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 systems approach that employs all our current knowledge and technology based on holistic and novel principles about natural and sustainable management practices. In a nutshell, *ECO-farming combines and complements continuous no-till, crop rotation, cover crops, and organic, recycled and natural soil amendments into a system to maximize ecosystem services.* Some examples of those ecosystem services are biological pest control by beneficial insects, weed suppression by cover crops and greater soil fertility thanks to more microbes in the soil. ECO-farming builds soil health and increases crops yields, reduces the use of reactive nutrients such as nitrogen and phosphorus, reduces the use of synthetic chemicals, diversifies farm income, and improves air and water quality by controlling soil erosion and reducing greenhouse-gas emissions. See Figure 1.

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

First, soil is considered a living breathing organism (system)_that needs to be fed and nurtured. Soil is meant to be protected, diversified and conserved, not degraded or destroyed with tillage.. Soil acts like a thin 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 organic matter loss, soil erosion, compacted soils, and nutrient and water runoff, and thus consequently a poor unhealthy soil.

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

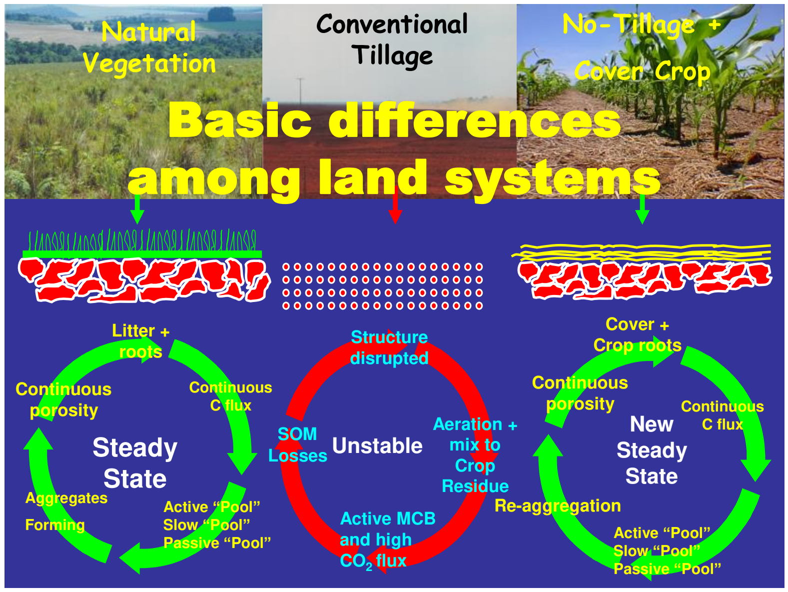

Figure 1: Basic differences among land-use/land cover systems. From Dr. Juca Morales Sa showing how conventional tillage results in an unstable soil ecosystem with a decrease in soil organic matter content and degraded soil structure and soil productivity. Natural vegetation and live roots enhance carbon sequestration and the retention and flow of carbon and nutrients in soil organic matter. 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 called ECO Farming.

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

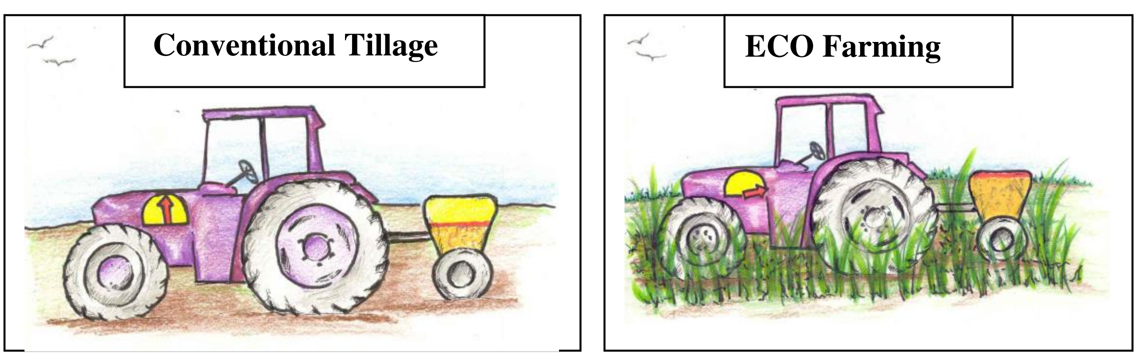

Figure 2: *Differences in conventional tillage versus ECO Farming systems in soil energy reserves. In a conventional tilled system, there are live roots only four to five months of the year putting energy into the soil. In a continuous no-till or zero-till system with cover crops, live roots put energy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

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

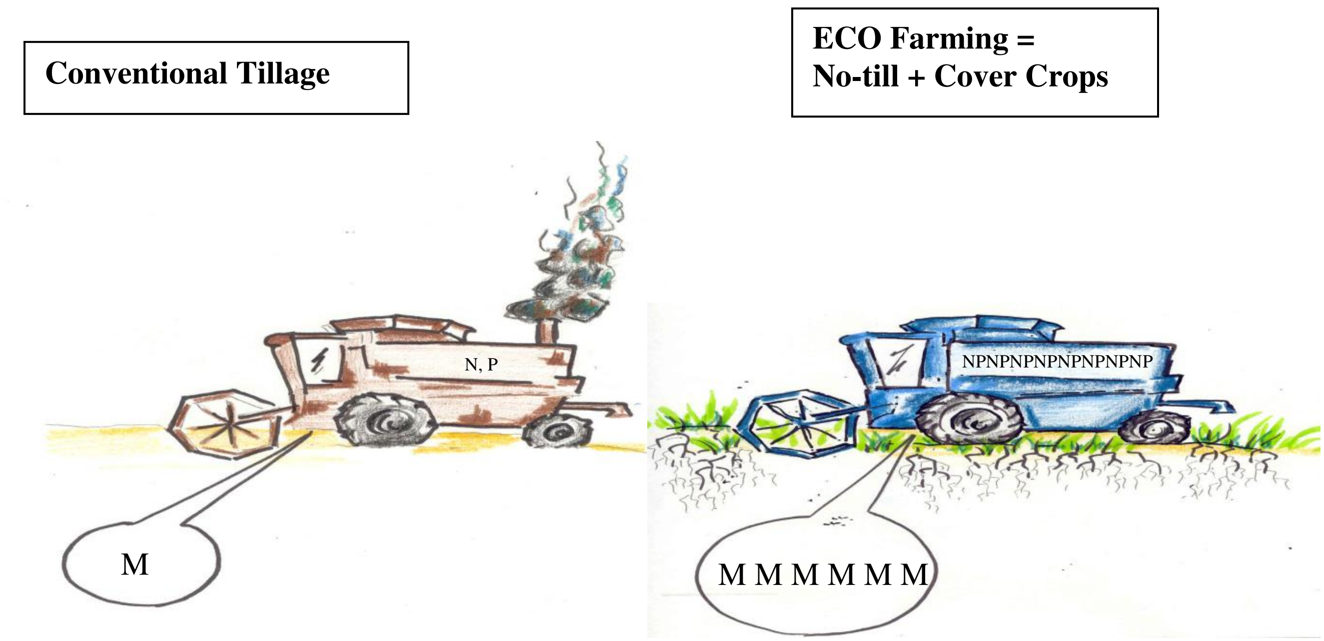

Figure 3: In a conventional tilled system, the microbial population is small and large amounts of carbon dioxide are lost to the atmosphere (black smoke), so few soil nutrients (N & P) are harvested or recycled represented by the rusty combine. In an ECO Farming system (blue combine), a large microbial population and live plants and roots keep recycling the soil nutrients (N &P) and less carbon is lost to the atmosphere. Illustration by Cheryl Bolinger-McKirnan & James J. Hoorman.

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 microbes is greatly diminished in conventional tillage systems. Active carbon promotes soil structure and a healthy soil.

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 add diversity and increase soil resiliency to adverse environmental conditions and weather events 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 more efficiently while protecting the environment* (Hoorman, 2013, 2015a).

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, soil amendments, and/or other best management practices (Hoorman 2013, 2015ab, Hoorman et al. 2011).

Using a continuous living cover with no-till in a controlled traffic system will help to manage soil compaction and may provide many benefits. Controlled traffic is used to control the impact of soil bulk density, improve hydrological 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 has little or no overlap which reduces costs of all inputs, including fuel and labor, seed, chemicals, and fertilizers.

Cover crop roots improve soil structure and allow surface water to move down into the soil profile so that the water table can be managed. Water table management is new drainage system that stores and controls water availability in the soil profile during or after the growing season to improve plant growth or to reduce nutrient leaching. 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 Degrades Soil

Tillage dramatically changes soil ecology. Reicoski, 2006 describes the damage done to soil from tillage to be like a series of natural disasters all happening at the same time. *Only the smallest soil microbes (viruses, bacteria) tend to survive tillage induced soil disturbance. Populations of other soil microorganisms (nematodes, fungi, bacteria, etc) tend to decline under tillage. A dominance of unbalanced and selective microbial populations upsets the natural ecosystem and results in reduced biodiversity and decreases nutrient cycling*.

Tillage results in a breakdown of soil macroaggregates into microaggregates, releases protected carbon, and results in more aeration for biochemical oxidation of organic carbon to carbon dioxide (CO_2) (Hoorman et al. 2011). Soil oxidation is like burning wood in a fireplace, once more than 60% of soil carbon is lost to the atmosphere (Lal, 2004), fewer soil nutrients (water, N, P) can be stored in the soil (Islam, 2008). Current nutrient efficiency for nitrogen is 30 to 50% and for phosphorus it is 25 to 50% (Sims et al 1995, Powers, 1978). Owen et al. (1995) states that most of the nitrate leaching from agricultural soils occurs during the fall and early spring months when the soil is fallow in the normal corn-soybean rotation employed in the US corn belt.t Carbon is the key factor in controlling and storing most soil nutrients, especially nitrogen in SOM needed for crop production (Reicosky, 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 late in the winter.

Tillage breaks open the soil macroaggregates releasing protected carbon and soluble nutrients and over stimulates opportunistic microbial (especially aerobic bacteria) populations. The bacterial 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 plant residues and native SOM. *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 nutrients and to form macroaggregates which improve soil structure (Hoorman et, al. 2011).*

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

Ecological Solutions to Environmental Issues

In natural systems, live plants cover the soil nearly continuously (Hoorman 2013, 2015a). A conventional corn-soybean crop rotation generally 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 in SOM is responsible for most of the soil chemical, physical, and biological processes (Hoorman, 2013, 2015ab). Carbon stores water and ties up essential soil nutrients (N, P, S, Zn, Bn, Cu Mn, etc.). By adding a cover crop to a grain crop rotation, farmers increase the total soil organic 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. Protecting the soil reduces soil erosion and nutrient runoff. Live plants and the addition of SOM increases water infiltration and improves water storage. Live plants increase microbial diversity and create a healthy soil system that recycles and stores soluble nutrients (Hoorman, 2013, 2015a, Hoorman et al 2009a)). See Figure 4.

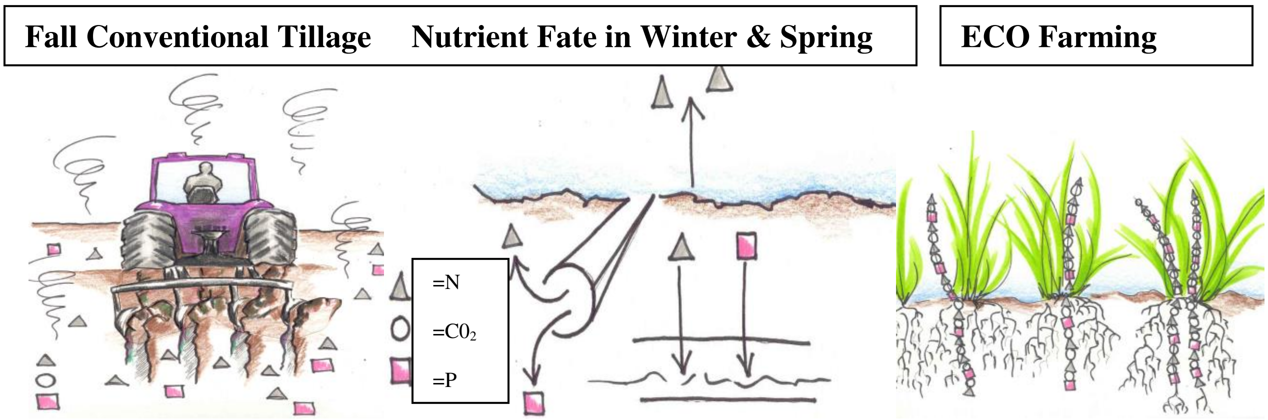

Figure 4: In conventional tillage, soil nutrients are released in the fall by tillage and the microbial population expands rapidly. However, they soon run out of food, energy and nutrients, and the nutrients are releases and may be lost in the winter and early spring with snowmelt and rainfall. In an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

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

A cover crop planted in late summer or fall provides active organic matter to feed soil microbes which 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 2011). Active carbon has to be continually produced because it only lasts five to seven days to as long as three months in the soil.

When farmers convert from conventional tillage to no-till, there is often a transitional period before crop yields recover. 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. 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 soil ecology recovers in the long-term, fewer inputs may be needed to produce sustainable and profitable crop yields (Hoorman, 2013).

The most pronounced effects from ECO Farming occur under “stressful” conditions since the organic matter added to the soil increases a soil’s 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. In wet years, the soil organic matter absorbs water and keeps soluble nutrients from running off or leaching. Soil organic matter acts like a buffer under environmental stressful conditions, improving crop productivity and performance (Hoorman et al. 2009).

Optimal Sustainable Economic Yields (OSEY) means that farmers should not try for maximum yields, but should instead strive for optimal sustainable economic yields. This economic concept suggests that short-term maximum yields are never the most economical in the long-term. By promoting more sustainable yields short-term, producers are also achieving maximum economic yields long-term. 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, the use of herbicides, fungicides, and insecticides may be minimized short-term to promote optimal cover crop growth, to improve mycorrhizal growth, and to increase beneficial insect predators. Crop yields may o decrease slightly for 1-3 years until the soil ecosystem is stabilized. A short-term loss in crop yields may be made up by a long-term gain in improved soil health and increased profitability by using less commercial inputs like fertilizer, pesticides, fuel, and labor.

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 clean drinking water, food production, clean air, among others. 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 (Soil Science Society of America). 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. For more information on selecting and managing cover crops, see Hoorman et al. 2009b.

Summary

ECO farming is a sustainable and economical way to improve the environment by using no-till or zero-till with continuously living crops on the soil year round to improve 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 in the vent of adverse environmental conditions that occur on a regular basis.

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