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2. A Way Ahead to Sustainable Agriculture: Zero-Tillage (Myth Vs Reality)

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2.1 Introduction:

Traditional agricultural production practices frequently result in environmental deterioration, economic difficulties, and social unrest. Modern day agriculture is facing issues like natural resources scarcity, increased population, poverty, hunger, and climate change due to global warming. According to a new report by United Nation, the current world population of 7.6 billion is expected to reach 9.8 billion in 2050 (United Nation, 2022) and according to Food and Agriculture Organisation (FAO), the world needs to produce 70% more food by 2050 to feed a larger and more urbanized population. According to another report by World Food Programme (2023), 690 million people suffer from chronic hunger and 25,000 people die each day from hunger and hunger-related causes, of which 10,000 are children. Achieving food security for an increasing population and reducing poverty while maintain farming practices amid depleting natural resources, negative impact of climate change, spiralling input costs, and uncertain food practices are the major challenges confronting most Asian countries (Bhan & Behera, 2014).

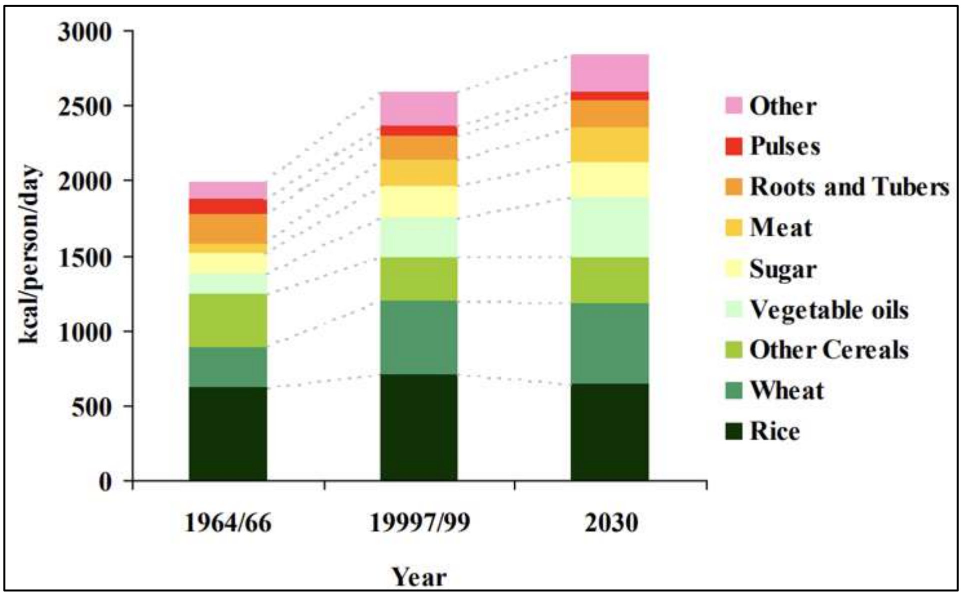


Figure 2.1: Progress graph of global food consumption Source: FAO, 2002

Non-sustainable agricultural systems are characterized by soil erosion, declining organic matter, and salinization. The primary causes of these include:

a. The decrease in soil organic matter is brought on by extensive tillage, soil structural deterioration, wind, and water erosion.
b. Decreased rates of water infiltration
c. Surface crusting and soil compaction
d. Inadequate organic material return
e. Monocropping

Consequently, to increase output in the future while protecting the environment, farming techniques must undergo a paradigm shift that involves getting rid of the unsustainable aspects of conventional agriculture, such as tilling and ploughing the soil, removing all organic material, and monoculture (Yadav, 2020).

Years of conventional agriculture with intensive tillage practices, mono-cropping or fixed crop-rotation, greater dependence on chemical fertilizer and other agro - chemicals have caused the erosion and degradation of the most fertile soil. If sustainable and economically viable agriculture is to be achieved, then the paradigms of agricultural production and management must be changed, and new farming practices must be implemented (Boudiar et al., 2022).

The use of green manure cover crops, diverse crop rotation for increased productivity, permanent soil cover from crop residues, integrated pest management, precision irrigation, little to no burning, and low soil disturbance are the fundamental components of conservation agriculture. Conservation Agriculture is a "basket" of agricultural techniques that is largely accepted as a feasible approach for implementing sustainable agriculture. Reducing and, ideally, eliminating runoff and improving water and nutrient efficiency are important parts of sustainable resource use (Derpsch, 2008).

This is best achieved by techniques that continuously improve the physical and biological qualities of the soil and guarantee that nutrients are adequately cycled, such as integrating crop and livestock production (Singh et al., 2022).

These criteria are satisfied by conservation agriculture, which uses no-till methods in conjunction with crop rotations and cover crops to create permanent soil cover. FAO strongly promotes conservation agriculture, particularly in emerging or developing nations.

Although smallholder farmers are likely the ones who need to embrace CA the most urgently, it has enormous promise for farms of all sizes and agro-ecological systems (FAO, 2009).

But farmers of developing countries are somehow reluctant to adopt no-tillage technology because small farmers who use conventional methods on fragmented land face low income and struggle to meet their basic needs and education expenses and particularly no tillage would result a greater short-term risk of reduced seedling emergence, crop yield, or, worse yet crop failure (Si et al., 2022).

2.2 Zero-Tillage:

To learn about zero tillage, we must first understand what tillage is. Tillage has been fundamental to crop production for centuries, to clean and soften nurseries and to control weeds., as the process of achieving crust fineness, smoothness, aeration, artificial porosity, friability and optimal water content to facilitate subsequent sowing and seed covering. Soil can be cut, accelerated, beaten, turned over, or pulverized to physically crush the soil to bury weeds, to dry the roots, or to cut and physically destroy the soil., explode, or throw. The purpose of tillage is to create weed-free, smooth, friable soil that a relatively simple seed drill opener can move freely (Baker et al., 2006).

Zero-tillage is one of the key elements of conservation agriculture which improves the livelihood of farmers along with conserving the natural resources. Indigenous cultures have adopted no-tillage and reduced tillage method since ancient times due to human limitations in manual tilling any significant areas of land. But in modern and mechanised agriculture, the idea of zero-tillage was given in early 1940s by Edward Faulkner, author of Plowman's Folly. The very first adopters of zero-tillage were Klingman, Edward Faulkner, L.A Porter, Laurence young. Jethro Tull is the father of ZERO-TILLAGE. Edward Faulkner is also credited with founding no-tillage (Derpsch, 2008). Edward Faulkner challenged the paradigm that tilling the soil is beneficial in his ground-breaking bestseller "Plowman's Folly". In a well-thought-out argument, he showed that all common wisdom used to justify ploughing or ploughing the soil was invalid.

According to Baker *et al*. (2006) no technology developed so far has been as effective as no-tillage in halting soil erosion and making food production truly sustainable. Warren (1998) stated that the long-term benefits of a widespread conversion to no-tillage will be greater than any other innovation in third World agricultural production.

Throughout hundreds of years, ploughing has been the standard. A drastic change in perspective was necessary to transition to the new no-till producing technique.

Farmers who are not psychologically ready for this shift will constantly find an excuse to till the land and will return to more conventional land management techniques. There needs to be a mental shift. Otherwise, successful no-till farming will be challenging (Dang et al., 2020). According to Bieber (2000), success depends on one's confidence in no-tilling as a mental notion rather than a farming practice. A farmer needs to be willing to adapt if he is to succeed with a no-till system. This is true for politicians, extension agents, researchers, and farmers alike. Perhaps the largest obstacle to no-till acceptance in the majority of the world is mindset.

Zero-Tillage Is Not Just About Soil Tillage; It Consists of Four Interconnected Management Methods

a. Minimal soil disturbance
b. Preservation of a permanent vegetative soil cover
c. Direct seeding
d. Proper crop rotation

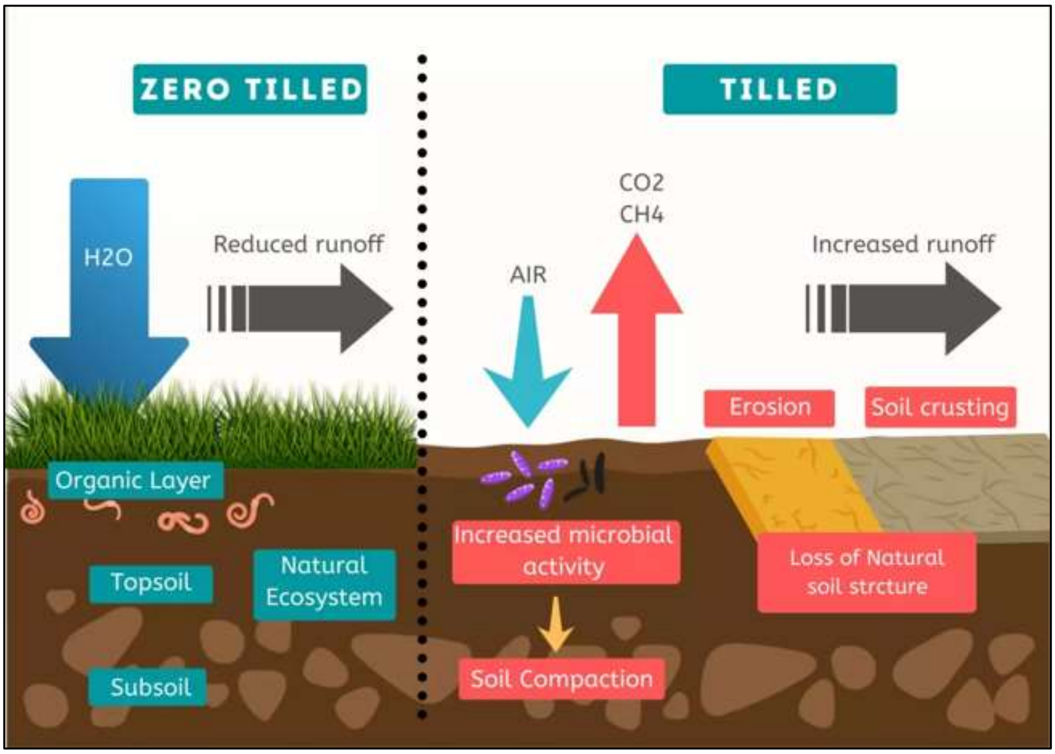


Figure 2.2: Comparison of tilled and zero-tilled soil structure

2.3 Zero-Tillage in India:

Nearly three decades ago, research on zero tillage (ZT) for wheat was initiated in India (Ekboir 2002). In the 1970s, a number of state agricultural universities attempted ZT; however, their attempts were unsuccessful due to technical issues, such as inadequate planting equipment and challenges with chemical weed control (Singh, Kumar, & Banga, 2010).

In the 1960s, Indian farmers invented the no-till method. The zero-tillage technique is applied in the plains of the Indo-Gangetic region, where rice and wheat are farmed. After the rice crop is harvested, wheat will be sown naturally. The same strategy is being used by hundreds of farmers to boost yields and profits while reducing cultivation expenses. The ZT technique is used in the production of rice and maize in the southern regions of Andhra Pradesh state, including Guntur and certain parts of West Godavari (Erenstein & Laxmi, 2008).

The development of rice and wheat in India's northwest was made possible by the green revolution. However, because rice is produced in the hot season and wheat follows rice in the winter, over time, rice and wheat yields become stagnant due to inadequate soil and water management techniques and late wheat planting. Zero tillage was developed in the 1990s to address the issue by planting wheat without any tillage or soil preparation (Erenstein & Laxmi, 2008).

The equipment used to plant the uncultivated ground determines whether zero tillage is successful or not. A sowing prototype was introduced by CIMMYT in the late 1980s. GB Pant University in India produced the first localized seeder with a single engine to cut expenses and make it more accessible. In systems for growing barley and rice, seeders are pulled by tractors (Govaerts & Sayre, 2005).

Zero tillage is most effective in the kharif season for direct-seeded rice, corn, soybean, cotton, pigeonpea, mungbean, clusterbean, and pearlmillet; in the rabi season, it is most effective for wheat, barley, chickpea, mustard, and lentil. With this approach, seeding wheat after rice can happen 10–12 days earlier than with conventional tilled wheat, and late sowing can prevent a fall in wheat production. ZT is an opportunity to guard against potential heat stress on the wheat crop. Because zero-tillage requires less field preparation, it lowers cultivation expenses by around Rs 2,500–3,000/ha and uses 50–60 liters less diesel per hectare.

Plants that receive zero tillage use less water and lose less organic carbon to oxidation. Zero tillage reduces the incidence of phalaris, a minor wheat disease. The state of soil carbon has significantly improved. In surface soil (0–5 cm), soil carbon status is greatly enhanced, especially when crop residue retention with little tillage is employed (Jagdish, 2023).

Why We Go for ZT?

From the historical perspective, several authors such as Edward Faulkner, Alsiter Bevin have questioned the wisdom of ploughing in their book *Ploughman's Folly* (Faulkner, 1943) and *The Awakening* (Bevin, 1944). Indeed, a sort of conservation tillage is said to have been practiced by ancient Peruvians, Scots, North American Indians, and Pacific Polynesians long before Faulkner and Bevin (Graves, 1994). Nevertheless, it is helpful to weigh the benefits and drawbacks of the practice generally in relation to tillage farming to concentrate on the methodologies and mechanization of no-tillage technologies in a realistic manner.

2.3.1 Advantages:

A. Farming expenses - By switching from tillage to no-tillage, fuel use can be reduced by 80%, labor by 60% and total expenditure by 50% (Creech, 2017).
B. Increased soil organic matter and Nitrogen - Leaving previous crop residues to decay on the soil surface increases soil organic matter, which feeds soil microorganisms. Tillage oxidizes organic matter, resulting in a cumulative reduction in OM, and mineralizes soil nitrogen, which may provide a temporary boost to plant development, but it is 'mined' from soil organic matter, lowering overall soil organic matter levels (Elliott, 2022).
C. Improves Soil Structure and Retains Soil Moisture – To promote organic matter and humus for soil structure regeneration, zero-tillage lessens soil structural breakdown. The soil is not disturbed, and any leftovers that remain prevent the soil from drying out. Additionally, the soil's ability to retain water is enhanced by the accumulation of organic matter (Spears, 2018).
D. Improved soil aeration, infiltration, earthworm preservation, and erosion prevention - By encouraging the growth of earthworms and other fauna—the most advantageous

allies acquired from the soil—no-tillage gradually improves soil aeration and porosity and keeps soils from getting harder and more compacted. Because earthworm populations are sustained by their incorporation of large amounts of soil potassium and phosphorus into the root zone, no-till farming benefits from increased plant nutrient availability. Soil residues slow down runoff water velocity and restrict surface sealing brought on by raindrop impact. More effectively than any other crop-production technique yet developed, earthworm activity, soil organic matter retention, and surface residues work together to protect the soil surface, encourage penetration, and so minimize water, wind, and soil erosion. Most importantly, this reversal usually occurs after 2-4 years of continuous use of zero-tillage techniques (Stroud, 2020).

E. Increased overall agricultural yields - All the aforementioned components have the ability to increase crop yields significantly more than tillage alone can. However, it may take years or even decades to see the benefits of increased productivity when converting from tillage to no-till farming.

F. Future enhancements are anticipated – In order to gain the long-term benefits of no-tillage, earlier assumptions about lower crop yields in the near term have been disproved by modern no-tillage techniques and equipment. Methods that eliminate short-term yield reductions while raising the expectation and magnitude of medium- to long-term yield enhancements have been developed as a consequence of ongoing research and experience.

2.3.2 Drawbacks:

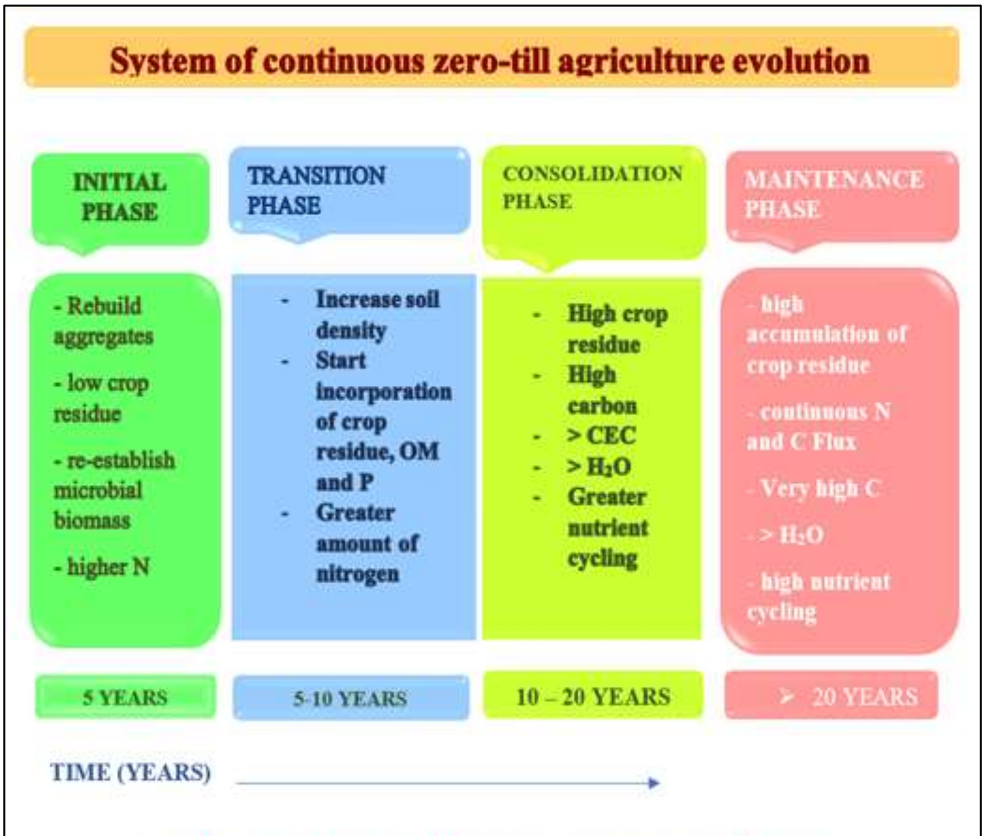
A. Crop failure risk: If weeds and pests are not properly controlled using no-tillage methods, crop yield could be negatively impacted or perhaps fail. Additionally, no-tillage is dependent on soil and weather conditions, which may not be ideal for some crops or areas. Short-term yield effects could be negative, neutral, or positive (which could discourage people from pursuing zero-tillage techniques) (Huggins & Reganold, 2013).

B. Emerging issues with diseases and pests: No-tillage modifies the soil ecosystem by preserving the residues on the surface. This might alter the habitats of some pests and illnesses, such nematodes, fungi, rodents, and slugs, and increase others like weeds and insects. No-tillage systems, however, also support the natural enemies and predators of these pests and illnesses, and no significant issues have been noted in long-term no-tillage systems (Paudel et al., 2020).

C. Incorporating insecticides and fertilizers is more challenging: The lack of tillage hinders the widespread application of herbicides and fertilizers by machinery, potentially reducing their efficacy and availability. No-tillage necessitates the precise application of herbicides and fertilizers during drilling, employing openers or banding devices with unique designs. Additionally, compared to tillage, no-tillage may need different kinds and dosages of pesticides and fertilizers) (Huggins & Reganold, 2013).

D. Use of agricultural chemicals: Herbicides are necessary for weed management in no-tillage farming, which could raise costs and have an adverse effect on the environment. But no-till also uses primarily environmentally friendly herbicides and lessens the surface runoff of other chemical contaminants like pesticides and fertilizers. Compared to tilled soils, small-scale agriculture may require more hand weeding, but less labor (Derpsch, 2008).

E. Change in the prevalent species of weeds: Since some weeds may be more tolerant or resistant to herbicides and the no-tillage circumstances, no-tillage practices may alter the weed population and spectrum in the fields. To prevent weed resistance and domination, no-tillage farming necessitates the more careful application of crop rotations and varied weed management techniques (Paudel et al., 2020).
F. The selection of a no-tillage drill is crucial: The most crucial piece of equipment for zero-tillage farming is the no-tillage drill, which makes all the difference in the success and yield of crop establishment. A no-tillage drill must be appropriate for the soil and crop kinds, the field's characteristics, and climate, as well as the farmer's spending plan and tastes. A no-till drill must have the ability to operate reliably under a variety of circumstances (Derpsch, 2008).



Evolution of Zero-Till From 0 to 20 Years Source: Stephen Ball, 2011.

Figure 2.3: System of Continuous Zero-Till Agriculture Evolution

2.4 Yield Effect of Zero-Tillage:

Because the world's population is growing and the demand for food production is steadily increasing, agriculture's top concern is to keep our soil healthy and productive while also conserving the environment. We are depleting our soil quicker than nature can replenish it by using conventional agriculture methods.

Moving from current tillage techniques to no-tillage farming will undoubtedly provide challenges and hazards. When compared to typical tillage practises, crop output from zero-tillage farming can be similar or higher. Yes, crop production may be reduced in the first few years of no-tillage practise since it takes time to re-establish healthy soil. This is known as "transition period reduction," and it may be overcome with judicious band fertiliser application and careful crop selection. The economic benefits of zero-tillage crop production are significant and remarkable.

However, ZT may not always increase crop yield, and may even reduce it in some cases. For example, ZT was associated with less biomass and grain yield of maize during the wet season, due to lower leaf chlorophyll concentration and higher ear rot incidence. Similarly, ZT resulted in less grain yield of rice, although it saved 44.84% of soil loss relative to CT (Phogat, 2020). The effect of ZT on yield may also depend on the residue management, as retaining residues can improve soil moisture and fertility, and suppress weeds.

Moreover, ZT may have different effects on different crop phenological parameters, such as days to silking, physiological maturity, and seed fill duration. Therefore, ZT should be combined with appropriate residue management and crop rotation to optimize its benefits for yield and **sustainability (Monneveux et al., 2006).**

2.5 Managing Natural Resources:

Resources are limited and depleting daily, and only humans can act as conservationists. In agriculture, it should be our top priority to provide those essential resources for future generations, as this is the only way to fulfil rising food demand without jeopardising the environment and natural resources.

A. Soil Health:

Healthy soil is the fundamental foundation of environmental quality. Carbon and soil organic matter [SOM] content can be raised by leaving previous crop remains on the soil surface. It is the most important soil quality because SOM influences soil microorganisms, often known as "black gold," which may significantly improve soil physical, chemical, and biological qualities. SOM can also improve infiltration rates via macropores, earthworm routes, and water retention capacity. It can speed up soil particle aggregation, making it simpler to transfer water through the soil and allow plants to grow roots more easily.

No-tilled soil reduces soil erosion by stabilising surface aggregation through reduced crust development. No-till soil has greater flexibility and rebound capabilities. Farming with minimal tillage allows the soil to restructure and is high in OM for improved nutrient and water availability.

B. Conservation of water:

Because no-tilled soil is coated with crop residues, there is less water evaporation, less ground water loss, and less need for regular irrigation.

2.6 Environmental Pollution Reduction:

Zero-tillage technology have the potential to yield major environmental benefits. Conservation tillage can effectively lower greenhouse gas (GHG) emissions from agriculture by using fewer fuels to prepare fields.

According to some claims, tilled soil generates 20% more net global warming than minimum-tilled land. This suggests that conservation-tillage can effectively mitigate the effects of climate change, given that these practices are maintained for a minimum of five to ten years following conversion.

Because it was the quickest and least expensive method, farmers in northern India burned almost 23 million tonnes of rice straw before planting wheat. This contributed to global climate change, produced lethal smog, and partially choked the local population. But after 2018, 0.8 million hectares of land were put to conservation tillage, increasing farmer profits by 10–20% and reducing greenhouse gas emissions by up to 75%. In addition to these advantages, zero-tillage lessens soil erosion, phosphate losses, and nitrogen leaching—all major problems that exist globally (Tripathi, 2010).

2.7 Success Stories:

A. Success story of adopting Zero-Tillage in Wheat, Saved Resources and Enhanced Income in north-western region:

From Ramba village in the Karnal district of Haryana, farmer Sardar Sahab Singh owns approximately 42 hectares of land with 600 mm of annual rainfall. He planted cereals like wheat and paddy in the sandy loam soil, along with fodder crops like berseem, sorghum, maize, coriander (which he sells as a green crop), turnip, and so forth. The advantages of zero-tillage technology, which other farmers in the Pehowa district of Haryana were using, astounded him.

When he applied this method to his farm in 1999, the outcomes were not what he had expected. Afterwards, he went to the ICAR-Indian Institute of Wheat and Barley Research in Karnal to consult experts. On the advice of specialists, he purchased two zero-tillage machines in 2000 and 2001 for a total of Rs 16,000 each. The devices have two sections: one for seeds and one for fertilizer. The seed is covered with fertilizer. The tines are fastened at 21 centimeters using knife tips. He had to plough the farm eight to ten times before using zero tillage, using 75 to 88 liters of fuel per hectare. The growing use of gasoline resulted in a lot of pollution. After learning how challenging it is to seed wheat in complete paddy residue, he bought the Turbo Happy Seeder. He occasionally had to use a reaper to clear residue from fields, but he found that crops under residue perform better than those removed with a lot of moisture. Labor costs have decreased significantly as a result of zero tillage. He found that there weren't many weeds in his field, which saved him money on pesticide expenditures. In 2007–08, his farm produced 6.0 tons of wheat per hectare on average with no tillage, which is equivalent to traditional methods. He harvested 7.0 tons per hectare in the 2015–16 farming season. Rs 25,000 was the operational cost per hectare. His net profit per hectare was therefore Rs 88750.

In comparison to traditional tillage, he obtained 2-3q/ha more produce while saving at least Rs 4000-5000 on labor and plowing costs. Other farmers in the surrounding areas have found inspiration in him.

Additionally, he has found that by minimizing terminal heat, increasing organic carbon, increasing water holding capacity, using less water, and requiring less lodging, the ongoing application of zero tillage technology enhances soil health. Regarding the surroundings, he considered it a useful method. He believes that this method is the only one that can address the residue burning issue (Nagar et al., 2020).

B. Success stories of adoption ZT in Coastal Area:

The majority of India's land is used for rice farming in its coastal and eastern areas, with the remaining portion being mainly uncultivated. In a few places, short-lived pulses or oilseeds are planted with relay or sequence cropping; however, low crop stands and weed growth result in low yields. In coastal Andhra Pradesh, the once-common blackgram crop is negatively impacted by the parasitic weed Cuscuta and the yellow mosaic virus (YMV).

Zero-till sorghum (in areas with less irrigation) and maize (in locations with guaranteed irrigation) are becoming more and more popular among farmers. Following the harvest of the previous rice crop in mid-December, seeds are manually sown in holes filled with moist soil. A month or so later, fertilizer is applied, and then two to three irrigations are carried out.

Shortly after planting but before crop emergence, weeds are suppressed using a tank-mix treatment of atrazine + paraquat (0.75 kg + 0.50 kg/ha). Reports state that zero-till agriculture yields 8–10 t/ha of sorghum and 6–8 t/ha of maize, respectively, while blackgram yields 0.5 t/ha. This technique, which has spread to almost 1 lakh acres in the region, is recognized as one of the success stories of the adoption of zero tillage in coastal Andhra Pradesh. Like way, there is a great deal of potential for growing maize, wheat, and greengram in the winter and spring in nearby regions like Orissa, West Bengal, Bihar, and Assam (Amarajyoti et al., 2019).

C. Zero-tillage in Bihar:

In Bihar, 22 female farmers connected to JEEVIKA have planted potatoes with the Zero Tillage technique for the first time. The International Potato Center in Peru helped introduce this technology to Bihar. Bihar women are encouraging others to use this technique after witnessing bumper production at lower costs (The Times of India, 2022).

2.8 Myths and Realities of Zero-Tillage:

Zero-tillage has become a contentious technique, with some experts hailing it as a success and a new paradigm in resource management and others dismissing it as impracticable in Indian circumstances. Indeed, it is the way people perceive and use it. Any new intervention will raise certain concerns at first, which must be addressed and adapted considering the unique circumstances of the area. CA misconceptions and reality are discussed more below.

Myth 1: ZT causes soil compaction and the development of hard pan.

Many people believe that when fields are not ploughed, soil compaction occurs and a hard pan form at the surface or subsurface layer. Plant roots do not develop in compacted soil, resulting in limited crop growth.

Reality - It is possible that this will occur if the ZT is only partially implemented. A zero-tillage system must always be supplemented with soil surface residue mulching. Because of the work of earthworms and other bacteria, there is naturally occurring biological tillage, which results in porous soil and improved plant root multiplication.

Myth 2: ZT causes limited water infiltration in the soil profile, which leads to water logging

Because to the observed creation of compacted soil and hard pan, water from irrigation or rain will either remain on the soil surface or will not penetrate the soil profile.

This causes water logging and has a negative impact on plant development.

Reality - When all three interconnected ZT principles are followed in harmony, there is more water penetration into the soil profile and almost no water stagnation on the soil surface.

Myth 3: ZT promotes weed growth.

Weed management is one of the primary purposes of tillage. Weeds represent a serious constraint for crop yield when ploughing is not done. In the long run, the problem of perennial weeds worsens.

Reality - Weed management is easier under the ZT system because weed seeds remain in the surface soil layer (0-5 cm) and emerge in 1-2 flushes. Weed seeds do not germinate and emerge at lower soil depths.

The primary goal of ZT is to eliminate weed seed banks, which prevents weeds from blooming and generating seeds. Adoption of integrated weed control strategies such as residue mulching, cover cropping, crop rotations, and herbicide usage before and after sowing results in a progressive reduction in weed infestation over time.

Myth 4: ZT competes with crop waste fed to livestock

Crop wastes are a significant food source for animals in countries such as India. As a result, they cannot be saved for recycling in agriculture areas.

In reality, crop wastes and other accessible biomass are regarded as waste products in large parts of India. Rice and wheat wastes are burned on a massive scale in north-western India. Similarly, enormous amounts of residue are burned on combine-harvested fields in central and southern India.

Myth 5: ZT necessitates the use of additional chemical fertilisers

Because the fields are not ploughed, fertilisers are not properly mixed with the soil before sowing. Plant growth is weak, hence more fertilisers are required to compensate for this.

Reality: All important nutrients are basally fertilised during seed drilling, with the fertiliser deposited 2-3 cm below the seed. It may be beneficial to use 25.0% more N during the first 2-3 years of ZT, however after a while (4-5 years), there is a decrease in fertiliser demand due to soil fertility enrichment caused by decomposition of additional crop residues.

Myth 6: ZT causes poor seedling germination and emergence

Because there is no appropriate seed-soil interaction under ZT, most seeds do not germinate. As a result, seedling emergence and crop stand are low.

In reality, under ZT, sowing is mostly accomplished with a seed-cum-fertilizer drill. The seeds and fertiliser are inserted in the profile at the appropriate soil depth. It is also critical to guarantee enough soil moisture at the time of seeding. When all safeguards are followed, seedling emergence and crop stand are better under CA than in conventional tilled systems.

Myth 7: ZT is not possible for small-holder farms.

Farmers in India have modest land holdings (5 acres), hence ZT-based heavy gear cannot function in such small areas.

Reality - Tractors are currently utilised for ploughing, even on tiny farms Power tiller-based seed drills are also now available. In most regions, these equipments may be rented on an as-needed basis.

Myth 8: CA encourages the invasion of insects and diseases

After crop harvest, when the soil is not disturbed, there is a higher chance of insect and disease infection. Since the soil is not directly exposed to the sun's rays, the harmful organisms are not destroyed. Under such ZT systems, termite and rat infestation rises.

Reality - Even with long-term ZT usage, there are no issues with increased insect or disease infestations. Rats and birds may cause some damage, but these may be readily managed with appropriate ZT adoption and other precautions.

Termites don't do much damage to the living crop plants; they mostly consume leftovers from dead crops.

Myth 9: ZT causes soil moisture loss because of evaporation

Due to evaporation, the unploughed soil dries up more quickly. Since tillage does not disrupt the continuous soil capillaries, moisture loss is increased.

Reality - When crop leftovers are kept on the soil's surface, they function as a barrier to stop the soil from losing moisture. When residue is retained on the soil surface and zero-till farming is used, the soil moisture is conserved more effectively in the profile.

Myth 10: ZT needs heavy equipment that is too expensive and unavailable in most places.

Small tractors (under 35 HP) should not be used for zero-till sowing. For most farmers, expensive, heavy equipment like joyful seeders is out of their price range. Additionally, many areas do not have access to these devices.

Reality - It is true that planting in fields with zero till consumes more energy, especially when crop leftovers are left on the soil's surface. Consequently, a heavy-duty tractor with 75 horsepower is required to operate a device like a happy seeder. Small farmers can access this expensive machinery thanks to specialised hiring services.

More than 20 companies in India are currently producing CA machines, and several state governments are offering subsidies (over 50%) in addition to various rewards for not burning agricultural wastes.

Myth 11: ZT does not boost profitability and productivity.

Crop yields are lower when ZT is used. Zero-till fields require more work and money to sow in.

Reality - The yields under ZT are equivalent to or even higher than conventional practice from the early years when ZT is applied holistically by individuals who have gained sufficient experience in sowing, fertilization, and weed control.

The timely seeding of crops is the main advantage of ZT. The ZT-based procedures are very cost-effective because ploughing is almost free.

Myth 12: Crop residue retention under CA prevents seedling emergence

There is no room for the germination of seedlings to emerge when a thick layer of rice or wheat residues is preserved on the soil surface, and the majority of them will perish owing to the excessive residue burden.

Reality - seeds are arranged in a row and the leftover material is trimmed away to make room for sprouting seedlings. In actuality, the sprouting seedlings always find a way to break through the dense debris.

Myth 13: ZT will gradually increase the amount of agricultural residue.

After 2-3 years, the thickness of the residue cover becomes excessively thick when considerable amounts of agricultural residues from crops like rice and wheat (6-8 t/ha) are left on the soil surface. Sowing and fertilisation will be too challenging as a result.

Reality - The action of irrigation water and top-dressing N fertilisers causes crop leftovers of rice, wheat, and other crops retained on the surface to decompose.

By the time the crop is harvested, the leftovers from the previous crop have practically all decayed and are no longer even visible.

Myth 14: Only certain soil and climate conditions make ZT acceptable.

Only healthy soil conditions allow it to function. Under normal soil circumstances, such as those with a very fine texture or flooded soils, it does not function.

Reality - It is accurate that ZT is site-specific and needs ideal soil, crop, climate, and other variables to succeed. The light-textured soils of north-western India, the vertisols of central India, and the heavy-textured soils of coastal Andhra Pradesh have all shown similar success with ZT.

Myth 15: ZT needs the use of environmentally unfriendly chemicals to manage weeds.

Herbicide use is more prevalent for weed management since the fields are not ploughed. This results in environmental contamination and soil toxicity.

Reality -Without herbicides, ZT cannot be performed since they are a crucial part of integrated weed control. There are now low-dose, high-potency compounds that, in most cases, don't leave hazardous residues in the soil or crop output. Herbicide burden is anticipated to eventually decrease as weed infestations decline over time.

Additionally, the availability of a significant amount of organic matter after crop residues decompose aids in reducing any negative effects of herbicides and their metabolites.

Myth 16: ZT results in the immobilisation of nutrients.

Nutrients from the natural soil as well as those provided through fertilisers get immobilised by cereal crop residues with unbalanced high C: N ratios, such as those from rice, wheat, and maize. As a result, plants have acute nutritional deficiencies and stunted development.

Reality - Since crop leftovers are not combined with the soil during ZT, there is no concern for nutrient immobilisation.

There is no direct interaction with agricultural residues or soil nutrients. Prior to irrigation, top dressings of N are also applied; this causes the N to become soluble and move to the root zone.

Myth 17: ZT needs to interrupt the cycle after a while.

ZT adoption cannot be sustained over the long term; the cycle must be broken after a few years. To shatter the hard pan that has formed in the subsurface layer, this is required.

Reality - There aren't many long-term ZT trials conducted in India. The findings of research conducted ten years ago suggest that the ZT cycle does not need to be broken. Additionally, no hard pan has formed. The CA method has been used consistently for more than 30 years in other nations including Brazil and the USA. ZT's advantages grow with crop cycles.

2.9 Tools and Equipment Used in Zero-Tillage Agriculture:

Broad fork Tool:

Sharp, six angled tines that need less effort to cut through the earth. It is also the finest method for loosening garden soil, outperforming hoes, cultivators, and rakes with a dig depth of over 10".

Figure 2.4: Broad Fork Tool

Rotary Weeder: used to remove weeds mechanically. It is helpful to farmers who uses minimal to zero number of herbicides. This weeder does three rows at a time and easy to operate.

Figure 2.5: Rotary Weeder

No-Till Planter: possess the capacity to drill a wide range of seed types and sizes into various planting situations, including high residue no-tillage, minimal tillage, and conventional tillage fields and having an all-seed wobble Slot for accurate seed singulation having an all-seed Wobble Slot for accurate seed singulation.

Figure 2.6: No-Till Planter

Subsoiler: A subsoiler, a tillage tool that helps to loosen up compacted soil and better prepare the soil for crop development

Figure 2.7: Subsoiler

Zero Till Seed Drill Cum Fertilizer Includes a seed box, a fertilizer box, seed and fertilizer metering mechanisms, seed tubes, furrow openers, a lever to modify the seed and fertilizer rate, and wheels to transmit power during travel. Used for simultaneous activities of seeding and fertilization process in a single operation.

Figure 2.8: Zero Till Seed Drill Cum Fertilizer

Mould Board Plough has broad, curved blades that dig deeply into the soil as they are driven over the ground by a tractor. They cut a row while twisting and aerating the soil simultaneously, creating a planting furrow with a rise of loose, aerated soil on the side. Additionally, it aids in blending the fertilizer applied before to turning the soil.

Figure 2.9: Mold Board Plough

2.10 Conclusion:

Since we are in the twenty-first century, our farmers have access to the technologies needed to grow crops sustainably employing a range of conservation tillage strategies. Crop residue management strategies and tillage techniques have been turned from a concept into a system that efficiently minimises erosion, decreases soil degradation, is cost-effective, and is ecologically acceptable thanks to an alliance of farmers, scientists, and agribusiness. The constraints and usefulness of adopting conservation tillage methods are determined by soil characteristics and their biological surroundings. Because they are important, natural resources must be managed wisely and sustainably. Zero tillage is a viable technique in this case. Although employing non-selective herbicides has more drawbacks, it is still less harmful than utilising traditional farming techniques. With no tillage, more profits may be made, and crops can be produced on schedule and with greater yields. Zero tillage has been found to increase farmer earnings and cut greenhouse gas emissions from agriculture by more than 75%.

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