ECO Farming in the 21st Century: Improving Farm Profitability and the Environment

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What is Ecological or ECO Farming?

Ecological or ECO Farming works with natural processes to improve soil productivity, improves nutrient efficiency, and protects and enhances the soil environment. ECO Farming allows natural processes like soil microorganisms and soil fauna to recycle soil nutrients for plant production and uses other agricultural inputs (fertilizer, pesticides, fuel, equipment, labor) as needed to maximize crop production. ECO Farming is a new concept that employs current best conservation management practices to increase carbon sequestration, improve biodiversity, and improves the soil environment so that crop production efficiency and crop yields may be maximized economically. See Figure 1.

ECO Farming is an acronym that is based on three major principles:

First, soil is considered a living breathing organism that needs to be fed and nurtured. Soil is meant to be protected and conserved, not destroyed with tillage. Soil acts like a protective layer of skin around your body. No one would voluntarily cut their skin from their body. Tillage is like peeling the skin away from your body, resulting in soil erosion, hard compacted soils, and nutrient and water runoff.

E = *Ecological farming* is a sustainable and profitable farming method that mimics natural ecosystems and provides many ecological and environmental soil benefits. ECO Farming starts with zero-tillage to reduce the physical disturbance to the soil ecosystem. Continuous long-term no-till protects the soil habitat, increases carbon sequestration, and allows the soil ecology and soil diversity to sustain crop production. Zero tillage promotes an ecological stable, sustainable, and viable habitat for plants, microorganisms, and soil fauna to live and thrive. This promotes an stable ecological viable habitat that is economically and environmentally sound because it mimics and enhances natural soil processes.

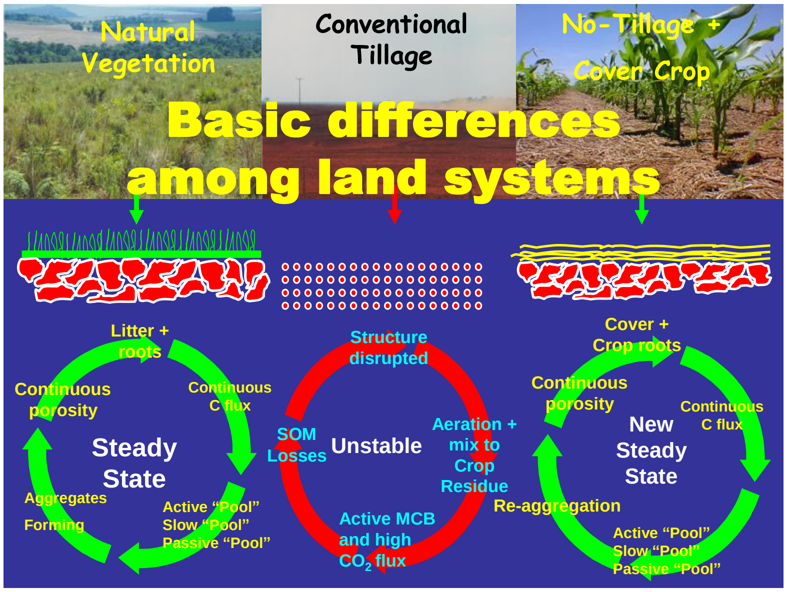

Figure 1: Basic Differences among land systems. From Dr. J. Morales Sa showing how conventional tillage results in an unstable soil ecosystem with a decrease in soil organic matter, soil structure and soil productivity. Natural vegetation and live roots enhance carbon sequestration and the retention and flow of carbon and nutrients in the soil. This leads to improved soil structure, increased water infiltration, higher water storage capacity, improved soil productivity, and a healthy soil. Cover crops and long-term no-till mimic natural vegetation; resulting in a new steady state that is healthy and productive. Long-term no-till and cover crops are essential components in a new farming system call ECO Farming.

Second, soil is meant to be covered with live plants, nurtured by soil microbes, year round. Live plants and microbes evolved together 400 million years ago and they are both mutually dependent on each other for survival. Live plants and roots promote healthy microbial populations which efficiently recycle soil nutrients. The soil microbes process over 90% of the soil nutrients and they get their energy directly from live plant roots. This process is so important to the plants that they exude 25% or more of their total root carbohydrate reserves just to feed the soil microbes (Kuzyakov, 2002). See Figure 2.

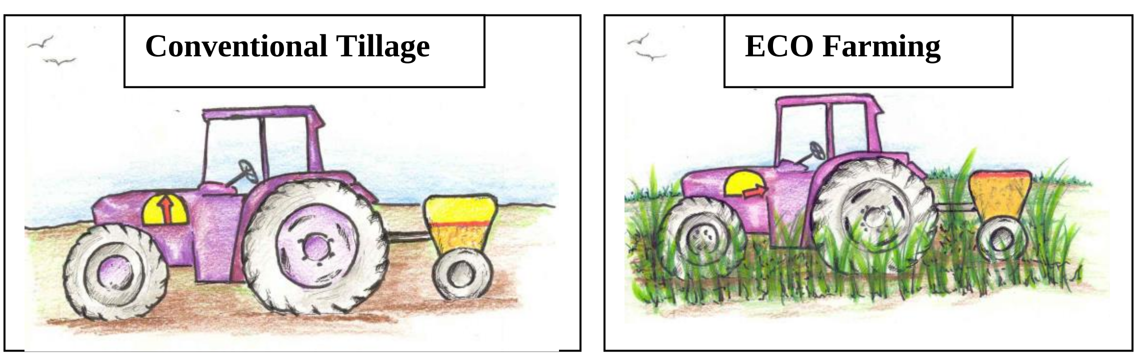

Figure 2: Differences in conventional tillage versus ECO Farming systems in energy soil reserves. In a conventional tilled system, there are live roots only four to five months of the year putting energy into the soil. In a continuous no-till or zero-till system with cover crops, live roots put energy into the soil twelve months of the year. This ECO Farming system has more energy or fuel to feed the microbes and to increase soil organic matter levels and improve soil structure. A healthy soil is a living organism that needs a constant source of energy to fully function.

There are 1,000-2,000 times more microbes associated with live plant roots than what there are in the bulk soil without live roots (Foster, 1988). Without live plants and live roots, microbial populations decline and nutrient efficiency decrecreases. Soil microbes are like "soluble bags of fertilizer", promoting plant growth and production. A healthy soil efficiently utilizes and conserves soil nutrients and promotes healthy plant growth without excessively utilizing supplement agricultural inputs like fertilizer. See Figure 3.

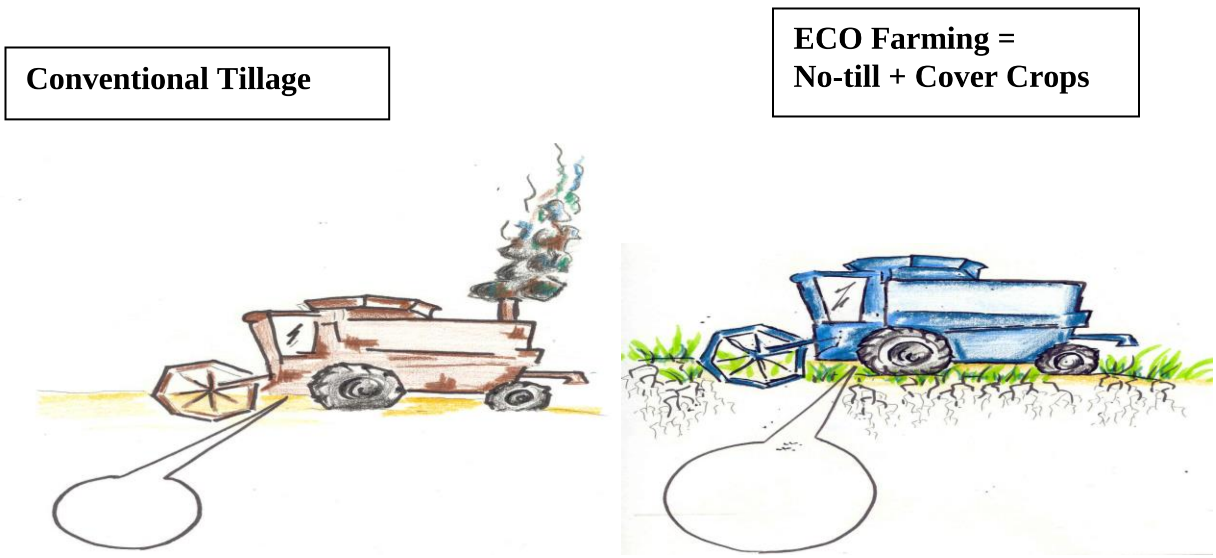

Figure 3: In a conventional tilled system, the microbial population is small and large amounts of carbon dioxide are lost to the atmosphere (black smoke) so few soil nutrients (N&P) are harvested or recycled represented by the rusty combine. In an ECO Farming system (blue combine), a large microbial population and live plants and roots keep recycling the nutrients (N&P) and little carbon is lost to the atmosphere. The balloons represent the amount of microbes in the soil.

C = *Continuous Living Cover* means keeping a living and growing crop on the soil during the entire year to protect and feed the soil ecosystem. A continuous living cover will increase the quantity, the quality, and the timing of organic residues in the soil. The "active carbon" from plant roots and microbial wastes is greatly diminished in conventional tillage systems. Active carbon in the soil promotes good soil structure.

A continuous living cover impacts soil ecology, nutrient cycling, soil structure and soil compaction, water movement and management, and global climate change. Annual crops like corn, soybeans, and wheat are grown but either a cover crop or another cash crop (like winter wheat or hay) are grown after the annual grain harvest. In ECO Farming, the soil is continuously covered with live plants to feed and maintain soil biology, maintain biodiversity, and improve soil productivity. Cover crop mixtures and multi-species cover crops add diversity and increase soil resiliency to adverse environmental conditions that occur on a regular basis.

Third, ECO Farming uses our full knowledge of modern best management practices to enhance crop production. The goal of ecological farming is to produce profitable high yielding crops that utilize crop inputs efficiently while protecting the environment (Hoorman, 2013).

O = *Operational technologies* used on the farm that protect and improve the soil ecosystem through human manipulation. Operational technologies may include controlled traffic, water table drainage management (where applicable), integrated pest management (IPM), precision farming, genetic manipulation (GMO), diverse crop rotations, livestock and crop integration, biological controls, and/or other best management practices.

Using a continuous living cover with no-till in a controlled traffic system will help to manage soil compaction and may provide many savings. Controlled traffic is used to control the impact of soil bulk density, improve hydraulic water functions, and improves soil structure and soil productivity, leading to maximum economic yields. Auto-steering with continuously maintained traffic patterns allows earlier planting and timely harvest because wheel tracks are firmer, resulting in less damage from soil compaction and higher grain yields. Auto-steering means no overlap which reduces costs of all inputs, including fuel and labor, seed, chemicals, and fertilizers.

Water table management may be used to store and control water in the soil profile during or after the growing season to improve plant growth or to reduce soluble nutrient losses. Operational technologies may also include genetic manipulation (GMO) of plant genomes to maximize sustainable economic yields, integrated pest management (IPM) to control pests (weeds, insects, crop diseases), and crop rotations and biological controls to promote a healthier bio-diverse soil ecology.

How Tillage Destroys Soil

Tillage dramatically changes soil ecology according to Don Reicosky, USDA-ARS who says that "soil disturbance to the soil microbes is like the worst hurricane, earthquake, forest fire, and tornado (HEFT) all occurring at the same time" (Reicoski, 2006). Only the smallest soil microbes (viruses, bacteria, protozoa) can survive disturbed soil conditions related to tillage but other soil microbes populations (fungus, nematodes) tend to decline with tillage. Unbalanced microbial populations upsets the natural ecosystem and results in reduced nutrient efficiency and less soil nutrient recycling.

Tillage results in a breakdown of soil macroaggregates into microaggregates, releasing carbon dioxide and results in excess soil oxygen. Soil oxidation is like burning wood in a fireplace, once the soil carbon is lost to the atmosphere (>60% lost, Lal, 2004), fewer soil nutrients (water, N, P) can be stored in the soil (Islam, 2008). Our current nutrient efficiency for nitrogen is 30 to 50% and for phosphorus it is 25 to 50% (Sims et al 1995, Powers, 1978). Most of the nitrate nitrogen leaching occurs during the fall and early spring months when the soil is fallow in the typical corn-soybean rotation of the U.S. Midwest (Owens et al, 1995). Carbon is the key factor in controlling and storing most soil nutrients needed for crop production (Reicoski, 2006).

Crop residues and living plants protect soil from adverse weather conditions. Soil stays cool in the summer due to a mulching effect of decomposing crop residues which improves water infiltration and acts like a sponge to increase water storage. Soil is insulated by crop residues in the winter and live plant roots allow soil to “honeycomb” and not freeze solid, allowing air and water to infiltrate the soil, even in the winter.

Tillage breaks open the soil macroaggregates releasing carbon dioxide and soluble nutrients and over stimulates bacteria populations. The bacteria microbial population thrives for a short period of time, consuming the released soluble nutrients and active carbon (sugars and easily digested nutrients) released from the decomposing residues. As the active carbon is consumed, the microbial population starts to decline and nutrients fail to be recycled due to a lack of carbon. Active carbon from plant roots is needed to tie up soluble soil nutrients and to form macroaggregates which improve soil structure.

Tillage generally occurs in late fall and early winter, so melting snow in late winter and spring rains wash many soluble nutrients to surface water (Hoorman, 2013). Most carbon in the soil (65-70%) comes from the roots (Aziz PhD thesis, 2011). Carbon is needed to tie up soluble nutrients and recycle the nutrients back to the plants. Also, live plants and live roots absorb soluble nutrients which can be lost in runoff to surface water. Without live plants and live roots, the natural ecological cycles are broken and our soil nutrient efficiency decreases. See Figure 4.

Ecological Solutions to Agricultural Environmental Issues

Hoorman says “In natural systems, live plants cover the soil nearly continuously. A conventional corn-soybean crop rotation generally only has live plants and roots four months of the year, so this system has less total energy (1/3) to feed the soil organism. A cover crop with live roots increases the soil energy needed to keep the soil ecosystem active and healthy.

Carbon controls most soil nutrients and is responsible for most chemical, physical, and biological processes. Carbon ties up and stores major nutrients (water, N, P, S) and micronutrients (zinc, boron, copper, manganese). By adding a cover crop to a grain crop rotation, farmers increase the total soil carbon because there are two sets of living roots adding carbon and energy to the soil continuously. Keeping the soil undisturbed and covered with live plants may greatly increase the soil carbon content.

Nutrient efficiency improves when plants exist on the soil year round because the soil is protected by crop residues 1) reducing soil erosion and sedimentation, 2) increasing water infiltration, 3) increasing the soil water holding capacity and water storages, 4) reducing water and nutrient runoff and flooding, and 5) creating a healthy soil system that recycles and stores soluble soil nutrients." (Hoorman, 2013).

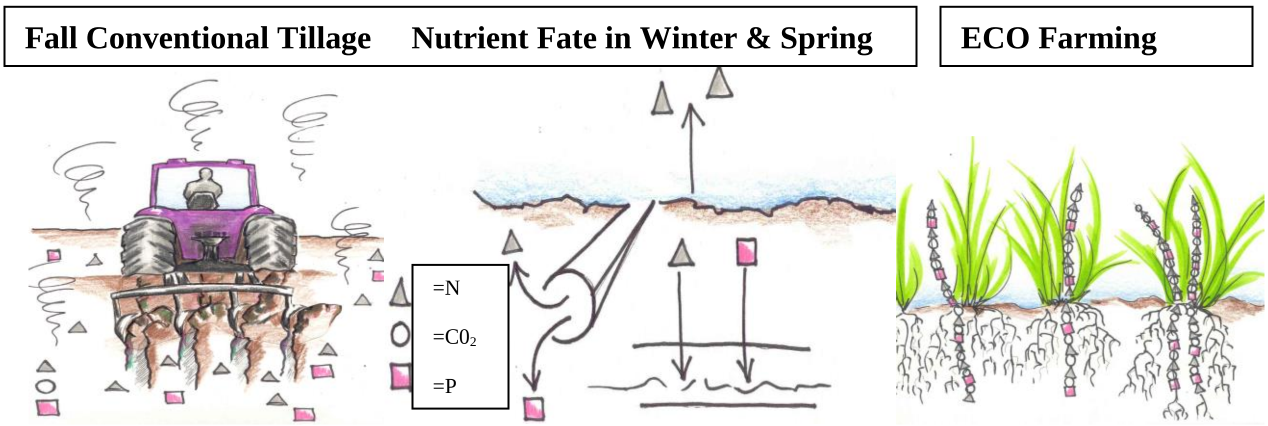

Figure 4: In conventional tillage, soil nutrients are released in the fall by tillage and the microbial population expands rapidly. However, they soon run out of food, energy and nutrients, and the nutrients are releases and may be lost in the winter and early spring with snowmelt and rainfall. In an ECO Farming system, the nutrients are tied up in the plant biomass and carried forward to the next crop.

Almost 90% of the available N (Espinoza, et al) and 50 to 80% of the P in the soil is tied up in an organic form (Dahl, 1977) and without carbon; these nutrients may be lost from the soil profile. Tillman found that crops acquire 40-80% of their N from organic soil reserves and an average of 50% of the N applied as fertilizer is lost from agricultural landscapes (Tilman 1999).

Cover crop planted in late summer or fall feed the soil microbes active organic matter and the soil microbes may recycle soluble nutrients and/or the nutrients may be taken up by the cover crops. Nutrient efficiency improves because the soluble nutrients are not as easily lost to surface runoff. Active carbon has two major functions: 1) food and energy to sustain the soil microbes, and 2) active carbon which is like glue that improves soil structure. (Hoorman et al., 2015).

Active carbon has to be continually produced because it only lasts five to seven days to as long as three months in the soil.

Farmers often report that the transition period may last 5-7 years with no-till, but with the addition of cover crops, the transition period may be reduced to 3-5 years or even 1-3 years if the soil has been in long-term no-till. Hoorman says "Higher yields and increased profitability may not occur until most of the initial soil problems (soil compaction, poor soil structure, lack of biodiversity) are resolved. As the ecological system recovers in the long-term, less farm inputs may be needed to produce sustainable and profitable crop yields" (Hoorman, 2013).

The most pronounced effects from ECO Farming occur under "stressful" conditions because ECO Farming increases a soil resiliency to change. In a dry year, the increased water infiltration and water storage accessed by deep growing roots along with increased nutrient availability associated with the active organic matter, allows the plants access to more available nutrients and water, increasing crop yields.

Optimal Sustainable Economic Yields (OSEY) means that farmers should not necessarily try for maximum yields, but should instead strive for optimal sustainable economic yields. This economic concept suggests that maximum yields are never the most economical and that by promoting more sustainable yields short-term, producers are also achieving maximum economic yields long-term. This means that sometimes producers may have to slightly sacrifice yields or change their management short-term if long-term higher economic yields are to be obtained. For example, herbicides, fungicides, insecticides, may be minimized short-term to promote optimal cover crop growth, to improve mycorrhizae growth, and to increase beneficial insect predators. Crop yields may or may not decrease slightly for 1-3 years until the soil ecosystem is stabilized.

Early maturing corn and soybean varieties may need to be planted to maximize cover crop growth. Cover crops typically need at least 60 to 90 days of growth before winter occurs (Midwest Cover Crops Field guide, 2014). Cover crops may also be inter-seeded into maturing crops so that the soil is constantly covered with live plants. The improved soil structure and environmental benefits of protecting the soil outweigh short-term negative effects that may occur during the transition to a biologically stable system. Weeds, insect infestations and soil-borne disease control tends to improve due to increased biodiversity and more beneficial predators in the soil profile. These benefits mean that less farm inputs may be needed to produce sustainable and profitable crop yields.

Humans benefit from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and include products like clean drinking water and processes such as the decomposition of wastes. Ecosystem services have been grouped into four broad categories: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and diseases, insects, and weeds; *supporting*, such as nutrient cycles and crop pollination; and *cultural*, such as spiritual and recreational benefits. Ecosystem services and functionality improves in an ECO Farming system since the continuous long-term no-till with continuous living crops mimics the natural biological world.

Summary

ECO farming is a sustainable and economical way to improve the environment by using eternal no-till or zero-till with continuously living crops on the soil year round to improve environmental functionality and environmental services. Operational technologies like controlled traffic, water table management, integrated pest management, genetic manipulation and other technologies may be utilized to improve soil structure, soil health, and soil productivity which ultimately lead to higher and sustainable crop yields that are more profitable to produce. ECO Farming creates diversity and increases soil resiliency and crop production resiliency to adverse environmental conditions that occur on a regular basis.

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