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### **India: No-till agriculture to reduce erosion, desertification, soil depletion, and herbicide usage**

India is the world's largest democracy and its economy is growing rapidly. Recently, India has seen a spike in farmer suicides due to crop failures and the inability to repay the debt taken on to buy genetically modified seeds and agricultural inputs. Genetically modified crops, the introduction of chemical inputs, and intensive tilling methods held great promise for large yields for Indian farmers, but the promise has gone largely unfulfilled. Alternative farming methods are being explored by many countries to not only increase yields but also to improve the sustainability of farming practices by reducing erosion, desertification, soil depletion and herbicide usage.

The majority of India's population lives in rural areas. Of the over eight hundred million people that live in rural areas about two hundred and thirty million live below the poverty line ("Statistics"). The average family size in rural areas is 5.4 people and typically all three generations live together in one household ("India" Data Highlights). Education is an important issue, with only 61% of the population literate ("India" CIA World Factbook). Illiteracy rates are even higher in rural areas. Children attend school for a country-wide average of ten years and the government spends 3.1% of the country's GDP on education ("India" CIA World Factbook). There is a lack of access to healthcare, as there are only 0.6 physicians and 0.9 hospital beds per 1,000 people ("India" CIA World Factbook). Access to healthcare is the lowest in rural areas due to lack of equipment in rural hospitals (Deogaonkar). Certain groups are at high risk for inadequate health care access, mostly women, lower-caste and indigenous groups (Haddad, Slim, Narayana et al). The government spends 2.4% of India's GDP on healthcare for its people ("India" CIA World Factbook).

Agriculture is a large part of the Indian economy, accounting for 18.1% of India's total Gross Domestic Product ("India" CIA World Factbook). Agriculture makes up a large part of the labor force with 52% of workers employed in agriculture ("India" CIA World Factbook). India has abundant arable land, with 1,451,810 km<sup>2</sup> available or 48.83% of India's total land mass ("India" CIA World Factbook). The large diversity of climates allows for a wide range of agricultural products to be produced. The main crops grown are rice, wheat, oilseed, jute, tea, sugarcane, lentils, onions, and potatoes ("India" CIA World Factbook). The average farm size is 3.3 acres ("India-Agricultural Economy"). Small farms make up 33% of the cultivated land and they produce 41% of the total Indian production of grains for human consumption (Sohani). The production of agricultural products needs to keep pace with the rapidly expanding population and nutritious foods need to be readily available for the rural population.

A huge problem in India is inadequate access to food supplies, especially in rural areas. The highest rates of hunger and malnutrition occur in the states of Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, Orissa, Rajasthan and Uttar Pradesh. They are located mostly in the middle of India, sandwiched between the northern states and the southern states. In India, 60% of children are malnourished and 230 million people are undernourished (Sohani). Malnutrition in married women is prevalent due to the willingness of wives to feed their families first. Women also see higher rates of malnutrition because of early marriage and early childbirth. In rural areas of northern India, 7.7% of men reported eating no servings of fruit or vegetables, while 20.2% of women reported the same (Yadav, Krishnan). On average, men ate 2.6 servings of fruit or vegetables per day and women ate only 1.8 servings (Yadav, Krishnan).

India's growing reliance on conventional farming methods prevents their agricultural output from increasing as much as it needs to without causing damage to its long term ability to feed its growing population. Most Indian farmers use high-yield varieties of wheat and rice, and take advantage of the

benefits of irrigation, fertilizers, herbicides and machinery that were introduced during the Green Revolution. Agricultural outputs greatly increased, but agricultural growth has now stagnated. Other barriers to better agricultural productivity include the salinization of soil, flooding, degradation of soil, erosion, access to infrastructure after harvesting and overuse of groundwater. This in turn has led to inadequate food for subsistence and for the market. There are many obstacles for farmers to earn sufficient money from their products, including the high cost of seeds and the inability to save seeds year to year, the cost of chemicals and fuel, and for larger farms, labor and machinery (“Vanita, Mahila, Mahasang”).

There are a variety of agricultural practices used in India. Different regions utilize diverse methods due to terrain, rainfall and altitudes. Under some cropping systems, the stubble left over from the rice harvest is burned (Homer). This is usually a tillage-intensive system of farming that also releases large amounts of greenhouse gases into the atmosphere. A small percentage, 0.3%, of India’s agricultural land, is farmed organically, and most of the crops produced go to exports (Rao). The use of irrigation has increased, and with that more incidences of waterlogging (Jayan, Sathyanathan). More recently, farmers have begun to adopt drip irrigation to conserve water and reduce the need for labor (Kumar, Suresh, Palanisami). One new method used for growing rice is alternatively growing rice then raising shrimp on the same land (Jayan, Sathyanathan). In the tropical areas of India the practice of shifting cultivation areas is used extensively and the main method for preparing fields is slash-and-burn (Raman, Shankar). This damages the forests and pollutes the air. Because of intensive and unsustainable farming methods, along with environmental degradation, 105 million hectares of fields were classified as degraded in 2009, contributing to a decrease in net sown area (Sharma).

No-till farming can provide a solution to many of the problems traditionally faced by Indian farmers. Usually, in conventional farming, the soil is tilled between plantings to prepare the soil and till in the remnants of the previous crop. No-till farming eschews tilling in favor of keeping the plant residue on the surface of the soil and only making small openings in the ground for seeds to be planted. No-till farming can provide many benefits to farmers and the environment. Using no-till farming methods can increase crop yields but, more importantly, it can increase crop yields for any size of farm, not just large ones (Derpsch, Rolf, Friedrich et al). Farmers can benefit greatly from the no-till method. Not only does it increase crop yields, but it can provide other cost saving benefits.

Since tilling has many costs associated with it, such as the purchase of machinery and the diesel fuel and labor to run it, no-till could eliminate or drastically reduce these costs. The no-till method does not require machines to prepare the soil for planting, though there are many machines designed to plant seeds without tilling (Kulvinder Singh, et al). Planting can be done by hand. If planting is done by hand it still requires a fair amount of labor, but not as much as first tilling, then planting. No-till can also allow farmers to plant their crops earlier for a longer growing period which can result in a larger harvest or more plantings of crops (Derpsch, Rolf, Friedrich et al). In one project, the Central Agricultural University of India (“CAU”), collaborated with the Directorate of Rapeseed-Mustard Research to grow rapeseed-mustard. During a season where crops are not usually grown due to the unpredictability of rain, the mustard grown in the project using no-till methods was substantially more successful than that grown with conventional methods (“Zero Tillage”). No-till methods have been experimented with on a similarly small scale in different regions of India under studies to assess how it would affect agricultural output and the environment.

The environmental benefits of no-till can be wide and far reaching. Usually, with the implementation of no-till methods an improvement in soil quality and air quality is seen. As many of the aspects of environmental degradation due to conventional farming methods are improved, many farmers could see increases in crop yields, their well-being and their income.

No-till can benefit the individual farmer. As global greenhouse gas emissions rise, different and unique ideas are being explored to reduce them. Tilling uses the most energy of any farming operation (Murugan). No-till farming needs less preparation for planting and therefore uses less fuel and decreases the total impact of farming on greenhouse gas emissions. This could also have a large impact on the input costs of farming, especially if fuel prices are high, and could serve as a protection from price fluctuations in fuel. Not tilling the soil can also aid in carbon sequestration, as the soil will store carbon that will not be released into the atmosphere from tilling (“No-Till Helps”). This helps the environment by reducing the main cause of climate change and increases the levels of a vital nutrient for plant growth (Venkateswarlu, et al). In addition, there is the possibility for farmers to receive carbon credits that could provide extra income (Venkateswarlu, et al). Under no-till farming, harvest residue is not burned. The burning of fields releases massive amounts of carbon dioxide into the atmosphere. This air pollution affects climate change and air quality, contributing to health problems.

Many researchers conclude that water scarcity will become a major problem as water use all over the world expands. Overuse of water resources in agriculture can lead to desertification. Tilling exposes soil to the open air which causes soil to dry out more rapidly as the water evaporates (Subbian, et al). No-till has been shown to improve water retention and absorption in soil (Subbian, et al). This is because there are more aggregates, mainly carbon, in the topsoil. When plant residues are left on the soil under the no-till system, the soil retains more moisture and the need for irrigation is reduced (Ngachan, et al). Less water is required for irrigation, not only with traditional irrigation methods but also with water-conserving irrigation techniques such as drip irrigation. The predicted effect of climate change in India is erratic monsoons, which could leave the country in long periods of drought. By using no-till the water retention of the soil is better and farming will be less affected by long dry spells (“How Climate Change Affects India.”).

Soil erosion is already a large problem in India. Many Indian farmers have to cope with it, and India loses soil at the rate of almost six billion tons per year (Venkateswarlu, et al). Soils that have not been tilled have greater rates of water infiltration (Duiker, Myers). The use of cover crops can keep soil from eroding because their roots prevent it (“No-Till Agriculture”). Studies have shown that no-till promotes the buildup of soil aggregates which provides structure to the soil and makes it up to seven times more resistant to being broken up by raindrops (“No-Till Farming”). The remnants of a previous crop also cover fields when nothing is being grown and protect the soil. According to one study, the amount of soil that had eroded during a period of four years under a conventionally tilled field was seven hundred times the amount from a similar field under no-till (Duiker, Myers).

Weed resistance to herbicides is another increasingly challenging barrier to improving agricultural production. One common weed, *Phalaris minor*, is becoming more of a problem for Indian farmers (Malik, Gurjeet, Sardana et al). Previously, experiments in no-till found it be incompatible with Indian farming systems (Malik, Gurjeet, Sardana et al). Since no-till farming allows farmers to plant earlier, crops are given a head start over weeds, and farmers are now experimenting with no-till more seriously as an alternative way to decrease the incidence of weeds where the conventional weed control method of using herbicides is no longer proving effective.

No-till can also provide more nutrients for the soil and increase the number of beneficial insects in fields. It raises the levels of many different nutrients in the soil that are vital for plant growth (Subbian, et al). By leaving plant residues on the soil, organic matter is added and the productivity of the soil is increased. Earthworms were found to be much more numerous in no-till fields (Subbian, et al). Tilling destroys the habitat of some kinds of earthworms by destroying burrows and reducing the plant residue they use to cover their burrows (Duiker, Myers).

Problems can arise with no-till farming, but they can generally be addressed. It can increase the need for herbicide use to control weeds because they are not tilled regularly. However, it has been shown that, with

minimal disturbance, after two or three years the seeds of weeds will no longer be in a position to germinate, and will not be moved to a spot with conditions that will allow for their germination because the soil is not being disturbed (Beck, Miller, Hagny). The planting of cover crops can also be used to reduce weed growth, erosion and to act as a natural fertilizer by adding more organic carbon (Schonbeck, Morse). Earlier planting can allow the crops to grow before the weed infestation.

Since fields under no-till have a perpetual source of food for pests, they can be harder to keep under control. One way this could be remedied is by rotating crops, so that there will not always be a source of food for insects that can only eat certain types of crops. On the other hand, no-till farming has been shown to increase the number of beneficial insects, such as earthworms (Subbian, et al). Beneficial insects can improve the health of soil, as they produce fertile material while decomposing the remnants of crops and they break up compacted soil which can help plant roots establish themselves.

To successfully implement no-till practices, Indian farmers must develop a system that fits their needs. With the goal of increasing crop yields in mind, no-till systems that have proven to be effective need to be studied. According to Beck, Miller, and Hagny, the key to increasing crop yields is to plant crops in rotations that are diverse and to have a high crop intensity. Crop intensity refers to the amount of water the crops use (Beck, Miller, Hagny). Since no-till systems can retain more water, a higher crop intensity, one that demands more water, should be used. Rotations should also be planned in a manner that will minimize the number of pests that can transition from crop to crop.

No-till could potentially benefit many Indian farmers, but they have to be shown that no-till can increase yields and decrease input costs. It may not be as effective in certain areas, and, while there have been studies to determine the factors common to its successful use, there needs to be research into which areas in India it would be most effective. Partnerships with Indian universities could be formed to guide the research into the suitability of different areas to no-till. In areas well-suited for its implementation, farmers must be educated about how to properly use it to plant, to control weeds and to improve the quality of their soil. Meetings held by the Indian Council for Agricultural Research could help with the awareness and education of farmers in alternative farming methods. There also needs to be more research on how no-till could be adapted to the needs of a typical Indian farmer. Research into efficient use of water and increased use of cover crops to reduce erosion, soil depletion, and the need for herbicides is necessary. There are many different options for the variety of cover crop used, but there are some that would work better than others depending on the climate and type of soil. Some cover crops can also be used to enrich the soil if the soil is lacking a certain nutrient.

Once farmers learn how to gain the most benefit from no-till farming systems, the switch from conventional tillage to no-tillage needs to be facilitated. For small farmers that use manual labor, the cost of switching to no-till should be low. Demonstrations could be made about how to plant seeds when the ground is not tilled, generally cuts are made in the ground and seeds are dropped in, resulting in minimal disturbance of the ground. In the previously mentioned CAU project, farmers attended a total of ten training programs to inform them of no-till methods (“Zero Tillage”). This can be considered a successful example because it was expanded to include three districts and 1,000 total hectares under cultivation (“Zero Tillage”). An example of what one farmer can do is Raju Titus. He switched to no-till twenty-five years ago and since then many people from all over the country have visited his farm and learned about the improvements he experienced after making the switch (Mayaram). If farm projects like this could be implemented in more communities farmers would be able to see firsthand what switching to no-till would involve.

For larger farms that are more mechanized, primarily the farms in northern India, the cost of switching would be greater. Making the switch would require the purchase of no-till drills that are specially designed to plant in no-till fields. The cost of the new machines can be offset somewhat by the sale of old tilling machines and other equipment associated with tilling. The governments of Haranya and Punjab

have offered subsidies to farmers for no-till technology (Malik, Gurjeet, Sardana et al). In Punjab, a twenty-five percent subsidy was offered for the purchase of drills (Grover, Sharma). If farmers that have large land holdings take the perceived risk of implementing no-till systems and buy subsidized no-till drills, they could be an example in their communities. This would show the other farmers that no-till can improve their livelihood. In 1998, farmers in Punjab purchased strip-till drills and by 2000 there were 72 working drills. Using these drills, the farmers saw increased yields and lower production costs, mostly because of the decrease in the amount of fuel used to prepare the fields (Grover, Sharma). If a generous subsidy was placed on the purchase of these drills, no-till practices might increase more rapidly.

If large farmers were able to purchase no-till drills that were within their budget, then other smaller farmers would be able to see the technology used in their own backyard and learn about the benefits of it. While these small-holder farmers may not be able to find the resources individually to purchase a drill, they could form a co-op or they could then learn about how to implement a no-till system using manual labor or smaller scale technologies. However, what could be the most useful in convincing farmers that using no-till would be beneficial to them is a demonstration farm in their community. This could show them that it would work well for their type of farm, and, if any problems are found when no-till is used in a specific community they could be worked out on this test plot. A partnership with a local university would also be helpful in this case because they could manage the test plot.

India is a large and growing country that aims to be agriculturally self-sufficient. Malnutrition is a large problem for many Indians but especially for rural farmers, workers and women. Much of the food grown by farms is not consumed by their families, but sold to provide income. If the overall productivity of farms increased it would lead to the ability of families to buy more nutritious food. Indian farms are generally small parcels of land where the crops grown are consumed by farm families or sold into the Indian market. This small size emphasizes any inefficiencies or hindrances to agricultural production.

Additional barriers to productivity occur due to environmental problems that are caused by unsuitable farming practices or other factors that are out of the farmer's control. With increased environmental degradation, a greater emphasis is being placed on environmental sustainability. Large amounts of water are used in irrigation and water scarcity is becoming a global issue as water resources dry up. The costs of conventional farming in India are evident. Current practices have led to soil erosion, runoff, and air pollution. In addition, modern tillage can have higher production costs, and contribute to nutrient loss and a reduction in soil biodiversity.

No-till farming could provide a great benefit to India's agricultural productivity. In some areas of India no-till systems have been tested and have proved to be effective (Gosain, Dalip). What needs to happen is a scaling up of these already existing projects. Information about the effect of no-till on crop yields, soil health, and production costs needs to be spread to farmers. The use of no-till is already increasing due to local projects and research. The impressions of Indian farmers who have tried no-till are overwhelmingly positive and no-till could be adapted to the many systems of farming in India, similar to what occurred in Punjab (Gosain, Dalip). No-till could potentially lead to a jump in the well-being of those that live in rural areas. It has been shown to increase the yields of crops in certain regions of India. Even if using no-till did not increase the yield of crops substantially, farmers would be better off because they would have lower production costs. No-till farming could potentially help to meet the Millennium Development Goals for food security, gender equality, and environmental sustainability. In many instances, no-till farming would be an improvement over the use of tillage. It has the potential to preserve the environment, increase crop yields and therefore improve the overall well-being of the rural farmer in India.

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