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Review Article

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The role of mycorrhiza in food security and the challenge of climate change

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ABSTRACT
Before the Industrial Revolution, the concentration of CO_2 in the atmosphere was 280 ppm and in time increasing fossil fuels use increased CO_2 concentration up to 416 ppm in a preset time. Meanwhile, increasing population growth (around 8 billion) has also started to put serious pressure on soil ecosystem for more food production demand. With the demand for more food production, intensive chemical inputs and soil cultivation practices applied to the soil has increased the amount of CO_2 released to the atmosphere. Increasing CO_2 concentration in the atmosphere triggers global warming and climate change which is negatively affect plant growth and consequently food security. In order to ensure food security under climate change conditions, it seems that the need to re-enact nature's own mechanisms has arisen. In this context, it is aimed to reduce the effect of climate changes by keeping more carbon as a sink by operating the effects of plant root mechanisms on the soil health according to ecological principles. Under long term filed conditions the effects of different soil-plant managements, especially mycorrhiza fungi, were investigated. Since 1996, several researches have been carried out under long-term field studies to see the effect of mycorrhizal fungi and other microorganisms on carbon sequestration, as well as the emission of CO_2 from the greenhouse gases to the atmosphere. Regularly CO_2 flux, emissions, photosynthesis rate, C, N sequestration and yield parameters are measured. Data are yearly evaluated. Results revealed that under long-term field conditions, organic fertilizers application and mycorrhizal inoculation sequestered more carbon in soil profile. It has been shown that, using animal manure, compost, biochar, nitrogen-fixing bacteria and mycorrhizal fungi significantly kept more carbon in plant tissue and soil. It is determined that there is an increase of 1.5 ppm CO_2 concentration in atmosphere per year. It has been determined that especially long-term addition of organic matter and management of natural mycorrhizae increase soil organic carbon and accordingly soil quality and productivity increase. As the effect of climate change and population growth have significant negative impact on food security, definitely a new agriculture revelation is needed to overcome of climate and food security problem. Soil and plant management must be managed according to low-input ecological principles.
Keywords: Greenhous gasses, Climate changes, Soil organic carbon, Soil-crop management, food security, mycorrhizal management

INTRODUCTION

Since the 20^{th}-century ever-increasing human population, depletion of global fertilizer (especial rock-phosphorus) sources and growing energy prices make current fertilizer production unsustainable and represent sizeable challenges to global food security Thirkell et al. (2017). Largely in developed countries because of using chemical pesticides, nitrogen and phosphorus-rich fertilizers, advances research in plant breeding dramatically increased agricultural productivity. However, because of crop biological production capacity in the last 20 years nearly many crop yields have plateaued.

Recently fossil carbon sources which are rapidly consumed for the increasing energy requirement, increase the carbon dioxide (CO_2) gas released into the atmosphere. CO_2 concentration in atmosphere is increasing exponentially. Since the industrial revolution around 1850, concentration of CO_2 has increased by 31% from 280 ppm to 380 ppm till 2005, and increased at the rate of 2 ppm year or 0.46% yr^{-1} (WMO 2006; IPCC 2007), and the current value is 415 ppm (Figure 1).

The annual mean increase rate for the past decade was ~2.08 ppm yr^{-1}. Atmospheric CO_2 concentration have significant effects on climate change and consequently have effects on the sustainability of ecosystem. The factors affecting the CO_2 emission from agricultural practices are crucial for global warming Figure 2.

Increased atmospheric CO_2 concentration negatively affects the functioning of the ecosystem. Elevated impact of CO_2 and climate change situation directly threatens food security. The rising atmospheric CO_2 concentration directly cause global climate change. Agricultural ecosystems have the significant potential to increase carbon sequestration in the soil systems. On the other hand, Agricultural lands are used for purposes other than their intended use. Gradually, the existence of agricultural lands is decreasing. Climate changes, global warming, drought reduce soil moisture content and adversely affect crop productivity.

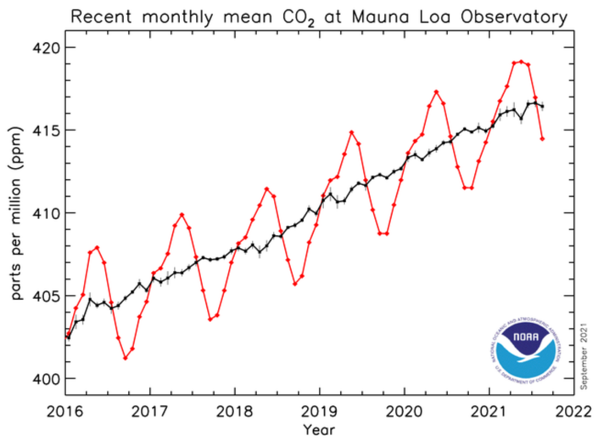


Figure 1. Recently measured atmospheric CO_2 concentration (Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases (noaa.gov) https://gml.noaa.gov/ccgg/trends/).

Since agricultural revelation human cultivate native ecosystems (e.g., peatlands, forests, grasslands) soil. With land-use soil accumulated OC is depredated and C loos is increase.

Sanderman et al. (2017) used HYDE v3.2 land-use dataset to predict the temporal evolution of soil OC stocks due to changes in land use alone. And they were estimated that a low annual rate of SOC loss (<0.05 Pg $C \cdot y^{-1}$) until AD 1800 and followed by a century of losses was > 0.3 Pg $C \cdot y^{-1}$, with a slight moderation of this rate during 20 century (0.13 Pg $C \cdot y^{-1}$) (Figure 2.)

Increased atmospheric CO_2 concentration is expected to increase global warming in between 1.5 to 4 ºC. It seems there is an imperative reduction in agricultural greenhouse gas emissions to atmosphere. For a large-scale emi and CO_2 removal needed to hold global warming below the 2 ºC threshold in the Paris Agreement (Paustian et al., 2020).

The climatic conditions such as precipitation and temperature directly influence the soil moisture. Soil moisture and temperature are the major factors controlling the rate of organic matter decomposition through their influence on microbial activity. Soil tillage and irrigation systems are the major agricultural practices to minimize CO_2 emissions under the Mediterranean soil conditions (Franco-Luesma et al., 2020). Also, low chemicals input and low-disturbance soil management as means of fostering soil biota communities. Many research results show that reduced tillage reduces the oxidation of organic matter.

Because of an increase in world population, global food production demand is increasing. Also growing populations and climate change have a significant procure on land and food and nutrition security as well. With heavy fertilize use soil is polluted and no more yield is increased. Day by day food security task is getting a challenging task. There is a new challenge is needssion reduction to have a climate-smart and sustainable agriculture management system. The role of soil biota especially AMF is believed to be of paramount importance (Sosa-Hernandez et al., 2019). Also, in other to mitigate the atmospheric CO_2 gases using organic fertilizers, symbiotic organisms, use of crop rotations and cover cropping with deep rooting mycorrhizal plants are vital important.

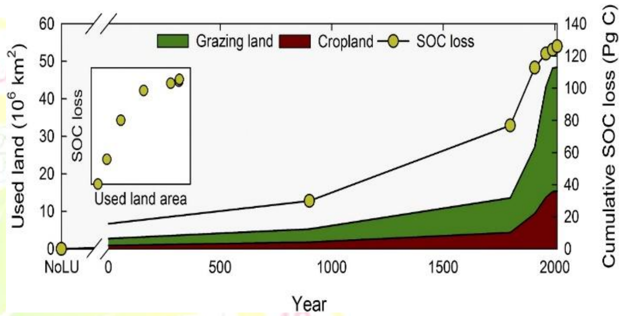
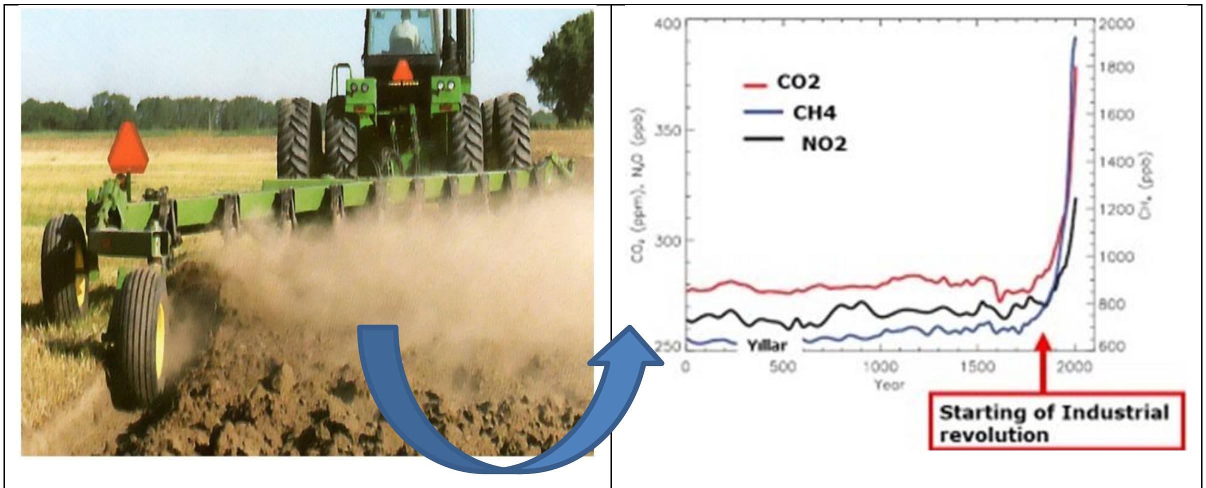


Figure 2. since 10000 years to update land use area and carbon mineralization relationship (Sanderman et al., 2017)

Factors affecting CO_2 emission

Agriculture and it management is an important contributor to greenhouse gases emissions; it is also a source of carbon store in soils. Soil carbon (C) is a dynamic and integral part of the global C cycle (Lal, 2010b). Since agriculture has an impact on climate change and agricultural management will be important to control mitigation of greenhouse gases from agriculture. Soil and crop management practices such as tillage, irrigation, fertilization, residue management, crop rotation have a significant influence on amount of CO_2 emission. Air temperature, precipitation, soil temperature, soil moisture, soil organic matter content and quality have influence on CO_2 emission. Not only CO_2 but other gases such as CH_4 and NO_2 also increase as well (Figure 3) Conventional agriculture is responsible for 25% of the greenhouse gases emission and global warming (e.g. 25% CO_2, 60 - 65% N_2O, and 70% CH_4). Mainly mechanized agriculture produces a substantial amount of CO_2 as a result of degradation and erosion. Disrupts of macro aggregates and breaks them into micro aggregates by letting in oxygen and releasing CO_2. Not only CO_2 but other gases also have effect on climate change. Climate change is directly related with soil. Greenhouse gas emissions are influenced by soil and crop mmanagementsuch as tillage, fertilizers ususend cropping cultivation.



Effects of soil management on CO_2 emission	Other greenhouse gases rather than CO_2

Figure 3. Greenhous gases concentration increases in to atmosphere

As can be seen in Figure 4 increased frequency of Mediterranean drought is obvious. Mainly in Central Anatolia and South East Anatolia are under doughtiness and consequently under high soil degradation. The major problem for cost of Mediterranean area and West Asia is water deficiency, low organic matter, erosion, salinization, degradation and desertification. Enhanced soil erosion depletes soil fertility and increases CO_2 emission and CH_4 from erosion –induced transport of SOC (Lal, 2003). Soil degradation, increasing atmospheric CO_2 level can increase temperature and cause water deficiency and consequently within time yield is supposed to be decreased. Possible climate change pressure, crop yields may decrease 11%. In a model work, it has been estimate that increase in air temperature by 2-3 ^{o}C, till 2070 wheat and maize biomass will decrease by 4 to 17 %and water demand will increase (Aydin et al., 2011).

Rainfall especially in the East Mediterranean countries such as Syrian, Israel and Turkey (Figure 5) is lower than plant growth demand. In Central Anatolia and South East Anatoly receives annual rainfall of less than 300 mm. For Turkey, low precipitation is 250 mm, high precipitation is 2500 mm and average precipitation is 643 mm/year. Thus, in arid and semi-arid regions, water demand for irrigation will increase by at least 10% with increase in temperature by 1°C (Fischer et al., 2002; Liu, 2002). Accordingly, SOC and soil fertility is declined. Arid and semi-arid region soils have low organic matter contents because of high temperature and decomposition rates. Soil organic matter and relation with erosion potential is directly related with climate change. Since Turkish soil's organic carbon content is low (around 1%), 72% of whole soil are under high risk of wind and water erosions.

Soil and crop management have significant effect on climate change. Also, there is a strong relation between climate change and soil quality. Soil quality is very important for atmospheric CO_2 elevation and mitigation of climate change. Since the area's climate is harsh, and agricultural production depends on rainfall.

What is the direct effect of climate change on ecosystem and human life?

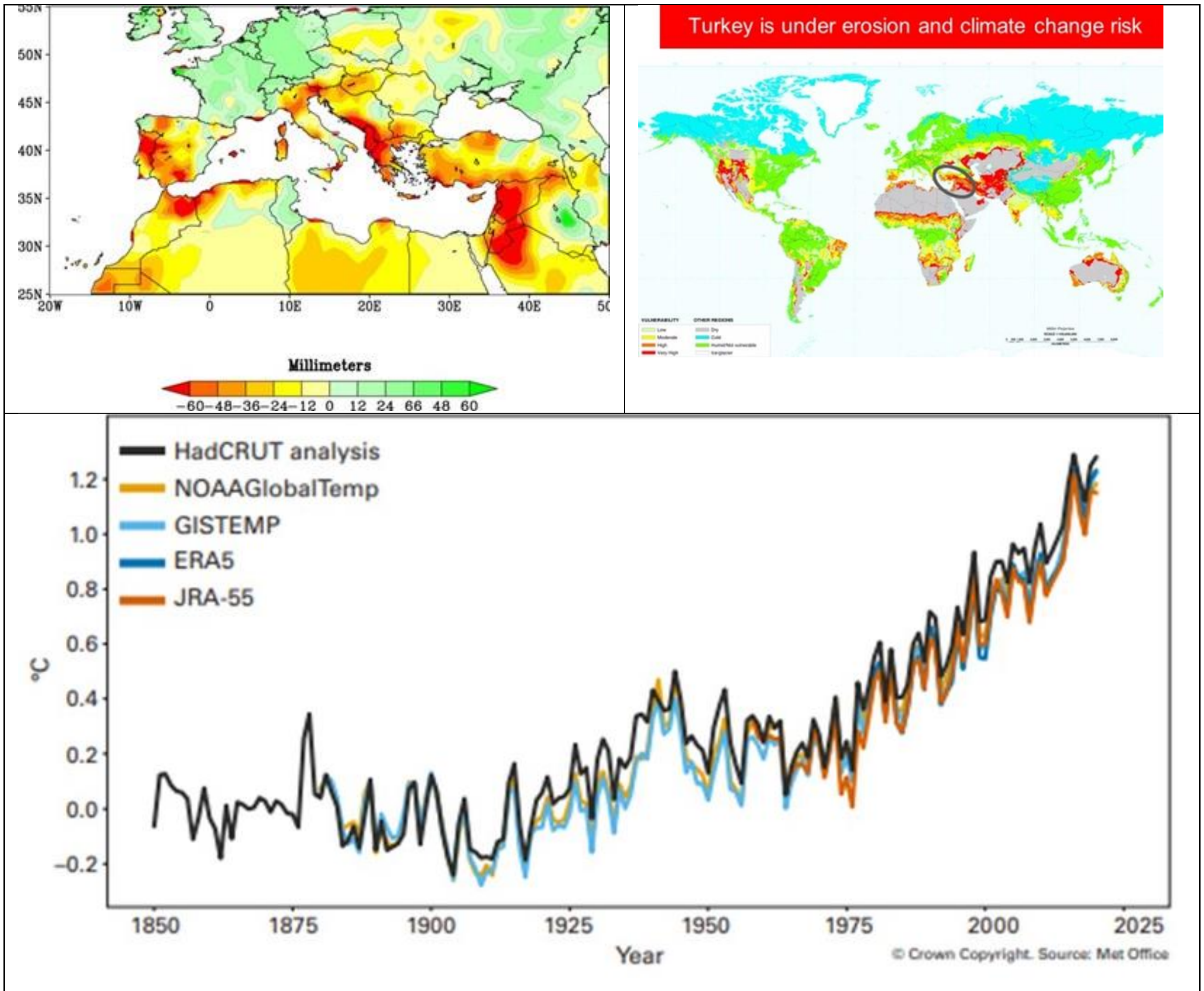
Increased C: N balance of plants,
Decreased plant protein,
Increased chemical defenses,
Resulting in: Reduced growth and /or
Increased compensatory feeding.

To have a better and sustainable food security, soil sustainability should be secured. This mainly depends on soil organic carbon pool and carbon sequestration (Ortas, 2016; Ortaş, 2017; Ortaş et al., 2017).

How Much Carbon is In Soils?

Agricultural soils can be both a storage and source of atmospheric carbon dioxide and can be managed to restrained the CO_2 emissions. Because of its crucial role in soil chemical, physical and biological characteristics, soil organic matter (SOM) or SOC is an significant component of soil fertility, productivity and quality. Lal (2004) calculated C pool in soil and atmosphere in which the soil organic C (SOC) pool is 3.3 times higher than atmospheric pool and 4.5 times of the biotic pool. All the CO_2 in air is only 40% of soil's total carbon holding capacity.

Compared to that in rocks and ocean, there is extremely less CO_2 in atmosphere. Thus, if greenhouses gas inputs and outputs are not closely balanced atmosphere would become overwhelmed especially with CO_2. Scientists believe increasing amount of carbon sequestered into the soil can impact global atmospheric CO_2 levels (Lal and Pimentel, 2008). So far, many scientists estimated total C pool in atmosphere, ocean, biosphere, soil and rocks. Soil has about 1500 Pg of carbon and 133-140 Pg of nitrogen worldwide.



Doughtiness of Mediterranean region	World erosion map

Figure 4. Effects of climate change on doughtiness and organic carbon concentration in the Mediterranean area.

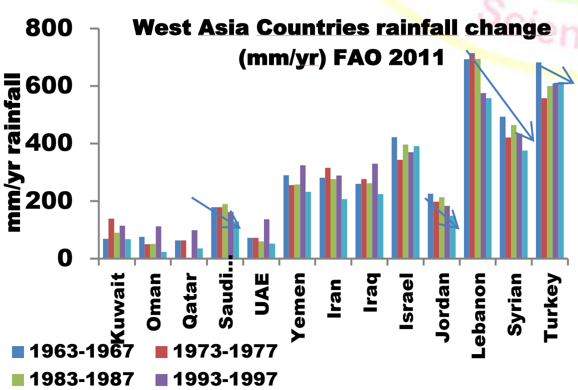


Figure 5. Rainfall in Middle East in different time internal (Ortas and Lal, 2011).

Since soil organic carbon is the main engine for the majority of soil parameters, in order to fix atmospheric carbon to soil the research question and its logic need to be set up correctly. For this work research question**;** By which plant and soil mechanisms can we reduce the effect of CO2, whose concentration in the atmosphere has increased, on climate changes? Rhizosphere beneficial organisms such mycorrhizae, exudates and soil carbon fixation capacity.

Monitoring CO_2 is Very Important

Increasing SOC can play an important role in mitigating greenhouse gas emissions. Thus, any small changes to the soil carbon pool may influence global C stability (McNally et al., 2015). The changes in soil management such as fertilization, crop rotation and soil quality cited as primary factors in the change of soil organic matter from native levels (Gregory et al., 2016). Also under long term inorganic and organic fertilizers management also enhanced SOC pool (Ortas and Bykova, 2020). Especially organic fertilizers and mycorrhizal inoculation are significantly accumulating more carbon sequestration in to soil. The SOC concentration directly affected biomass production (Ortas and Lal, 2014) by improving soil quality (Lal, 2009). Improvement in soil fertility through nutrient management is also important to SOC sequestration (Lal, 2005) as well.

Soil management have significant effects on C and N mineralization (N loss) and increased CO_2 flux (C loss) into atmosphere. In this changing process, plant and bacteria population responses to gasses fluxes (Figure 6). Since soil is a sink for atmospheric CO_2, thus reducing CO_2 emissions which is normally associated with agricultural ecosystems, and mitigating the 'greenhouse effect' can be storage in the soil. There are several techniques to capturing atmospheric CO_2 which can be fixed to terrestrial and water ecosystems.

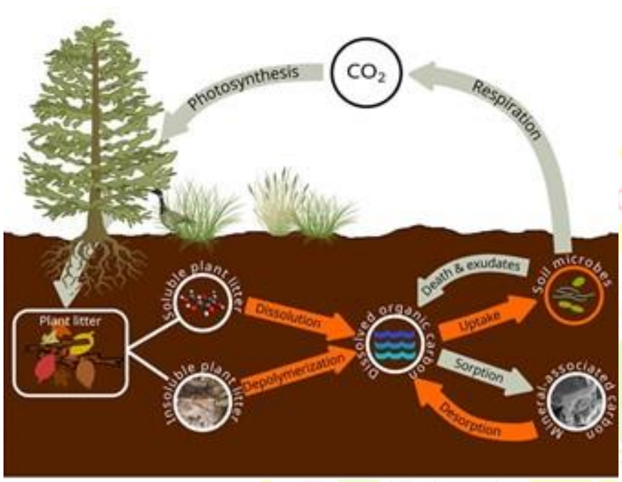


Figure 6. Carbon cycles respiration and photosynthesis process (Woolf and Lehmann, 2019)

Since the soil and crop management systems such as tillage, water and cultivation have effects on soil degradation and CO_2 flux, it is important to monitor and measure CO_2 flux from the soil into atmosphere for a better understanding terrestrial carbon stocks and cycle on climate change. Bationo and Fening (2018) reported that the soil C stocks reflect a balance between C input and C loss during decomposition, erosion and leaching. Soil organic matter content and soil C stock is varied an estimated that 1400-1600 Pg (Peter gram = 10-5 g=million metric tons) organic C and 700-900 Pg inorganic carbon. In cold and wet environment organic C are highest, however in duster and tundra soils is lowest. (Horwath and Kuzyakov, 2018) reported that the average lower and upper limits for agricultural SOC sequestration are 0.14 and 0.38 Mg g C ha^{-1} y^{-1}, respectively. It was estimated that an average critical C input of 2.0 Mg C ha^{-1} y^{-1} (Wang et al., 2015). Soil C input is needed to maintain existing soil C level in global crop and soil, management and also climatic conditions as well. The actual amount of C sequestration depends on soil and crop management approaches (e.g., residue retention and organic and inorganic fertilizer input) and environmental conditions.

Previously Fornara et al. (2016) indicated that in the course of 43 years of liquid manure applications at one site, SOC stocks had increased by ~21 Mg ha^{-1} as compared to control treatments. In generally organic and/or inorganic fertilization application on SOC dynamics are certainly more complex than a simple change in carbon inputs. Conant et al. (2001) found a significantly positive effect of both organic and inorganic fertilization on SOC stocks with an annual carbon sequestration rate of 0.3 Mg ha-1 y-1.

Cai and Qin (2006) reported that in 0-20 cm soil depth, there was a significant logarithmic relationship in between plant roots and compost input with organic carbon content. Keeping more C sequestration in soil depth is the vital important. Research has shown that the optimum level of organic carbon in the soil; crop rotation, tillage and fertilization are effective (Gong et al., 2009; Jagadamma and Lal, 2010). Most of the farmers are potentially amenable to adopting no-till or reduced tillage practices because of low-input cost under these practices compared to other conventional tillage practices.

Role of Plant Root on Carbon Fixation and SOC Budget.

Agriculture, natural vegetation (food supplier for animal) and forestry under good management strategy is an example of the management of a modified ecosystem to yield for optimal productivity. Also, management of the soil microbes that live in the rhizosphere of nearly all terrestrial plants which are getting more attention as well. New innovative technologies including plants produce carbon compounds through the photosynthesis, and part of that carbon is subdivided to the roots and microorganisms.

There is a close relationship in between the ratio of relative extension rates in a nutrient-rich soil to that in a nutrient-poor soil and the mean root diameter of terminal roots among many plant species. Root growth is strongly affected with nutrient supply. Under the controlled conditions (Drew, 1975) used barley (Hordeum vulgare) plants to test the effects of mineral nutrient on root growth. He funds that only part of plant root system exposed to high concentrations of phosphate, nitrate (NO3−), ammonium (NH4+) or potassium (K) responded by increasing nutrient concentration. The length and number of primary and secondary laterals given high response to phosphate, NH4+ and (NO3− but not potassium nutrient increase (Figure 7).

Since mineral elements especially nitrogen and phosphorus nutrient have significant contribution on root growth, this has any effects on soil organic carbon. Although Paustian et al. (2020); Van Groenigen et al. (2017) strongly rejected the nitrogen have no effects on carbon fixation. It was indicated soil C:N ratio should be 12:1 (Van Groenigen et al., 2017). Carbon demanded by plant root by free-living microorganisms such as mycorrhiza is very important natural mechanisms to be managed. At the moment photosynthesis is the most powerful mechanism/tool to mitigate the atmospheric CO_2 capturing.

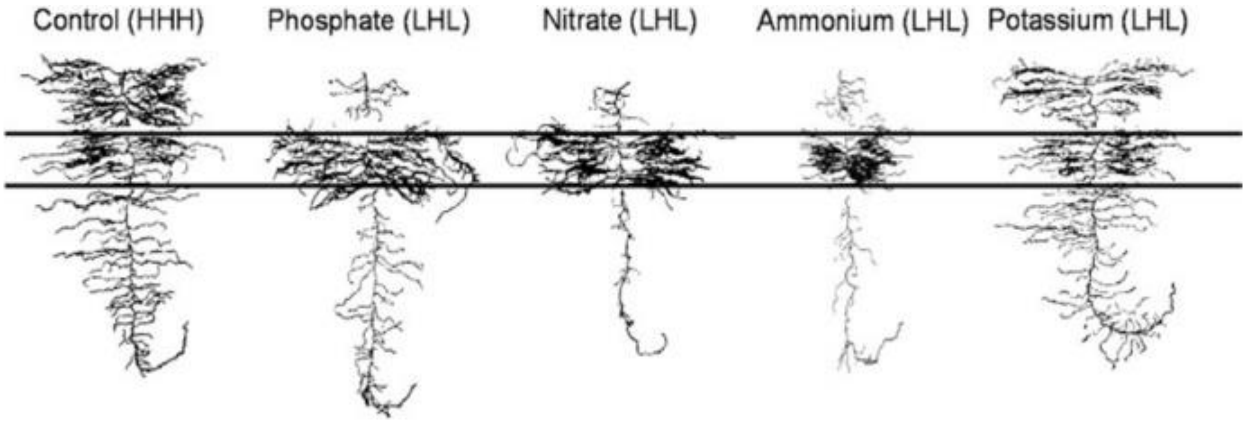


Figure 7. Proliferation of primary and secondary laterals by barley (*Hordeum vulgare*) seedling grown in solution culture with the middle root section exposed to a 100-fold greater concentration of phosphate, NH_4^+ , (NO_3^- and K^+ ions (Drew, 1975).

Important of Soil and Crop Management on Climate Change

Globally a soil, plant and climate-mitigation strategy should be taken account in soil-crop management specific aspects. It may be better to identify the import areas where SOC storage can improve soil quality and crop yields. To motivate farmers to storage SOC in their land some priority areas should be selected and also supported by governments, Other forest and natural vegetative regions can be excluded for wild life and ecosystems restoration.

Management practices such as reducing or no-tillage application of mineral fertilizers (Zhao et al., 2016); use of organic fertilizers including biochar, compost or animal manure. Also crop residue managements, such as eliminate open field burning or removal, use of cover crops (Mazzoncini et al., 2010), and crop rotation diversity (i.e., including deep root crops (Peixoto et al., 2020). Deep root plants cultivation should be considered for increasing soil SOC content of less fertile soils. Cultivation of deep-rooting crop species such as alfalfa, sunflower and grasses are able to transfer carbon (root exudates) into subsurface depth. Deep-rooting crops also can use water and nutrients resources from the subsurface depth, preventing N leaching and making plants more resilient to drought conditions. It has been indicated in several works the conversion of natural or semi-natural ecosystems to man-managed agroecosystems determines a reduce in SOC stocks (Schlesinger and Bernhardt, 2013). Also Cerri et al. (2007). Reported that the conversion of forest to pasture may result, over the long-term in similar or even higher OC stocks, despite an initial decay of soil organic carbon stocks The uncertainties associated with guessing SOC are the largest due in part to natural soil variation and lack of extensive soil sampling (Eswaran et al., 1993). Knowledge of spatial patterns of SOC pool is essential for development and identification of techniques for conserving and enhancing the terrestrial C pool. Paustian (2005) indicated that the significant deriver of soil C change, both past and future is depended on land use and management. Sweet sorghum is a drought tolerant C4 double sugar crop well-adapted to grow on degraded lands as well.

In general, use of organic fertilizers increased SOC pool compared with that of chemical fertilizers and control treatments. Such an increase may be due to the maintenance of plant residues and root biomass, and hyphae and other soil biological factors that increase the SOC in deeper soil layers. In Germany, the data on agronomic yield indicated a strong relationship between SOC concentration in the rhizosphere area and grain yield of wheat. Regression equations in these graphs were used to recalculate the relationship between soil organic carbon concentration and the agronomic yield of wheat, pepper, and maize crops (Lal, 2010a). Similar work was done by Ortas and Lal (2014) and it was found that under long term organic fertilizers application increase whish and maize plant yield.

Soil and crop management effects on soil organic carbon pool calculation is useful for better management. The Kızıltaper soil series in the Mediterranean Basin, (Ozbek et al., 1974) located in the Çukurova University experimental farm contains olive and citrus orchards established in 1974, and update, where some tree plants were uprooted unfortunately for construction purposes. The carbon budget of the bulk and root-zone soil of these trees was calculated during the struggle against the inappropriate use of the land to prove the value of the olive root zone in sequestering carbon. From 1974 to 2010 carbon content after the 36 years of the establishment of the orchard was higher in carbon in the rhizosphere when compared to the non-rhizosphere soil (Table 1). More carbon accumulated in rhizosphere (root-zone) than in the non-rhizosphere soil. It is better to concentrate on rhizosphere management for high carbon accumulation.

Mycorrhiza İncreased Soil Organic Carbon Content

The mycorrhizal state is one of the associated microbes with plant roots for better growth and survival of plants. Majority of important horticulture and filed crops form symbioses relationship with arbuscular mycorrhizal (AM), and this has help to get more mineral nutrients and water availability. factors.

Table 1. Soil carbon sequestration change from 1974 to 2010 under cultivates land

Sampling Time	Soil Horizon	Soil Depth	Organic Carbon	Bulk density	Soil Organic C	Differences from 1974 to 2010
2010		cm	%	G cm^{-3}	Mg ha^{-1}	
Non-rhizosphere	Ap	0-13	1.45	1.3	24.5	6,4
	Bt1(BA)	13-28	0.93	1.3	18.1	-22,9
	Bt2	28-43	0.99	1.4	20.7	5,5
2010						
Rhizosphere	Ap	0-20	2.43	1.25	60.8	34,4
	Bt1	20-40	1.62	1.3	42.2	22,3
	B2t	40-60	2.11	1.5	63.3	15,2
1974	Ap	0-11	1.32	1.25	18.1	
Non-rhizosphere	B1	11-38	1.21	1.25	41.0	
	B2t	38-50	1.11	1.15	15.2	

Not: C and N sequestration was calculated on base of 1974 and 2010 year's data (Ozbek et al., 1974)

In majority of crops AMF symbiosis can be highly beneficial in many ways such as improving soil structure, resistance to biotic and abiotic strass. AMF is a significant part of agroecosystems to mitigate atmospheric greenhouses CO_2 gases. Mycorrhizal fungi also can help the plant to capture more CO_2 by mitigation of atmospheric CO_2. The mediated effects of AMF on plant growth can increase net primary production, potentially resulting in greater carbon sequestration, particularly in nutrient-limited environments. Root and mycorrhizal fungi are the main sources have significant effects on rhizosphere dynamic changes. Since the mycorrhizal hyphae and roots are food for other organisms and become part of the nutrient cycling at the rhizosphere, some other organisms are also involved to root growth. It has been shown that mycorrhizal plants also have lower root: shoot ratios than their non-mycorrhizal counterparts (Baas and Lambers, 1988). Since mycorrhizal root system are more efficient per unit root nutrient uptake and transplanted to the shoot comparison on mycorrhizal roots. In a split pot experiment it was found that mycorrhizal inoculated citrus root systems receive nearly 6-8% more of current photosynthetic than non-mycorrhizal root systems (Douds et al., 1988).

Colonization of plants by AM fungi results in both increased transfer of photosynthate to the roots (Wang et al., 1989) and root proliferation (Torrisi et al., 1999). Colonization of arbuscular mycorrhiza fungi (AMF) play an important role in SOC build up and stabilization. Cambardella and Elliott (1992) reported that the particular organic matter C in the native sod represented 39% of the total soil organic carbon. Net C changes depend on the magnitudes of increase in soil C inputs and microbial activity.

It has been indicated that carbon is originating from the host photosynthesis and need to support the growth of fungi. Mycorrhizal inoculated C3 and C4 plants allocated 3.9% more recently fixed photosynthesis C to belowground than did their non-mycorrhizal (NM) counterparts (Rezacova et al., 2018). In another work, Snellgrove et al. (1982) measured carbon allocation in three different experiments and they found that nearly 7% of more total fixed C was translocated from shoot to root in M plants than compared to NM plants. If 10% of the annual C fixed by plants was stored in soils as humus, as suggested by Follett et al. (1997) for crop residues, then about 5 g C m^{-2} per year which would be stored in the soils. In many works, it has been shown that mycorrhizae have the potential to increase net soil C gain.

Mycorrhiza need carbon for three reasons such as production fungal hyphae, fungal respiration and for increase the host tissues metabolism. Mycorrhizal plant has been estimated that C requirement ranged from 4 to 20% of fixed C (Douds et al., 1988). Similarly it has been estimated that measurements of plant carbon allocation to mycorrhizal fungi have been estimated to be around 5-20% of total plant carbon uptake (Pearson and Jakobsen, 1993). In some ecosystems also the biomass of mycorrhizal fungi can be comparable to the biomass of fine roots as well. AMF colonization would help to agricultural practices such as low-till, low input of chemicals and increase plant quality. Intraradical hyphae can occupy 5% of the volume (Schwab et al., 1983), also reported that 2-17% of dry weight of root system is mycorrhizae hypha (Kucey and Paul, 1982).Root and mycorrhizae hyphae release organic compounds such as polysaccharides, carbohydrates, lignin and lipids are making aggregate. Most of the fixed carbon is hidden in aggregates as a SOC. The aggregates also play an important role in stabilizing SOC and act and play a significant role to storage more carbon in soil (Ortaş et al., 2017; Ortas, 2017). The results of Ortas et al. (2013) showed that mean weight diameter (MWD) values of soil aggregates were positively correlated with values of total hyphal length and hyphal density of the AM fungi utilized. They also indicated that the MWD of macro aggregates of 1-2 mm diameter, was significantly higher in mycorrhiza inoculated soils compared to the non-mycorrhizal soils.

Under long term field conditions mycorrhizal inoculation compare to control and mineral fertilizer increased soil organic carbon content. Especially in 0-15 cm surface soil (Table 2). In 0-15 cm soil depth, after 23 years in control treatment 0.30 Mg ha-1 SOC accumulated, in mineral fertilizer 3.57 Mg ha-1 and with mycorrhiza and compost application 10.42 Mg ha-1 SOC was gained. In the same experiment area previously Ortas et al. (2013); Yucel et al. (2020) showed a significant increase in fresh and dry mater yield (tons per hectare) in response to all the organic fertilizer applied in comparison with mineral fertilizer and control treatments. The highest increase was observed in animal manure (25 tons per hectare) treatment followed by compost (25.0 tons per hectare), and Com +Mycor. (10 tons com per hectare) in the fresh and dried stover yield of the maize crop. Our results like all previous works are shown that different soil use types have an influence on SOC pools (Sainepo et al., 2018).

Nieder et al. (2003) reported that animal manures are more effective than any plant residues in contributing to the labile soil organic matter pools, because they have already been subjected to the speedy initial decomposition. Liu et al. (2010) indicated that under long-term additions of animal manure have the most beneficial effects on grain yield and soil quality among the investigated types of organic fertilization. However, the frequent addition of animal fertilizers will significantly effect on C and N coupling with potential consequences for changes in soil C and N stocks. Eriksen and Mortensen (1999) showed the application of manure or mineral fertilizers increased the content of organic C and S in a sandy soil.

Table 2. Under long term mineral and mycorrhizal inoculation on soil organic carbon accumulation

Soil Depth cm	Organic and inorganic fertilizers	%C	Bulk density	1996 SOC Mg ha-1	2019 SOC Mg ha-1	SOC 2019-SOC 1996
0-15	Control	0,88	1,34	17,59	17,88	0,30
	Mineral Fertilizer				21,16	3,57
	Compost + Mycorrhiza				28,01	10,42
15-30	Control	0,78	1,34	15,70	22,44	6,74
	Mineral Fertilizer				23,25	7,55
	Compost + Mycorrhiza				24,43	8,73

For food security and challenging with climate change the best management practices (BMP) need to sequestrate more carbon in the soil depth.

For long term conservation soil and crop management practices that are often referred the “climate-smart regenerative agriculture”. Sustainable conservative management (Paustian et al., 2020) should be done on the base of;

1) maintaining (to the degree possible) continuous vegetation cover on the soil surface,
2) reducing soil tillage (disturbance),
3) increasing the amount and diversity of organic residues addition to the soil and
4) maximizing mineral nutrient and water use efficiency by plants.

Lal (2018) concluded that” adopting best soil and crop management practices based on continuous vegetative cover crops, rotations, integrated nutrient management and no soil disturbance (no-till) can protect the SOC stock and strengthen ecosystem services”.

At present time, as indicated by Paustian et al. (2020) climate change as well as food security, resilience of climate, biodiversity and health soil are all interrelated with parts of a new global imperative and paradigm shift.

CONCLUSION

After the industrial revolution, the increasing use of underground fossil fuels started to increase the atmospheric CO_2 concentration. Increasing CO_2 concentration in the atmosphere triggers global warming and climate changes. Meanwhile, increasing population growth has also started to put serious pressure on the demand for more food production on the earth's surface. Increasing CO_2 in the atmosphere causes the global climate changes and warming, drought and imbalance of precipitation negatively affect food production and security. Nature needs to be managed again by humans in accordance with ecological principles and in a holistic manner within the principles of sustainability.

For sustainable life and human health there is a need to challenge with greenhouse gasses and CO_2 emission to atmosphere. In this context, there is new agricultural revelation reduce the effect of climate changes by keeping more carbon as a sink by operating the effects of plant root mechanisms.

The only power that reduces the atmospheric 414 ppm CO_2 gas to the earth's surface is the photosynthesis mechanism of plants. Up to 90% of plants are infected by mycorrhizal fungi and plant are getting benefit of nutrients and water from mycorrhizae hyphae.

In this context, it is important to growth plant growth with natural mechanism such as mycorrhizal fungi to demand more carbon and mitigate atmospheric CO_2 gases.

A regionally appropriate climate-smart regenerative agroecosystems should be redesigned to maintain food security. Definitely there is a new agriculture revelation to overcome of climate and food security problem.

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