12 Soils and Humans

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Abstract

Soil has a great and holy position worldwide. This position has been acquired from the importance of soil in saving food, feed, fuel, and fibre for animals and humans. Egypt was and still one of the most important countries, which soils played a crucial role in the Egyptian civilization. Therefore, very strong link between soils and humans has been reported based on the great roles of soils in plant and human nutrition. On the other hand, there are several anthropogenic activities, which cause many problems for soils such as pollution, degradation, and erosion. There are direct and/or indirect effects of soils on human health as well as plants. Therefore, this chapter is an attempt to emphasize the great roles of soils in plant and human health as well as the security of soils under pollution conditions.

Keywords

Soils • Human health • Human creation
Plant nutrition • Soil security

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12.1 Introduction

Soils and humans were and still are one of the most important relationships, and scientists are seeking for new approaches and facts in this relationship (Brevik and Burgess 2012, 2014; Winiwarter 2014; Brevik and Sauer 2015; Brevik et al. 2017; Carré et al. 2017). This interaction between soils and humans includes many fields or issues such as (1) the role of soil in human emergence or creation, (2) its role in plant and human nutrition or biofortification, (3) its role in human health, and (4) the role of this interaction in soil security. Definitely, the plant and human nutrition mainly depends on soils and their status. In other words, right plant nutrition is important for proper and safe human health. This could be proved through the fact that "elements or nutrients, which could be found in soil, plant, and human including carbon, nitrogen, phosphorus, potassium; are the same and beneficial for all" as reported by Osman (2013). Only 11 elements, nearly constitute 99.9% of the human body (as atoms) including the major elements (C, H, O, and N) that represent 99% and minor elements (P, K, Ca, Mg, S, Na, and Cl) that represent 0.9% of the body (Combs 2005), and with the exception of C, H, and O, these elements come from the soil. Therefore, a strong interdependence between humans and soil exists. As mentioned before, the history of human civilization is based mainly on the strong relation between soil and humans as well as the influence of humans on soil quality, and humans' perception of how to manage soil resources (Lal 2005).

Therefore, this chapter will focus on the relationship between soils and humans including the role of soils in supporting proper human health, causing diseases for humans, supplying nutrition for both plants and humans through biofortification, and finally, soil pollution and security as it relates to human health. These previous issues, nowadays, are very important in drawing the plan for human health and maintaining the security of all our lives.

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12.2 Soils and Human Health

Human health depends on and still supports by soil and its characterization (Balks and Zabowski 2016; Prasad and Shivay 2016). So, it is very common to hear "*feed the soil to feed the human*" as shown in Fig. (12.1). It is also reported that approximately 78% of the average per capita calorie consumption worldwide comes from crops grown directly in soils, and another nearly 20% comes from terrestrial food sources that rely indirectly on soils (Brevik 2013a). The relationship between soils and human health and its potential has been recognized for thousands of years and is recorded from the time of the Pharaohs. There are many direct and indirect impacts of soils on human health including (1) the role of soils in food security (food availability and quality), (2) effect of various soil chemicals and pathogens on humans, and (3) acting as natural filters to remove different contaminants from water. Thus, there are several complicated soil variables which makes the investigations of soils and human health difficult and also means that the complete study of soils and human health should involve many different specialties such as soil scientists, medical professionals, toxicologists, anthropologists, etc. These specialty groups traditionally do not work together on research projects and do not always effectively communicate with one another (Pepper et al. 2009; Brevik and Hartemink 2010; Brevik 2013a, b; Pepper 2013; Shishkov and Kolev 2014; Brevik and Burgess 2014; Brevik and Sauer 2015; El-Ramady et al. 2015; Brevik et al. 2017).

Recently, a large number of studies regarding the effects of soils on human health have been published including issues such as exposures to radioactive elements in soils (Balonov et al. 1999; Dushenkov et al. 1999), the effects of pollution with heavy metals in soils (Alloway 1995;

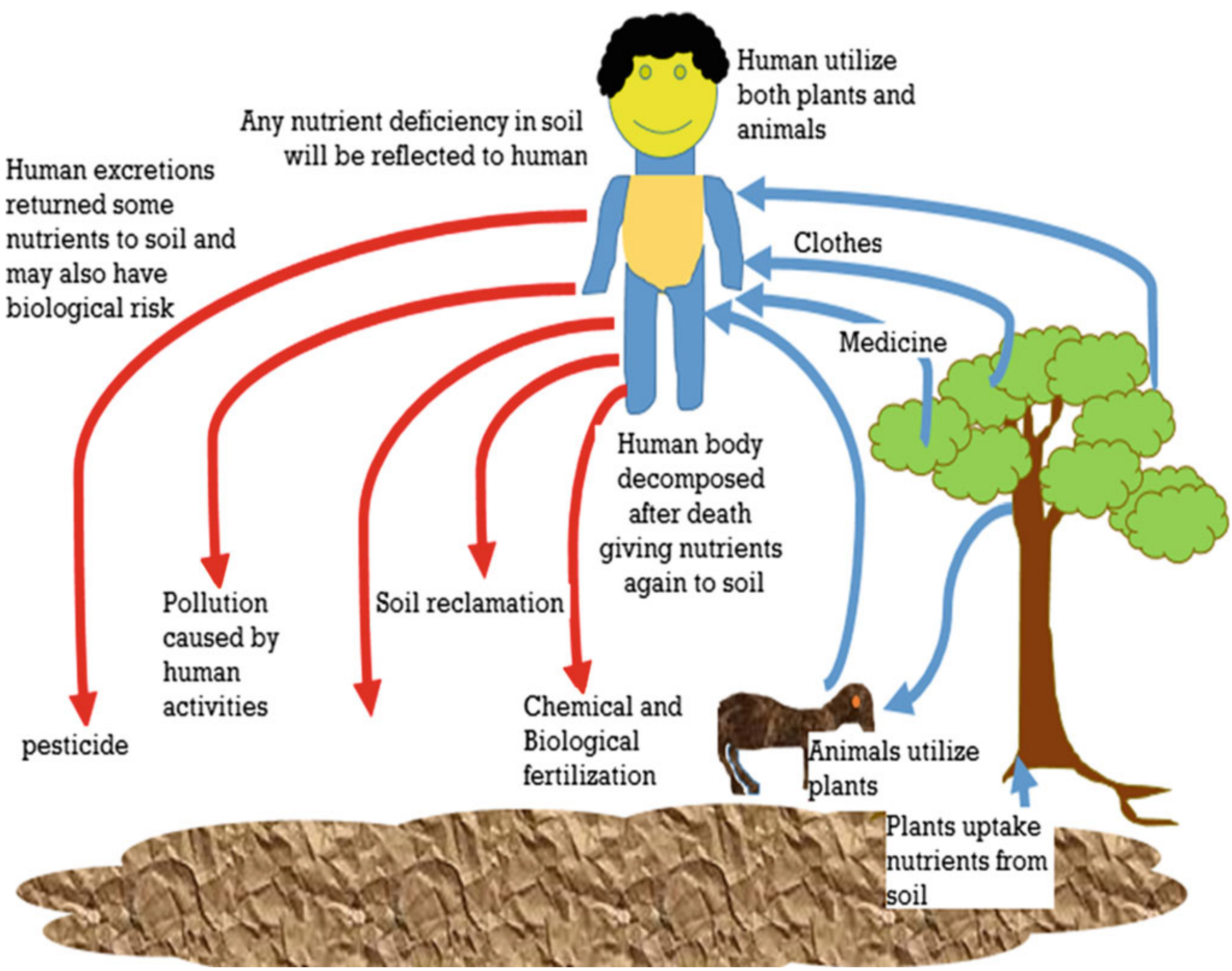

Fig. 12.1 The strong relationship between soils and humans in general include two sides: the first represents the harmful or negative action (destroying the soil through human activities like pollution) and the second includes the positive activities, which leads to increase soil health or quality. Source: authors

Albering et al. 1999; Gu et al. 2016; Li et al. 2017; Tepanosyan et al. 2017; Zhang et al. 2017) and organic contaminants in soils (Pohl et al. 1995; Simcox et al. 1995; Burgess 2013; Burras et al. 2013; Liu et al. 2016; Cai et al. 2017; Wei et al. 2017), geophagy or medical geology (Selinus et al. 2005; Hooda and Henry 2007; Henry and Cring 2013), biofortification (Cakmak 2002, 2008; El-Ramady et al. 2015a; El-Ramady et al. 2016a, b; dos Reis et al. 2017), and many other subjects (Lichtfouse 2012; Bini and Bech 2014; Alshaal et al. 2017; Bourliva et al. 2017; dos Reis et al. 2017).

On the other hand, soils are the main source for production of antibacterial agents and cancer drugs, with 78 and 60% of these drugs having a soil origin, respectively (Pepper et al. 2009). Furthermore, several other medicines have been derived from soils and soil organisms. Geophagy (the practice of eating soil) was common behavior in the rural parts of Egypt, especially for pregnant women. These women suffer from a deficiency of certain elements, so they eat clay particles that may supply nutrients such as calcium and iron. This phenomenon (geophagy) has attracted the interest of several geographers and anthropologists for many years (Hooda and Henry 2007; Henry and Cring 2013; Brevik and Sauer 2015). So, new approaches concerning the effects of soils on human health include investigating the transfer of nutrients from soils to plants to humans (e.g., Kabata-Pendias and Mukherjee 2007; Cakmak 2008; Spiegel et al. 2009; Roivainen et al. 2012; Simon 2014; El-Ramady et al. 2015b, 2016a; Ávila et al. 2017), from soils to plants to animals to humans (e.g., Jones 2005; Klasing et al. 2005; Abreu et al. 2014; Krajcarová et al. 2016; Saha et al. 2017), or even directly from soils to humans (e.g., Abrahams et al. 2006; Hooda and Henry 2007; Young 2007; Angelone and Udovic 2014; Brevik and Sauer 2015; Diami et al. 2016; Baran et al. 2017; Saha et al. 2017).

The effects of soils on human health can be either positive or negative. Positive effects of soils include (1) soils are the main source for the production of food, feed, fiber, and fuel for humans (Khalifa and Moussa 2017), (2) soils are the natural filter in removing and/or degrading a number of pollutants (Saha et al. 2017), (3) production of drugs and vaccines extracted from soil microbes (Bush and Page 2017), and (4) soil plays the main role in food security through production of sufficient amounts of nutritious cultivated crops (Bashour 2017; Blanco et al. 2017; Zdruli et al. 2017). On the other hand, negative impacts of soils on human health include its containing and leading to exposure to toxic levels of heavy metals, airborne dust, chemicals, and/or pathogens that have the potential to harm human health. It is worth mentioning that direct and/or indirect soil processes can lead to reduced crop production that will impact on food security and through that human health (Brevik and Burgess 2014).

In Egypt, like other nations, soils are considered the backbone of food production and its security, where soils were and still are the main source for agricultural production. Geohelminths distribution is one of the serious environmental problems in Egypt, and many researchers have investigated this problem in different Egyptian Governorates like Sharkyia (e.g., Etewa et al. 2016; Farghly et al. 2016) and Sohag (Melegy et al. 2014). The natural radioactivity levels in Egyptian soils are considered one of the most pressing problems facing people in locations like Assiut (El-Gamal et al. 2013), Port Said (Attia et al. 2015), Red Sea (Issa et al. 2015), Aswan (El-Gamal 2017), and Minia (El-Gamal 2017). Soil pollution is one of the most serious environmental problems in Egypt, and many researchers have investigated this problem in different Egyptian soils (e.g., Salman et al. 2017; Negm and Eltarabily 2017) and the Nile River (Abdel-Satar et al. 2017; Elhaddad and Al-Zyoud 2017) as well as aquifer system (e.g., El Baz 2015; Galal and Farahat 2015; Arnous and Hassan 2015; El-Kassas and Gharib 2016; Snousy et al. 2017).

12.3 The Role of Soil in Plant and Human Nutrition

The mineral elements that are needed for the growth of both plants and humans (or animals) are called the essential elements. Exactly which elements are essential is still under debate, although there is a common agreement for some nutrients by the plant nutrition scientists (e.g., Jones 2003; Kirkby 2012; El-Ramady et al. 2014a, b). This essentiality may also include new dimensions such as understanding the acquisition, accumulation, and transport of these nutrients in addition to their functions in plants. In other words, the latest available knowledge about the role of these elements play in plant physiology and molecular biology should be recognized (Fig. 12.2). This should also include analyzing the effects of the deficiency of different elements on both soils and the human diet or on both crop production and human health (Cakmak et al. 2017). Therefore, new dimensions of the essential mineral elements should be considered as regards to biofortification. Also, recent promising investigations of the role of elements should include the study of these elements in soil, plant, animal, and human nutrition.

The human body requires at least 29 mineral elements for survival (Welch and Graham 2004; White and Broadley 2005; Graham et al. 2007; Meena et al. 2016; Brevik et al. 2017), which are supplied by an appropriate diet. It is estimated that more than 60% of the world's people are iron (Fe) deficient, over 30% are zinc (Zn) and iodine (I) deficient and 15% selenium (Se) deficient (Thavarajah et al. 2014). This deficiency list also includes calcium (Ca), magnesium (Mg) and copper (Cu) as common in many developed and

Fig. 12.2 Proper plant nutrition with irrigation to modify surface irrigation in salt-affected rice paddy soils is presented in these photos from the Kafr El-Sheikh area. Photos by El-Ramady (2015)

developing countries (Meena et al. 2016). Therefore, there is a need to supply these nutrients. The process of increasing the density of minerals and vitamins in a crop through agronomic practices, plant breeding, or transgenic techniques is called biofortification. Regular consumption of biofortified staple crops can lead to improvements in human health and nutrition (Zhao et al. 2012; Bouis and Saltzman 2017). Common biofortified staple crops include wheat, rice, maize, cassava, sweet potato, etc. with either mineral elements (Fe, Zn, I, Se, Cu, Ca, Mg, etc.) or nutritional enhancers such as amino acids (methionine), folate, fatty acids, vitamins A and E (tocopherol), lycopene, flavonoids being enhanced (El-Ramady et al. 2015b, 2016a, b; Meena et al. 2016; Bouis and Saltzman 2017; dos Reis et al. 2017; Giuliano 2017; Goyer 2017; Gonzali et al. 2017; Mène-Saffrané and Pellaud 2017; Pearce 2017; Singh et al. 2017; Strobbe and Van Der Straeten 2017; Vasconcelos et al. 2017).

In Egypt, the common mineral element deficiencies include iron, zinc, selenium, and iodine. Iodine is often fortified in salt, whereas Fe, Zn, and Se can be biofortified in staple crops. The reader is referred to dos Reis et al. (2017) for more information on investigations into selenium deficiency and toxicity in Egypt and its effects on human health. Egypt has been listed on the HarvestPlus program biofortified global crop map as using staple foods to overcome micronutrient deficiencies (Bouis and Saltzman 2017). Further studies are needed concerning biofortification in Egypt and these investigations should include nutritional enhancers such as amino acids (methionine), folate and vitamins (like A and E) in addition to the previously mentioned mineral elements (Fe, Se, Zn, and I).

12.4 Soil Pollution and Its Security Towards Human Health

As mentioned before, soil pollution is considered as one of the most important environmental problems. So, human health also should be considered as a major challenge of global soil security taking into account that soil pollution has a global scale and soil also has full resilience in dealing with pollutants (Carré et al. 2017; Hirsch et al. 2017). Soils have the ability to reduce contaminants by biodegradation, filter and then store them or to transform them resulting in different metabolites, all of which contributes to human health (Figs. 12.3, 12.4 and 12.5). Therefore, soil security includes dimensions that consider the societal and scientific challenges that are related to soil-human health studies and soil security (Brevik et al. 2017; Carré et al. 2017). This also emphasizes that soil-human health studies are very complicated endeavors and should be included in more than one dimension as mentioned before (Brevik and Sauer 2015; Carré et al. 2017).

This relationship between soils and human health should be linked to soil security and the five dimensions (soil capability, condition, capital, connectivity, and codification) of soil security should be tied to soils and their impact on the health of humans (Brevik et al. 2017; Carré et al. 2017; Kim et al. 2017). The maintenance and improvement of different soil resources is called soil security, which is very close to other security concepts including food, water, and energy security. The different dimensions of soil security and their relationships to human health can be summarized as follows:

(1) **Soil capability and human health**: the ability of soils to produce enough high-quality food (food security) and to produce clean and safe water (water security) through soil biogeochemical degradation and filtration of wastes. The ability of soil to provide different essential nutrients to humans could be through direct and/or indirect pathways including providing nutrients from soils to plants and/or animals to humans. The maintenance of important soil properties (e.g., soil structure, thickness, fertility, aeration, biology, etc.) helps in maintaining the capacity of the soil to promote human health (Hirsch et al. 2017; Brevik et al. 2017; Bouma et al. 2017).

(2) **Soil condition and human health**: soil conditions including physical, chemical, and biological soil properties impact the nutritional quality of agricultural products. The condition dimension is closely related to soil health and healthy soils often produce abundant nutritious crops that can support the world's dietary needs and provide a positive contribution to human health (Brevik et al. 2017; McBratney et al. 2017a).

(3) **Soil capital and human health**: soil capital has a value that is evaluated in dollars and cents. This value includes several soil services, which could provide to human health (e.g., nutrients that are supplied), ecosystem services (e.g., neutralization of pollution), filtration of water, carbon sequestration and the supply of medications. All previous services might promote human health (Brevik et al. 2017; McBratney et al. 2017b).

(4) **Soil connectivity and human health**: this refers to the connection that societies form with soils, which influences how those soils are valued and managed. This, in turn, influences interactions between soils and surrounding agroecosystems. The connectivity of soils can also influence the loss of land through degradation processes, which may negatively impact on human health. Degraded soils represent a great threat to the stability of society due to deterioration of soil fertility and then human activity. Furthermore, both human

Fig. 12.3 Plants are an important part of the relationship between soil security and human health, as plants derive most of their nutrients from soils and grazing may support soil productivity, as resulted from manure of sheep and other farm animals in the middle photo, thus introducing sufficient nutrients to the food web. Photos in the Kafrelsheikh area by El-Ramady (2016)

Fig. 12.4 Non-healthy soils often suffer from a deficiency of essential elements to support healthy plants. The saline and alkaline soils in the Kafrelsheikh area have many problems that impede productivity and thus human health. Photos by El-Ramady (2016)

Fig. 12.5 A healthy soil, which has good biological, chemical, and physical properties, is able to produce safe and nutritious food that supports human health like in the Botanic Garden in Aswan, where a low level of pollution supports the security of soils. Photo by El-Ramady (2010)

health and soil security will be destroyed under highly polluted and degraded conditions (Brevik et al. 2017; Carré et al. 2017; Kim et al. 2017).

(5) **Soil codification and human health**: this dimension has typically focused on water and soil conservation more than directly on human health. Appropriate conservation practices can improve water and soil quality, leading to high-quality crop production in those soils and improving human health. This dimension refers to governmental programs, policies, and goals, which impacts the production conditions of soil and finally, all harvested crops is consumed by humans (Amundson 2017; Brevik et al. 2017; Koch 2017). It can be concluded that soils greatly contribute to the quality of the necessities of our life (water, air, and food), which are directly linked to the health of humans. This human health definitely depends on the soil security. This soil security also, in turn, will be affected by all factors and processes that lead to or contribute to the deterioration of soils, like pollution. Therefore, further investigations are crucial to focus on the direct and indirect link between soil security and human health under different conditions.

In Egypt, soil security should be considered for more than the current situation. For example, all advanced nations criminalize infringement on soils and punish the infringer. This advanced behavior protects both the government and people. In the USA, on the other hand, agricultural policies are based on encouraging proper maintenance of soils rather than punishment for improper soil management. There are punishments for pollution of soils in certain circumstances, such as with industrial contamination. In Egypt, the main problem in this context is represented in the urban sprawl that is devouring vast areas of agricultural land in the Nile Delta (Fig. 12.6). The radioactivity of soils also has been become a serious problem in Egypt. The radioactive materials found in Egyptian soils may result from some industries

Fig. 12.6 The urban sprawl that is devouring vast areas of agricultural land in the Nile Delta represents one of the biggest challenges in Egypt. This urban crawl and resulting pollution could threaten soil security and then human health. Photo for Tanta City by El-Ramady (2015)

Table 12.1 List of some phosphate rocks, phosphogypsum, and phosphate fertilizers used in Egypt including trade names, plants, and the radioactive activity concentration (Bq kg^{-1}) as adapted from El-Bahi et al. (2017)

Plant (or Region)	Activity concentration (Bq kg^{-1})				
	^{40}K	^{226}Ra	^{232}Th	^{235}U	^{238}U
Phosphate rocks					
Abu-Tartor	891	1496	200	86.2	2032
	893	974	83.2	53.0	1151
Wadi Qena	610	1226	118.4	65.8	1694
Abu-Zabal Factory (El-Sebaeya)	687	422	51.8	33.4	687
	572	463	32.4	26.6	639
El-Nasr Company (El-Sebaeya)	796	1141	107.4	60.1	1378
Single super phosphate (SSP)					
El-Nasr Company (El-Sebaeya)	901	466	N.D	22.6	491
Kafr El-Zayat Factory	891	351	53.6	28.1	594
Tri granular phosphate fertilizer					
Abu-Zabal Factory (El-Sebaeya)	737	302	193.9	10.9	1849
Phosphogypsum					
Abu-Zabal Factory (El-Sebaeya)	785	397	11.5	51.7	283
	954	702	147.3	42.6	1041

N.D Not Detected

(El-Zakla 2013; Attia et al. 2015), mineral fertilizers like phosphate fertilizers (El-Bahi et al. 2017) (Table 12.1), natural materials like phosphate rock (Issa et al. 2015; El-Bahi et al. 2017), or phosphogypsum (El-Didamony et al. 2013; El-Bahi et al. 2017), and other sources (Badawy et al. 2013; El-Gamal et al. 2013; Mohamed et al. 2016).

According to many studies, it is very important to build and develop a database for a radio-ecological atlas as soon as possible for Egypt.

12.5 Conclusion

The relationship between soils and human health has been represented in public regulations including the traditions, morals, ethics, and customs that have acquired crucial importance in civil societies (Shishkov and Kolev 2014). The relationship between soils and humans has been recognized as having critical importance over time as an intransitive global issue. It is also worth mentioning that the relationship between soils and humans is primarily a relationship between man and earth. This fact penetrates the development of mankind over all ages, civilizations and historical social formations (Brevik et al. 2018). Thus, the nature of this relationship is very complex and soil is essential for the reproduction of biota including human beings. Soils are also a natural resource sui generis for humans and are essential for the creation, existence, development, and prosperity of the human race. Soil security is an approach that shows the close link between soil services and human ability to solve different key issues for sustainable development including the security of food, water, energy, climate regulation, and biodiversity. An important cycle for the relationship between soil security and human health starts with plants, which derive most of their nutrients from soils, continues to animals that can eat those plants, and both plants and animals supplying those nutrients to the food web (including humans). Therefore, healthy soils are essential for the health of plants and animals, including humans, which eat the plant products grown in those soils or other products from further up the food web.

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