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MICROBIAL CONTRIBUTIONS TO PROVISIONING SERVICE OF SOIL

Zerihun Ango and Indris Abdu
Department of Biology, Mekdela Amba University, Tulu Awliya Ethiopia
Corresponding Author**:** Indris Abdu:

Abstract: *Provisioning services of soil refers to products such as nutrients, water and other materials that are important for the growth and production of food and fiber products; fuel-wood, potable drinking water, medicinal Products, provided by soil ecosystem services make available for human use. One or more soil functions are the foundation for the goods and services supplied by ecosystems that benefit human society. In the same way, soil functions are supported by a narrow to wide range of microorganisms. This indicates that there is an important role of soil microbial biomass in the ecosystem services as a whole. In one and another way, microorganisms play a crucial role in the Soil formation and provision of raw materials; in maintaining soil health and promoting of plant growth; in provisioning of food; in providing bioactive compounds of medical and commercial value; in generating of energy i.e. in the production of next-generation biofuels, thereby supply different products that are useful to mankind. In this respect, the review paper mainly identified and summarized under-examined aspects of the roles of microbes particularly in provisioning services of soil to human society. And it's suggested that further investigations may be important if it could be conducted on the contributions of microbes at species and subspecies level on the identified provisioning services of soil to find their value in the areas.*

Keywords: phrases: Bacteria, Microorganisms, Soil

Introduction

Provisioning services of soil refers to products provided or produced by soil ecosystem services make available for human use. These products include nutrients, water and other materials that are important for the growth and production of food and fiber products; fuel-wood, potable drinking water, medicinal Products, and genetic resources (MEA, 2005). The linkage between plant-based food products and soils are easy to understand. Majority of nutrients that are important to human health are soil origins. They are supplied to plants as they grow in soil, and are then passed on to humans who consume plant products directly or indirectly from the meat of animals that fed on those plants (Brevik and Sauer, 2015; Handy and Shaw, 2007; and Brevik *et al.*, 2017).

In a broad sense, one or more soil functions are the foundation for the goods and services provided by ecosystems that benefit human society. Similarly, soil functions are supported by a narrow to wide range of microorganisms (Wakelin, 2018). Microorganisms represent a large biological mass of the soil (Aislabie and Deslippe, 2013). A large number of bacteria occur in the soil, however due to their small size, they form a smaller biomass. Actinomycetes are a factor of 10 times smaller in number but are larger in size so they are similar in biomass to bacteria. Fungus populations are smaller but they are the dominant biomass soil at normal conditions.

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Bacteria, actinomycetes and protozoa withstand more soil disturbance than fungi (Okoth *et al.*, 2013). This soil microbial biomass (SMB) are important in the ecosystem services because it depends on the flow of chemical signals, carbon, and nutrients across the trophic levels achieved by microbial interactions in the soil-plant-animal food web (Seneviratne, 2015). Besides the importance of physico-chemical and biological processes to maintain soil health, SMB may be the keystone biological driver of ecosystem functioning (Borie, 2008; Trivedi *et al.*, 2016; Singh and Gupta, 2018). Soil health conditions have a tremendous impact on environmental sustainability including sustainability in agriculture, horticulture, and forestry. Moreover, soil health is directly connected with the production of healthy food which impacts public and animal health (Frac *et al.*, 2018). These points out the central role that microbes play in soil services. Therefore the core aim of this review is to identify under-examined aspects of the roles of microbes particularly in provisioning services of soil to human.

1. Microbes play part in the Soil formation and provision of raw materials

Soil formation is the result of a complex system of biological, chemical and physical processes. The role of soil microbes is of high interest, since they are involve in most biological transformations and generating labile pools of carbon (C), nitrogen (N) and other nutrients, which in turn facilitate the sequential development of plant communities (Schulz *et al.*, 2013).

Moreover, Microbes contribute to the development of soil structure through production of organic matter. They produce lots of sticky substances such as polysaccharides and mucilage, which help to cement soil aggregates. This cement makes aggregates less likely to crumble when exposed to water. Mycelial strands of fungi also stabilize soil structure because these branches out throughout the soil, surrounding particles and aggregates like a hairnet thereby improving soil structure making it more habitable for plants (Johns C, 2017).

Soils provide raw materials such as peat and clay minerals. Peat is a spongy substance which the result of microbial partial decomposition of plant residues. It is useful in different areas: for energy like fuel heat production and electricity; for industrial or residential aims; for agricultural or horticultural aims like compost content or growth medium; and also for chemical and organic products like activated carbon, medicinal products like antibiotics, or therapeutic applications like baths of peat (Anonymous, 2013).

Additionally, Microorganisms induce the nucleation and growth of clay minerals. Their interactions are involved in the formation and transformation of the minerals and cycles of many elements. The fungi/actinomyces are associated with clay minerals, but bacteria are more widely linked (Li, *et al.*, 2019). Kaolin minerals, typically kaolinite and halloysite, are among the prevalent clay minerals in nature. Kaolinite is extensively utilized in the manufacturing of porcelain, paper and rubber. Also it is used in the fields of refractory materials, medicine, perfumery and textiles. It has been showed that microorganisms adhere electrostatically to the surface of kaolinite and induce biofilm formation, nucleation and crystallization of kaolinite. Microorganisms can be used to remove coloring materials such as iron oxide, titanium oxide, silica and feldspars, and such a process can be used in purifying kaolinite (Freebairn *et al.*, 2013; Khalek A *et al.*, 2014).

Soil microbes produce antimicrobial agents and enzymes used for biotechnological purposes. Today, steroid manufacturing takes a prominent place in the pharmaceutical industry with an annual global market over ten billion dollar. The synthesis of steroidal active pharmaceutical ingredients (APIs) such as sex hormones (estrogens, androgens, and progestogens) and corticosteroids is recently carried out by microbiological and chemical processes. Several mycobacterial strains capable of naturally metabolizing cholesterol and phytosterols are act as biological catalysts to accelerate

the transformation of phytosterols into steroidal intermediates, which are subsequently used as key precursors for the APIs production in chemical processes (Cabezon F *et al.*, 2018).

2. Microbial role in maintaining Soil health and promoting of plant growth

Soil health is determined by the capacity of soil to function as a vital living system, through possessing biological elements that play part to ecosystem function within land use boundaries. Microorganisms have the ability to give an integrated measure of soil health. They are key players in the cycling of nitrogen (N), sulfur (S) and phosphorus (P) and the decomposition of organic residues (Wani *et al.*, 2015).

In soils the majority of N, P, and S atoms are organically associated; on the other hand large number of N is found in molecular form, N_2 molecule in the atmosphere. Therefore plants access these nutrients by the aid of metabolic activities of soil microbes. Microbes, such as mycorrhizal fungi or nitrogen fixing symbiotic bacteria, play important roles in plant performance by improving mineral nutrition. Moreover current genomic studies are beginning to report the specific strains of microbes that contain metabolic pathways acting in a beneficial way for plant nutrition (Muller et al., 2016; Jacoby *et al..*, 2017). Besides, Actinomycetes are aerobic and gram-positive spore forming bacteria which play roles in the cycling of organic matter as well as inhibiting several plant pathogens in the rhizosphere. As they secrete enzymes such as proteases and chitinase, actinomycetes have been act as a natural controller of phytopathogenic fungi and insects that cause losses in agriculture (Gomes *et al.*, 2018).

3. In provision of Food for Human

Soil microbes underpin key benefits that soils provide for human, such as food production. This desirable soil service could be generated by healthy interaction of plants, microorganisms and soil and so that humans depend on it for sustenance. They have a big impact on plant productivity. Correspondingly, food security and sustainable agriculture ensured as far as the microbes promote plant health by providing plants with access to nutrients that are often limited in soils, such as nitrogen and phosphorus. Generally, Plant growth is improved by beneficial microbes through at least two modes of action. Enhancing nutrient availability is one mode of action. Many soil microorganisms help plants obtain otherwise unavailable nutrients by converting these nutrients into plant-available form in exchange for energy from their hosts. Another mode of action is the stimulation of plant growth without actually increasing nutrient availability to plants. Certain beneficial bacteria and fungi stimulate plant growth through the production of metabolites or by their physical interactions with host plants. (Bender *et al.*, 2016; Ragnarsdottir *et al.*, 2015; Hayes and Krause, 2019).

Moreover, Mushrooms have a long history in association with humankind. From ancient times, man has consumed wild mushrooms with delicacy probably, for their taste and pleasing flavor. Edible mushrooms are known to provide high quality of protein that can be produced with greater biological efficiency than animal protein, rich in fiber, minerals and different types of vitamins especially, vitamin B-Complex and Vitamin C and have low fat content, with high proportion of polyunsaturated fatty acids relative to total content of fatty acids. Fresh mushrooms contain relatively large amount of carbohydrate (4-5%) and fiber but, in mushrooms, starch is absent (Girma Waktola and Tasisa Temesgen, 2018).

4. Medicinal uses

There are numerous ways that soils improve human health, from food production and nutrient supply to the provision of medications. They are of important in providing bioactive compounds of high commercial value. For instance, many antibiotics used today originate from soil organisms, for example penicillin, isolated from the soil fungus *Penicillium notatum* by Alexander Fleming in 1928, and streptomycin, derived in 1944 from

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a bacteria living in tropical soil. As a whole, Microbes for secretion of bioactive compounds includes bacteria (*Bacillus sp., Pseudomonas sp.*), Actinomycetes (*Streptomyces sp.*), Fungi (*Penicillium, Yeasts, Slime moulds),* Microscopic algae (Seaweeds, dinoflagellates, diatoms etc.) (Shukla, 2015). In nature, one of the most widely available microbial groups in the soil is actinomycetes. Nearly eighty percent of the world's antibiotics are derived from actinomycetes, particularly from the genera *Streptomyces* and *Micromonospora* (Sudha *et al.*, 2011; Hassan *et al.*, 2011; Brevik *et al.*, 2020). In general, majority of the bioactive compounds of actinomycetes categorized into six structural classes amino glycosides (e.g., streptomycin and kanamycin), ansamycins (e.g., rifampin), anthracyclines (e.g., doxorubicin), ß-lactam (cephalosporins), macrolides (e.g., erythromycin) and tetracycline (Singh *et al.*, 2012).

In addition to antibiotic properties and antimicrobial products found in soil, exposure to soil-borne microorganisms probably plays a role in development and regulation of the human immune system. This is tied to microbiome-gutbrain axis principle, which emphasizes the function of gut microbiome composition and microbiome-driven signaling pathways in host immune system activity and even human behavior. Furthermore, Medical research fields investigated the linkages between contacts with the soils and immune-regulatory responses driven by microbes in humans positively influence mental and physical wellbeing. This has been especially studied seeing that it relates to allergy prevalence. For example, early environmental exposure to allergy-causing microbial products such as endotoxins may promote allergen tolerance in children (Hertzen *et al.*, 2011; Forsythe *et al.*, 2012; Hanski *et al.*, 2012; stilling *et al.*, 2016; Fahrlander B *et al.*, 2002).

5. Microbes in Biofuels Production

Microbes used in the production of next-generation biofuels such as bioethanol, biodiesel and biomethane (Singh, 2015; Singh and Seneviratne, 2017; Peralta-Yahya and Keasling, 2010; Medipally *et al.*, 2015). Bioethanol become the dominating and relatively advanced in production process from waste feedstocks has been greatly improved by new technologies. This may be achieved through conversion of lignocelluloses into ethanol by bacteria and fungi; alternatively, through CO2 conversion into biomass by microalgae; or through the use of methane generated from landfill in to biofuels production. Lignin in feedstock plant material represents a barrier to more efficient plant biomass conversion and can also hinder enzymatic access to cellulose, which is critical for biofuels production, but bacteria could play a role in lignin decomposition through anaerobic digestion (DeAngelis *et al.*, 2011). These substrates can be directed to the biosynthetic pathways of various fuel compounds and optimize biofuels production by engineering fuel pathways and central metabolism (Liao *et al.*, 2016). In addition, algal biofuel production can be carried out via conventional trans-esterification technology. The microbes produce biodiesel by converting their high energy lipid oils to alcohol esters using trans-esterification and it has captured the attention of nation and the world (Darzins *et al.*, 2010).

CONCLUSION AND FUTURE PERSPECTIVES

Microorganisms directly and indirectly involve in different provisioning service of soil. This comprises products that are useful to human society that are supplied by the soil. The areas in which they play a role includes, in soil formation and provision of raw materials; in maintaining soil health and promoting of plant growth; in provision of food for human; in providing bioactive compounds of medical as well as commercial value and in energy generating process. On the basis of this review, it is suggested that further investigations may be important if it could be conducted on the contributions of microbes at species and subspecies level on the identified provisioning services of soil to find their values in the areas.

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