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Cover Crops: Soil and Agricultural Sustainability

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Abstract

Cover crops (CC) act as multifunctional and vital component in present agricultural system where sustainability and agriculture productivity at core of its full exploitation. The land resources are decline and soil loses its functionality abruptly. Cover crops cultivation can improve crop yield, soil and environmental quality. Cover crops are multifunctional and contribute to soil quality and deliver ecosystem services. The crops also enhance organic matter and aid in nutrient cycling, suppress weeds, and control pests. There is a need to continually explore and appropriately manage CC utilization over local specific adoption to obtain their window use.

Introduction

Enhancing ecosystem services of current cropping systems is a priority for sustaining crop and livestock production, developing biofuel industries, and maintaining or improving soil and environmental quality. Integrating Cover crops (CCs) with existing cropping systems has the potential to enhance ecosystem services such as: (i) food, feed, fiber, and fuel production, (ii) C and other nutrient and water cycling, and (iii) soil, water, and air quality improvement. This is particularly important with increased concerns about the following challenges to agriculture: high production costs, environmental degradation, food security, and climate change.

Cover Crop: Genesis and Properties

Cover crops are defined as a "close-growing crop that provides soil protection, seeding protection, and soil improvement between periods of normal crop production, or between trees in orchards and vines in vineyards. Cover crops are usually seeded in the alleyways between crop rows (Figure 1) to limit weed presence and reduce erosion, runoff, nutrient losses, and soil compaction (Winter *et al.*, 2018). Historically, CCs have been used to meet a few specific needs (*i.e.*, soil conservation, N_2 fixation, and weed and pest management), but now CC management questions increasingly revolve around the potential multi-functionality of CCs including soil C sequestration, mitigation of greenhouse gas emissions, benefits to "soil health," feed for livestock, biofuel production, farm economics, and others.

Figure 1: Demonstration of cover crop effects in field

Soils Ecosystem Services

Soil ecosystem services are defined as conditions and pro-cesses through which soils provide benefits to agricultural sustainability and environmental quality. Soils provide numerous ecosystem services that have both local and global implications, including (i) climate regulation, (ii) provision of food, fiber, and fuel, (iii) regulation of water and air quality, and (iv) agricultural sustainability, among others. Cover crops services delivery includes water and wind erosion control, improvement in soil physical properties, soil C sequestration, mitigation of greenhouse gas fluxes, enhancement of soil microbial biomass, forage for livestock production, feedstock for cellulosic ethanol production, weed suppression, yields of subsequent crops, and enhanced economics.

Sequestering Soil Organic Carbon

Cover crops should increase soil organic C due to additional above- and below-ground biomass C inputs dictates mass balance of C (inputs and outputs of C). In general, inclusion of CCs in no-till systems leads to accumulation of soil organic C. The use of deep-rooted CCs can favor soil organic C accumulation in deeper no-till soil depths. Cover crop benefits are detectable more rapidly under no-till management due to reduced residue decomposition rates compared with conventional tillage. Both quantity and quality affect soil C accumulation (Figure 2).

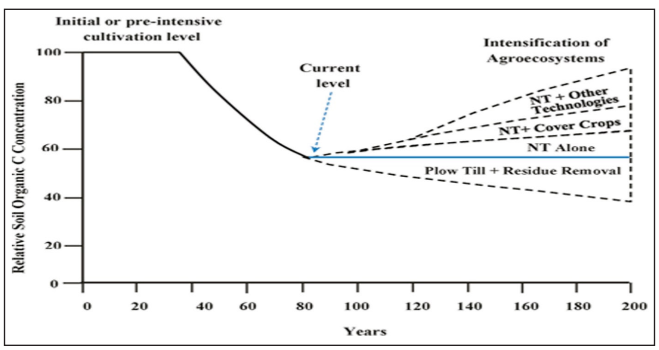

Figure 2: Effect of cover cropping and no tillage on organic carbon of soils over a long-term practice

Reducing Soil Erosion

Water Erosion

Cover crops reduce runoff losses and sediment loss due to function of increase biomass production and its incorporation in soils. Cover crops also reduce the loss of dissolved nutrients in runoff, particularly total P and NO_3-N, which can result in improved water quality, soil fertility, and crop productivity.

Cover crops reduce losses of sediment and nutrients in run-off by:

- Providing protective cover to the soil,
- Absorbing raindrop energy,
- Reducing soil aggregate detachment,
- Increasing soil surface roughness,
- Delaying runoff initiation,
- Intercepting runoff,
- Reducing runoff velocity,
- Increasing the opportunity time for water infiltration, and
- Promoting the formation of water-stable aggregates.

The effectiveness of CCs depends on the CC species due to differences in biomass cover. Planting a mix of different CC species (*i.e*., grasses and legumes) can provide more canopy cover, more total biomass yield, and more uniform surface cover than a single species alone (Wortman *et al*., 2012) resulting in greater water erosion control.

Wind Erosion

Adding CCs to cropping systems with limited annual residue input can reduce wind erosion. Cover crops reduce wind erosion risks by physically protecting the soil surface, improving soil structural properties, increasing the soil organic C concentration, and anchoring the soil with their roots when primary crops are not in place, thereby reducing potential soil erodibility. An increase in soil organic C with CCs is one of the main factors contributing to increased aggregate stability and reduced wind-erodible fraction because organic C can physically, chemically, and biologically bind soil particles and form stable macroaggregates.

Improving the Soil Physical Environment

It is well documented that compaction reduces water, heat, and gas flow, nutrient and water uptake, root growth, and crop yields. Cover crops can (i) alleviate soil compaction and (ii) reduce the susceptibility of the soil to compaction. Cover crops can reduce compactness (susceptibility of the soil to compaction) by improving soil aggregation and increasing the soil organic C concentration (Figure 3).

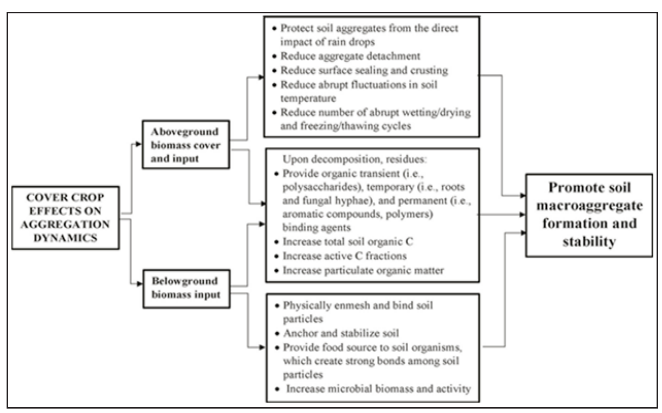

Figure 3: Cover crops effects on soil physical and aggregation stability (Blanco *et al*., 2015)

Nutrient Cycling and Microbial Environment

Cover crops primarily affect soil nutrient dynamics and balance by: (i) fixing atmospheric N_2, (ii) scavenging nutrients, (iii) reducing nutrient leaching, and (iv) reducing nutrient erosion. Including CCs in intensively managed agroecosystems could thus affect nutrient accumulation, recovery, storage, and cycling. Legume CCs can symbiotically fix N_2 and supply significant amounts of N in low-fertility soils, thereby supplementing N for the next crop and reducing N application requirements. Cover crops associated Changes in soil microbial biomass, microbial community structure, fungal biomass, and fungal hyphal biomass and necro mass under CCs affect other soil processes such as aggregation. Cover crops can improve the microbial biomass by increasing the root biomass concentration and increase arbuscular mycorrhizal fungi.

Weed Management Component

Cover crops can be a useful means to suppress weeds within agroecosystems. There are two ways that CCs can influence weed populations (Teasdale *et al.*, 2007). One is through direct competition with growing weed species, referred to as a smother crop or living mulch. The second approach uses indirect suppression resulting from physical or chemical suppression or manipulation of nutrient cycles. Cover crops generally provide weed suppression through competition for light, soil water, and nutrients but can negatively affect the main crop too. Leguminous CCs are often used because they will compete less for soil N.

Soil Water Management

Cover crops have positive, negative, or neutral effects on the soil-profile distribution of water, depending on soil type and climatic region. CCs also reduce water losses by reducing runoff, increasing water infiltration, and improving other physical processes. Cover crop roots and surface residues generally improve soil aggregation and soil macro-porosity, which increase rain or irrigation water infiltration. Residues left on the soil surface after CC termination contributes to soil water storage by reducing evaporation. The soil organic C concentration is positively correlated with soil water storage and retention capacity. CCs reduce daytime soil temperatures, which can reduce excessive evaporation and maintain the soil water content compared with bare soils. Soil water content under CCs increases as soil temperature decrease.

Improving Crop Yields

High-N_2-fixing (*i.e.*, legume) CCs can have more rapid and greater effects on increasing crop yields than CCs with low or no N_2-fixing capacity. Crop yield are correlated with CC-induced changes in soil physical properties, concentrations of soil organic C and total N, and soil water content and temperature.

Producing Feedstock for Biofuel

Cover crops can contribute to the production of renewable energy. Cover crops meet the increasing demand for cellulosic biomass for biofuel production. Planting CCs or forage crops after crop residue removal for biofuel production can be a potential strategy.

Conclusion

The cover crops are the potential signature of restoration and conservation principles of ecological science. Cover crop role in soil quality, nutrient cycling, weed management, organic matter restoration and improvement in soil physical, chemical and biological properties of soil is well documented, the management practices of cover crop like selection of species and method of harvesting ground the successful convoy of cover cropping. But still there is a need to research on its interactions with ecosystem components like weeds, microbial flora in rhizosphere and nutrient cycling and sustainability role at micro level.

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