NO-TILL FARMING AND THE ENVIRONMENT: DO NO-TILL SYSTEMS REQUIRE MORE CHEMICALS?

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Why does the question ‘Do no-till systems require more chemicals?’ matter?

The sustainability of agricultural production is regaining importance, particularly in view of the predicted population increase. Terms such as “sustainable production intensification” are widely discussed within the global development agenda. In the area of agricultural crop production one term – no-till – is leading to increased polemic and polarization of the parties. No-till or no-tillage describes a form of cropping which does not use mechanical tillage of the soil for crop establishment. Mechanical tillage, a standard operation in agriculture since ancient times, is mostly symbolized by the use of the plough. Where ever it has been practiced, it has led to soil degradation and erosion and is considered as the root cause for severe and large scale signs of landscape degradation or even desertification. One of the most spectacular soil erosion events caused by soil tillage was the famous dust bowl in United States of America in the 1930s, but soil erosion problems are still observed around the globe. David Montgomery in his book Dirt – the erosion of civilizations describes how, in most parts of the world, soil tillage has led to soil erosion in quantities that exceed the natural soil formation by orders of magnitude. In human history, the decline of major civilizations can be attributed to erosion events, i.e. to a loss of productive capacity of the soil. Hence, soil tillage can no longer be considered to be compatible with sustainable agriculture and therefore the possible solution to address the threat of unsustainability of the agricultural soil resource base would include the avoidance of mechanical soil disturbance, or no-till. Those who oppose this notion argue that no-till is equated with an abusively high use of herbicides and even genetically modified organisms (GMOs) are synonymous with unsustainable agriculture, with no-till taking all the blame. Unfortunately, both sides are right, and therefore, to get closer to the answer of the initial question, we have to take a deeper look into no-tillage systems, to find out, whether no-tillage is really the problem, or whether there are other associated problems which are falsely blamed on no-till?

What are no-tillage systems?

When agricultural systems are compared there is a lot of confusion in the terminology. This confusion even led to a specific session during the recent 5th World Congress on Conservation Agriculture on “defining no-tillage”. The majority of conventional agriculture relies on the plough as the primary tillage tool, resulting in the most disruptive form of soil tillage, “inversion” tillage, where literally the soil is turned upside down and its structure destroyed. Any reduction in tillage intensity from this extreme situation is considered to constitute “reduced tillage”, leading to a wide spectrum of “minimum tillage” approaches. These approaches include “conservation tillage” comprising any forms of tillage that leave a minimum of 30% of the soil surface covered with residues, but not limiting tillage intensity in the soil at one end of the range to complete avoidance of tillage, no-till, at the other. This means, from a traditional point of view, no-till is considered to be the extreme within a group of reduced tillage approaches which are often treated as belonging to a single category, although being fundamentally different. But even within the term no-till, a distinction has to be made between high-disturbance no-till, where the seeding machine itself might carry out a shallow tillage operation, or low-disturbance no-till, where the seeding machine just cuts or opens a slot in the soil surface for seeding or punches the seeds into the soil without any soil movement.

For hardcore no-tillers, any form of mechanical tillage, including high disturbance no-till, is not considered as no-till (Figure 1). For this group no-till is also a permanent feature of soil management, for all seasons and all crops. Therefore, some people refer to true no-till systems as “never till” or “zero till”. In fact, the real shift in the agricultural paradigm is not between full tillage and reduced tillage, but between tillage and no-tillage, or till and no-till. Tillage-based systems, even with reduced tillage or conservation tillage, have a completely different dynamic in terms of weeds, pests and nutrients compared to permanent no-till systems. In addition,
there are also different permanent no-till systems: there are systems where no-till is just used as a practice without changing any other feature of conventional cropping systems. And, within the low disturbance permanent no-till systems, there is a system, which is specifically designed for enhanced environmental performance and productivity (efficiency) by adding complementary elements to the no-till, such as soil cover and crop diversity. This system is also known as “Conservation Agriculture” and to avoid confusion, this term should only be used for such system as defined by FAO (see below).

**What makes people think no-till systems need more inputs?**
The first reason for the confusion and misconception is the inaccuracy in using the terminology: the indiscriminate use of the terms around reduced tillage and no-tillage systems makes no distinction between systems that indeed might use more agrochemicals and others that do not. After all, even in conventional tillage systems with full tillage we have a continuum of farmers using high quantities of agrochemicals, GMOs and other external inputs and those that do not use them at all such as organic farmers. However, there is never a debate about “tillage-based agriculture needing more chemicals”. It is also important to mention that only production systems at similar intensity levels of outputs should be compared to determine whether a system needs more inputs than another. Yet, the perception that no-till systems need more inputs would not have become an issue if there was not some truth in it. Obviously tillage is used in agriculture for certain purposes. Some of them are related to weed management, others to pest management and again others to nutrient or water management. If tillage is reduced or even completely eliminated, this will have an impact on all these areas, unless other coping strategies are introduced to offset those impacts. This means, if a farmer reduces or abolishes tillage without changing anything else in the cropping system, for example in terms of a crop rotation or handling of crop residues, this will result in most cases in problems with weeds, pests and nutrients availability and hence require more herbicides, more pesticides and more fertilizer. However, these are not an unavoidable consequences of eliminating tillage.

**What are the conditions under which no-tillage systems require fewer inputs?**
Natural environments produce significant amounts of biomass and in most cases this is very sustainable. If we accept the initial statement that tillage in most cases leads to unavoidable soil erosion and degradation, a sustainable agricultural production system should be based on no-tillage. Yet, agricultural production is an unnatural system that must find ways to learn from nature in order to make most use of natural control mechanisms, for example against insect pests, pathogens and weeds, to reduce the need of further artificial interventions. Soil tillage causes a major disruption of natural systems and therefore no-tillage systems should provide much better opportunities to reduce the need of inputs than do tillage-based systems. To mimic natural systems no-tillage needs to be complemented with additional elements:

First of all, no-tillage needs to be a permanent feature, to allow soil life to establish in the soil profile to its full potential and diversity and to avoid damaging the soil structuring processes facilitated by the different forms of soil life.

Secondly, the soil needs to be covered permanently with organic material, which provides shelter and protection from sun, rain, heat, cold and wind and which also provides the substrate for the soil organisms to feed on and to perform a variety of ecosystem services such as carbon sequestration, water infiltration and erosion control.

Thirdly the crops grown need to be as diverse as possible under given market conditions. Natural systems in very few cases are pure stands of one species; the more stable and resilient systems show a high degree of diversity. In agriculture, this can be achieved either by diverse crop rotations, or by crop associations, inter-, under- or relay cropping.

These three elements together are commonly known as a specific no-till system called Conservation Agriculture (CA). The full definition of Conservation Agriculture is provided by the UN Food and Agriculture Organization (FAO) on its website (http://www.fao.org/ag/ca/1a.html). The definition further describes CA as follows: “CA principles are universally applicable to all agricultural landscapes and land uses with locally formulated and adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfall and irrigated production. Complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as...
as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.”

Keeping this in mind, the key for using fewer inputs in agriculture is actually conditional upon using natural processes to the maximum extent possible, and this in no-till systems is actually easier to achieve than in tillage-based systems. To achieve this soil disturbance needs to be kept at a minimum for all crops and operations in a rotation and field experience shows that this is also possible for root crops such as sugar beets, cassava or even potatoes or peanuts by adapting the cropping practices and the harvest equipment.

For example weed problems: tillage prepares not only a seedbed for crops, but also for weeds. In addition, tillage incorporates weed seeds into the soil, where they can be protected and conserved for many years. It also brings conserved weed seeds to the soil surface, where they can germinate. Tillage may also spread perennial weeds by cutting and distributing rhizomes and other propagating parts. Work by different scientists, such as R.L. Anderson, shows that the pressure of annual weeds over time is reduced the less disturbed is the soil, including in the seeding operation (Figure 2). It also shows that weed pressure is reduced the more diverse a crop rotation is and the better a soil is sheltered from the sun with mulch (Anderson, 2005) (Figure 3). All these effects apply to a good Conservation Agriculture system, contrary to tillage-based systems. As a result the long term experiences in mature and well managed no-till systems, such as in Western Canada, show that herbicide use did not increase with the shift to no-till, but in many cases decreased over time in the absolute amount used and in the amount used per unit of biological output. In a long term case study “Landscapes Transformed” (Lindwall & Sonntag, 2010) the perception of higher herbicide use in no-till systems is dispelled as a myth. Specific cases here are cropping systems depending only on manual labour and traditionally not using herbicides. For such systems, using herbicides results in a dramatic reduction in labour, especially for women who are often in charge of manual weeding (Leonard Gianessi & Ashley Williams, 2011). But even without the use of herbicides such systems can show significant reduction of labour requirements for crop management. First of all the drudgery and hard work is reduced, since manual tillage is one of the hardest forms of farm works. Secondly the peak labour demands shift, since land preparation also has the highest labour demand. The increase in labour for weeding in the absence of tillage and without herbicides is often assumed to require the same weeding strategies as under tillage-based systems, i.e. deep heavy hoeing, which in the presence of crop residues and in a no-tilled soil results in even harder work than in tillage based systems. Yet, adopting alternative manual weeding strategies, such as shallow weeding, chopping, manual pulling and applying good Conservation Agriculture methods can reduce the labour demand. This effect is now also increasingly documented, such as in a recent case study from Tanzania published by FAO (Owenya et al, 2012; Figure 4).

For example pest and disease pressures: mature no-till systems such as well managed Conservation Agriculture systems are characterized by high biodiversity below and above the ground. The systems provide a fairly stable habitat
for predators and natural enemies of insect pests and pathogens, including antagonistic fungi and other microorganisms. Most of these natural enemies would not exist in tillage-based systems at a level to give a beneficial effect, hence their effect and impact in agriculture was mostly unknown. However, even in tropical climates, farmers applying good Conservation Agriculture techniques, particularly with diversified crop rotations, experience a significant reduction in pest and disease pressures over time, often resulting in not having to apply any pesticides for long periods. Obviously such effects are not always visible from the first year of conversion but build up over time, so that, depending on the level of degradation of the original cropping system, there could be unexpected pest and disease outbreaks in the first years after shifting to no-till, creating the impression that there are more pest problems in no-till. Yet, the problems usually are not greater, but only different and unknown to the farmer. In most well managed no-till systems, adhering to Conservation Agriculture principles, pesticide use over time is reduced and only systems with monocultures tend to suffer from increasing pest and disease problems.

For example plant nutrients: Another myth is that fertilizer, particularly nitrogen, has to be increased when shifting to no-till. In fact, the build-up of soil organic matter through natural processes can only take place if the carbon supply is matched with a corresponding nitrogen supply. Yet, the locking up of soil nitrogen in the presence of crop residues such as straw, leading to acute shortage of nitrogen for the crops because the nitrogen is used for decomposing the straw, only takes place if the straw is brought into direct contact with the soil, for example by tillage. In no-till systems the straw decomposition would only take place to the extent that the soil microorganisms come into contact with the straw or residues. In the first years the soil nutrient level is said to increase in degraded soils, until the entire system operates at a higher level, requiring obviously higher input rates. Those higher input rates are, however, offset by a dramatic reduction in fertilizer and nutrient losses through erosion and leaching and, in the case of nitrogen, by better options such as the use of legume cover crops in the system as an additional nitrogen source. Further, no-tillage systems, once the usual plough pans are broken, provide a deeper rooting environment and hence a bigger nutrient pool, and the availability of soil nutrients is increased by organic matter and organic acids, as well as by living organisms such as mycorrhizas or free living rhizobia. Overall, there are many cropping systems which would not require higher fertilizer rates at the point of shifting towards no-till systems, without resulting in the famous “yield dip”. If relatively higher fertilizer rates are necessary, this is only the case for a few years until soil fertility is recovered. In general, the long term experience again shows a significant increase of yields with a significant reduction in fertilizer requirements, which could amount to 50% reductions. These effects have been researched in different climates and cropping systems, for example by G. Lafond in Canada (Lafond et al., 2008), but similar results exist from the tropics and from a number of farmers’ observations.

The only areas where there is general agreement that no-till systems save inputs are energy, fuel and machinery. Energy and fuel savings can be up to 70%, but also the over-

all need for machinery in terms of tractor power and capacity per farm and total machinery investment can be reduced by 50%, provided the farm shifts 100% to a full permanent no-till system and does not keep a tillage option open “just in case”. These cost reductions usually result in immediate higher profits when adopting a no-till system, even in those cases, where yields, for example, do not respond positively in the first few years.

What are the conclusions?
The initial statement that no-tillage systems require more chemicals can be considered a misconception. The problem with systems that use higher levels of inputs is not no-till, but other unsustainable practices, such as monocropping and exposed soil surface. In fact, no-till is a necessary, but not a completely sufficient condition to arrive at truly sustainable agriculture eventually. No-till as a practice has to be complemented with other practices to arrive at such true sustainability of a farming system in which the environmental footprint, be it from soil management or the use of agrochemical inputs, is smaller than the recovery capacity of the natural ecosystem. This can only be achieved in the absence of soil tillage, but it also requires a very careful and moderate use of agrochemicals, which will lead to a reduction in their use. While both systems, tillage-based as well as no-till systems can be operated at high as well as at low external input levels, the well managed no-till systems provide in the long term better chances to reduce the use of external inputs to levels even below the ones of well managed tillage based systems, without sacrificing production. This is the true core of a sustainable production intensification as described with the “Save and Grow” concept recently published by FAO. Examples from real productive agriculture in countries with mature, long established no-till systems such as Conservation Agriculture, exist, for example in Southern Brazil, Western Canada and Western Australia.
The answer to the question in the title is, therefore, a very clear NO!

References

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