materials or with fossil fuels. However, it is important to realize that sustainable management practices are critical in order to achieve environmentally responsible production of these products. Future studies need to investigate the links between these overlooked soil ES and human health.

1. Introduction

Assessing the impact of lost ecosystem functions on human well-being and biodiversity was the original reason for the development of

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the ecosystem services (ES) concept (Pröbstl-Haider, 2015), and the links between ecosystem health and human health cannot be denied (Chiabai et al., 2018). In recognition of this, a number of studies have investigated the links between ES and human health (Chivian and Bernstein, 2008; Ford et al., 2015; Sandifer et al., 2015; Bayles et al., 2016; Chiabai et al., 2018). Specific ES-human health links that have been investigated include biodiversity (Sandifer et al., 2015), climate change (Chiabai et al., 2018), green infrastructure (Coutts and Hahn, 2015), freshwater resources (Horwitz and Finlayson, 2011), oceans (Sandifer and Sutton-Grier, 2014), social depravation (Henke and Petropoulos, 2013), poverty alleviation (Suich et al., 2015), well-being (Agarwala et al., 2014), air quality (Manes et al., 2016) and urban areas (Elmqvist et al., 2015; Salmond et al., 2016). Soil functions provide an important number of ES that are crucial for human activities (Pereira et al., 2018). There has been increasing interest in the study and assessment of soil ES over the last 20 years (Adhikari and Hartemink, 2016; Baveye et al., 2016). However, to date there are a paucity of studies that investigate the links between soil ES and human health (Brevik et al., 2018).

While there are different ways to subdivide ES, two of the most frequently used classifications are the Common Classification of Ecosystem Services (CICES) and the Millennium Ecosystem Assessment (MEA) (Pereira et al., 2018). The CICES classifies ES as 1) provisioning (biotic and abiotic), 2) regulation and maintenance (biotic), and 3) cultural services (biotic) (Haines-Young and Potschin, 2018). Provisioning services are defined as all nutritional, non-nutritional material, and energetic outputs from living systems as well as abiotic outputs. This includes cultivated terrestrial plants grown for nutritional purposes, to provide fibers and other similar materials, and that are grown as a source of energy. It also includes domesticated animals raised to provide nutrition, fibers and other similar materials, and energy from abiotic sources (e.g. underground resources), including mechanical energy (Haines-Young and Potschin, 2018). The MEA, which provided the starting point for development of the CICES (Haines-Young and Potschin, 2018), defines provisioning services as products that soil ES make available for human use (MEA, 2005).

Even though soil ES-human health connections have not received much study, the links between soils and human health have received a large amount of attention (Baumgardner, 2012; Brevik and Burgess, 2013; Pepper, 2013; Oliver and Gregory, 2015; Zornoza et al., 2015; Steffan et al., 2018). Many of the soil-human health connections identified fall under the category of provisioning services. These include the provision of nutritious plant and animal based foods (Oliver and Gregory, 2015; Steffan et al., 2018), micronutrients (Lyons and Cakmak, 2012; Oliver and Gregory, 2015), and the supply of medications, particularly antibiotics from soil organisms (Pepper et al., 2009; Mbila, 2013). Micronutrients have been a dominant theme in many soil and human health studies (Brevik and Sauer, 2015; Oliver and Gregory, 2015). However, several soil provisioning services that are important to human health have not received much attention from the soil science community to date. These include the supply of building materials, clothing, and fuel. While these provisioning services are broadly recognized in the general ES literature (MEA, 2005; Smith et al., 2015; Haines-Young and Potschin, 2018), they have not been addressed in the soils and human health literature. Investigating these relationships is crucial to understanding how ES can shape our well-being. Therefore, this paper seeks to investigate this knowledge gap and provide a framework for advancing future work in this area.

2. Shelter

Proper shelter is critical to human health as it provides protection against extremes in weather and other dangerous conditions and situations (Lillibridge, 1997; Krieger and Higgins, 2002). Nowadays, about 40% of the natural resources utilized globally go into buildings, and buildings are responsible for about 33% of worldwide greenhouse gas emissions (Asdrubali et al., 2015). Over 30 years ago the United Nations determined that access to affordable basic building materials was insufficient for much of the world's low-income population (UNCHS, 1985), and appropriate utilization of local natural resources in construction remains a major challenge to the socio-economic improvement of developing counties (Khoso et al., 2014). Local materials play an important role in the sustainability of construction, the local economy, and poverty reduction (Sameh, 2014). The United Nations recognizes three categories of construction materials: 1) modern building materials (e.g., brick, concrete, steel, glass), 2) traditional materials (e.g., bamboo, laterite, straw, stabilized earth), and 3) innovative materials (e.g., fiber reinforced concrete, ferrocement) (UNCHS, 1985). Soils play an important role in providing much of the material used in construction of the shelters used by humans today (Alam et al., 2015) and have the potential to play an even larger role in a future where sustainable construction materials and techniques become more important (UNEP DTIE IETC, 2003; Rodrigues, 2015). However, despite the fact that links between soil and shelter were recognized by some humans as far back as 1500 BCE (Oliver and Gregory, 2015), the provisioning of shelter has received little attention in modern soil and human health investigations (Brevik et al., 2018). Soils provide an array of materials that are important to the construction of shelters, and thus to human health, through their ES.

Soil properties are important in the production of agroforestry crops (Latshaw and McClinton, 1984; Zwolinski et al., 2002; Molina et al., 2016), and timber (lumber) is an important component of shelter construction. The worldwide use of wood as timber was approximately 400 Mm^3 (100 Mt) in 2010. This remained relatively steady between 1961 and 2010 while wood-based panel use increased from slightly above 0 Mm^3 (0 Mt) in 1961 to approximately 225 Mm^3 (55 Mt) in 2010 (O'Brien, 2015). In addition to timber-based construction being viewed as environmentally responsible, recent advances in timber techniques allow the construction of large buildings in ways that were not possible just a few years ago (Koppelhuber et al., 2017). Environmental reasons and new technologies have driven a rise in global timber demand, with an expected 44% increase in consumption between 2005 and 2030 (O'Brien and Bringezu, 2018).

The use of crop residues as construction material was prevalent in pre-industrial societies and is still commonplace in many developing countries (Godts et al., 2014; Valbuena et al., 2016). Straw bales are now extensively used for insulation in buildings and can even be load-bearing in small structures (Lecompte and Le Duigou, 2017). Many advantages have been demonstrated in straw bale construction, including energy efficient, durable, and non-toxic structures that are fire and insect resistant and have improved indoor air quality and thermal comfort compared to many other structures (Rodrigues, 2015; Wei et al., 2015). Approximately 67% of European residential energy demand is for the heating of buildings. Mineral wool and plastics, which are energy intensive to manufacture, currently make up 93% of the insulating materials used in buildings (Asdrubali et al., 2015). Bagasse (the dry pulpy residue left after extracting juice from sugar cane), pineapple leaves, reeds, sunflower pitch, straw bales, recycled cotton and cotton denim (cloth), and recycled textile and paper fibers are all among the natural materials produced in soil that are used or have shown promise for use as renewable insulation materials (Asdrubali et al., 2015). One of the main advantages insulation provides to buildings is a space where temperatures can be regulated with a reasonable amount of energy consumption (Lillibridge, 1997), and temperature extremes are the most dangerous weather events affecting human health (Bell et al., 2016). Climate change is expected to exacerbate human health problems due to temperature extremes, and one effective line of defense against this is climate-controlled shelters (Sarofim et al., 2016).

Raw earth is one of the oldest building materials used by humanity. About one-third of the Earth's population currently lives in housing made of earth materials, and mixing a small amount of straw into the earth materials (which combines two soil-based building materials)