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A Review on: Management of Carbon in Dry Land Agriculture

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Abstract

Dry land areas are defined as regions in which the ratio of total annual precipitation to potential evapotranspiration (P:ET or the Aridity Index, AI) ranges from 0.05 to 0.65. Dry lands have a strong impact on the global C cycle, in which Land-use changes, land degradation and desertification holds the major share on emission of CO2 into the atmosphere. Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. C Management and land use can be used to mitigate greenhouse gas emissions by encouraging practices that sequester carbon (C) in the soil, thus creating a C sink for atmospheric CO2. Plowing native lands in dry land leads to dramatic losses of SOC through intensive soil disturbance that disrupts soil structure and enhances decomposition, in addition to accelerating soil erosion. Converting degraded lands to perennial vegetation, increasing net primary productivity (NPP) of agricultural ecosystems, and converting plow tillage to conservation reserve program and/or no-till farming are the most principal options to achieve carbon balance. Fruit tree based cropping systems in which the tree–cereal or tree-vegetable combination is useful strategy for mitigating the atmospheric CO2 in both plant as well as in the soil pools. And has maximum CO2 mitigation potential. Converting degraded lands to perennial vegetation and /or protected natural fallow, converting conventional tillage system to conservation reserve program and/or no-till farming system and application of integrated soil management are also use full agricultural practices for dry land carbon management.
Keywords: dry land areas**,** Carbon sequestration, greenhouse gases, SOC

1. INTRODUCTION

Dry land areas are defined as regions in which the ratio of total annual precipitation to potential evapotranspiration (P:ET) or the Aridity Index, AI ranges from 0.05 to 0.65, and include dry sub-humid regions, semi-arid regions, arid regions, and hyper arid regions. These regions cover about 47.2% of the earth's land area or about 6.15 billion hectares, predominantly in northern and southwestern Africa, southwestern and central Asia, northwestern India and Pakistan, southwestern United States and Mexico, western South America, and Australia(Lal, 2004). The world's dry land soils contain 241 metric ton of soil organic carbon (SOC), which is about 40 times more than what was added into the atmosphere through anthropogenic activities, estimated at 6.3 metric ton during the 1990s. Management of both SOC and SIC pools in dry land ecosystems can play a major role in reducing the rate of enrichment of atmospheric CO2. Because of the vast areas and the importance of these soil C pools, dry lands have a strong impact on the global C cycle. However, land degradation and desertification are pervasive in dry land regions, often resulting in emission of CO2 into the atmosphere as well as other environmental degradation (Beniston et al., 2014).

The generic term soil organic matter (SOM) refers to the sum of all organic substances in the soil comprising: a mixture of plant and animal residues at various stages of decomposition, substances synthesized through microbial and chemical reactions, and biomass of live soil micro-organisms and other fauna along with their metabolic products. Soil carbon is the last major pool of the carbon cycle. The carbon that is fixed by plants is transferred to the soil via dead plant matter, including dead roots, leaves, and fruiting bodies. This dead organic matter creates a substrate which decomposes and respires back to the atmosphere as carbon dioxide or methane, depending on the availability of oxygen in the soil. Soil carbon is also oxidized by combustion and returned to the atmosphere as carbon dioxide(Schlesinger, 1999).

The rate of soil organic carbon sequestration with adoption of recommended technologies depends on soil texture and structure, rainfall, temperature, farming system, and soil management. Strategies to increase the soil carbon pool include soil restoration and woodland regeneration, no-till farming, cover crops, nutrient management, manuring and sludge application, improved grazing, water conservation and harvesting, efficient irrigation, agroforestry practices, and growing energy crops on spare lands. An increase of 1 ton of soil carbon pool of degraded cropland soils may increase crop yield by 20 to 40 kilograms per hectare (kg/ha) for wheat, 10 to 20 kg/ha for maize, and 0.5 to 1 kg/ha for cowpeas. As well as enhancing food security, carbon sequestration has the potential to offset fossil fuel emissions by 0.4 to 1.2 gigatons of carbon per year, or 5 to 15% of the global fossil-fuel emissions (Lal et al., 2007).

Peatlands constitute a substantial sink of atmospheric carbon dioxide (CO2) via photosynthesis and organic

matter accumulation, but also release methane (CH4), nitrous oxide (N2O), and CO2 through respiration, all of which are powerful greenhouse gases (GHGs). Lowland peats in boreo-temperate regions may store substantial amounts of C and are subject to disproportionately high land-use pressure (Haddaway et al., 2014).
Increased emissions of greenhouse gases (GHGs), especially CO2, to the atmosphere and their contribution to global warming are one of the most debated environmental issues. Land-use changes, deforestation and forest/soil degradation play an important role in these emissions. These activities were estimated to be responsible for about 20% of the total anthropogenic CO2 emission during the period 1989–1998 (Upadhyay et al., 2013).Soil C pool can be a source or sink for atmospheric pool depending on land use and management. There is a direct relationship between soil C pool and the atmospheric pool. Increase of soil C pool by 1 Pg is equivalent to reduction in atmospheric CO2 concentration of 0.47 ppm, and vice versa(Haddaway et al., 2015).
Compounds that contain the element carbon are referred to as "organic." They are present in all living things. Carbon is continually moving among Earth's lithosphere, hydrosphere, biosphere, and atmosphere in various forms: as carbon dioxide (CO_2) in the atmosphere, sugars or carbohydrates ($C_nH_{2n}O_n$) in living organisms, and calcium carbonate ($CaCO_3$) in rocks and minerals. But the only source of carbon for plants is the atmosphere where plants absorb it in the form of co_2.

- The objective of this paper is to review the carbon management practices in dry land agriculture and their effects on C sequestration and CO2 emission

2. *LIETRATURE REVIEW*

2.1 Carbon Sequestration in Soils of Dry Land Ecosystems

The term soil C sequestration implies transfer of atmospheric CO2 into soil C pool through: humification of crop residue and other bio solids added to the soil, and formation of secondary carbonates or leaching of bicarbonates into the ground water such that CO2 thus captured is not immediately re-emitted. The residence time of C thus sequestered ranges from a few weeks to millennia depending on the nature of carbonaceous substances, stability of secondary carbonates formed and depth of leaching (Lal, 2007).
Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere through respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose. The primary way that carbon is stored in the soil is as soil organic matter (SOM). SOM is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and humus – carbon associated with soil minerals. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere through respiration by soil microbes. Climatic conditions, natural vegetation, soil texture, drainage, and human land use all affect the amount and length of time carbon is stored in soil(Schlesinger, 1999).
Lal and others (1999) estimated historic loss of ecosystem C due to desertification at 9 –14 metric ton of SOC pool, with losses from the biotic/vegetation pool at 10 –15 metric ton. Similarly, (Rajput et al., 2015) estimated that grasslands and drylands of the world have lost 13–24 metric ton C due to desertification. Although all estimates of ecosystem C loss due to desertification are speculative, the numbers are large (20 –30 metric ton).

2.2 **Dry land Carbon management**

Land use and management of agricultural systems is known to change the storage of soil organic carbon (SOC) through variation in land use, tillage, cropping practices (intensity and types of crops), irrigation, fertilization, and other activities. Consequently, management and land use can be used to mitigate greenhouse gas emissions by encouraging practices that sequester carbon (C) in the soil, thus creating a C sink for atmospheric CO2. Moreover, policy makers have included the usage of C sinks for mitigation purposes in international negotiations, set forth in the Kyoto Protocol (Article 3.3 an d 3.4, UNFCCC 1997) (Ogle et al., 2005).
Plowing native lands in dry land leads to dramatic losses of SOC through intensive soil disturbance that disrupts soil structure and enhances decomposition, in addition to accelerating soil erosion. Cultivation also redistributes organic C deeper in the profile through the mixing action of tillage implements.
World soils have been a source of atmospheric carbon dioxide since the dawn of settled agriculture, which began about 10 millennia ago. Most agricultural soils have lost 30% to 75% of their antecedent soil organic carbon (SOC) pool or 30 to 40 t C ha^{-1}. The magnitude of loss is often more in dry land agricultural soils. On a global scale, CO_2-C emissions since 1850 are estimated at 270 ± 30 giga ton (billion ton or Gt) from fossil fuel combustion compared with 78 ± 12 Gt from soils. Consequently, the SOC pool in dry land agricultural soils is much lower than their potential capacity. Therefore, conversion to restorative land uses (e.g., afforestation, improved pastures) and adoption of recommended management practices (RMP) can enhance SOC and improve soil quality. Important RMP for enhancing SOC include conservation tillage, mulch farming, cover crops, and integrated nutrient management including use of manure and compost, and agroforestry. Restoration of

degraded/desertified soils and ecosystems is an important strategy. The global potential of SOC sequestration is estimated at 0.6 to 1.2 Gt C $year^{-1}$, comprising 0.4 to 0.8 Gt C $year^{-1}$ through adoption of RMP on cropland (1350 Mha), and 0.01 to 0.03 Gt C $year^{-1}$ on irrigated soils (275 Mha), and 0.01 to 0.3 Gt C $year^{-1}$ through improvements of rangelands and grasslands (3700 Mha). In addition, there is a large potential of C sequestration in biomass in forest plantations, short rotation woody perennials, and so on. An increase in the SOC pool within the root zone by 1 t C ha^{-1} $year^{-1}$ can enhance food production in developing countries by 30 to 50 Mt $year^{-1}$ including 24 to 40 Mt $year^{-1}$ of cereal and legumes, and 6 to 10 Mt $year^{-1}$ of roots and tubers (Halvorson et al., 1999).

The strategy of soil C management is to increase the amount of crop residues and biosolids to the soil surface through: minimizing soil disturbance, providing continuous ground cover, strengthening nutrient recycling mechanisms, creating a positive nutrient balance, enhancing biodiversity, and reducing losses of water and nutrients out of the ecosystem. There are three principal options to achieve these: converting degraded lands to perennial vegetation, increasing net primary productivity (NPP) of agricultural ecosystems, and converting plow tillage to no-till farming (Figure 3). Degraded lands may involve either agriculturally marginal lands (e.g., too shallow, too steep, too wet, too dry, too rocky, or physically inaccessible) or soils which have been degraded by a multitude of factors leading to decline in soil's physical, chemical or biological quality. Principal degradation processes include soil erosion by water and wind, decline in soil structure leading to crusting and compaction, salinization, nutrient/elemental imbalance, water imbalance (inundation, drought) or invasion by obnoxious species.

2.2.1 Cropping Systems that Increase Soil Carbon Sequestration

In agricultural systems, the amount and length of time carbon is stored in the soil is largely determined by how the soil resource is managed. A variety of agricultural practices that can enhance carbon storage have been proposed. The benefits of these practices as well as their potential hidden costs must be considered when management decisions are made. Though not discussed here, there may also be direct or indirect costs and benefits to farmers implementing these techniques. Removing CO2from the atmosphere is only one significant benefit of enhanced carbon storage in soils. Improved soil and water quality, decreased nutrient loss, reduced soil erosion, increased water conservation, and greater crop production may result from increasing the amount of carbon stored in agricultural soils.

Branca et al. (2013) reported that rainfall distribution is a key determinant of the mitigation effects of adopting specific sustainable land management practices. With the exception of water management, the mitigation effects of sustainable land management adoption are higher in areas of higher rainfall. In general, the evidence base on the mitigation effects of sustainable land management in dry areas water management and agronomic management helps to mitigate more carbon.

2.2.1.1 Conservation tillage

Minimized or eliminated plowing of soil for crop production through practices such as no till (no plow) farming or mulch tillage improves dry land C. These procedures generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the topsoil, leading to a significant increase in soil CO2 sequestration. Conservation tillage can also lower the amount of fossil fuel consumed since it reduces the operation of farm machinery.

Long-term cultivation reduced SOC storage in almost every study based on the response ratios. At a couple of arid land sites, SOC storage remained near levels found under native vegetation. Apparently these soils lost little C with long-term cultivation, but there was a redistribution of C deeper in the profile with plowing. Tillage management had a more variable impact on SOC storage than long-term cultivation in terms of both increases and decreases in storage with the implementation of reduced and no-till practices.

Ogle et al. (2005) stated that Long-term effect of cropland management from 1900 through 1989 on SOC stocks was modeled using the conventional cropping scenario. Subsequently, either continued intensive crop management, or a change to CRP, to reduced tillage or to no-till management was modeled for the 1990–2030 period. The Conservation Reserve Program (CRP) scenario assumed continuous grass cover with no inputs and saves (minimal) fertilizer (Zimmerman et al., 2005).

2.2.1.2 Cover cropping

Many researchers reported that crops such as clover and small grains used for protection and soil improvement between periods of regular crop production. Cover crops improve carbon sequestration by enhancing soil structure and adding organic matter to the soil.

2.2.1.3 Crop rotation

It is sequences of crops grown in regularly recurring succession on the same area of land. It mimics the diversity of natural ecosystems more closely than intensive mono cropping practices. Varying the type of crops grown can increase the level of soil organic matter. Effectiveness of crop rotating varies by region, crop type, and crop rotation timing.

2.2.2 Agroforestry system

Sequestering C through agroforestry is now considered an attractive economic opportunity for mitigating global climate change and C trading in addition to providing multiple products. Tree-based systems with short rotation species either in a farm forestry or agroforestry system have the potential to sequester carbon in a short period. Agroforestry has been recognized as a carbon sequestration strategy because of its applicability in agricultural lands as well as in reforestation programs. The tree component in agroforestry systems is a significant sink of atmospheric carbon due to their fast growth and high productivity. By including trees in agricultural production systems, agroforestry can, arguably increase the amount of carbon stored in lands devoted to agriculture, while still allowing for the growing of food crops (Rajput et al., 2015).

The total biomass production was found to be maximum under the orchard - cereal–cereal 99.25Mg ha-1) land use systems, followed by orchard - cereal–vegetable, orchard - vegetable–vegetable, pure orchard, cereal–cereal, cereal–vegetable and vegetable–vegetable land use systems, respectively in the descending order(Rajput et al., 2015). Fruit based agroforestry systems exhibited significantly higher values of total biomass than the pure orchard and annual based cropping systems. Biomass carbon density in respect of different land use systems revealed that carbon biomass was significantly influenced due to land use system. Maximum carbon density (49.61Mg/ha) was demonstrated by orchard - cereal–cereal based land use system which was closely followed by other fruit based cropping systems only.

a study in different land use types (30,599 ha) cover a large proportion of total area having forests, plantation and agricultural land (18%, 22% and 56% respectively) was conducted and the total amount of carbon stored were 2977.23 Gg C, 2211.85 Gg C and 2091.54 Gg C, respectively (Kumar et al., 2010). These results indicate that a relatively large proportion of the C loss was due to the conversion of forest to agricultural land.

Vertical distribution of SOC varied among three land-use types (forest, reforestation and agricultural land). The overall average proportion of SOC was higher in the forest and the reforestation than in the agricultural land. In all land-use types, the deposition of SOC was generally higher in the top soil (0–20 cm) and decreased with soil depth. The highest proportion of SOC content was deposited in the 0–20 cm depth. SOC content was found to be 30.04%, 35.76 and 44.25%, in the forest, reforestation and agricultural land respectively. The total SOC content in the forest (196.24 ± 22.81 Mg·ha-1) was significantly higher than the content in the reforestation (146.83 ± 7.22 Mg·ha-1) and the agricultural land (95.09 ± 14.18 Mg·ha-1)(Pibumrung et al., 2008).

SOC pool and soil properties are heavily influenced by land use. The SOC is generally found to decrease rapidly following the conversion from a natural to agricultural ecosystem. Soil C loss in the agricultural land is caused by cultivation along with removal of crop production and crop residues.

fine root carbon (FRC) in forest was much higher than in reforestation and the agricultural land. A study found that highest proportion of FRC content was in the top layer of soil in the agricultural land (70.68%), followed by the reforestation (49.08%) and the forest (42.81%). However, the plant composition in each land-use type evolves differently due to the root structure of annual and perennial plants. The total root carbon content decreased from 25.51 Mg ha-1 in the forest to 1.91 Mg ha-1 in the agricultural land (Pibumrung et al., 2008).

2.2.3 Natural fallow

Beniston et al. (2014) reported that cropland soils contained significantly less SOC than the grassland soils from 0 to 40 cm depth, and at 80 to 100 cm depth. The cropland soils contained 30 % less SOC in the top 60 cm, and 25 % less SOC up to 1 m depth, than the grassland soils. SOC concentrations declined significantly with increasing depth in both systems. There was 15 % less SOC from the 40–80 cm depth in the croplands compared to the grassland.

Land-use change from a grassland where deep rooting vegetation types predominate to wheat, which has a much smaller root system, caused a significant loss of SOC over 75 years. The natural abundance C-density values of the native grasses compared to the crop allowed the mean residence times for the different pools to be estimated. The SOC content of all soil C pools was reduced and was less in the sand-sized fractions, which had the most rapid Mean residence times of the soil pools (Beniston et al., 2014).

Intensification of agriculture and land-use change from grasslands to croplands are generally known to deplete SOC stocks. The depletion is exacerbated through agricultural practices with low return of organic material and various mechanisms, such as oxidation/mineralization, leaching and erosion (Bo Söderström and Jørgensen, 2014).

perennial biomass feed stocks had much lower emissions per unit harvested biomass compared to maize grain production ((Wightman et al., 2015) as annuals require more energy to establish the system while perennial grass and willow only require one planting every 10 or22 years. In the case of maize Stover where all production costs and emissions were attributed to the grain, emissions are low. Emissions ranged from 0.01 MgCO2e/Mg for hardwood to 0.61 MgCO2e/Mg for maize grain.

2.2.4 Agricultural Intensification and integrated nutrient management

Adoption of recommended management practices (RMPs) on dry land soils with good supplemental irrigation can increase SOC concentration. Enhancing water use efficiency (WUE), by reducing losses due to surface runoff and evaporation and decreasing soil temperature by residue mulching, is important.

(Zhang et al., 2016) indicated that both control and synthetic fertilizer applications ensured not optimum SOC but only the manure amendment significantly elevated SOC content. Additional strategies aimed at reducing CO2 in the atmosphere include tree planting and ocean sequestration of carbon. As forests grow, for example, they store carbon in woody tissue and soil organic matter. The net rate of carbon uptake is greatest when forests are young, and slows with time. Old forests can sequester carbon for a long time but provide essentially no net uptake. production of "second generation" biofuels from cellulose, for example, has the potential to decrease greenhouse gas emissions relative to gasoline or corn ethanol. Cellulosic ethanol is produced from crop residues (e.g., stalks, hulls), forestry residues (e.g., forest thinning, wood byproducts), energy crops (e.g., switch grass), and sorted municipal wastes. All of the above efforts combined may reduce CO2 concentrations in the atmosphere and help alleviate the impacts of climate change.

application of 100% &150% of recommended dose of N through FYM enhanced the organic carbon content of soil significantly over that of control. Microbial biomass carbon was ranged from 178 mg kg−1 in control to 340 mg kg−1 in 100% of recommended dose of N through FYM, where 120 kg N/ha were applied through FYM(Verma et al., 2010).Do Kyong Lee (2005) reported that high amount of C (800mg/kg) were found from manure applied soils while low(200mg/kg) of C was found from synthetic fertilizer(NP) applied soils.

2.2.5 Livestock integration into dry land farming systems

The impact of livestock activities on the dry land environment is either direct like grazing or indirect through production of forage crops for narrowed livestock feeding. Presently, livestock production accounts for 70 % of all world agricultural land and 30 % of the Earth's land area (Teferi et al., 2013). In relation to ecological conditions and environmental changes, the increase in the demand of animal products affect more intensely grasslands in arid, semiarid, and tropical.

Despite the inherently low SOC sequestration rates that have been reported in grasslands when compared with other land uses, their global impact can be significant given the surface covered by this land use. The potential C storage in grasslands varies according to climatic conditions and management. For instance, soil C contents of 200 Mg C ha−1 in the first 100-cm soil depth in annual grass-dominated rangelands in California was recorded (Plaza-Bonilla et al., 2015).

3. CONCLUSION

Fruit tree based cropping systems in which the tree–cereal or tree- vegetable combination is useful strategy for mitigating the atmospheric CO2 in both plant as well as in the soil pools. And has maximum CO2 mitigation potential. Converting degraded lands to perennial vegetation and /or protected natural fallow, converting conventional tillage system to conservation reserve program and/or no-till farming system and application of integrated soil management are also use full agricultural practices for dry land carbon management.

Land-use change from a grassland where deep rooting vegetation types predominate to cereal crops, which has a much smaller root system, causes a significant loss of SOC over long period of time. SOC content of all soil C pools was reduced and was less in dry lands, which had the most rapid Mean residence times of the soil pools SOC pools (KMnO4-oxidizable and microbial biomass carbon) are more sensitive to the alteration of nutrient management practices. It appears that organic materials with wider C/N ratio (e.g., FYM and CR) had more impact on relatively stabilized fractions of SOC (quantity).

A meaningful fraction of C in dryland soils has been lost as a consequence of inadequate management practices and land use decisions. Global warming may exacerbate the current scarcity of water that most dryland areas face, thus adding great challenges for agricultural production and social development. However, with proper decisions, soils in dryland areas have a large potential to sequester C and will result in positive regional and global externalities.

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