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Short Communication

Conservation agriculture and its principles

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Abstract

Conventional agriculture is the greatest enemy of healthy soil; it wasn't designed for the betterment of the soil, but rather for the rapid economic growth. If we want to improve soil quality and with that our life quality, we should turn our field of interest to the application of so-called conservation agriculture, which belongs to the principles of sustainable nature. Conservation agriculture is based upon three principles: minimum tillage and soil disturbance, permanent soil cover with crop residues and live mulches, and intercropping. Minimum tillage minimizes soil organic matter losses and leads to increase soil carbon and nitrogen stocks. One percent increase in organic matter can capture 10 times more tons of carbon dioxide. In this way, the release of carbon dioxide into the atmosphere is significantly reduced. In addition, to maintain healthy soil system, there shouldn't be any bare soil left. Permanently covered soil leads to many advantages: Maintaining water capacity in soil which stops drying of soil (water is constantly being absorbed by crop), it reduces erosion and soil compaction, manages nutrients, controls weeds and increases yields. Additionally, intercropping is a way to create ecological balance, increase diversity in an agricultural ecosystem, increasing the quantity and quality of crops and reduce yield damage to pests, diseases and weeds. Conservation agriculture gives us the opportunity how to use natural resources more efficiently with the minimal impact on the environment.

Introduction

If we stop and think about healthy soil, we should come to the conclusion that soil is a living organism. Soil contains the entire universe of life [1]. There is about 1000 pounds of biological material under the soil surface. Everything from microscopic protozoa and bacteria, through earthworms, insects and finally to larger organisms such as burrowing rodents. As human population is constantly increasing, it is estimated that by 2060 soil is the one that will be obliged to give us as much food as we consumed in the last 500 years [2].

Quality of food, in most cases, is depended on the quality of soil. As a consequence of intensive tillage, hard irrigation and adding of chemicals soil "is dying". Additionally, due to the growth of irrigation water market price, the inevitable increase in the price of agricultural land is expected. Furthermore, the irrigation water shortage could have an indirect and direct impact on crops, which can lead to crop production reduction [3]. Top soil (13 - 25cm), which contains highest concentration of organic matter and soil microbes needed for most of the Earth's biological soil activity, is constantly being exposed to

chronic stress of conventional agriculture. It is estimated that remaining top soil will be gone in 60 years. In the other words unless we find a way to save our soil, we will have 60 harvests left [1].

Conventional agriculture is the greatest enemy of healthy soil. It wasn't designed for the betterment of the soil, but rather for the rapid economic growth. But what good will money have if we lose our health and our land? If we want to improve soil quality and with that our life quality, we should turn our field of interest to educating ourselves about conservation agriculture and its principles. By learning to use nature sustainably, we could reverse global warming in 30 years [1]. The aim of this paper is introduction to conservation agriculture clarification of its principles and explanation of the benefit it could have in stopping global warming.

Definition of conservation agriculture

Function of conservation agriculture is to protect the soil physically from sun, rain and wind and to feed soil biota. The soil microorganisms and soil fauna take over the tillage function and soil nutrient balancing. Mechanical tillage disturbs

this process. Therefore, it is estimated that zero or minimum tillage and direct seeding lead to reduction in wind and water erosion [4]. Based on Food and Agriculture Organization of the United Nations (FAO), conservation agriculture is based upon three principles: minimum tillage and soil disturbance, permanent soil cover with crop residues and live mulches, and intercropping [5]. With different principals emerge diversity of branches. Branches that are related to conservation agriculture are: permaculture, agroecology, holistic management, restoration ecology, Keyline design, agroforestry.

Advantages of conservation tillage

Conservation tillage is a practice used in conventional agriculture to reduce the effects of tillage [5]. It includes the concepts of no-tillage (zero tillage) or minimum-tillage and direct seeding [6]. It is characterized by the retention of at least 30% surface residues cover [4]. Some of its benefits are fuel, time and labor conservation, increase of soil organic matter, increase of nitrogen in soil, improved aeration and infiltration, preservation of soil fauna and soil structure, reduced germination of weeds, reduced irrigation requirements [5]. Additionally, conservation agriculture is balancing application of chemical inputs and it implements careful management of residues and wastes. This reduces land and water pollution and soil erosion, improves water quality and water use efficiency, reduces long-term dependency on external chemical inputs, and reduces emissions of greenhouse gases through diminished use of fossil fuels. It all leads to enhanced environmental management [6].

No-till/minimum tillage, in conjunction with other regenerative practices, enhances soil aggregation, water infiltration and retention, and carbon sequestration [4]. Combined with permanent soil cover, has been shown to result in a build-up of organic carbon in the surface layers [7]. No-tillage minimizes soil organic matter losses and is a promising strategy to maintain or even increase soil carbon and nitrogen stocks [7].

Instead of using regular drills which ruin top soil, in conservation agriculture, so-called “no tilled drills” are used. “No tilled drills” (Figure 1A,B) usually consist of front disk, middle two parallel disks, back wheel and tubes that pump seeds. Front disk cuts the ground and opens a little slit. Additional two parallel disks spread the soil, seeds are dropped in the slits via pumps and at the end back wheels compress soil back. Actually, no till is a till, you are tilling tiny spot dropping a seed and compacting the ground back. No till drills grow top soil that contains organic matter. One percent increase in organic matter can capture 10 times more tons of carbon-dioxide (CO₂) [1].

Permanent soil cover

One of the basic principles of conservation agriculture is having permanent soil cover, even when regular crops are off the field. To maintain healthy soil system, there shouldn't be any bare soil left. When we leave our soil bare, there aren't any plants to absorb water and those results in water evaporation

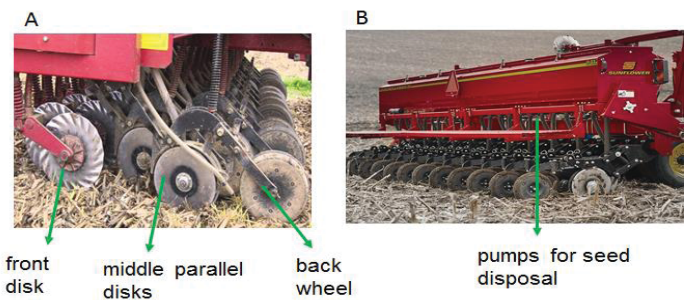


Figure 1A,B: A. Parts of no-till drill. B. No-till drill.

and run off [8]. Furthermore, when raindrops fall on a bare soil it results in destruction of soil aggregates, clogging of soil pores and rapid reduction in water infiltration with resulting run-off and soil erosion [9]. When we have permanently covered soil water is constantly being absorbed by our crop, cover crop or mulch, they are maintaining water capacity in soil, and stopping drying of soil. Additionally, permanent soil cover reduces erosion and soil compaction, manages nutrients, controls weeds and increases yields.

Cover crops are plants planted when regular crops are off the field, they are planted to protect soil rather than for the purpose of being harvested. Mulch is a material spread to enrich soil and it is formed when a previous crop is left anchored or loose after harvest or when a cover crop is grown and killed or cut. Externally applied mulch in the form of composts and manures can also be applied [4]. “No tilling” plus mulch reduces surface soil crusting, increases water infiltration, reduces run-off and gives higher yield than tilled soils [10].

Compost is a form of mulch it is made by natural decomposition of organic matter. It is filled with nutrients and carbon. Compost is considered a “natural sponge” because of its ability to absorb and retain water [1]. Food waste could be drastically reduced if we collected it and turned it into compost to be used by local farms.

Intercropping

Intercropping can be defined as a multiple cropping system, with two or more crops planted in a same field during a growing season. Intercropping is a way to create ecological balance, increase diversity in an agricultural ecosystem, increasing the quantity and quality of crops and reduce yield damage to pests, diseases and weeds [11].

Today, with modernization of agricultural equipment crops are mainly monocultural. That means that soil biota and root exudate is feed with only one type of nutrients given by monocultural crop. Advantages of intercropping in the crop production in comparison with pure cropping are due to the difference in competition for the use of environmental resources [12]. Intercrops components are not in a competition for the same niche (ecological nest) due to morphological and physiological differences; competition between species is less than competition within species [13]. Furthermore, with intercropping there is a contribution to field diversity, feeding

the soil biology with many types of nutrients that accelerate its growth. Different types of nutrients in soil reduce the need for chemical/fertilizer application. By having different types of crops soil built its resilience and becomes more stable. Intercrop field also bring an economic benefit. When several crops grow at the same time, risk of one crop failure is not tragic because there are other crop types left. In addition, by planting different types of produce manufacturer is not affected by change of price of one type of crop. Risk of agronomy failure in multi cropping systems is lower than pure cropping systems [1].

The intercropping is divided into the following four groups [13]:

1. Row-intercropping - growing two or more crops simultaneously where one or more crops are planted in regular rows, and crop or other crops may be grown simultaneously in row or randomly with the first crop;
2. Mixed intercropping - growing two or more crops simultaneously with no distinct row arrangement, this type of can be suitable for grass-legume intercropping in pastures;
3. Strip intercropping - growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically;
4. Relay intercropping - growing two or more crops simultaneously during part of the life cycle of each; a second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest

Table 1.

Difference between transpiration and evaporation

Practicing conservation agriculture is taking off the usual risks of agriculture. Namely, risk of losing crop to hail or drought can be eliminated. When rain falls on bare tilled area, runoff and evaporation occur. On the contrary, when rain falls on "no-tilled area", water is absorbed and goes right into the soil. That way "no-tilled soil" holds more water. More water leads to more plant growth which leads to higher rate of transpiration. The aim should be to achieve more plant transpiration than evaporation. Transpiration is process of losing water through plant cells, surface remains wet, humidity is raised which results in more local rain. And the circle established by the "local rain" is constantly repeating [1,15].

Carbon sequestration by soil

One of the aims of conservation agriculture is to capture carbon in soil and aboveground biomass, reversing current global trends of atmospheric accumulation. This aim should be of great importance because since 1750, which is taken as the beginning of Industrial Revolution. We have released 1000 gigatons of CO₂ from land. We reached a point where it isn't enough just to switch to renewable energy [1]. We need bring that carbon back to the ground and learn to use our fields sustainably. Soil has unique ability to sequester

CO₂ out of the atmosphere. It represents the biggest tank for carbon sequestration it can hold more carbon than plants and atmosphere together (Figure 2).

Table 1: Difference between transpiration and evaporation (based on [14]).

Transpiration	Evaporation
Biological process	Physical process
Slow process.	Comparatively a fast process.
Occurs in living tissues. Involves non-living matter.	Occurs in living tissues. Involves non-living matter.
Water is lost from plant cells	Water is lost from the surface of plant parts.
Occurs through stomata, cuticle or lenticel.	Occurs from the entire outer surface.
Occurs during daytime.	Occurs during day and night.
Regulated by temperature, light, concentration, pH, hormones and carbon dioxide.	No regulations.
Surface remains wet.	Surface becomes dry.
Helps in uptake of minerals and nutrients.	Not associated with minerals and nutrient uptake.
Makes the surface of leaves and young stems wet and protects them from sunburn.	Provides dryness to the free surface.

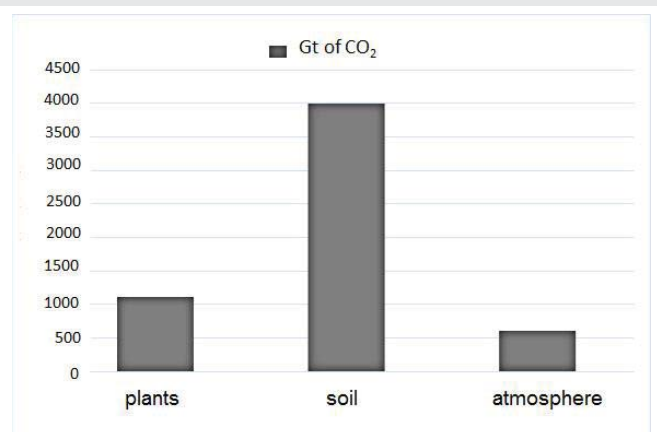


Figure 2: Amount of CO₂ that could be sequestered by plants, atmosphere and soil.

Plants absorb CO₂ from the atmosphere. That CO₂ is with water used in photosynthesis to make sugars needed for plant growth. Carbon dioxide by photosynthesis gets captured in plant, it goes through the plant and 40% of carbon dioxide is sent down to roots, leaking it out in a strategic way for soil microorganisms. Plants feed microorganisms with carbon. In the return organisms process organic matter that is in the soil and put nutrients into a form that plant needs. Microorganisms make carbon glue (glomalin) from carbon fuel. Glomalin with humic acid is significant component of soil organic matter, which binds mineral particles together, improving soil quality. Glomalin has high carbon storing properties, which is how carbon gets fixed in the soil. Carbon storing by soil microorganisms could make significant impact on carbon sequestration [1].

Analyses of Giller and associates [15] suggest using of conventional agriculture on larger mechanized farms (where farmers harness the soil by using the tools of modern science:



highly-sophisticated machines, potent agrochemicals, and biotechnology), and proposes limited uptake of conventional agriculture by smallholder farmers in developing countries.

Application of „smart agriculture technologies”

Innovation of agricultural technologies could have significant impact in reducing the effects of various climate changes with an additional goal to improve food production [16]. The variability in soil distribution and weather conditions across different locations is a determining factor to grow crops. In order to monitor these differences in more detail and easier way, various electronic systems for their monitoring can be used. One of the proposed systems is an Internet of things system that shows climate variability with connection to mobile networks, existing Geographical Information System and remote sensing stations [17]. In most countries biosensors and biosensing machineries are used for solving some of the challenges in food production, agricultural activities and its sustainability. Namely, biosensing technologies and their application in climate smart organic agriculture would ensure that biochemical and other categories of contaminants don't affect the quality of agricultural products [18]. The application of climate smart agriculture technologies would play a significant role in the aspect of intelligent management of natural resources [19]. Moreover, the application of biosensors may be a reliable technology for effective detection of pathogen and pests, affecting the increase in the agricultural production with the aim to reduced use of pesticides (it can have a beneficial effect on the health of the farmers and residents). Biosensors are also applicable as chemical analyzes of food composition, and could be used in monitoring safety of the stored fresh agricultural produce [20].

Conclusion

As number of people is in constant increase and healthy, fertile land is in continuous decrease. Food production will be obliged to learn how to use natural resources more efficiently with the minimal impact on the environment. Our only hope of preserving healthy soil for future generations is by education ourselves on sustainable soil management, and on practices described in this paper. Minimum tillage, in conjunction with permanent ground cover made up of plantations of different plant cultures enhances soil aggregation, water infiltration and retention, as well as build-up of organic carbon in the surface layers of soil. No-tillage minimizes soil organic matter losses and is a promising strategy to maintain or even increase soil carbon stocks. This can prevent excessive accumulation of CO₂ in the atmosphere. Only by accepting that covered planet is the healthy planet, we could get to the healthy soil, because healthy soil leads to healthy plant, healthy plant, leads to healthy animal, healthy animal leads to healthy human, healthy water and healthy climate. Today, innovative technologies in agriculture can cause significant improvement in sustainable agriculture application, reduction of the effects of climate change and could have a great impact in checking the safety of fresh products in storage and chemical analysis of food.

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