

Zero Tillage/ Minimum Tillage



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Table of Contents

1.0 Introduction	4
1.1 Tillage	4
1.2 Definition.....	4
1.3 Zero tillage - Introduction	5
1.4 History	5-6
2.0 No-tillage Farming System	7
2.1 What is no-till?.....	8
3.0 No-till and conservation agriculture	9-10
3.1 Agroecological differences between conventional tillage and no-tillage practices.....	10
3.2 No-till Today.....	11-12
4.0 Section guideline for implementation	13-15
4.1 Implements and Tools for zero tillage:	15
4.1.1 No till planter	15
4.1.2 A roller/crimper	16
4.1.3 A broadfork	17
4.1.4 A subsoiler	18
4.1.5 A no-till seed drill.....	18-19
4.1.6 Zero till seed/grain drill cum fertilizer	19
4.1.7 Metal cutting blade mould board plough.....	20
4.1.8 Rotary weeder	21

5.0 Management of zero tillage.....	22
5.1 Cover crops.....	22
5.2 Integrated disease and pest management	23
5.3 Crop rotation	23
5.4 Light implements	23
6.0 Farmer adoption of no-tillage practices.....	24
7.0 Advantages and disadvantages of notillage practices.....	25
7.1 Advantages:	25-28
7.2 Disadvantages:.....	28-30
8.0 Bibliography.....	31-32

1.0 Introduction

1.1 Tillage

Tillage is the manipulation of the soil in to a desired condition by mechanical means: tools are employed to achieve some desired effect (such as pulverization, cutting or movement). Soil is tilled to change its structure, to kill weeds, and to manage crop residues. Soil-structure modification is often necessary.

1.2 Definition (Zero tillage)

It is an **extreme form of minimum tillage**. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation in the **row zone only**.

- Placement of seed in to soil without soil preparation
- It is the direct sowing of seed in the field without any disturbance to the soil.
- There are different forms of tillage systems which are practiced by the farmers and their levels of crop residues formations are different for each tillage practices.



Figure 01: Different terms related to the zero tillage

Source: <https://www.pennington.com/resources/agriculture/covercrop>

1.3 Zero tillage – Introduction

Zero tillage is an extreme form of minimum tillage and it is also known as **no till farming** or as **direct drilling**. (Figure 01)

- It is a way of growing crops or pasture from year to year without disturbing the soil through tillage
- It is also an agricultural technique which increases the organic matter retention and cycling of nutrients and increases the amount of water that infiltrates in to the soil.
- It reduces or eliminate soil erosion in many agricultural regions.
- Help to increases the amount and variety of life in an on the soil including disease- causing organisms and disease suppressing organisms. The most powerful benefit of zero tillage is improvement in soil biological fertility making soil more resilient. Farm operations made much more efficient, particularly improved time of sowing and better traffic ability of farm operations.

1.4 History

The term No-tillage or minimum-tillage have been used since ancient times. Therefore, it called “primitive cultures” for the production of crops, simply because man has not the muscle force to till any significant area of land to a significant depth by hand. The concept of zero tillage was started in early 1940s by Edward Faulkner.

Tilling of soil is used to remove weeds, shape the soil into rows for crop plants and furrows for irrigation. This leads to unfavorable effects like soil compaction; loss of organic matter; degradation of soil aggregates; depths of destruction of soil microbes and other organisms and soil erosion where top soils washed or blown away.

Zero tillage avoid these effects by excluding the use of tillage. With this way of farming, crop residues or other organic amenities are retained on the soil surface and sowing or fertilizing is done with minimal soil disturbance. Continuous zero till needs to be managed very differently in order to keep or increase yield on the field.

2.0 No-tillage Farming System

No-tillage farming systems or no-till, as an aspect of conservation farming, are actively promoted internationally to conserve soils and by this, ensure food security, biodiversity and water conservation. Instead of tilling before seeding, seeds are deposited directly into untilled soil by opening a narrow slot trench or band.

No-till can significantly reduce soil erosion and conserve water in the soils. This is regarded as a basis for higher and more stable crop yields – but science shows that this is not necessarily true.

Discouragingly, there are numbers of examples of no yield benefits or even yield reductions under no-till in developing countries, especially in the first up to ten years. However, particularly the crop yields are crucial for the food security of small-scale farmers and not whether a method is more efficient or not.

Even if no-till became a promising mitigation option, other environmental problems would remain. No-till farming systems often come along with the industrialization of agriculture with high inputs of agrochemicals. On the one hand, small-scale farmers are not skilled in handling such chemicals. On the other hand there remains a risk that they apply cheap chemicals, which persist long-term in the environment. Efforts should therefore be strengthened on how to combine sustainable production systems such as organic agriculture with no-till practices. To summarize, there are too many open questions and uncertainties concerning the impact of no-till on crop yields and carbon sequestration, so that no-till could not be sold as the solution for hunger reduction and adequate option to mitigate climate change but as an important part of integrated strategies.

2.1 What is no-till?

No-tillage or no-till, also referred to as zero tillage, is a soil cultivation system in which seeds are deposited directly into untilled soil. It is defined “as a system of planting (seeding) crops into **untilled soil by opening a narrow slot trench or band only of sufficient width and depth to obtain proper seed coverage**. No other soil tillage is done.”

Conventional tillage completely inverts the soil, while no-till cause’s only negligible soil disturbance and the residues from previous crops remain largely undisturbed at the soil surface as mulch. Seeding systems that till and mix more than 50% of the soil surface while seeding cannot be classified as no-tillage.

No-till farming is not concerned only with soil tillage – it encompasses four broad, intertwined management practices:

- Minimal soil disturbance (no ploughing and harrowing),
- Maintenance of a permanent vegetative soil cover,
- direct sowing and
- Sound crop rotation

These management practices also **meet the definition of conservation agriculture**. No-till farming is also sometimes regarded as a **component of sustainable land management (SLM) and better land husbandry (BLH) approaches**.

3.0 No-till and conservation agriculture

No-till and conservation agriculture are therefore difficult to distinguish from each other. Further it defines the tillage practice of conservation agriculture as follows: “The practice of conservation agriculture advocates minimal soil disturbance and hence much less or no tilling is carried out.” This means that conservation agriculture can imply either less deep and/or less frequent tillage practices. No-till as a component of conservation agriculture is today actively promoted by a growing number of research and extension programmes.

Certain prerequisites must be met for successful implementation of no-till farming. Like other agronomic technologies, it requires know how and a detailed understanding of soil-plant interactions. Special no-till equipment is needed: no-till is bound to fail if techniques for drilling seed into residues at the proper depth are not available.

In principle, the method always involves the following stages:

- Handling loose straw or living mulch by cutting/moving aside or rolling;
- Application of seeds and fertilizers;
- Furrow closing;
- Seed/soil compaction.

In developed countries this is done using sophisticated farm machinery. In developing countries, a variety of no-till equipment is available to smallholders. Planting devices range from manual tools to animal-powered devices and tractor-driven seeders.

Manual seeding of crops into plant residues is relatively easy and can be performed using equipment such as the jab planter.

The simplest method involves using a hoe or pointed stick to make small holes at the required spacing; seed is then placed in these holes preferably with fertilizer or manure placed in another hole a few centimeters away.

3.1 Agroecological differences between conventional tillage and no-tillage practices

To understand the differences between conservation and conventional tillage practices at an economic, environmental and social level, it is essential to look at the agroecological functions of each of the systems, specifically the production of CO₂, aeration, water movement, runoff and infiltration.

In an open soil-plant system such as conventional tillage the following characteristics occur:

- This soil plant system is drought prone; accelerates soil surface erosion; requires high input level to maintain fertility
- Soil Organic Matter (SOM) oxidation, intense nitrate fluxes, the soil porosity collapses, water infiltration capacity is reduced, runoff increases and fluxes of nutrients are washed away.
- Tillage unlocks the potential from microbial activity by creating more reactive surface areas for gas exchange on soil aggregates that are exposed to higher ambient oxygen concentration (21%) and higher temperatures.
- Over time, ploughing creates a compaction zone which further prevents upward soil fauna movements and downward root development.
- Intense nitrate leaching and accompanying cations, e.g. Ca, Mg, out of the shallow root zone, results in soil acidification and groundwater pollution.

No-tillage practices represent a closed soil plant system, characterized by the following:

- The soil plant system mimics a natural soil ecosystem. It is more drought resistant, it ensures highly efficient use of existing nutrients.
- Due to the intense biological activity, the soil pore atmosphere is richer in CO₂, Soil temperature is also lower.
- Both conditions lead to reduced oxidation rates and accumulation of SOM.
- Permanent soil cover protects from the soil from the rain drops' energy, increases water infiltration, and hence drastically reduces water runoff and soil erosion risks.
- Increased population of earthworms, insects and greater root development contribute to better soil aeration.
- Efficient water and nutrient cycling as a result of root development and stable biological porosity.
- Clean water drained

3.2 No-till Today

No-tillage started in the USA in 1930s. This served as a wake-up call, highlighting the non-sustainable nature of agricultural systems that involve excessive soil cultivation.

- Recent studies estimate that there are about 111 million hectares of farmland under no-till worldwide.
- This is about 8% of global cropland.

- No-till is practiced on farms of all sizes and using mechanized, animal-powered and/or manual methods — it encompasses diverse farming systems under temperate, subtropical and tropical conditions.
- The adoption of no-till in developing countries is currently negligible by comparison with the expansion of this technology in developed and emerging countries.

4.0 Section guideline for implementation

Usually the full benefits of ZT take time and, during the initial transition years the advantages might not be seen thus discouraging farmers from adopting ZT systems.

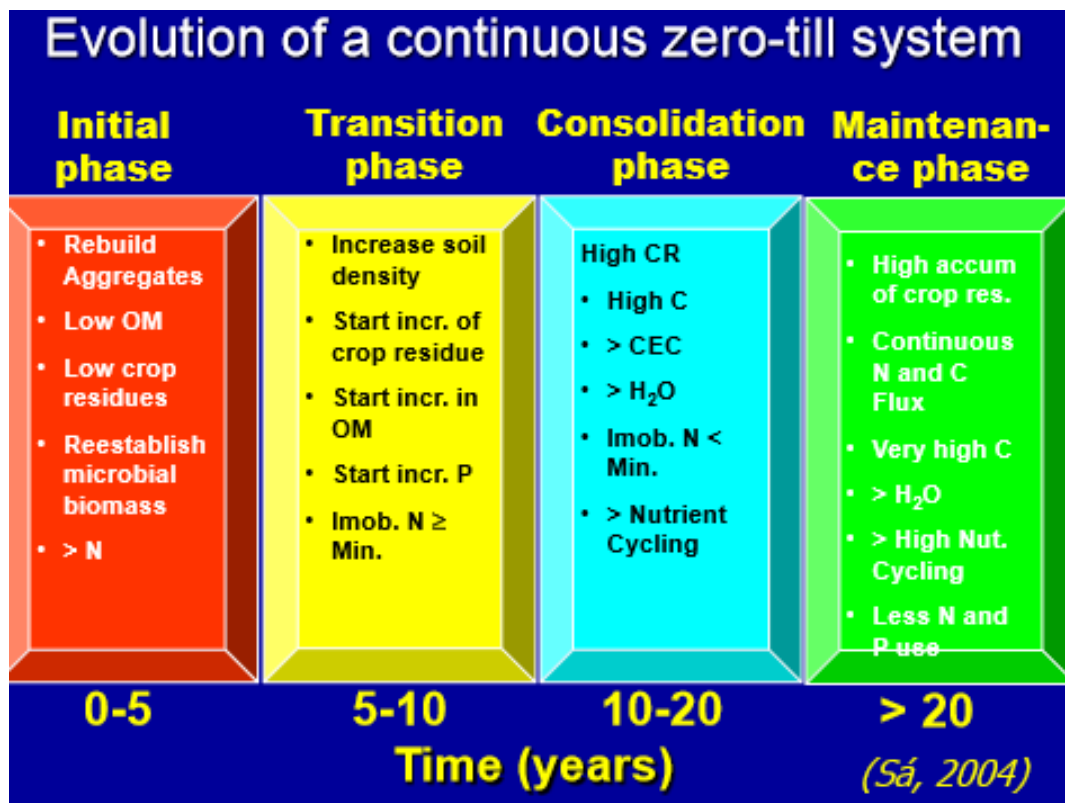


Figure 02: Evolution of zero- till from 0 to 20 years

Source: Stephen Ball, 2011

- Weeds are often a **major initial problem** that requires integrated weed management over time to get them under control.
- Soil physical and biological health also takes time to develop. According to experts, **around three to seven years** (minimum) may be needed for all the benefits to be realized. (Figure: 02)

- To ensure an adequate implementation of these practices, it is pivotal to conduct a critical assessment of the ecological and socio-economic conditions under which ZT is best suited for smallholder farming.

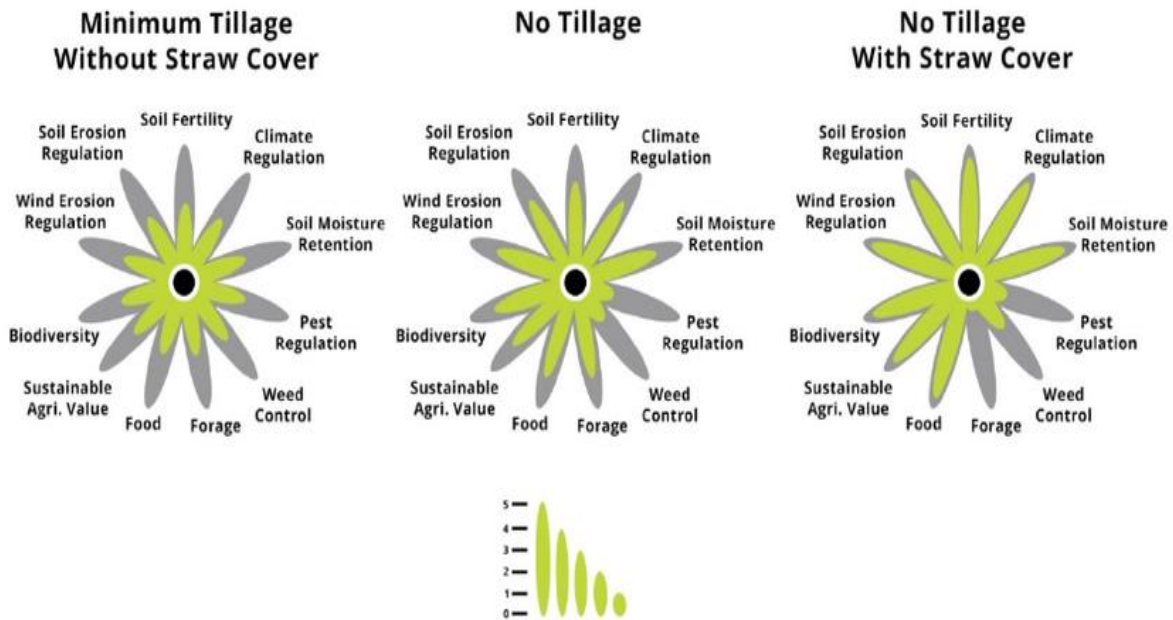


Figure 03: Comparison of the impact on ecosystem service delivery of no tillage alternatives in reference to minimum tillage.

Source:<https://www.researchgate.net/figure/Rose-plots-showing-a-comparison-of-the-impact-on-ecosystem>

To adopt no-tillage practices successfully, recommends that farmers consider the following before starting with the no-tillage system.

- Improve the knowledge about all aspects of the system but especially in weed control
- Analyze the soil and if necessary incorporate lime and correct nutrient deficiencies
- Avoid soils with bad drainage
- Level the soil surface if this is rough for any reason
- Eliminate soil compaction using chisel ploughs or subsoilers
- Produce the highest amount possible of mulch cover (Figure: 03)
- Buy a no-tillage machine.

- Start on only 10% of the farm to gain experience
- Use crop rotations and green manure cover crop to reap the full benefits of the system
- Be prepared to continuously learn and be up to date with new developments

The difficulty of weed control without tillage is one of the most important limits on the use of zero tillage practices for crop production.

The general practice in reduced tillage systems is to substitute herbicides, mowing, or burning for cultivation to kill the existing vegetation before the vegetable crop is planted, but few options exist for weeds that germinate after the crop is planted. Since the herbicide cannot be incorporated into the soil except in strip tillage systems, the herbicide must be applied over the mulch or stubbles and moved into the soil by rainfall or irrigation.

4.1 Implements and Tools for zero tillage:

There can be find several equipment's which are used for no-till farming. Farmers use these implements to facilitate no till farming practices.

4.1.1 No till planter

- Planter is arguably one of the most important pieces of equipment for farmers, especially if you are planning on going into no-till farming.
- **To ensure that crops planted at the same depth and spacing have to use a fine-toothed comb.** (Figure:04)
- This will ensure that every seed is in the exact same soil moisture and temperature environment, allowing for the crops to come out evenly.



Figure: 04 No till planter

4.1.2 A roller/crimper



Figure: 05 Roller/crimper

- Organic, no-till farming begins successfully with a cover-crop, which turns into mulch once it is killed or has died.
- In order to accelerate this process, it is able to 'kill' the cover crop by hand with tools if your plot is small enough but for a larger piece of land, it will need farming implements to help you.

- It is a large, heavy cylinder with long blades welded onto it in a chevron pattern. As it is rolled over a cover crop, the blades crimp the stems of the plants, killing them in place to make moisture-conserving mulch as part of the ground cover for your crops. (figure :05)
- This mulch adds organic matter to the soil as it degrades. Because a cover-crop needs to be thick, a roller/crimper is the ideal piece of farm equipment to use.

4.1.3 A broad fork



Figure: 06 Broad fork

- This tool is used to avoid soil compaction.
- Loosening the soil with a broad fork allows to have the benefits of deep tillage without actually performing any tilling.
- Broad forks are hand tools with long tines that are perfect for digging deep into the soil when turning it. (figure :06)

4.1.4 A subsoiler



Figure 07: Subsoiler

- Similar to a broad fork that is considered to be low or no-till.
- A subsoiler is a tractor attachment that can be dragged through the soil to loosen compacted bed. (Figure: 07)
- Using a broad fork or other hand tools is an effective no-till method that eliminates compacted soil and other issues.

4.1.5 A no-till seed drill



Figure 08: No seed drill

- Piece of equipment that places seeds at correct depth and space apart.
- The front 'openers' or blades cut a trench into the soil, then the double disk seed drill places the seed at the correct depth. The packer wheels cover the hole and pack the soil for the correct seed-to-soil contact. (figure :08)
- A no-till drill ensures accurate planting of crops, and also means that less seed needs to be used, saving farmer's money and effort.
- The price of seed can become expensive, which means that accurate planting is necessary to save money and make a profit from your crops.
- No-till may sound like a practice that does not use machinery, but equipment such as a no-till seed drill makes it a more labour-saving process.

4.1.6 Zero till seed/grain drill cum fertilizer



Figure 09: Zero till seed/grain drill cum fertilizer

- Zero-till drilling of wheat is becoming an attractive alternative to the conventional tillage and sowing of wheat after rice.
- With seed cum fertilizer drill the seeds are sown along with basal placement of fertilizer over a well-prepared seed bed.

4.1.7 Metal cutting blade mould board plough



Figure 10: Metal cutting blade mould board plough

- Mould Board Plough is the most important plough for primary tillage in canal irrigated or heavy rain areas where too much weeds grow.
- The objective for ploughing with a Mould Board is to completely invert and pulverize the soil, up-root all weeds, trash and crop residues and bury them under the soil.
- The shape of mould Board is designed to cut down the soil and invert it to right side, completely burying the undesired growth which is subsequently turned into manure after decomposition. (figure :10)

4.1.8 Rotary weeder



Figure 11: Rotary weeder

- The Rotary Weeder is a tool used to remove weeds either manually or mechanically.
- It is helpful to farmers who use minimal to zero amount of herbicides or tillage. Manual weeding takes about 25 days solo work to finish one hectare.
- Latest mechanical weeder is light, one horsepower (HP), and does three rows at a time and easy to operate, making it possible even for women to work with.
- Two weeders can do a hectare of rice in just five hours. However, the latest model is still subject for further development.

No-till farming is fast becoming popular among both commercial and private farmers. It is a way to save water and help to conserve the environment, as well as saving both money and time. The best equipment for the job includes a no-till planter, a broad fork to eliminate compacted soil, a roller/crimper and a no-till seed drill for accuracy. Those tools make the progress of no-till farming easier.

5.0 Management of zero tillage

Zero tillage requires some different skills in order to do it successfully with any production system, if zero tillage is not done correctly, yield can drop. So, a combined technique is required for the management of zero tillage.

5.1 Cover crops

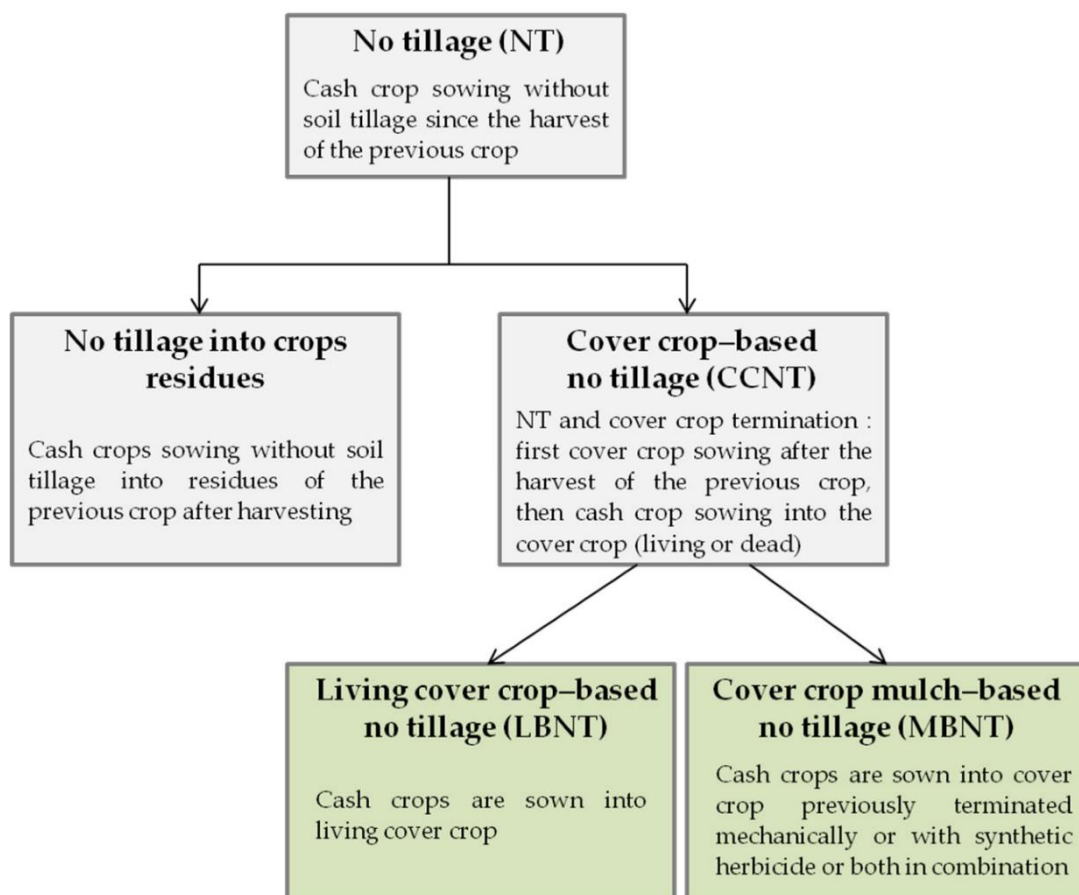


Figure 12: Cover crop mulch based Zero tillage production as an innovative, alternative practice in organic farming to reduce intensive soil tillage.

They are occasionally using in agriculture as guard crops, they leave residue to the soil and also kill various weeds. Farmers use them for controlling of weeds so that the succeeding crop may get enough energy resource for their growth, nutrition and development.

5.2 Integrated disease and pest management

Nowadays, it is very popularly adopted in western countries. The approach is very simple. Here the ecosystem is not hurt at all. So, farmers adopt this practice to get optimum yield using zero tillage.

5.3 Crop rotation

With zero tillage, the residue is kept at the soil surface and thus it increases the soil moisture. But this may also bring the disease or pest outbreak to the crop field. So to manage this problem, farmers should use crop rotation, by the rotation of crops, the completion of pathogen life cycle can be stopped and thus they can be easily managed.

5.4 Use of light implements

The proper zero tillage can be done with the help of light implements. So, it is necessary to use light tractors as it escapes the chances of soil compaction.

6.0 Farmer adoption of no-tillage practices

Farmer adoption on no-tillage practices is over 106 million ha. About 47% of all no tillage farming is practiced in the USA and Canada. In Asia it is not practiced very much. No-tillage practices have limited adoption with only small groups of adopters. However, the results have not being very promising in some regions because of the increased labour demand for weed management and the lack of access to external inputs such as machinery.

Adoption on no-tillage practices in Asia has been low in comparison to Europe. Evidence suggests that environmental benefits, both on and off the farm, can be delivered across the range of European cropping systems.

Soil structure and health improve and biodiversity is encouraged. Soil erosion and diffuse water pollution are reduced. In the long run, costs of labour, energy and, often, agrochemical and fertilizer inputs decrease, even if yields are sometimes lower. Early adopters, and ultimately advocates, of ZT are most likely to be found in younger or more entrepreneurial farmers, more willing and able to change their approach and systems.

7.0 Advantages and disadvantages of no tillage practices

No-tillage systems have a number of advantages and disadvantages. It is important to note that 'no-tillage' needs to be adapted to site-specific conditions, therefore it is important to ensure a comprehensive management that ensures the selection of the most appropriate system for particular soil and climatic conditions on the farm in question and the selection and operation of appropriate equipment.

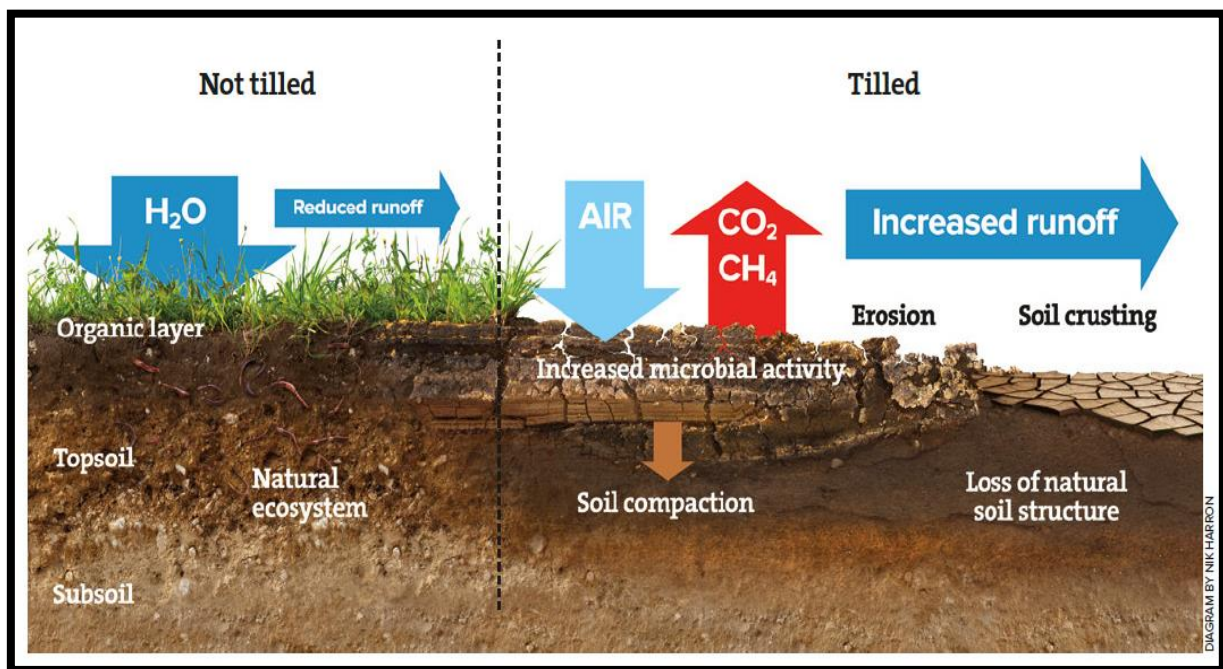


Figure 13: Comparison of tilled and zero tilled soil structure

There can be find environmental, social and economic advantages:

7.1 Advantages:

Economic Advantages

- Energy and Labour costs over the total production process can be reduced
- Reduced use of fertilizers and lower production costs
- Crop productivity increased

Social Advantages

- Better profitability and higher crop yields mean that the farming family could have a greater chance of succeeding and remaining on the land

Environmental Advantages

- Crop yields are equal to or better than under conventional tillage
- Maintenance or increase in the SOM content (enhancement of soil quality)
- Soil improvement (chemical, physical and biological characteristics).
- Studies of no-tillage have shown that it leads to significant changes in the physical and biotic characteristics of the soil environment. Most studies have shown that the soil becomes more dense, primarily because the number of larger pore spaces in the soil is reduced and the number of smaller spaces is increased. This reduces aeration somewhat, but tends to increase the water holding capacity of the soil.
- No tilled soils tend to be cooler than others, partly because a surface layer of plant residues is present. Carbon is sequestered in the soil enhancing its quality, reducing the threat of global warming.
- Planting times are more flexible. Planting can take place immediately after rain and there is no wait for tillage operations. In double cropping situations (cowpeas after maize, for instance), harvesting, slashing, spraying, and planting can take place within a few days
- Water runoff is reduced, which is beneficial in two ways: more water is available for the crop and soil erosion is reduced
- Reduced wind and water erosion. Reduced erosion can lead to off-site benefits such as a reduced rate of siltation of water courses and increased recharge of aquifers,
- Increased water infiltration into the soil and increased soil moisture

Less soil erosion:

- In no till farming, the soil is more resistant to erosion caused by wind and water.
- This is especially true when an abundance of mulch cover (stalks, straw, leaves, pods, chaff) is maintained on the soil surface.

Less soil compaction:

- Ground that is not tilled is less compacted than soil that is tilled.
- Tillage makes soil more vulnerable to compaction.
- Many people think that soil needs to be loosened with tillage, for water infiltration and root growth. However, after a heavy rain, tilled soil has all ran back together again – so people think that more tillage is needed.
- In the long run, tillage leads to more tillage, and the soil becomes in ever worsening condition.

Saves time

- No till farming saves you in labor costs and can also help you get your crops planted before the soil dries too much.

Lower fuel costs:

- Fewer passes across the field in no till farming will dramatically reduce fuel costs.

Less soil moisture loss:

- No till seeding leaves plant residues on the ground, which can help keep the soil moist and protect against evaporation caused by sun and wind.

Healthier soil:

- In fields that are not tilled, when the plant residues decompose at a natural pace on the soil surface, many life forms increase in and on the soil.
- This creates a healthier field ecology, which contributes to fewer flare-ups of damaging insects. By avoiding tillage, soil organic matter can increase, and this is the Number One factor for productive soils.

7.2 Disadvantages:

On the other hand, the disadvantages of minimum and no-tillage systems are:

➤ **Economic Disadvantages:**

- Short term yield effects have been found to be variable (positive, neutral or negative yield responses which can discourage the adoption of zero tillage practices).
- The variability in short-term crop responses to ZT is principally the result of the interacting effects of crop requirements, soil characteristics and climate.

➤ **Social Disadvantages:**

- Not tilling the soil may result in increased weed pressure. The increased amount of labour required for weeding with ZT may outweigh the labour-saving gained by not ploughing,
- Herbicides are used to control weeds. It enhances environmental pollution.
- no tillage has resulted in increased labour requirements when herbicides are not used
- In some countries, no-tillage might result in a gender shift of the labour burden to women

➤ **Environmental Disadvantages:**

- Herbicides must be used often and with accuracy.
- Application of herbicides is critical in cases where the farmer does not plough or till to control weeds and grasses.
- Before planting, any vegetation present must be killed with a broad – spectrum herbicide, the effects of which are non-persistent.
- After planting, more specific and more persistent herbicides are usually required to control specific weeds particular to the crop situation.

➤ **Initial Cost of No Till Equipment:**

- The initial investment in no till equipment and parts can be one of the major deterrents to switching from conventional tilling to no till planting.
- Money can be recovered through higher crop yields, labor savings and selling off of old tillage equipment and downsizing tractors or eliminating extra tractors that are no longer needed.
- Good used no till equipment is readily available in most places.
- If cropping diversity is increased, seeding equipment can be smaller (narrower) and still be very timely.

➤ **Learning curve for no till planting:**

- Some people do not want to learn the new techniques of no till farming
- Preferring to stick with conventional tillage.
- But there are numerous resources and products being developed, to make no till farming easier and more profitable.
- Still, no till does require more skilled management.

➤ **Gullies can form:**

- As a long-term result of no till seeding, gullies can form, potentially getting deeper by the year, because the field isn't continually being smoothed with tillage (thus hiding how much erosion was really occurring).
- Using underground tile lines, cover crops, and grass waterways can help intercept and carry this runoff from the field.
- Maintaining high amounts of mulch cover also reduces runoff and the tendency to form rills or gullies.
- Low-pressure radial tires, tracks, and changing up the traffic patterns across the field also reduce the tendency for gullies to form.

➤ **Potential increased chemical use:**

- No till farming encourages the growth of fast-growing weeds.
- Most types of no till farming still require the use of herbicides.
- Leaving weed seeds on top of the soil surface where they are prone to being eaten by insects, birds, and mice, or rotting away, helps keep weeds in check.

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