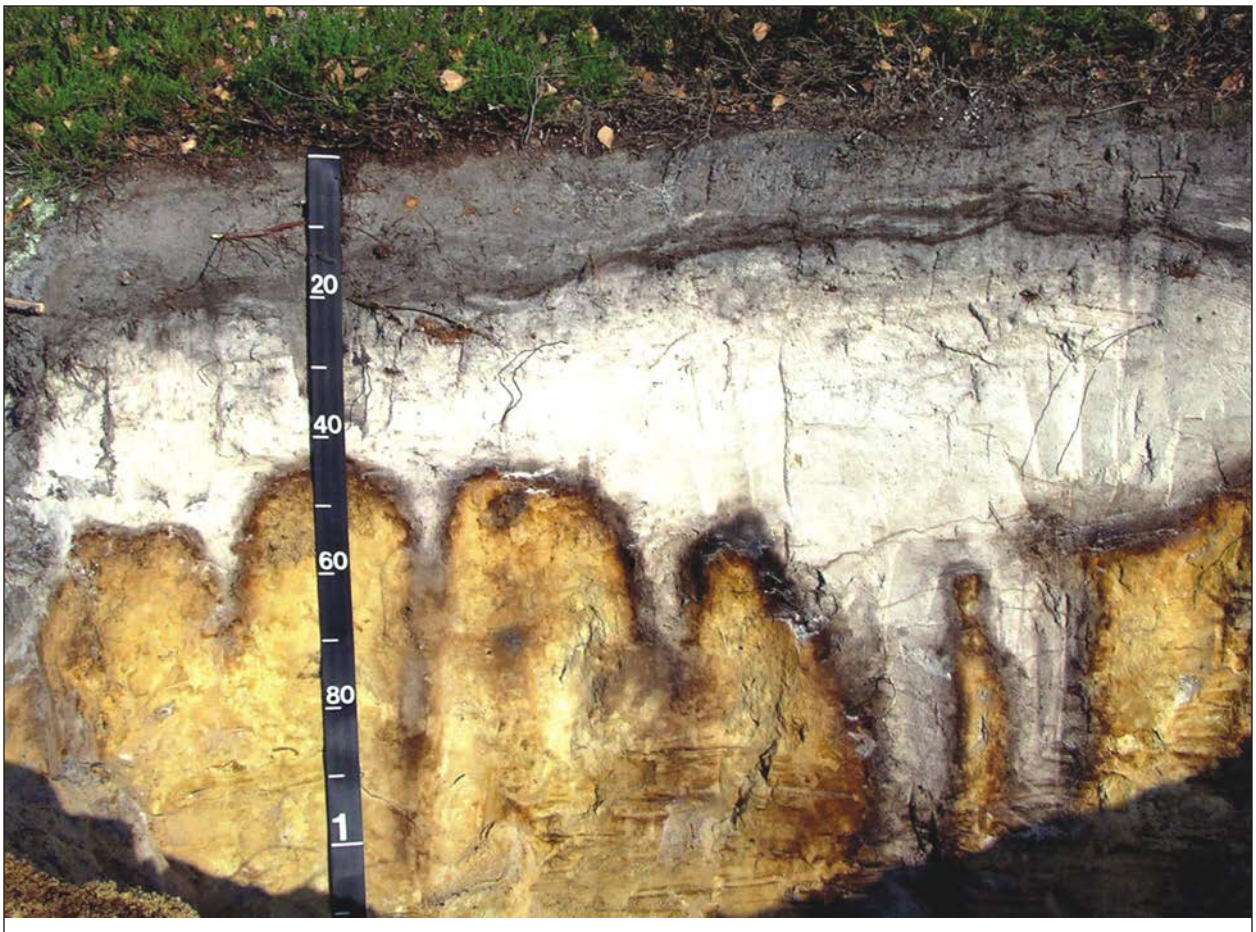

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Mini Review Article
Role of Soil Science: An Answer to Sustainable Crop Production for Economic Development in Sub-Saharan Africa

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Abstract
The Sub-Saharan Africa needs urgent sustainable crop production for economic development. Poverty and hunger, soil degradation and decline soil quality are increasingly alarming in the region. Soil science is the mainstay of the economic development for the Sub-Saharan African region. Soil science provides support to crop production, raw materials to million industries, water quality for biota, animal and human survival, recycling of abundant dead materials, landscaping for engineering and research purposes, foreign exchange for national income and accommodation for animal and human interactions. This study outlined and discussed these functional services of soil science as an answer to sustainability and renewability of crop production for economic development in Sub-Saharan Africa.

Key words: Soil science, crop production, sustainability, economic development

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soil is the most important economic industry for the millions of people in rural areas of Sub-Saharan Africa. For decades, soil has been associated with the production of vital crops, herbs, raw materials and variety of human needs for sustainable development (Brady and Weil, 2007). However, in recent years there has been a remarkable increase in human population in most part of the Sub-Saharan African region. Hunger and poverty have become endemic (Eswaran *et al*., 1997; Ehui and Pender, 2005). While, soil degradation caused by combined social and climate factors has reached the level of acceptance. Its economic impact has affected many regional developments as it touched the national and international financial budgeting (Warren *et al*., 2001; Bationo *et al*., 2006). As a result, poor soil quality, declined soil fertility and environmental quality have capitulated decreased in food production and economic profits in the entire African region (FAO., 1995). Crop production depends fully on quality of soil and its fertility (Lal, 1998). It is the highest priority of soil science to improve and promote the understanding of soil and it function for economic crop production (Brady and Weil, 2007). The achievable objective is providing adequate and reliable soil information on how to protect, restore and manage soil resources on agricultural land for high and healthy crop yield, globally. Hence, the role of soil and its applied science is of utmost important for sustainable crop production and economic development in Sub-Saharan Africa. The water quality, land quality, forest quality, animal and environmental qualities are factors, which must be maintained for better livelihoods of Sub-Saharan citizens (Lal, 1998). These five factors are closely related to the role of soil science for increasing agricultural economic developments in the region (Bouma, 2005; UNCCD., 2012). Therefore, the rational of soil science for the sustainable crop production would undoubtedly provide huge opportunities to Sub-Saharan African's economic developments (Greenland, 1991; Bouma, 2001; Bekunda, 2006). This study outlines the role of soil science as an answer to sustainability and renewability of crop production for economic development in Sub-Saharan Africa.

Sub-Saharan Africa: The concerned region is a substantial part of Africa where millions of people live in the rural areas, geographically, located South of the Saharan desert. Their cultural background differs with significant variation in languages, religion, norms, values and behaviors. The quality of their life is poor and needs urgent sustainable development particularly in the aspect of crop production. The climate has been characterized as semi-arid with an average rainfall equaling 600 mm (more or less) and variations of up to 30 or 40% (FAO., 1995). Soil and land are bare, vegetation is poor while drought, soil erosion, desertification and declined in soil quality, soil fertility and crop production are serious and alarming (Eswaran *et al*., 2001). The most affected countries of the region include; Benin, Cameroon, Chad, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Somalia, Sudan and Togo. The geographical location of these countries is depicted in Fig. 1.

Vital roles of soil science for an economic development: Soil and soil functional services are backbone of agricultural economic development in Sub-Saharan, Africa (Kalpage, 1976; Okigbo, 1991; Hartemink, 2006a). Soil science as an independent sub-discipline of science and technology of crop production has played and continuous to plays a vital roles in Sub-Saharan African economic developments (Muchena and Kiome, 1995). Essentially, soil plays a key role in the entire crop production systems (Zachar, 1982). Thus, soil could be refers to as production, promotion and distribution of essential services needed for the sustainable crop production in Sub-Saharan Africa. The most important roles of soil science as an answer to sustainability and renewability of crop production for the economic development of Sub-Saharan African nations are outlined and discussed bellow (Greenland, 1991; Dobrovolskii, 1999; Bouma, 2001; Brady and Weil, 2007; UNCCD., 2011; Usman, 2013).

Economic environment for crop production: Soil served as a potential environment for growth and development of all kinds of crops and plants. It provides suitable conditions for root germination and growth. Soil is the basis of all production systems in agriculture, forestry and fishery. Soil stored water and nutrients in order to make them available for proper growth and development of crops, grazing land, forest and vegetations. Soil texture (relative proportion of sand, silt and clay), soil structure (arrangement of aggregate particles in soil), soil colour (an indicator of soil status), soil consistency (degree of cohesion and adhesion among soil particles) and soil water (available water and moisture in soil) are important soil physical properties, which support plant growth and development for many economic benefits (Brady and Weil, 2007). They tell us whether the soil has the potential to store enough water to keep plants growing through a drought, to resist a flood, and to provide a right condition of chemical nutrients to plant so that the crops will grow healthy for economic development (Levine, 2001).

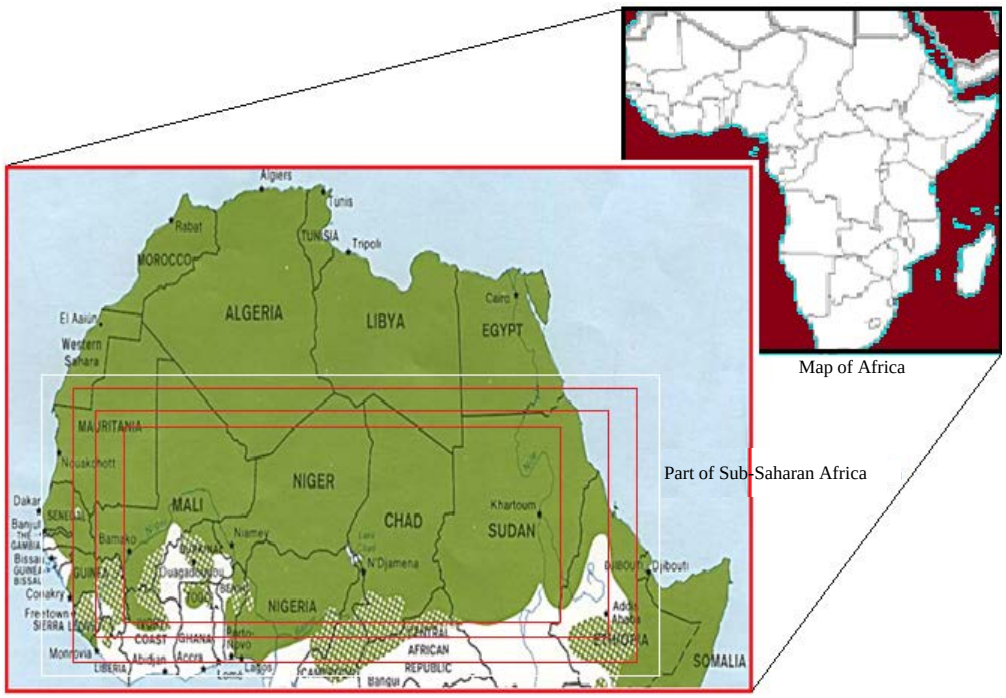

Fig. 1: Geographical location of Saharan, Africa

Store house of water supply: Soil store large amount of water between and within the network of pores of various sizes as well as within and around the various horizons of soil profile. This water is useful for an ideal growth of plant roots, animals and microorganisms. Under agricultural crop production, soil-water functions according to its nature and conditions. Soils having micro-pores hold water very tightly whereas those soils having larger pores (macro) hold their water loosely (Johnson, 1991). In saturated soil condition, these pores become accommodated with water, when drained-out of larger pores the soil will become unsaturated, and finally ends in the ground as ground water (Johnson, 1991). This ground water is useful for various human economic benefits. Besides crop productions, the available underground water stored in soil is used for human and animals drinking, industrial productions, forest development, educational purposes, engineering constructions, environmental management and health services.

Home for animal interactions: Soil provides numerous important services to animals living in forests, deserts and vegetation areas. The wildlife living in different areas of Sub-Saharan Africa stayed well-protected around the vast land of the region. The human populations used these animals for commercial and industrial purposes. The interactions between soil environment and variety of wild-animals as well as reared cattle have resulted in many economic benefits between one country to another and between Sub-Saharan Africa to other continents. Soil environments support these animals with abundant of feeding materials, drinking water and shelter. The meats, feathers, animal skins and variety of wildlife materials are used by human population for diverse economic developments. These served as an important source of revenue, job creation and industrial developments to many countries in Sub-Saharan Africa. The value of soil must be recognized and considered in all aspects of global economic developments.

Habitat for soil biota and their biodiversity: Soil is the home of millions organisms. The biota (micro and macro-organisms) depends fully on soil for their basic needs and survival: air, water, food and shelter (Coleman, 2001; Barrios, 2007). Soil accommodates diverse living organisms: Bacteria, fungi, actinomycetes, yeast and algae; earthworms, termites and arthropods; protozoa and nematodes (Ritz *et al*., 2010). These organisms interact with one another and with variety of living and non-living materials to improve soil quality, soil fertility and soil health for economic development of crop productions (Coleman, 2008; Castro-Huerta *et al*., 2015). They also serve as machinery that helps to decompose and transform various organic materials in the production of bio-organic fertilizers (Li *et al*., 2014). Thus, soil provides a

source of energy and functional support for economic development in crop production systems.

Raw materials for industrial uses: Soil serves as number one source of raw materials to most of Sub-Saharan African economic development. Agriculture that covered all components of agronomic productions depends fully on soil and its quality (Brady and Weil, 2007). All cash and economic crops such as cotton, sugarcane, tobacco, edible and non-edible oils, rice, wheat, maize etc., are grown on soil. The variety of fruits, forest timbers and vegetables are used by many industries in the productions of wood materials, juices, medicines etc.

Recycling of dead materials: Soil serve as natural mechanism that recycle and transform abundant of materials in the global ecosystem. This function of soil is of utmost important to all Sub-Saharan African countries. The abundant of dead materials-plants and animals, unwanted food and non-foods materials are recycled by soil through decomposition processes-physically, chemically and biologically (FAO., 2005). The fully decomposed materials add organic matter to the soil and enhance soil quality and soil fertility for high and economic crop yield production (Li *et al*., 2014). This recycling process, also improves environmental quality, water quality and human health conditions by minimizing the risk of mosquito populations as well as beautifying environment and its biological surroundings.

Source of rural livelihood: Soil remains the most important source of income to millions of rural farmers in Sub-Saharan Africa. Approximately 60-75% of rural people in Sub-Saharan Africa depend greatly on crop production (UNCCD., 2011). Soil, through agriculture has provided many job opportunities to rural farmers in the region. Some worked in fadama areas under irrigation system, some in dryland for rainy season cultivations and still many others in forest and through commercial production.

Foreign exchange development: Soil provides an economic means of foreign exchange between one country to another. The Sub-Saharan African export trades depend largely on crops that grown on soils: Cowpea, coco, tobacco, tea, rice, wheat, maize, cotton etc. these crops are exported from Sub-Saharan Africa to many regions in the world for economic development. The export services have created many ways of revenue generation to Sub-Saharan African nations.

Reactor and transformer of natural resources: Soil integrates the influence of solar radiation, atmosphere, ground and underground water, biological and ecological resources (Varallyay, 2010). It is the pedosphere environment, where, four entities (Brady and Weil, 2007): Atmosphere (world of air, gases), hydrosphere (world of water-oceans and seas), lithosphere (world of rocks and mountains) and biosphere (world of living organisms) interact and communicate for the benefits of global ecosystem, crop production and human developments. This function creates an environment that support natural vegetation and cultivated crops for economic development.

Engineering and landscaping industry: Soil serve as the base environment for homes, roads, educational institutes, health centers, government and non-governmental buildings. Millions of people are directly or indirectly depend on this function of soil. Hence, millions of jobs could be lost without this function of soil-in government or non-governmental sectors.

Reservoir of natural resources: Soil is the store house of abundant natural resources in the ground: oil, gold, metal, heat, limestone, potash, water etc. Many countries depend greatly on these resources for the growth and development of their economy.

Environmental laboratory: Soil is an environmental laboratory for research and developments. Most of the agricultural researches are carried out on soils. Soil science provides reliable and adequate information for economic development through these studies.

Soil science, sustainable crop production and economic development: The multifunctional services of soil science as an answer to sustainability and renewability of crop production for the economic development of Sub-Saharan Africa is considered to be determined, by the combined influences of soil properties, soil quality and soil management (Brady and Weil, 2007). These are substantial part of soil processes: Physical, chemical, biological and ecological that control the overall systems in soil formation and soil conditions (Jenny, 2009). The sustainability of crop production is of great challenges to soil and crop scientists and of course a task to governments of Sub-Saharan Africa. However, the most important roles of soil science as an answer to the subject matter are discussed in the last session.

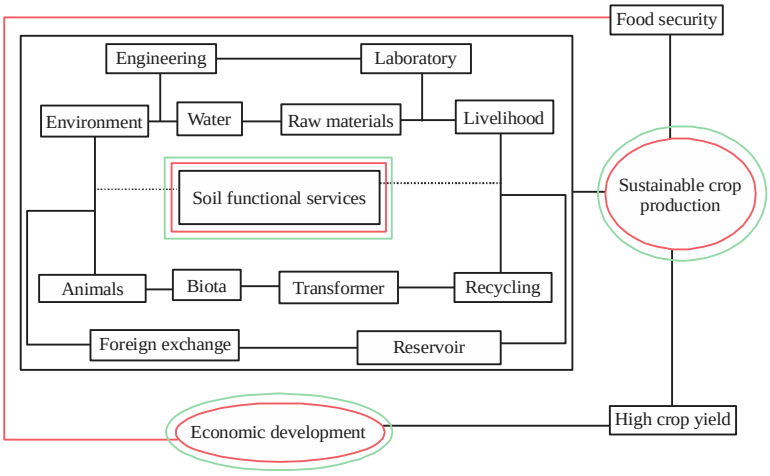

Fig. 2: Relationship between soil, sustainable crop production and economic development

Figure 2 provides an improve understanding of the common relationship between soil science, crop production, sustainability and economic development.

The sustainable management of this relationship requires a join hands to help obtain adequate soil-crop information that could serve as a guide to the achievement of sustainability and renewability of crop production for economic development in Sub-Saharan African region. It is understood that proper managements of soil-crop relationship could improve soil organic matter, enhance soil quality and soil fertility, sustain and restore water quality and soil biodiversity and potentially reserve the natural identity of soil productivity and soil health for an increase crop production (Simonson, 1991; Doran *et al*., 1994; Ditzler and Tugel, 2002; Carter *et al*., 2004). Available record shows that by 2025, Africa would be able to feed only 40% of its growing population (FAO., 1995). Millions of people in rural areas of Sub-Saharan Africa live below the poverty line and more than half of them are extremely needy (Ehui and Pender, 2005). Sustainability of crop production for economic development can only be achieved if the soil and soil resources are conserve and manage, properly. This does not only mean to increase food production but also to minimize hunger, poverty and social crises.

The meaning of sustainable economic development entails (Greenland and Szabolcs, 1993): Management and conservation of the natural resources base and the orientation of technological and institutional changes in such a manner, as to ensure the attainment and continued satisfaction of human needs for the present and future generation. This has emphasize that if we do not join hands to protect, manage, conserve and restore soils properly, the multifunctional roles of soil science to crop productions would not provide a satisfactions of human needs in Sub-Saharan Africa. Similarly, it will not serve as a means to alleviate rural poverty and hunger or even ready to feed the growing population for economic development by 2025 as stressed in FAO (1995) report. Therefore, the sustainability of crop production in Sub-Saharan Africa must include efficient multifunctional services (Varallyay, 2010), using environment-friendly, energy and materials-saving technology and paying special attention to quality and a socially acceptable rural development, concurrently. Hence, the multifunctional sustainable soil management for economic crop production must meet the requirement of soil to be classified and described as 'soil quality'. Karlen *et al*. (2001) considered soil quality as the capacity of soil to sustain plant and animal productivity, maintain and enhance water and air quality and support human health and habitation. This could offers an enormous opportunity to diminish hunger and poverty, improves crop production, vegetation quality and biological heritage.

Generally, there are many contradictions regarding the links between sustainability, soil environment and economic development (DFID., 2000). This will continue to be a long term debates because of the relationship that always exist between sustainable development and other components of human life-economic, social, political and environment (DESA., 2013). Nevertheless, it is the aims of the World Economic (WE) and Social Survey (SS), 2013 to make sure that any contribution towards the considerations on sustainable development focus on three important issues, which are: sustainable cities, food security and energy transformation (DESA., 2013). Our paper lays emphasis on the role of soil science towards achieving sustainability and renewability of crop production for economic development. This would undoubtedly help to increase food security and proper energy transformation for the millions rural people living in

Sub-Saharan Africa. Besides, it would also provide an opportunity for export and trade communication within and outside Africa, reduce poverty and hunger and creates many jobs opening for the growing population. Therefore, if soil and soil resources are given the considerations they deserved, much can be achieved in Sub-Saharan Africa.

There are many resources information generated by soil science in Sub-Saharan Africa (Muir *et al*., 1957; Moss, 1965; Jones and Wild, 1975; Chartres, 1982; Kundiri *et al*., 1997; Warren *et al*., 2001; Ehui and Pender, 2005; Bationo *et al*., 2006; Usman, 2011; Petersen, 2008; Furian *et al*., 2011). Similarly, the soil conservation and management in developing countries (FAO., 1985), Soil and water conservation in semi-arid areas (FAO., 1987), land husbandry: components and strategy (Roose, 1996) and world reference base for soil resources 2014 (FAO., 2015) are resources information provided by soil science and can be used for many economic developments. However, it is regretted that little attention has been given to most of these resources information in the region for economic development. In Rwanda, Rushemuka *et al*. (2014) critically observed that much time and funds have been lost as a consequence of poor consideration of soil resource information in agricultural research and extension planning and implementation during the last 50 years. The soil science discipline can become more effective in Sub-Saharan Africa (Bouma, 2014).

- Reconnecting the knowledge chain, linking tacit with scientific knowledge both ways
- Simplifying soil terminology
- Learning to deal with wicked environmental problems for which no single solutions exist but only a series of alternative options for action, balancing economic, social and environmental considerations
- Educating knowledge brokers, linking science with society in land-related issues, acting within a Community of scientific practice
- Modernizing soil science curricula

Therefore, application of soil science resources information into vast environmental resources available would help to increase crop production, forest management, water quality, animal production and poverty reduction.

Soil science: Role, challenges and gaps in future: There have been several developments in the past decades regarding the role and challenges of soil science in future (Hartemink, 2006b). These allowed soil scientists to expand the recovery of many important soil research projects that are sustainable in ensuring the goals of soil science for the next 75 years to come (Simonson, 1991). Starting in the 1960 to date, some major developments in soil science were noted (Mermut and Eswaran, 2001), although ideas and challenges on the future of its science are expanding more dynamically than ever. In Sub-Saharan Africa (for example), there is need for qualitative and quantitative communication on what soil is and how the identity of the soil science discipline relates to the subject of its study, sustainability, crop production and economic development as well as other sciences including the basic and applied environmental studies (Hartemink, 2006a). This lack of communication is a limitation to the consideration of soil science in the context of its role as an answer to sustainable economic development in the region (DESA., 2013). Although, to our understanding this problem can be control if the governments engage fully into economic agricultural practices. Therefore, soil science will undoubtedly plays an increasingly important role in answering substantial part of the questions related to sustainable economic developments in Sub-Saharan Africa due to continuous demand for agricultural lands, globally (UNCCD., 2012).

Previously, considerable researches have the same views, which indicate how soil science is a major player in world economic development (Greenland, 1991; Sanchez, 2002; Frossard, 2006; Bouma, 2014). Despite this contribution in the field of soil science, there is however, some contradiction opinions that achieving sustainable economic development in any form requires integration of ideas from different perspectives (DFID., 2000). This is because, the global challenges to sustainable development have been driven by a broad set of mega-trends, which include; changing demographic profiles, changing economic and social dynamics, advancements in technology and trends towards environmental deterioration (DESA., 2013). Therefore, soil science as a disciplinary of science could be regarded as one of the key components that play role towards achieving sustainability in Sub-Saharan Africa. And, also could be part of most effective means for integrating economic, social, political and environmental objectives in reducing poverty and hunger (DFID., 2000).

Generally, there is significant population increase and demand for food, water and shelter in the entire Sub-Saharan African nations (DESA., 2013). According to Dobbs *et al*. (2011), meeting this demand would means requiring about 175-220 million ha of additional cropland, globally. It is quite true that this need will never be achieved if our soils are not been preserve and maintain, properly (UNCCD., 2012). This may support the ideas and notion of soil scientists in respect to the subject entitle 'the future of soil science'. There are

many views and contributions on the theme. In Sub-Saharan Africa (for example), Rushemuka *et al.* (2014) noted that the future of soil science depends on the continent's distinct characteristics: Its high concentrations of poor farmers using poor agronomic tools to work soils dominated by low inherent fertility in support of national economies. Globally, the contributions of soil scientists regarding this idea have been forwarded and edited by Hartemink (2006b). The summary of diverse opinions presented by some members of the International Union of Soil Science (IUSS) is outline below (Hartemink, 2006a):

- **According to H. Eswaran's opinion:** The future of soil science depends on how well we manage smoother and stable scientific progress and soil science must retain its identity while demonstrating its value to other sciences; it must contribute to but not be skewed by accomplishments in related sciences. The challenge for soil science is to remain relevant, produce results that are meaningful not just to scientists but to the public and continue to push new frontiers in the field. The future hinges on how we meet this continuing challenge
- **According to R. Fowler's opinion:** The soil science specialists need to be developed-holistically well-informed scientists who hear the needs of advisers and farmers and finally get out there and discover root causes with scientists and representative farmers and advisers, developing possible solutions, testing them in the laboratory or research station, suggesting alternatives which farmers can compare for themselves, then disseminating results effectively to all potential users, not least those training or in-training
- **According to E. Frossard's opinion:** To achieve the future in soil science, information derived from soil research must be made available to the scientific community, to soil users namely-the farmers, agronomists, foresters, civil engineers and to the society. Soil research activities-either oriented to a better understanding of soil functioning and/or better soil management, must be undertaken at all levels, from the laboratory and field to the global scale involving scientists from developing countries in efficient networks as the International Union of Soil Science. Besides, soil scientists must be able to convince politicians to adopt pro-soil measures, and also convince the citizens that the ground they walk and build on, is one of the basis amenities of life on this earth
- **According C. Gachene's opinion:** Who foresee that the future of soil science can only be achievable, if the science is integrated with other fields-citing example on soils in relation to environment, revision of old curriculum with a view of re-looking the role of soil science and the society in general. And, stressing that the future is not so bright if it is business as usual of traditional soil science
- **According to S. Grunwald's opinion:** Soil science must continue to expand beyond its traditional identification with agriculture as it becomes a partner in the earth, ecological and environmental sciences. While soil scientists will need to effectively participate in interdisciplinary studies without loosing their own roots and identity, play an active role in generating datasets and information; transfer and share knowledge with stakeholders, decision makers, land use planners, politicians and others
- **According to A. Hartemink's opinion:** Soil science has always had two ways of thinking: to show how the world is working and show how the world should be working and change it. It has been good in both but there has been a shift towards the second way of thinking, emphasizing the usefulness of our activities. It may be that soil science is done more efficiently as computers are involved all the way from data collection up to electronic publishing. It may be that we are just recycling ideas
- **According to C. Hartmann's opinion:** Soil science will have to increase soil productivity to maintain food production, rehabilitate degraded agro-ecosystems, avoid 'collateral effects' and provide techniques of sustainable soil management economically acceptable. The future soil science will probably be a more complex an integrative science than presently, having a wider scope with a multidisciplinary approach able to associate traditional aspects (physics, chemistry, etc.) with more innovative ones (soil ecology, 'soil economy', etc.). Soil scientists should have to be in a leading position to respond the challenges of the 21st century. Our success might not depend on technical improvement but rather on a shift in some of our basic concepts and paradigms
- **According to J.J. Ibáñez''s opinion:** Updating soil inventories is one of the main fields where new technologies should facilitate data samplings and acquisition. Work needs to be carried out with non aggressive techniques with a view to obtaining the most detailed information as possible, as well as three dimensional information on the soil-regolith system. Soil monitoring programs need to start from updated soil inventories, more detailed than the existing ones in many countries

- **According to Y.P. Kalra's opinion (among others listed):** Today soil scientists are concerned about the future of soil science at universities. The challenge for scientists is to assert soil science as an independent discipline with a coherent body of knowledge about natural bodies on the landscape. Soil science is perceived as an adjunct of plant science. It is being fragmented and dispersed among disciplines such as; engineering, biology, chemistry, agriculture and forestry. Such fragmentation must be resisted by firm knowledge of the discipline

The above broad sets of opinions could be remarkable in addressing many issues related to sustainability and renewability of crop production for economic development in Sub-Saharan Africa. And, it is believed that if this can be achieved scientifically, traditionally, politically and socially, there is a strong backing that soil science will emerge number one contributor in agricultural transformation systems for sustainable economic development in Sub-Saharan Africa.

CONCLUSION

Soils are the most important economic environment that we have for ensuring foods, raw materials, industrial developments and sustainable livelihoods of millions Sub-Saharan African people. The soil scientists understood that soil is part of earth crust where mineral particles are formed as a result of physical, chemical and biological processes. And, the agronomists understood that soil is the medium in which plant roots anchor and from which they extract water and nutrients (Ritzema, 1994). These provided a sound knowledge that soil is vital to people for various economic opportunities. Generally, soil covers many important areas of economic developments: Lands, forest, water bodies, roads, buildings, industries and education.

The science of soil has played and continues to plays a key role for the improvements and understanding of soil and its function in the global ecosystem for sustainable economic development. This function of soil has long been recognized in the development of various systems of agriculture, land quality, water quality and types of social, cultural and industrial civilizations. Consequently, soil science can be considered a key to sustainable crop production for economic development in Sub-Saharan Africa. This could mean that the wealth of Sub-Saharan African nations depends on their ability to sustainably conserve and manage soil resources. It is therefore stressed that the time has come for the Sub-Saharan African countries to integrate ideas to improve and manage soils for permanent economic development, sustainably. One of the imperative ways to achieve this is by supporting soil-crop researches for reliable, detectable, accurate and quantitative soil information.

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