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Cover Crops Dual Roles: Green Manure And Maintenance Of Soil Fertility, A Review

[1]Mohammed D. Toungos (Ph.D.) & Zambua Wada Bulus

Crop Science Department, Adamawa State University Mubi, Adamawa State, Nigeria.

Corresponding Author Email: dahiru.toungos@gmail.com; toungosm@adsu.edu.ng

ABSTRACT

Cover crops are plants grown outdoors for the purpose of enhancing the quality of the soil. They help make soil fertile, prevent erosion, regulate water, reduce weeds, increase biodiversity, and improve farming as a whole. These types of crops are also used in landscaping to enhance the look of a property. They are also commonly used to suppress weeds, manage soil erosion, help build and improve soil fertility and quality, and control diseases and pests. Cover crops are typically grasses or legumes but may be comprised of other green plants. Cover crops may be an off-season crop planted after harvesting the cash crop. The cover crop may grow as a sole or mixed crops. They are also called "living mulches" because they can prevent soil erosion. A mulch is a layer of organic material, such as crop residue, left on the surface of the soil to prevent water runoff and protect the soil from the damaging effects of heavy rainfall. A cover crop is also planted to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife in an agroecosystem - an ecological system managed and shaped by humans. Cover crops may be an off-season crop planted after harvesting the cash crop. Cover crops can also improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. Increased soil organic matter enhances soil structure, as well as the water and nutrient holding and buffering capacity of soil. It can also lead to increased soil carbon sequestration, which has been promoted as a strategy to help offset the rise in atmospheric carbon dioxide levels. Thick cover crop stands often compete well with weeds during the cover crop growth period, and can prevent most germinated weed seeds from completing their life cycle and reproducing. In agriculture, green manure is created by leaving uprooted or mown crop parts to wither on a field so that they serve as a mulch and soil amendment. Incorporation of green manures into a farming system can drastically reduce the need for additional products such as supplemental fertilizers and pesticides. One of the primary uses of cover crops is to increase soil fertility. These types of cover crops are referred to as "green manure." They are used to manage a range of soil macronutrients and micronutrients. Cover crops plays significant roles as a green manure, nitrogen fixing capability, reclaiming nitrogen lost, stabilizing soil fauna and flora and for maintaining soil fertility for the production of crops in order to meet up the demand of the increasing population.

Keywords: Cover crops, green manure, soil fertility, living mulches, nitrogen fixation.

INTRODUCTION

Cover crops are plants grown outdoors for the purpose of enhancing the quality of the soil. They help make soil fertile, prevent erosion, regulate water, reduce weeds, increase biodiversity, and improve farming as a whole. These types of crops are also used in landscaping to enhance the look of a property. They are also commonly used to suppress weeds, manage soil erosion, help build and improve soil fertility and quality, and control diseases and pests. Cover crops are typically grasses or legumes but may be comprised of other green plants. Cover crops may be an off-season crop planted after harvesting the cash crop. The cover crop may grow as a sole or mixed crops.

Benefits: They are also called "living mulches" because they can prevent soil erosion. A mulch is a layer of organic material, such as crop residue, left on the surface of the soil to prevent water runoff and protect the soil from the damaging effects of heavy rainfall. A cover crop is planted to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife in an agroecosystem - an ecological system managed and shaped by humans. Cover crops may be an off-season crop planted after harvesting the cash crop, Carlson, S. (2013).

Although cover crops can perform multiple functions in an agroecosystem simultaneously, they are often grown for the sole purpose of preventing soil erosion. Soil erosion is a process that can irreparably reduce the productive capacity of an agroecosystem. Dense cover crop stands physically slow down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff, Ronkems,. *et al* (1990). Additionally, vast cover crop root networks help anchor the soil in place and increase soil porosity, creating suitable habitat networks for soil macrofauna, Tomlin., *et al* (1995). It keeps the enrichment of the soil good for the next few years. Many types of plants can be used as cover crops. Legumes and grasses (including cereals) are the most extensively used, but there is increasing interest in brassicas (such as rape, mustard**,** and forage radish) and continued interest in others, such as buckwheat. Legume cover crops can fix nitrogen from the air, supplying nitrogen to the succeeding crop as well as protecting the soil from erosion and adding organic matter. The amount of nitrogen fixed varies between species**,** although generally, more top growth equals more nitrogen fixed.

Cover crops can also improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. Increased soil organic matter enhances soil structure, as well as the water and nutrient holding and buffering capacity of soil, Patrick, *et al* (1957). It can also lead to increased soil carbon sequestration, which has been promoted as a strategy to help offset the rise in atmospheric carbon dioxide levels. Kuo, et al (1997); Saintu, et al (2002) and Lal, (2003).

By reducing soil erosion, cover crops often also reduce both the rate and quantity of water that drains off the field, which would normally pose environmental risks to waterways and ecosystems downstream, Dabney, S.M., *et al* (2001). Cover crop biomass acts as a physical barrier between rainfall and the soil surface, allowing raindrops to steadily trickle down through the soil profile. Also, as stated above, cover crop root growth results in the formation of soil pores, which in addition to enhancing soil macrofauna habitat provides pathways for water to filter through the soil profile rather than draining off the field as surface flow. With increased water infiltration, the potential for soil water storage and the recharging of aquifers can be improved, Joyce, B.A., *et al* (2002).

Just before cover crops are killed (by such practices including mowing, tilling, disking, rolling, or herbicide application) they contain a large amount of moisture. When the cover crop is incorporated into the soil, or left on the soil surface, it often increases soil moisture. In agroecosystems where water for crop production is in short supply, cover crops can be used as a mulch to conserve water by shading and cooling the soil surface. This reduces evaporation of soil moisture. In other situations farmers try to dry the soil out as quickly as possible going into the planting season. Here prolonged soil moisture conservation can be problematic.

While cover crops can help to conserve water, in temperate regions (particularly in years with below average precipitation) they can draw down soil water supply in the spring, particularly if climatic growing conditions are good. In these cases, just before crop planting, farmers often face a tradeoff between the benefits of increased cover crop growth and the drawbacks of reduced soil moisture for cash crop production that season. C/N ratio is balanced with this

Thick cover crop stands often compete well with weeds during the cover crop growth period, and can prevent most germinated weed seeds from completing their life cycle and reproducing. If the cover crop is flattened down on the soil surface rather than incorporated into the soil as a green manure after its growth is terminated, it can form a nearly impenetrable mat. This drastically reduces light transmittance to weed seeds, which in many cases reduces weed seed germination rates, Teasadale, J.R. (1993). Furthermore, even when weed seeds germinate, they often run out of stored energy for growth before building the necessary structural capacity to break through the cover crop mulch layer. This is often termed the cover crop smother effect, Kabayashi, Y.; *et al* (2003).

Some cover crops suppress weeds both during growth and after death as reported by Blackshaw, R.E.; *et al* (2001). During growth these cover crops compete vigorously with weeds for available space, light, and nutrients, and after death they smother the next flush of weeds by forming a mulch layer on the soil surface. For example, researchers found that when using *Melilotus officinalis* (yellow sweet-clover) as a cover crop in an improved fallow system (where a fallow period is intentionally improved by any number of different management practices, including the planting of cover crops), weed biomass only constituted between 1-12% of total standing biomass at the end of the cover crop growing season, Blackshaw, R.E.; *et al* (2001). Furthermore, after cover crop termination, the yellow sweet-clover residues suppressed weeds to levels 75–97% lower than in fallow (no yellow sweet-clover) systems.

In addition to competition-based or physical weed suppression, certain cover crops are known to suppress weeds through allelopathy. Creamer, N.G.; *et al* (1996); Singh, H.P.; *et al* (2003). This occurs when certain biochemical cover crop compounds are degraded that happen to be toxic to, or inhibit seed germination of, other plant species. Some well-known examples of allelopathic cover crops are *Secale cereale* (rye), *Vicia villosa* (hairy vetch), *Trifolium pratense* (red clover), *Sorghum bicolor* (sorghum-sudangrass), and species in the Brassicaceae family, particularly mustards. Haramoto, E.R.; Gallant, E.R.; (2004). In one study, rye cover crop residues were found to have provided between 80% and 95% control of early season broadleaf weeds when used as a mulch during the production of different cash crops such as soybean, tobacco, corn, and sunflower. Nagabhushana, G.G.; *et al* (2001).

In a recent study released by the Agricultural Research Service (ARS) scientists examined how rye seeding rates and planting patterns affected cover crop production. The results show that planting more pounds per acre of rye increased the cover crop's production as well as decreased the amount of weeds. The same was true when scientists tested seeding rates on legumes and oats; a higher density of seeds planted per acre decreased the amount of weeds and increased the yield of legume and oat production. The planting patterns, which consisted of either traditional rows or grid patterns, did not seem to make a significant impact on the cover crop's production or on the weed production in either cover crop. The ARS scientists concluded that increased seeding rates could be an effective method of weed control, USDA (2010).

Soil quality is managed to produce optimum circumstances for crops to flourish. The principal factors of soil quality are soil salination, pH, microorganism balance and the prevention of soil contamination

In agriculture, green manure is created by leaving uprooted or mown crop parts to wither on a field so that they serve as a mulch and soil amendment. The plants used for green manure are often cover crops grown primarily for this purpose. Typically, they are ploughed under and incorporated into the soil while green or shortly after flowering.

In agriculture, green manure is created by leaving uprooted or sown crop parts to wither on a field so that they serve as a mulch and soil amendment as defined by Dictionary.com. The plants used for green manure are often cover crops grown primarily for this purpose. Typically, they are ploughed under and incorporated into the soil while green or shortly after flowering. Green manure is commonly associated with organic farming and can play an important role in sustainable annual cropping systems.

Functions of green manure: Green manures usually perform multiple functions that include soil improvement and soil protection thus:

i. Leguminous green manures such as clover and vetch contain nitrogen-fixing symbiotic bacteria in root nodules that fix atmospheric nitrogen in a form that plants can use. This performs the vital function of fertilization. If desired, animal manures may also be added.

Depending on the species of cover crop grown, the amount of nitrogen released into the soil lies between 40 and 200 pounds per acre. With green manure use, the amount of nitrogen that is available to the succeeding crop is usually in the range of 40-60% of the total amount of nitrogen that is contained within the green manure crop Sullivan, P. (2003).

Average biomass yields and nitrogen yields of several legumes by crop:	**Biomass tons $acre^{-1}$**	**N lbs $acre^{-1}$**
Sweet clover	1.75	120
Berseem clover	1.10	70
Crimson clover	1.40	100
Hairy vetch	1.75	110

ii. Green manure acts mainly as soil-acidifying matter to decrease the alkalinity/pH of alkali soils by generating humic acid and acetic acid.

iii. Incorporation of cover crops into the soil allows the nutrients held within the green manure to be released and made available to the succeeding crops. This results immediately from an increase in abundance of soil microorganisms from the degradation of plant material that aid in the decomposition of this fresh material. This additional decomposition also allows for the re-incorporation of nutrients that are found in the soil in a particular form such as nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sulfur (S).

iv. Microbial activity from incorporation of cover crops into the soil leads to the formation of mycelium and viscous materials which benefit the health of the soil by increasing its soil structure (i.e. by aggregation), as reported by Sullivan, P. (2003).

The increased percentage of organic matter (biomass) improves water infiltration and retention, aeration, and other soil characteristics. The soil is more easily turned or tilled than non-aggregated soil. Further aeration of the soil results from the ability of the root systems of many green manure crops to efficiently penetrate compact soils. The amount of humus found in the soil also increases with higher rates of decomposition, which is beneficial for the growth of the crop succeeding the green manure crop. Non-leguminous crops are primarily used to increase biomass.

v. The root systems of some varieties of green manure grow deep in the soil and bring up nutrient resources unavailable to shallower-rooted crops.

vi. Common cover crop functions of weed suppression. Non-leguminous crops are primarily used (e.g. buckwheat) as stated by Lawrence, J. (1980). Vasilakoglou N. and Cholliaras, N. (2011) also reported that, the deep rooting properties of many green manure crops make them efficient at suppressing weeds.

vii. Some green manure crops, when allowed to flower, provide forage for pollinating insects. Green manure crops also often provide habitat for predatory beneficial insects, which allow for a reduction in the application of insecticides where cover crops are planted.

viii. Some green manure crops (e.g. winter wheat and winter rye) can also be used for grazing as opined by Lawrence, J. (1980).

ix. Erosion control is often also taken into account when selecting which green manure cover crop to plant.

x. Some green crops reduce plant insect pests and diseases. Verticillium wilt is especially reduced in potato plants as observed by Robert, P.; *et al* (2011).

Incorporation of green manures into a farming system can drastically reduce the need for additional products such as supplemental fertilizers and pesticides.

Limitations to consider in the use of green manure are time, energy, and resources (monetary and natural) required to successfully grow and utilize these cover crops. Consequently, it is important to choose green manure crops based on the growing region and annual precipitation amounts to ensure efficient growth and use of the cover crop(s).

Nutrient creation: Green manure is broken down into plant nutrient components by heterotrophic bacteria that consumes organic matter. Warmth and moisture contribute to this process, similar to creating compost fertilizer. The plant matter releases large amounts of carbon dioxide and weak acids that react with insoluble soil minerals to release beneficial nutrients. Soils that are high in calcium minerals, for example, can be given green manure to generate a higher phosphate content in the soil, which in turn acts as a fertilizer as stated by Lawrence, P. (1980).

The ratio of carbon to nitrogen in a plant is a crucial factor to consider, since it will impact the nutrient content of the soil and may starve a crop of nitrogen, if the incorrect plants are used to make green manure. The ratio of carbon to nitrogen will differ from species to species, and depending upon the age of the plant. The ratio is referred to as C:N. The value of N is always one, whereas the value of carbon or carbohydrates is expressed in a value of about 10 up to 90; the ratio must be less than 30:1 to prevent the manure bacteria from depleting existing nitrogen in the soil. Rhizobium are soil organisms that interact with green manure to retain atmospheric nitrogen in the soil, Lawrence J. (1980). Legumes, such as beans, alfalfa, clover and lupines, have root systems rich in rhizobium, often making them the preferred source of green manure material.

Soil Fertility And Productivity. It is the capacity of soil to produce crops of economic value to man and maintain the health of the soil for future use. Or The soil is said to be fertile when it contains all the required nutrients in the right proportion for luxuriant plant growth.

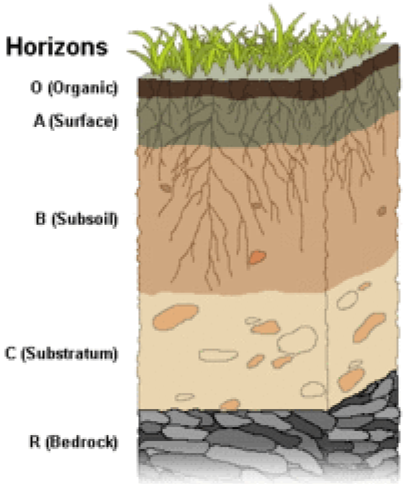
Soil fertility refers to the ability of soil to sustain agricultural plant growth, i.e. to provide plant habitat and result in sustained and consistent yields of high quality, Dictionary.com. A fertile soil has the following properties according to USDA (2010).

a. The ability to supply essential plant nutrients and water in adequate amounts and proportions for plant growth and reproduction; and
b. The absence of toxic substances which may inhibit plant growth.

The following properties contribute to soil fertility in most situations:

1. Sufficient soil depth for adequate root growth and water retention;
2. good internal drainage, allowing sufficient aeration for optimal root growth (although some plants, such as rice, tolerate waterlogging);
3. topsoil with sufficient soil organic matter for healthy soil structure and soil moisture retention;
4. soil pH in the range 5.5 to 7.0 (suitable for most plants but some prefer or tolerate more acid or alkaline conditions);
5. adequate concentrations of essential plant nutrients in plant-available forms and
6. presence of a range of microorganisms that support plant growth.

In lands used for agriculture and other human activities, maintenance of soil fertility typically requires the use of soil conservation practices. This is because soil erosion and other forms of soil degradation generally result in a decline in quality with respect to one or more of the aspects indicated above.



Soil scientists use the capital letters O, A, B, C, and E to identify the master horizons, and lowercase letters for distinctions of these horizons. Most soils have three major horizons—the surface horizon (A), the subsoil (B), and the substratum (C). Some soils have an organic horizon (O) on the surface, but this horizon can also be buried. The master horizon, E, is used for subsurface horizons that have a significant loss of minerals (eluviation). Hard bedrock, which is not soil, uses the letter R.

Soil fertility management: One of the primary uses of cover crops is to increase soil fertility. These types of cover crops are referred to as "green manure." They are used to manage a range of soil macronutrients and micronutrients. Of the various nutrients, the impact that cover crops have on nitrogen management has received the most attention from researchers and farmers, because nitrogen is often the most limiting nutrient in crop production.

Often, green manure crops are grown for a specific period, and then plowed under before reaching full maturity in order to improve soil fertility and quality. Also the stalks left block the soil from being eroded.

Green manure crops are commonly leguminous, meaning they are part of the *Fabaceae* (pea) family. This family is unique in that all of the species in it set pods, such as bean, lentil, lupins and alfalfa. Leguminous cover crops are typically high in nitrogen and can often provide the required quantity of nitrogen for crop production. In conventional farming, this nitrogen is typically applied in chemical fertilizer form. This quality of cover crops is called fertilizer replacement value as stated by Vasilakoglou, N.; and Cholliaras, N.; (2011).

Another quality unique to leguminous cover crops is that they form symbiotic relationships with the rhizobial bacteria that reside in legume root nodules. Lupins is nodulated by the soil microorganism *Bradyrhizobium* sp. (Lupinus). Bradyrhizobia are encountered as microsymbionts in other leguminous crops (*Argyrolobium*, *Lotus*, *Ornithopus*, *Acacia*, *Lupinus*) of Mediterranean origin. These bacteria convert biologically unavailable atmospheric nitrogen gas (N2) to biologically available ammonium (NH+4) through the process of biological nitrogen fixation.

Prior to the advent of the Haber-Bosch process, an energy-intensive method developed to carry out industrial nitrogen fixation and create chemical nitrogen fertilizer, most nitrogen introduced to ecosystems arose through biological nitrogen fixation, Robert, P.; *et al* (2011). Some scientists believe that widespread biological nitrogen fixation, achieved mainly through the use of cover crops, is the only alternative to industrial nitrogen fixation in the effort to maintain or increase future food production levels, Lawrence, J. (1980). Industrial nitrogen fixation has been criticized as an unsustainable source of nitrogen for food production due to its reliance on fossil fuel energy and the environmental impacts associated with chemical nitrogen fertilizer use in agriculture, Green manure (2015). Such widespread environmental impacts include nitrogen fertilizer losses into waterways, which can lead to eutrophication (nutrient loading) and ensuing hypoxia (oxygen depletion) of large bodies of water.

An example of this lies in the Mississippi Valley Basin, where years of fertilizer nitrogen loading into the watershed from agricultural production have resulted in a hypoxic "dead zone" off the Gulf of Mexico the size of New Jersey. Smalling, E. (1997). The ecological complexity of marine life in this zone has been diminishing as a consequence, Bjonnes, R. (1997).

As well as bringing nitrogen into agroecosystems through biological nitrogen fixation, types of cover crops known as "catch crops" are used to retain and recycle soil nitrogen already present. The catch crops take up surplus nitrogen remaining from fertilization of the previous crop, preventing it from being lost through leaching as reported by Kotke, W.H. (1993). or gaseous denitrification or volatilization as found in garden noted on managing soil tilth ; Colorado University 2014.

Catch crops are typically fast-growing annual species adapted to scavenge available nitrogen efficiently from the soil as observed by Oregon University USA during managing irrigation water quality in 2014. The nitrogen tied up in catch crop biomass is released back into the soil once the catch crop is incorporated as a green manure or otherwise begins to decompose.

An example of green manure use comes from Nigeria, where the cover crop *Mucuna pruriens* (velvet bean) has been found to increase the availability of phosphorus in soil after a farmer applies rock phosphate.

Soil quality management

Bioavailable phosphorus is the element in soil that is most often lacking. Nitrogen and potassium are also needed in substantial amounts. For this reason these three elements are always identified on a commercial fertilizer analysis. For example, a 10-10-15 fertilizer has 10 percent nitrogen, 10 percent (P_2O_5) available phosphorus and 15 percent (K_2O) water-soluble potassium. Sulfur is the fourth element that may be identified in a commercial analysis—e.g. 21-0-0-24 which would contain 21% nitrogen and 24% sulfate.

Inorganic fertilizers are generally less expensive and have higher concentrations of nutrients than organic fertilizers. Also, since nitrogen, phosphorus and potassium generally must be in the inorganic forms to be taken up by plants, inorganic fertilizers are generally immediately bioavailable to plants without modification, Perie, C. and Ouimet, R. (2008). However, some have criticized the use of inorganic fertilizers, claiming that the water-soluble nitrogen doesn't provide for the long-term needs of the plant and creates water pollution. Slow-release fertilizers may reduce leaching loss of nutrients and may make the nutrients that they provide available over a longer period of time.

Soil fertility is a complex process that involves the constant cycling of nutrients between organic and inorganic forms. As plant material and animal wastes are decomposed by micro-organisms, they release inorganic nutrients to the soil solution, a process referred to as mineralization. Those nutrients may then undergo further transformations which may be aided or enabled by soil micro-organisms. Like plants, many micro-organisms require or preferentially use inorganic forms of nitrogen, phosphorus or potassium and will compete with plants for these nutrients, tying up the nutrients in microbial biomass, a process often called immobilization. The balance between immobilization and mineralization processes depends on the balance and availability of major nutrients and organic carbon to soil microorganisms, as stated by Jain, T.B.; *et al* (1997) and Troeh, F.R. and Louis, M.T. (2005). Natural processes such as lightning strikes may fix atmospheric nitrogen by converting it to (NO_2). Denitrification may occur under anaerobic conditions (flooding) in the presence of denitrifying bacteria. Nutrient cations, including potassium and many micronutrients, are held in relatively strong bonds with the negatively charged portions of the soil in a process known as cation exchange.

In 2008 the cost of phosphorus as fertilizer more than doubled, while the price of rock phosphate as base commodity rose eight-fold. Recently the term peak phosphorus has been coined, due to the limited occurrence of rock phosphate in the world.

Light and CO_2 limitations: Photosynthesis is the process whereby plants use light energy to drive chemical reactions which convert CO_2 into sugars. As such, all plants require access to both light and carbon dioxide to produce energy, grow and reproduce.

While typically limited by nitrogen, phosphorus and potassium, low levels of carbon dioxide can also act as a limiting factor on plant growth. Peer-reviewed and published scientific studies have shown that increasing CO_2 is highly effective at promoting plant growth up to levels over 300 ppm. Further increases in CO_2 can, to a very small degree, continue to increase net photosynthetic output as stated by Juma, N.G. (1999).

Soil depletion: Soil depletion occurs when the components which contribute to fertility are removed and not replaced, and the conditions which support soil's fertility are not maintained. This leads to poor crop yields. In agriculture, depletion can be due to excessively intense cultivation and inadequate soil management.

Soil fertility can be severely challenged when land use changes rapidly. For example, in Colonial New England, colonists made a number of decisions that depleted the soils, including: allowing herd animals to wander freely, not replenishing soils with manure, and a sequence of events that led to erosion. William Cronon wrote that "...the long-term effect was to put those soils in jeopardy. The removal of the forest, the increase in destructive floods, the soil compaction and close-cropping wrought by grazing animals, plowing--all served to increase erosion." Glossary/NRCSS SQ Archived (2006).

Karl Marx also wrote of the role of capitalism in soil depletion. In *Capital, Volume I*, he wrote:

...all progress in capitalistic agriculture is a progress in the art, not only of robbing the labourer, but of robbing the soil; all progress in increasing the fertility of the soil for a given time, is a progress towards ruining the lasting sources of that fertility. The more a country starts its development on the foundation of modern industry, like the United States, for example, the more rapid is this process of destruction. Capitalist production, therefore, develops technology, and the combining together of various processes into a social whole, only by sapping the original sources of all wealth — the soil and the labourer, Brady N.C.; (1984).

One of the most widespread occurrences of soil depletion as of 2008 is in tropical zones where nutrient content of soils is low. The combined effects of growing population densities, large-scale industrial logging, slash-and-burn agriculture and ranching, and other factors, have in some places depleted soils through rapid and almost total nutrient removal.

The depletion of soil has affected the state of plant life and crops in agriculture in many countries. In the middle east for example, many countries in that find it difficult to grow produce because of droughts, lack of soil, and lack of irrigation. "The Middle East" has three countries that indicate a decline in crop production. the highest rates of productivity decline are found in hilly and dryland areas, Mergel, A. (1998). Many countries in Africa also undergo a depletion of fertile soil. In regions of dry climate like Sudan and the countries that make up the Sahara Desert, droughts and soil degradation is common. Cash crops such as teas, maize, and beans that require a variety of nutrients in order to grow healthy. Soil fertility has decline in the farming regions of Africa and the use of artificial and natural fertilizers has been used to regain the nutrients of ground soil, Skjemstad, J.O. (2002).

Topsoil depletion occurs when the nutrient-rich organic topsoil, which takes hundreds to thousands of years to build up under natural conditions, is eroded or depleted of its original organic material as stated by Ochoa, H.R.; *et al* (2019). Historically, many past civilizations' collapses can be attributed to the depletion of the topsoil. Since the beginning of agricultural production in the Great Plains of North America in the 1880s, about one-half of its topsoil has disappeared according to Batjes, N.H. (1996).

Depletion may occur through a variety of other effects, including overtillage (which damages soil structure), underuse of nutrient inputs which leads to mining of the soil nutrient bank, and salinization of soil.

Irrigation water effects: The quality of irrigation water is very important to maintain soil fertility and tilth, and for using more soil depth by the plants as observed by Batjes N.H. (2016). When soil is irrigated with high alkaline water, unwanted sodium salts build up in the soil which would make soil draining capacity very poor. So plant roots cannot penetrate deep into the soil for optimum growth in Alkali soils.

When soil is irrigated with low pH / acidic water, the useful salts (Ca, Mg, K, P, S, etc.) are removed by draining water from the acidic soil and in addition unwanted aluminium and manganese salts to the plants are dissolved from the soil impeding plant growth, Lal, R. (2004). When soil is irrigated with high salinity water or sufficient water is not draining out from the irrigated soil, the soil would convert into saline soil or lose its fertility. Saline water enhance the turgor pressure or osmotic pressure requirement which impedes the off take of water and nutrients by the plant roots.

Top soil loss takes place in alkali soils due to erosion by rain water surface flows or drainage as they form colloids (fine mud) in contact with water. Plants absorb water-soluble inorganic salts only from the soil for their growth. Soil as such does not lose fertility just by growing crops but it lose its fertility due to accumulation of unwanted and depletion of wanted inorganic salts from the soil by improper irrigation and acid rain water (quantity and quality of water). The fertility of many soils which are not suitable for plant growth can be enhanced many times gradually by providing adequate irrigation water of suitable quality and good drainage from the soil.

Soil organic matter: Soil organic matter (SOM) is the organic matter component of soil, consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. SOM exerts numerous positive effects on soil physical and chemical properties, as well as the soil's capacity to provide regulatory ecosystem services, Brady, N.C.; and Well, R.R.; (1999). Particularly, the presence of SOM is regarded as being critical for soil functions and soil quality as observed by Beare, M.H.; *et al* (1994).

The positive impacts of SOM result from a number of complex, interactive edaphic factors; a non-exhaustive list of SOM's effects on soil functioning includes improvements related to soil structure, aggregation, water retention, soil biodiversity, absorption and retention of pollutants, buffering capacity, and the cycling and storage of plant nutrients. SOM increases soil fertility by providing cation exchange sites and acting as reserve of plant nutrients, especially nitrogen (N), phosphorus (P), and sulfur (S), along with micronutrients, which are slowly released upon SOM mineralization. As such, there is a significant correlation between SOM content and soil fertility.

SOM also acts as a major sink and source of soil carbon (C). Although the C content of SOM is known to vary considerably as opined by Perie, C.; and Ouimet, R. (2008) and Jain, T.B.; et al (1997). SOM is typically estimated to contain 58% C, and the terms 'soil organic carbon' (SOC) and SOM are often used interchangeably, with measured SOC content often serving as a proxy for SOM. Soil represents one of the largest C sinks on the planet and plays a major role in the global carbon cycle. Therefore, SOM/SOC dynamics and the capacity of soils to provide the ecosystem service of carbon sequestration through SOM management have received considerable attention in recent years.

The concentration of SOM in soils generally ranges from 1% to 6% of the total topsoil mass for most upland soils. Soils whose upper horizons consist of less than 1% organic matter are mostly limited to desert areas, while the SOM content of soils in low-lying, wet areas can be as high as 90%. Soils containing 12-18% SOC are generally classified as organic soils as explained by Troeh, F.R and Louis M.T.; (2005).

It can be divided into three general pools: living biomass of microorganisms, fresh and partially decomposed residues, and humus: the well-decomposed organic material. Surface plant litter is generally not included as part of soil organic matter as stated by Juma, N.G.; (1999).

Sources of soil organic matter: The primary source of organic matter contained in soil is vegetal. In forest or prairies, as well as agricultural fields, dead plants are transformed by different kinds of living organisms. This process involves several steps, the first being mostly mechanical, and becoming more chemical as it progresses. The small living beings that work on that decomposition chain are themselves part of the soil organic matter, and form a food web of organisms that prey upon each other and are preyed upon.

There are also other animals that consume living vegetal material, whose residues are passed to the soil. The products from the living organisms metabolism are the secondary sources of soil organic matter that also includes the corpses of these organisms. Some animals, like earthworms, ants and centipedes contribute to both vertical and horizontal translocation of organic material, Brady, N.C.; (1984).

Additional sources of soil organic matter include plant root exudates as observed by Skjemstad, J.O.; (2002). and charcoal, Ochoa, H.R.; *et al* (2019)

Composition of plant residues: The water content of most plant residues is in the range of 60% to 90%. The dry matter consists of complex organic material composed mainly of carbon, oxygen and hydrogen. Although these three elements make up about 92% of the dry weight of the organic material in soils, there are other elements that are of great importance for the nutrition of plants. They include nitrogen, sulfur, phosphorus, potassium, calcium, magnesium and a range of micronutrients, Brady, N.C (1984).

Organic compounds found in plant residues include:

a. Carbohydrates, made up of carbon, hydrogen and oxygen, and range in complexity from rather simple sugars to the big molecules of cellulose.
b. Fats, consist of glycerids of fatty acids, like butyric, stearic, oleic. They are also made up of carbon, oxygen and hydrogen atoms.
c. Lignins, are complex compounds that form the older parts of wood, and consist also mainly of carbon, oxygen and hydrogen. They are resistant to decomposition.
d. Proteins, contain nitrogen in addition to carbon, hydrogen and oxygen, and also small amounts of sulfur, iron, and phosphorus, Brady, N.C.; (1998).
e. Charcoal is elemental carbon derived from incomplete combustion of organic matter. Charcoal is resistant to decomposition.

Decomposition: The vegetal residues in general are not water-soluble, and they are not usable by the plants. They constitute, nevertheless, the raw materials from which plant nutrients are derived. The decomposition is carried out as enzymatic biochemical processes by soil microorganisms, that obtain the necessary energy from the same residues, and produce the mineral compounds that are apt to be absorbed by plant roots, Ochoa H.R.; *et al* (2019). This process by which organic compounds are broken down and transformed into mineral (inorganic) compounds is also referred to as *mineralization*. A portion of organic material is not mineralized, but transformed into stable organic matter humus, as reported by Brady, C.N.; (1984).

The breakdown of the organic compounds is done at very different rates, depending on their nature. The ranking, from fast to slow rates are as follow:

1. Sugars, starches and simple proteins;
2. proteins;
3. hemicelluloses;
4. cellulose,
5. lignin and fats.

The reactions that take place can be included in one of three groups thus:

a. Enzymatic oxidation, that produces carbon dioxide, water and heat. It affects the bulk or major portion of the material.
b. The essential elements, nitrogen, sulfur, phosphorus are liberated and mineralized by a series of specific reactions.
c. Compounds that are resistant to microbial action are formed by modification of original compounds or by synthesis of new ones by microbes, creating humus as reported by Brady, N.C.; (1984).

The list of mineral end products are as follows:

Element	Mineral end products
Carbon	CO_2, CO_3^{2-}, HCO_3^{-}, CH_4, C
Nitrogen	NH_4^{+}, NO_2^{-}, NO_3^{-}, N_2 (gas), N_2O (gas)
Sulfur	S, H_2S, SO_3^{2-}, SO_4^{2-}, CS_2

Phosphorus $H_2PO_4^-$, HPO_4^{2-}

Others H_2O, O_2, H_2, H^+, OH^-, K^+, Ca^{2+}, Mg^{2+}, etc.

Humus: As vegetal material undergoes decomposition, some microbial resistant compounds are formed. These include modified lignins, oils, fats and waxes. Secondly, some new compounds are synthesized, like polysaccharides and polyuronids. These materials form the basis for humus. New reactions take place between these compounds and some proteins and other nitrogen containing products, incorporating thus nitrogen and avoiding its mineralization. Other nutrients are also protected in this way from mineralization.

Humic substances classification: These classified into three groups, based on solubility in acids and alkalis, and also related to stability.

a) **Fulvic acid:** Is the group which contains the materials that have the lowest molecular weight, and are soluble in acids and alkali, and susceptible to microbial attack.
b) **Humic acid:** Group contains the intermediate materials, with medium molecular weight, soluble in alkali, but insoluble in acid, and intermediate resistance to microbial attack.
c) **Humin:** Is the generic name for the materials with highest molecular weight, that are darkest in color, insoluble in acid and alkali, and with the most resistance to microbial attack, as classified by Brady, N.C.; (1984)

Role in carbon cycling: Soil plays a major role in the global carbon cycle, with the global soil carbon pool estimated at 2500 gigatons. This is 3.3 times the size of the atmospheric pool (750 gigatons) and 4.5 times the biotic pool (560 gigatons). The pool of organic carbon, which occurs primarily in the form of SOM, accounts roughly 1550 gigatons of the total global C pool, Batjes N.H.; (1996); (2016), with the remainder accounted for by soil inorganic carbon (SIC). The pool of organic C exists in dynamic equilibrium between gains and losses; soil may therefore serve as either a sink or source of C, through sequestration or greenhouse gas emissions, respectively, depending on exogenous factors, as stated by Lal, R. (2014)

CONCLUSIONS

Cover crops plays significant roles as a green manure, nitrogen fixing capability, reclaiming nitrogen lost, stabilizing soil fauna and flora and for maintaining soil fertility for the production of crops in order to meet up the demand of the increasing population.

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