

Stocks and Ecological Significance of Soil Carbon in Tanzania

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Abstract Numerous documentations have paid a few attentions to the mapping of soil organic carbon (SOC) in Tanzania. To any country, the estimation of SOC is very important as provide social, ecological and economic values just to mention a few. Here we reviewed over 55 publications be journal papers, government and international organization reports to ascertain on the amount of SOC, factors influencing its accumulation, and highlight its ecological and socio-economic significance. Despite of the limited information, the Eastern Arc Mountains seem to have an average carbon stock of 100 – 400MgCha⁻¹ in the undisturbed and 85 MgCha⁻¹ in the disturbed areas; while the semi-arid areas have about 0.4-10 MgCha⁻¹ only. In most cases, SOC were highest on the surface (0-20cm) and decreased with increasing soil depth. This is because most anthropogenic activities i.e. organic fertilizations take place at the top sub-soils. Edaphic and climate factors had as well significant contribution to the accumulation of SOC. Rainfall and temperature appeared to facilitate numerous soil processes that lead to SOC accumulation. Potentially, SOC improves soil fertility for higher crop yields, mitigates the emission of greenhouse gases and eventually improves the people's livelihoods. For example, maize yields were significantly higher under SOC 1.9 ton per hectare than has without it 0.9 ton per hectare. In addition thousands of carbons dioxides tones are seized in the soil. Otherwise, its offset would have serious atmospheric pollution. We therefore, recommends for more original researches on SOC to harness its economic, social and ecological potentials for the benefits of the people.

Keywords Climate, Organic Soil Management, Histosols, SOC, Tanzania

1. Introduction

Soil organic carbon (SOC) is among the essential components of soil organic matter [7, 46]. Carbon (C) exists

in the soil in the form of organic and inorganic [25]. Organic carbon (OC) is formed by elemental carbon such as coal, charcoal, and graphite, while inorganic carbon (IC) is composed of carbonate minerals, such as calcite and dolomite [5, 6, 25]. The amount of carbon stored in soil is determined by the balance of two biotic processes: production of organic matter (OM) by terrestrial vegetation and its decomposition by soil organisms [25, 46]. The degree of magnitude of how SOC serve the socio-ecological livelihoods may differ over space and time. Soil carbon is good at improving the biological conditions for soils microorganisms to function as well as elevating soil fertility for crops yield optimization. In addition, it seizes atmospheric greenhouse gases (sequestration) such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) and thus, mitigating climate change impacts.

However, this paper focused on the SOC i.e. OC under natural conditions such as forests and rangeland. The purpose of this article was to review the existing knowledge on analytical techniques and amount of SOC in Tanzania and reflecting other sub-Saharan Africa [20, 29, 33, 57]. In doing so, we reviewed 57 publications related to the study. Priority is given to scientific publications from international peer-reviewed journals from the web of sciences. Despite of the missing of some information, we tried to correct that discrepancy. This work has significant contribution to scientific research. It gives what has done and not yet and thus brings insights to original research. In addition, the study has economic implications as SOC contributes significantly to increased yields for both consumptions and sale. Ecologically, SOC favors the functioning of soil microorganisms especially mycorrhizal fungi which influence the capacity of nutrients uptake from the soils.

We argued that, the emerging insights into the significance of SOC quantification should be seized globally with special consideration of sub-Saharan Africa, some Asian countries, Latin America and some parts of Eastern Europe [21, 25]. However, the need for SOC estimation in developing countries is higher than in developed countries where a bit more studies have been conducted on the same.

The estimated SOC is important because of the human environment interactions under the auspices of socio-ecological development. In addition, most of these studies have significantly contributed to novelty and scientific rigor of SOC science in the planet Earth.

Nevertheless, in most sub-Saharan African countries including Tanzania, the estimation of SOC is an emerging discipline and therefore, the quantification of SOC in the region is quite important [15, 18]. Thus, reviews and practical implementation on SOC estimation need to be adhered. Very few studies with limited information have been conducted in Tanzania to estimate SOC stock in different climatic condition of the country [21, 26, 46, 48, 49]. Most of these studies have been squeezed to specific ecosystems especially forests. Thus, it has been quite difficult to establish the general overview that estimate the SOC stock and the factors for its dynamism in the country.

Few studies which have been conducted on SOC because very little surveys and researches have been done, contrary to the developed countries where intensive researches have widely been done to inform the same [51]. Similarly, Solomon [50] reported that poor technology is among the technical barriers to undertake intensive studies in Sub-Saharan African countries. This limits the process of data inputs in the model and it ends up feeding little data which may not reflect the whole scenario. Advanced technology is capable to transact large quantities of data especially those about the litter decomposition. This provides good results that reflect the actual scenario of the area. Most of the models like ROMUL [14], Roth C [13], CENTURY [41] are difficult to apply because they demand large quantities and specific data for inputs. However, Yasso or Yasso07 [31, 53] method seem to support soil carbon modeling in some developing countries because it needs few and general data as inputs for SOC modeling.

Little studies have been conducted in some areas to estimate the amount of SOC [28]. Some of these studies are [21, 26, 46, 48, 49] just to mention a few. However, these studies have not yet grasped actual estimation of available carbon stock despite of enlisting some causes for its changes. They have mostly earmarked on the forested land with little attention on pasture and crop land especially in semi-arid areas. Probably this has been done deliberately because forest ecosystems are potentials for mitigating the emission of greenhouse gases and to acquire certificates for carbon trade as recommended by Kyoto Protocol 1997.

According to Batjes [7,] SOC needs to be quantified because it has a substantial contribution to both crop production and ecological balances. Other authors like Baldock [5], Munishi and Shear, [36] added that, SOC improves soil fertility and mitigate the emission of greenhouse gases. In the area, soil with high SOC content has significantly increased maize yields by 1.9 ton per hectare compared to 0.9 ton per hectare without or with deficit [16]. In addition thousands of carbons dioxides tones are seized in the soil [14]. Lal [29] argued that climatic conditions, soil types, vegetation types and agronomic

practices are among the prominent factors influencing carbon stock and changes in most tropical areas. All these concepts and factors are also acknowledged by different authors [7, 8, 20, 26, 30].

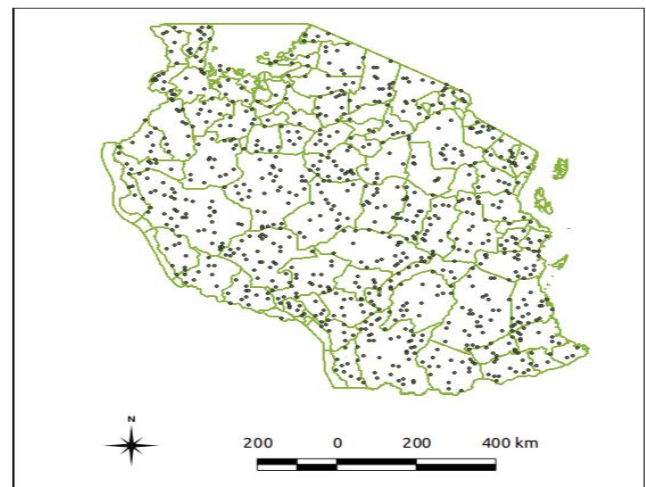
Therefore, this study aimed at reviewing some studies which have estimated the amount of SOC in the country. This review would help to determine the amount of SOC stock and predict its changes due to natural factors and anthropogenic activities. Similarly, this review can provide current information that will be valuable to provide insights into priorities for soil carbon studies in Tanzania.

2. Materials and Methods

2.1. Profile of the Study Site

Tanzania is located on the eastern coast of Africa, south of the equator between latitudes 1° 00' S and 11° 48' S and longitudes 29° 30' E and 39°45'. It borders the Indian Ocean to the east, Uganda and Kenya to the north, Burundi, Rwanda and the Democratic Republic of Congo to the west, and Mozambique, Zambia and Malawi to the south. Its total land area is 945 087 km². Agricultural land accounts for about 40% of the total land area and 30% is reserve areas such as national parks, game reserves and game controlled areas [55]. An estimated 55% of the land in the United Republic of Tanzania could be used for agriculture, and more than 51% for pasture. Specifically, Tanzania has about 44million hectares of land potential for agriculture but less than 24% of this potential is harnessed [55]. Subsequently, shifting cultivation is the major cause of deforestation and land degradation in various areas of the country.

Figure 1 below shows the locations where soils samples were picked during the survey. Thus, we reviewed by having informed on the work done by Mäkipää [34] and other scholars.



Source: Mäkipää [34]

Figure 1. A map of Tanzania showing the location/landscape of the permanent sampling clusters. It shows the distribution and coverage where were sampled in the country. It gives a general picture of the surveyed areas as sources of SOC data.

2.2. Biophysical Characteristics of the Country

2.2.1. Climate

Tanzania experiences temporal and spatial rainfall variability [2, 3, 47]. The country has varied weather and climate according to season and place. Average temperature ranges between 17°C and 27°C, depending on location. The hottest period spreads between November and February (25°C - 31°C) while the coldest period occurs between May and August (15 °C - 20 °C). The mean annual rainfall varies considerably from place to place ranging from less than 400 mm to over 2,500 mm per annum. Rainfall in about 75% of the country is erratic and only 21% of the country can expect an annual rainfall of more than 750 mm with a 90% probability (Rowhan et al., 2011).

Similarly, Ahmed [3] and Adger [1] reported that rainfall is predicted to increase in areas with bimodal rainfall while decreasing in areas with unimodal rainfall. To recognize the impacts of this climatic variation; Intergovernmental Panel on Climate Change has grouped Tanzania among the thirteen countries in the world which are most affected and vulnerable to climate change impacts [24].

2.2.2. Ecology

Ecologically, the country has seven agro-ecological zones [55]. These include: Coastal; Eastern plateau and mountain blocks; Southern highlands; Northern Highlands/Northern rift valley and volcanic high lands, Arid Lands/Central plateau; Alluvial Plains/Rukwa-Ruaha rift zone; and Semi-arid lands/inland sedimentary plateau [14].

2.2.3. Soils

The country has different types of soils which are generally grouped as clay, loam and sand. Tanzania adopted the World Reference Base of Soil Resource (WRB) as the system of nomenclature and correlation [54]. According to WRB; Tanzania has 19 dominant soil types and they are grouped into two groups namely; *organic soil and mineral soils* [40, 54]. The structure, concepts and definitions of the WRB are strongly influenced by (the philosophy behind and experience gained with) the [14] and UNESCO Soil Classification System.

3. Sources of Soil Carbon

Soil Organic Carbon (SOC) is mainly found in the natural environments such as crop land, pasture/grassland and forest land [56]. It mostly comes from natural soil rich in carbon, animal manure, decomposed crop straws, green manure and other organic soil management. In most developing countries, the accumulation and utilization of SOC is very low to the extent that inorganic soil fertilization is promoted instead. However, chemical fertilization causes significant negative impacts to the soil and environment. Soil and vegetation types provide harmony to the environment for SOC accumulation [46].

Some soil types are good sources of carbon while others are not. *Dystric Histosol* is rich in carbon while *Yermosols* is poor [18]. Overall, clay soil (especially vertisols) has significant impact in the stock and changes of SOC. Likewise, some miombo vegetation such as *Brachystegia microphylla* and *Cordia africana* are good sources in the formation of litter for soil organic matter and soil carbon [45].

Therefore, the major sources of soil carbon are from the natural environment (soil and plants) supported by organic soil management [27]. Thus, for sustainable conservation; semi- arid areas demand more soil organic management to increase its capacity to replenish soil fertility. Tables 1-3, are hereunder to support these scientific assertions.

Table 1. The estimated current area extent and carbon stocks of the major forest biomes

Forest biome	Area (Mha)	C Density:	C Density:	C Pool:	C Pool:
		vegetation (t ha)	soils (t ha)	vegetation (Gt)	soils (Gt)
Boreal	1372	64	343	88	471
Temperate	1038	57	96	59	100
Tropical	1755	121	123	212	216
Total	4165	Mean 86	Mean 189	359	787

Source: Adopted from Dixon [12]

Table 2. The change of carbon pool in forested area in different climatic regions since 1850

Biome	Area 1850 (Mha)	Area 1980 (Mha)	Area change (%)	Net C release (Gt C)
Boreal	1172	1167	0.5	4
Temperate	1583	1492	6	27
Tropical	2675	2167	19	52
Total Forest	5430	4827	11	83

Source: Adopted from Houghton [8]

Table 3. Potentials of SOC Sequestration

Land use and management	Tropical climate		Tropical climate	
	Humid Mg C ha ⁻¹ yr ⁻¹	Dry Mg C ha ⁻¹ yr ⁻¹	Humid, Mg C ha ⁻¹ yr ⁻¹	Dry Mg C ha ⁻¹ yr ⁻¹
Conservation tillage	0.25–0.5	0.25–0.5	0.25–0.5	0.1–0.25
Cover cropping/cropping systems	0.1–0.2	0.1–0.2	0.1–0.2	0.05–0.1
Integrated nutrient management	0.2–0.4	0.2–0.4	0.2–0.4	0.1–0.2
Water management	0.05–0.1	0.25–0.5	0.05–0.1	0.2–0.4
Erosion control/waste conservation	0.2–0.4	0.1–0.2	0.2–0.4	0.05–0.1
Agroforestry	0.4–0.8	0.2–0.4	0.4–0.8	0.2–0.4
Improved grazing	0.4–0.8	0.1–0.2	0.4–0.8	0.1–0.2
Soil restoration	0.8–1.2	0.4–0.6	0.8–1.2	0.2–0.4

Source: Modified from Lal [29]

Table 3 Shows Contribution of different farming systems to SOC accumulation

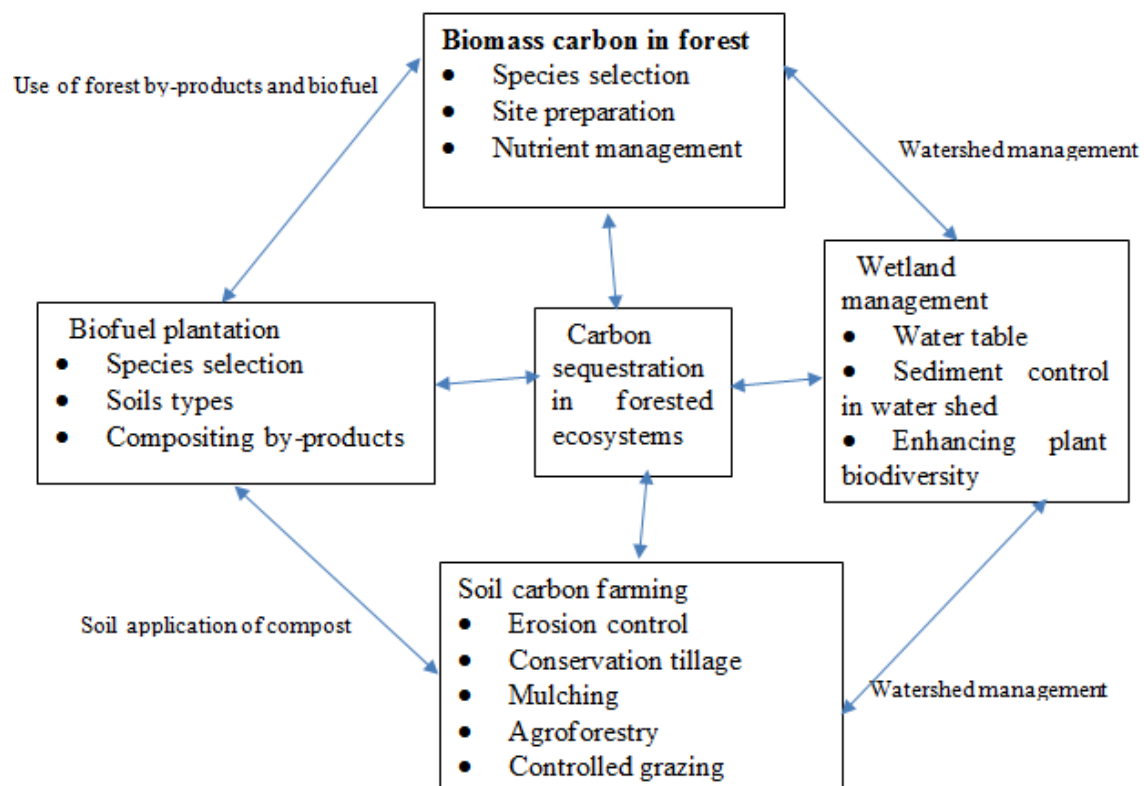
A negative sequestration in humid and semi-arid climates is caused by drainage of poorly drained wetland soils. Agroforestry, soil restoration and water management are good sinks for carbon sequestration (see table 3). In tropical climates of Tanzania; carbon pool is higher (216Gt ha^{-1}) in soil than (212Gt ha^{-1}) in vegetation (see table 1). Subsequently, the net carbon release seems to be greater, 52Gt ha^{-1} , compared to that of other biomes (see table 2). This stance is realizable by the high conversion of natural forest to agricultural ecosystems in the tropic and semi-arid areas leads to emission of tons of carbon per annum. The emitted carbon accumulates as greenhouse gas at the atmosphere and thus, influencing climate change.

Since forest biome is the major reserve for terrestrial carbon; its destruction poses significant impact to carbon emission [36]. Therefore, for SOC accumulation to occur, a number of factors need to be in place ranging from natural to human factors. In this case, water management, soil

restoration, agroforestry and manuring are among the significant practices to be considered (see table 3).

There is a significant correlation between the increase in carbon pool and its capacity to sequester carbon. Land use change such as conversion of natural forests to agricultural production increases the magnitude of carbon emission (see fig. 2). In tropical biome including Tanzania, the conversion of forest and grassland to crop land is a usual routine. It is done through shifting cultivation and rotation farming. Thus, there is enormous carbon emission in place. This is supported by Munishi and Shear [36], who urged that the amount of carbon loss in the soil is equivalent to that emitted in the atmosphere (carbon dioxide). Therefore, effective management of wetland ecology is significant to reduce carbon emission (see table 3).

To reduce the rate of conversion of natural ecosystem to agricultural, a number of strategies are required to be in place. Among these are conservation agriculture, biofuel plantation and wetland management (see fig. 2). This will reduce the magnitude of the problem albeit at a modest pace.



Source: Modified from Lal [29]

Figure 2. Technological options for carbon sequestration in terrestrial ecosystem. Soil C farming can be promoted through trading of C credits and generating another income stream for farmers

4. Factors Affecting Soil Carbon

4.1. Climate

Rainfall and temperature are the major components of climate and they have significant contribution to the formation of soil carbon [56]. Rainfall provides moisture to the soil and facilitates the rate of decomposition of organic matters to form organic fertilizers [29, 39]. On the other hand, temperature acts as catalyst to increase the rate of chemical reactions particularly the decomposition of litter which is a useful data input in SOC modeling. When other factors are constant; soil organic matter is higher in cooler climate than warmer climate [21, 30].

On the other hand, in dry climate such as semi-arid areas the rate of soil carbon formation is lower than that of tropical and equatorial climate. The latter provides suitable condition for soil replenishment while the former does not [38]. Therefore, it is advisable to adopt organic soil management practices in semi-arid areas to curb the problem. This will enable the revival of the soil biological processes which will increase soil fertility [42].

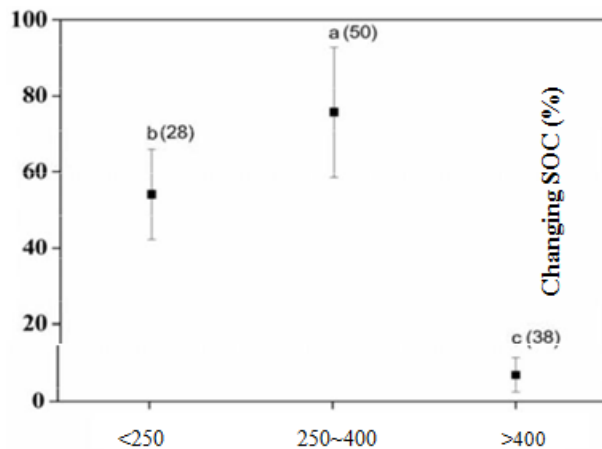
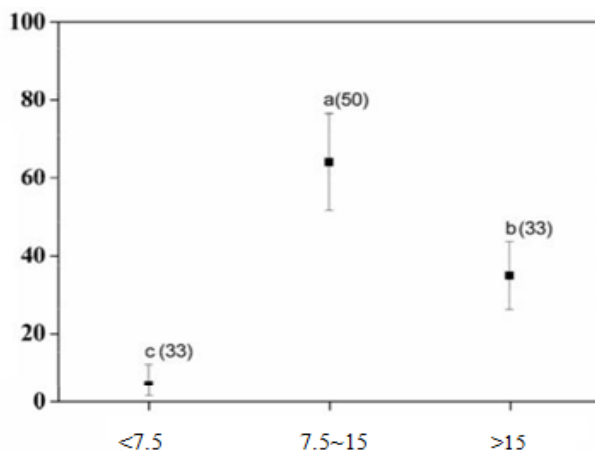


Figure 3a. Mean annual precipitation (mm)



Source: Modified from Zhang et al., 2013

Figure 3b. Mean annual temperature (°C)

Fig. 3a Influence of precipitation on changes in SOC stocks after afforestation. The error bars are the standard

errors of the mean. A different letter means a difference significance at $P < 0.05$. Fig. 3b: Influence of mean annual temperature on changes in SOC stocks after afforestation. The error bars are the standard errors of the mean. A different letter means difference significance at $P < 0.05$.

The optimal accumulation of SOC happens at around 250-400mm of rainfall and 7.5- 15°C of temperature (see fig. 3a&b). This implies that an area with increasing temperature and rainfall can provide good condition for carbon accumulation. Soil microorganisms and other natural processes can do well under the prevalence of moisture. Further, temperature has a great influence in SOC accumulation as it facilitates the decomposition of organic material to form organic matter. Thus, the accumulation of SOC may increase after some years in future as predictions show that temperature is expected to increase by 2°C by 2050 and 2-4°C by 2100 [37]. Here, the temperature is the major determinant as it regulates seasonal processes that lead to both carbon gain and carbon loss in temperate and boreal forest.

4.2. Vegetation Types

Vegetation plays a significant role in the soil carbon formation [48]. Similarly, Bengoetxea [15] added that vegetation is a source of litter which is a significant component in the formation of soil carbon. Tanzanian forests are mainly dominated by tropical forests (woodlands). Miombo woodlands "*Brachystegia*" are found in large portions of the country. The areas with rich forest ecosystem like the Eastern Arc Mountain are as well endowed with woodlands. Subsequently, in areas where agroforestry system is practiced; *Luciana plants* and *Grevellia Robusta* provide good condition for decomposition of organic materials [11]. Vegetation types vary over agro-ecological zone significantly. Stone [51] and Gray [17] supported that the quantity and quality of plants biomass are determined by the types of plants and thus determining the amount of SOC to be formed and accumulated. Therefore, vegetation types are significant in determining the amount, stock and changes of soil carbon.

4.3. Soil Types

Soil with clay content has strong impacts of SOC accumulation and its changes [29]. Some of these soil types are rich in carbon while others are poor [4,54]. For example; *Dystric Histosol* is rich in carbon with 116kgC per meter square while *Yermosols* is poor in soil carbon with 1.39kgC per meter square [18]. Therefore, different types of soil possess different types of soil carbon. Soil carbon is also spatially distributed over the country and has spatial magnitude to biological functions [8, 35].

4.4. Human Activities

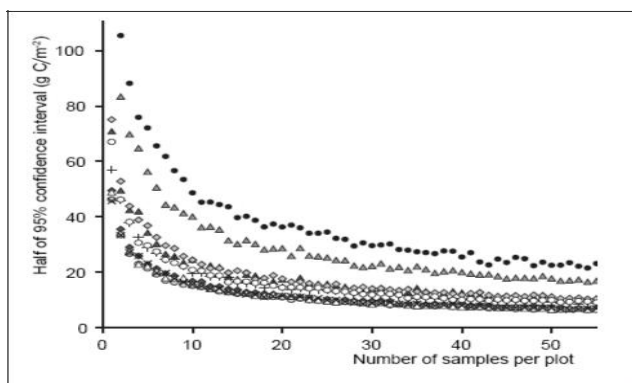
Anthropogenic activities have significant impacts to the

SOC accumulation [43,44]. These activities can be constructive or destructive. Cropping system and soil organic management like agroforestry, rotation agriculture and application of animal manure play a remarkable role to the accumulation of SOC stock and changes in the soil [6, 51]. Similarly, conservation agriculture such as no tillage, application of cover crop, straw composite and the farming of leguminous crops tend to increase the amount of soil carbon in the soil [32].

This is contrary to cropping system like monoculture that reduces the amount of SOC in the soil through soil degradation [16]. Therefore, monoculture does not give favorable condition for carbon replenishment in the soil. Similarly, deforestation has negative impacts to SOC deposit. According to Lal [29] the conversion of natural environment to agricultural ecosystems decreases SOC pool by 50–75% over 20–50 years in tropical climates. This decrease in SOC can be realizable as tons of carbon will be emitted to the atmosphere from the soil. Further, the conversion of wetland ecosystems contributes to carbon loss through carbon off-set. Therefore, various human activities have remarkable contribution to the accumulation of SOC and its changes in the soil.

5. Survey and Modeling of Soil Carbon in Tanzania

Few surveys have been conducted in the country as directives from Intergovernmental Panel on Climate Change [24] and UNFCCC. The major SOC survey was done in 2012 under [14]. It was about monitoring the stock and changes using surveys and modeling. Despite of taking a wide and representative sample, the study was subjected to sampling and measurement errors, thus its quality was affected. Systematic and stratified sampling was employed to correct these errors. Mäkipää [33] gives a detailed report about the procedures and location where samples were picked for analysis. Figure 1 and 4 depict the real situation on the locations of sampling and confidence intervals of the carbon stock.



Source: Mäkipää [33]

Figure 4. Confidence intervals of the carbon stock of the organic layer according to sample size for ten different study sites.

According to Stone [51] and URT [54] soil carbon needs to be surveyed basing on the five spheres namely: above-ground biomass, belowground biomass, litter, dead wood and soil carbon. Subsequently, litter and soil are important carbon stocks on the earths' surface [10].

The study by Tomppo [52] on soil carbon monitoring using surveys and modeling in Tanzania among other things, showed how the monitoring of carbon stock and changes can be undertaken in the country. It further exemplified the approaches and sampling to represent the whole population. Over thirty sections/areas were specified for the study to represent the seven agro-ecological zones of Tanzania [14]. Systematic sampling was the best recommendation for specific soil sample. However, it brought some errors which were rectified later by stratified sampling.

The modeling of soil carbon was also a big challenge. Despite of having multiple models for soil carbon, majority of them were difficult to apply because of a number of reasons. For example, CENTURY [41]; ROMUL[11], RothC [13] are difficult to apply because they demand large quantities and specific data for inputs. Also, in Tanzanian context, it is difficult to adopt these models due to shortage of large quantities and specific data for input.

Among these, The Yasso07 model [1, 53] seems to be a user friendly method because it supports soil carbon modeling and needs few and general data which are available in most developing countries. Therefore, more repeated surveys and modeling of soil carbon needs to be done recapping from the previous surveys' results. This will establish the up to date database of this resource. From there, monitoring of the changes in the SOC stock will be simpler than starting afresh [38].

6. Errors of Survey and Modeling of Soil Carbon in Tanzania

In most developing countries soil survey, sampling and modeling of soil carbon are likely subjected to error [52, 57]. The actual and potential error emanates from the sampling process and laboratory modeling [21]. Sampling and data entry comes from the field and laboratory respectively. In the site, sampling such as random, systematic or/and stratified are subject to error depending on the application. Systematic sampling seems to bring some errors especially if the sample is not well calibrated. However, stratified sampling is regarded to correct the error caused by systematic sampling of soil carbon in the field [52, 57]. In the laboratory, the challenge may emanate from the data entry. Litter decomposition is among the significant process which affect the changes in carbon pool and the related heterotrophic soil expiration. Therefore, proper data entry in terms of actuality and best entry is very crucial [21].

7. Results of the Survey

Different surveys and studies have been conducted in the

country attempting to estimate the SOC reservoir. Tanzania's soil carbon varies over depth and place [52]. It was reported that the quantity of SOC is 4227Tg and 7810Tg for the depth of 0 – 30 and 0 – 100cm respectively [21].

Similarly, the study by Kaaya [26] and Saha [48], estimated the amount of carbon in the forest ecosystem. They found that SOC to 10cm depth in the Miombo "*Brachystegia*" woodlands in Tanzania to be 37 Mg C ha⁻¹ and 38 Mg C ha⁻¹ in closed Miombo and open Miombo respectively. Likewise, Shelukindo [49], added that for undisturbed ecosystem of the Eastern Arc Mountains of Tanzania the amount of carbon can be 100MgCha⁻¹ to 400MgCha⁻¹ while for the *disturbed* ecosystem, the stock is about 85MgCha⁻¹.

Further, Burgess [9] predicted that; SOC pool in the area will experience some serious reduction due to increased anthropogenic activities such as deforestation and conversion to cropland. Arid and semi-arid areas have little SOC pool ranging from 1 to 30 MgCha⁻¹. Therefore, the Eastern Arc Mountain has more carbon stock than the arid and semi arid areas.

In semi-arid regions of Tanzania; SOC seems to decrease because of drought and poor replenishment of soil organic matter. Rossi [46] and Solomon [50] reported that the quantity of soil carbon in arid and semi arid areas is less than 50% compared to that of forestry biomes. Therefore, it is obvious that there is a variation of carbon stocks and changes over different agro ecological zones. Subsequently, soil types have different contents of soil carbon. For example, *Dystric histosols* is rich in soil carbon with 116kgCm⁻² while *Yermosols* is poor in soil carbon with approximate 1.3 kg Cm⁻² [8, 49].

In Africa, there is spatial variation of SOC deposit. Despite of the spatial and depth variation of carbon stock, the recorded cumulative stock is assumed to vary from 133,420Tg – 184,116Tg at the depth of 0–30cm depth. This information is according to Harmonized World Soil Database. Likewise, spatial data from other soil databases including Digital Soil Map of the World shows that the amount of soil carbon in Africa is 166,397Tg for 0 – 100cm depth. Logically, the two findings give a variation of about ±30% on the same issue. We expected the quantity of carbon in the depth of 0–100cm to be significantly greater than that of 0 – 30cm due to cumulative impacts of soil carbon to the greater depth.

Despite of all these, large deposits of soil carbon seems to be in Congo with 8.20kgm⁻² and the least deposit is found in Western Sahara with 0.4 kgm⁻² [19, 21]. Carbon stock has a significant impact to socio-economic and ecological development in most African countries. Democratic Republic of Congo, Gabon, Congo and Equatorial Guinea are among the countries rich in soil fertility and soil carbon [21, 52]. It increases soil fertility through organic matter decomposition. As well, soil carbon is a good platform for carbon sequestration [43]. In actual fact, the amount of organic matter and soil carbon is a result from the equilibrium between inputs and output to the ecosystem [52]

Meanwhile, the decrease of soil organic matter in the top soil can have dramatic negative effect on water ecosystem and its lodging capacity [52]. Subsequently, the decrease in soil organic matter affects the structure stability and compactness, nutrient storage and supply to the plants [20]. Then, the biological process of mycorrhizas, nitrogen fixing bacteria and carbon cycle are subject to stress when soil organic matter decreases in the particular ecosystem [20, 22]. This goes together with the decrease of Net Primary Production of the soil. The conversion of forest and woodland ecosystem to farmland reduces the soil-carbon content in most tropical countries [40, 41, 48]. This happens through reduced production of detritus and increased erosion.

The discrepancy indicate that, Tanzania and other African countries have a long way to go in documenting an actual or close estimate of SOC. This difficulty is exacerbated by poor technology and usual land use changes especially the conversion of forest/woodland into farmland and therefore affects carbon stocks and changes. Further studies on spatial within site variation and inter site variation have to be conducted for effective soil inventory [44].

8. Significant of Conducting Soil Survey

Soil survey is very crucial for updating the status of soil carbon from local, regional, and national to global level [52]. Information from the surveyed area can provide data and link among the forest, cropland and pasture land carbon reservoirs [21]. Then, the documented survey's results can serve as a benchmark for SOC estimation. In Tanzania; usual survey for carbon assessment is significant because it enriches information to the National Forest Resources Monitoring and Assessment. Similarly, this will approximate the magnitude of land use and carbon changes over time and place.

It is obvious that it can be difficult to take soil sample that sufficiently represent the whole country due to poor technology. However, effective representation of the area or widening the size of the sample can be a best way of reducing the error during survey [46, 48, 52].

9. The Future Management of Terrestrial Carbon Resources

No country has its own atmosphere; all nations need to cooperate in the management of carbon resources and abide to all concerned regulations regardless of their development levels. Globally, all nations should adhere to the Agreement of Kyoto Protocol of December 1997 which among other things proclaimed the reduction of carbon emission and advocated increased carbon sequestration. Similarly, they should also adhere to Clean Development Mechanism and carbon trade. This will help to reduce the magnitude of carbon emission. At national and local levels (mostly in

developing countries such as Tanzania), the reduction of deforestation and other environmental degradation practices should be the major concern [45].

Meanwhile, a number of techniques such as restoration of saline that increase the leaching of Ca (HCO₃)₂ and deep placement of biomass carbon needs to be employed to reserve SOC in the sub-soil where anthropogenic activities do not disturb. Therefore, reduction of carbon emission should be done in all countries as all people live in the same planet.

10. Conclusions

There is limited information on the quantification of carbon stock in Tanzania and Africa in general due to limited researches and surveys conducted in the area. At least the Eastern Arc Mountain seems to have more carbon stock than other places because of litter decomposition than the arid and semi arid areas which lacks vegetation. This review has shown that SOC is potential for improving soil fertility and that higher crop yields are obtained under SOC. In addition, it is potential for SOC sequestration and therefore, it mitigates the emission of greenhouse gases. In forestry aspects, it is highly associated with trading of carbon credit under the umbrella of Kyoto Protocol. By that not, SOC is significant for human life and thus, more surveys and researches (original researches) should to be conducted on the same for the betterment of ecology, social and economic aspects.

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