CHALLENGES AND OPPORTUNITIES

o Productivity Improvement in Agriculture

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INTRODUCTION

With an ever increasing global population, the demand for food and cash crops will continue to grow. However, this growth curve may not be as herald and increase in resources such as available farmland as has been the case in past years. A synergy of resources and farm practices would be required to achieve significant improvements in yield based on new plant varieties and farming technologies. Productivity must increase on all the lands where farmers seek a living, not just in the well endowed areas. More varieties and packages for crops other than the three key cereals need to be developed. And the potential of resource conserving approaches such as an Integrated Nutrient Management Supply system needs to be fully realized.

Livestock production looks to raising the amount of livestock in circulation such as beef cattle, sheep, and hogs as well as establishing dairy farms, poultry/egg farms; animal specialty farms, such as apiaries (bee farms) and aquaculture (fish farms). Crop production includes the growing of cash grains, such as wheat, corn, and barley; field crops, such as cotton and tobacco; vegetables and melons; fruits and nuts; and horticultural specialties, such as flowers and ornamental plants.

1. No Till/Conservation Agriculture (NT/CA)

The industrial agric era has, among its disadvantages, a regular disturbance of the structure and ecology of the soil, usually in the form of land tillage by tractor-drawn implements. Although tilling is used to remove weeds, mix in soil amendments like fertilizers, shape the soil into rows for crop plants and furrows for irrigation, and prepare the surface for seeding, it has unfavorable effects, like soil compaction; loss of organic matter; degradation of soil aggregates; death or disruption of soil microbes including mycorrhiza, arthropods, and earthworms[1]; and soil erosion where the top-soil is blown or washed away, principle to eutrophication.

Furthermore, the significant effects of tillage includes the obvious loss of soil fertility, increased air and water pollution, intensified drought stress, increased fuel consumption [2][3].

With an ever increasing demand on farmers to increase food production, the pressure falls on farmers to improve on farm practises. However, the first bottle-neck to tackle would be the declining soil quality, which is caused by soil tillage. As a result, No Till/Conservation Agriculture (NT/CA) has been developed.

It is an effective technique to reduce the degradation of soil. With this way of farming, crop residues or other organic amenities are retained on the soil surface and sowing/fertilizing is done with minimal soil disturbance.

Although a few obstacles may present itself during a switch to this practise, prevoius experience seems to indicate that many problems during the transition are temporary and become less important as the no-till system matures and equilibriates. The judicious use of crop rotations, cover crops and same soil disturbance may help reduce agronomic risks. Farmers switching to continuous no-till must often seek new knowledge and develop new skills and techniques in order to achieve success with this different way of farming[4].

The advantages of this practise include;

- **Soil**. NT/CA improves soil quality (soil function), carbon, organic matter, aggregates[5], protecting the soil from erosion[6], evaporation of water[7], and structural breakdown. A reduction in tillage passes helps prevent the compaction of soil.
- **Carbon**. NT/CA has carbon sequestration potential through storage of soil organic matter in the soil of crop fields [8]. Tilled by machinery, the soil layers invert, air mixes in, and soil microbial activity dramatically increases over baseline levels. The result is that soil organic matter is broken down much more rapidly, and carbon is lost from the soil into the atmosphere. This, in addition to the emissions from the farm equipment itself, increases carbon dioxide levels in the atmosphere. Cropland soils are ideal for use as a carbon sink, since it has been depleted of carbon in most areas. It is estimated that 78

billion metric tones of carbon that was trapped in the soil has been released[9] because of tillage. Conventional farming practices that rely on tillage have removed carbon from the soil ecosystem by removing crop residues such as left over corn stalks, and through the addition of chemical fertilizers which have the above mentioned effects on soil microbes. By eliminating tillage, crop residues decompose where they lie, and growing winter cover crops such as grains, alfalfa, or crimson clover, field carbon loss can be slowed and eventually reversed.

- **Soil Biota/Wildlife/Etc**. In no-till farming the soil is left intact and crop residue is left on the field. Therefore, soil layers, and in turn soil biota, are conserved in their natural state. No-tilled fields often have more beneficial insects and annelids[10], a higher microbial content, and a greater amount of soil organic material. Since there is no plowing there is less airborne dust. No-till increases the amount and variety of wildlife[11]. This is the result of the improved cover because of surface residue and because the field is disturbed less often than conventional fields.
- **Water**. Crop residues left intact help both natural precipitation and irrigation water infiltrate the soil where it can be used. The crop residue left on the soil surface also limits evaporation, conserving water for plant growth. Since there is less soil compaction and no tillage-pan, soil absorbs more water and plants are able to grow their roots deeper into the soil and suck up more water. Tilling a field reduces the amount of water, via evaporation, around 1/3 to 3/4 inches per pass[12]. By no-tilling, this water stays in the soil, available to the plant.
- **Economic/Yield**. Studies that try to identify whether or not it is more profitable have found that it can be[13] [14] if done right. Less tillage of the soil reduces labor, fuel[15][16], irrigation [17] and machinery costs[18]. No-till can increase yield because of higher water content[19] and much lower erosion rates. Another benefit of no-till is that because of the higher water content, instead of leaving a field fallow it can make economic sense to plant another crop instead[20](depending on your specific local circumstances). This potentially earns more money, because even though each individual crop earns less the total amount earned can be larger since more crops are produced in the

same amount of time. As sustainable agriculture becomes more socially popular, monetary grants and awards are becoming readily available to farmers who practice conservation tillage. Some large energy corporations which are among the greatest generators of fossil-fuel-related pollution are willing to purchase carbon credits to encourage farmers to engage in conservation tillage[21][22]. The farmers' land essentially becomes a carbon sink for the power generators' emissions. This helps the farmer in several ways, and it helps the energy companies meet demands for reduction of pollution.

- **Preserving archaeological relics**. Tilling regularly damages ancient structures under the soil such as long barrows. In the UK, half of the long barrows in Gloucestershire and almost all the burial mounds in Essex have been damaged. According to English Heritage modern tillage techniques have done as much damage in the last 6 decades as traditional tilling did in the 6 centuries. By using no-till methods these structures can be preserved and can be properly investigated instead of being destroyed. [23]

The rotation of cereals and leguminous plants has been shown to reduce chemical fertilizer use by up to 30 percent, as cereals absorb the nitrates released from the decaying roots and nodules of leguminous plants.

2. Integrated Pest Management

With the world’s population on the rise, food production has also increased to meet demand. The awareness of the effect of globalisation on the environment, activist groups and concerned citizens in various countries, pressure is on governments and producers to increase food production without damaging the ecological foundations of agriculture. This underlies the need for generation and diffusion of new technologies that produce sufficient food and protect the environment and human health. An integrated pest management (IPM) system is and incorporates such technology.

Insect pests, diseases and weeds are the major constraints limiting agricultural productivity growth.

About a fifth of the overall crop production is lost to insects. Emerging problems such as insecticide resistance, secondary pest outbreak and resurgence further add to the cost of plant protection.

In developed countries, losses in production are on the rise. New cropping patterns and intensive agricultural practises have led to the emergence of new pests. To combat this, IPM systems apply a combination of pest control strategies, peculiar to the region involved. These strategies include the use of biological, chemical, cultural and resistant variety control strategies. IPM is thus more complex for the producer to implement, as it requires skills in pest monitoring and understanding of the pest dynamics, besides the cooperation among the producers *en mass* for effective Implementation.

IPM is an ecologically based strategy that focuses on long-term solution of the pests through a combination of techniques such as biological control, habitat manipulation, modification of agronomic practices, and use of resistant varieties. Embracing a single tactic to control a specific organism does not constitute IPM, even if the tactic is an essential element of the IPM system. Integration of multiple pest suppression techniques has the highest probability of sustaining long term crop protection. Pesticides may be used to remove/prevent the target organism, but only when assessment with the help of monitoring and scouting indicates that they are needed to prevent economic damage. Pest control tactics, including pesticides, are carefully selected and applied to minimize risks to the human health, beneficial and non-target organisms, and environment.

The foundation of this system is the creation of a database of susceptible pest types and their causing effect. The information obtained from this database aids in selecting the best possible combinations of the pest management methods.

IPM also looks at the continuous pest resistance breeding process, using genetic techniques to combat pathogens with the ability to co-evolve with their host. This is a peculiarity among plant pathogens. An example of this is the incorporation of genetic material from *Bacillus thuringiensis* (Bt), a naturally occurring bacterium, in cotton, makes the plant tissues toxic to the insect pests.

An IPM should also include crop production practices that make crop environment less susceptible to pests. Crop rotation, fallowing, manipulation of planting and harvesting dates, manipulation of plant, row spacing and destruction of old crop debris are a few examples of cultural methods that are used to manage the pests. Planting of cover crops, nectar-producing plants and inter-planting of different crops to provide habitat diversity to beneficial insects are important management techniques.

Examples of IPM system being practised include the placement of plastic-lined trenches in potato fields to trap migrating Colorado potato beetles, installation of dead as well as live bird perches in cotton and chickpea fields has proved effective in checking the bollworm infestation. These make up part of the physical control measures. Biological control measures of IPMs include augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, parasitic nematodes, fungi and bacteria.

Direct chemical control measures would involve the spraying of pesticides, which are used to keep the pest populations below economically damaging levels when the pests cannot be controlled by other means. Pesticides include both the synthetic pesticides and plant-derived pesticides. Ideally, pesticides should be used as a last resort in IPM programmes because of their potential negative effect on the environment.

Botanical pesticides are a potential replacement for its synthetic counter-part. It can be prepared in various ways. They can be as simple as raw crushed plant leaves, extracts of plant parts, and chemicals purified from the plants. Pyrethrum, neem, tobbaco, garlic, and pongamia formulations are some examples of botanicals. Some botanicals are broad spectrum pesticides. Botanicals are generally less harmful to the environment, because of their quick degrading property. They are less hazardous to transport. The major advantage is that these can be formulated on-farm by the farmers themselves. [24]

3. Integrated Plant Nutrient Management & Supply (INMS)

Continuous crop production without adequate management tends to reduce the nutrient reserves in the soil. If kept unchecked, this cumulative depletion leads to a reduction in agric production in addition to crop yields, soil fertility and degradation.

Techniques to conserve and add nutrients to the soil through the application of organic or inorganic fertilizers can help to maintain and increase the nutrient reserves of the soil.

However, one must note that an over supply of nutrients can cause serious problems including harm to the end consumers of the products, harm to the plants themselves, etc. The relative low cost of fertilizer is a problem as well in that it leads some farmers to apply it in amounts that far exceeds the plant needs, as well as in quantities that far exceeds the soil capacity to hold nutrients.

An integrated plant nutrient management and supply (INMS) system has been developed in many countries and research institutes to strike this balance.

The application of regulated measures of both organic and inorganic fertilisers is one approach of an INMS system to correct nutritional imbalances. This not only increases crop yield, it also reduces the need to cultivate unsustainable marginal lands. In Kenya, the application of nitrogenous fertilizer on nitrogen-poor soils increased maize yields from 4.5 to 6.3 metric tons per hectare, while application of a less-appropriate fertilizer increased yields to only 4.7 tons per hectare.

Incorporating the use of (manmade) inorganic fertilizers is a crucial resource-tool of INMS. Participating governments in support of INMS programs can boost its production potential by enacting policies/programs make organic and inorganic fertilizers easily available and affordable.

An INMS system also looks at utilising waste as an extra plant nutrient source. Although this is a relatively poor substitute for commercial fertilizers, wastes, in the form of urban sludge, improve soil structure and both contain secondary and micronutrients as well as NPK.

In addition to the above, the use of waste (especially treated waste) as a supplement to fertilisers is economically viable as it reduces the cost of disposal and health risks associated with landfill disposal. This is extremely beneficial to farmers who cannot afford inorganic fertilisers.

An INMS system also looks at reducing the occurrence of volatilization; a process by which crops loss nitrogen into the atmosphere. This aids in improving the efficiency of nutrient uptake by crops. New techniques, such as deep placement of fertilizers and the use of inhibitors or urea coatings, have been developed to address this problem.

An Integrated Nutrient Management Supply system requires a range of actors in the areas of research, extension, evaluation and dissemination of technologies.
The different climates, soil types, crops, farming practices and technologies mandate that a correct balance of nutrients necessary for any one farm may be quite different from that necessary for a farm somewhere else in the world. In Africa for example, the challenge is intimidating because of the severe climatic and soil conditions and the diversity of smallholder farmers.

Successful INMS adoption programs thus must facilitate an exchange of information between farmers, extension programs, and researchers that help these participants learn about what actually works on farms in their area. Adoption programs also require greater monitoring and testing of plants and soils to ensure that INMS is establishing the best environment for plant growth. [25]

4. A paradigm shift to organic agriculture

Organic agriculture, according to USDA definition, is a system that is managed in accordance with the Organic Foods Production Act and regulations to respond to site specific conditions by integrating cultural, biological and mechanical practises that foster cycling of resources as well as promotes ecological balance and conserve biodiversity.
It involves a set of practices in which the use of external inputs is minimized. Synthetic pesticides, chemical fertilizers, synthetic preservatives, pharmaceuticals, GM organisms, sewage sludge and irradiation are all excluded. The interest in organic agriculture has been boosted by public concerns over pollution, food safety and human and animal health, as well as by the value set on nature and the countryside.
In developed countries, like Germany, government subsidies have helped to make organic agriculture economically viable.
In the late twentieth century, the total area of organic land in Europe and the United States tripled, albeit from a very low base. However, many European countries have

ambitious targets for expansion, with the result that Western Europe may have around a quarter of its total agricultural land under organic management by 2030.
With the likes of Tesco, Wal-mart, Asda, etc a number of large supermarket chains have bought into this recent organic explosion, compelling them to invest more as potential demand far outstrips supply. In many industrial countries, sales are growing at 15 to 30 percent a year. The total market in 2000 was estimated at almost US$20 billion still less than 2 percent of total retail food sales in industrial countries but a sizeable increase over the value a decade ago. Demand is expected to continue to grow, perhaps even faster than the 20 percent or so achieved in recent years. The supply shortfall offers opportunities for developing countries to fill the gap, especially with out-of-season produce.
The progress of organic agriculture is fostered by certified inspection agencies on clearly defined methods.

Organic agriculture offers many environmental benefits. Agrochemicals can pollute groundwater, disrupt key ecological processes such as pollination, harm beneficial micro-organisms and cause health hazards to farm workers. Modern monoculture using synthetic inputs often harms biodiversity at the genetic, species and ecosystem levels. The external costs of conventional agriculture can be substantial.
In contrast, organic agriculture sets out to enhance biodiversity and restore the natural ecological balance. It encourages both spatial and temporal biodiversity through intercropping and crop rotations, conserves soil and water resources and builds soil organic matter and biological processes. Pests and diseases are kept at bay by crop associations, symbiotic combinations and other non-chemical methods.
Water pollution is reduced or eliminated. Although yields are often 10 to 30 percent lower than in conventional farming, organic agriculture can give excellent profits. In industrial countries, consumer premiums, government subsidies and agro-tourism boost incomes from organic farms. In developing countries, well-designed organic systems can give better yields, profits and returns on labour than traditional systems.

Organic agriculture also has social benefits. It uses cheap, locally available materials and usually requires more labour, thereby increasing employment opportunities. This is a considerable advantage in areas where, or at times when, there is a labour surplus.

By rehabilitating traditional practices and foods, organic agriculture can promote social cohesion. Certain policy measures are essential if the progress of organic agriculture is to continue.

Support for agriculture is increasingly shifting from production goals to environmental and social goals, a trend that could favour organic agriculture. Agreed international standards and accreditation are needed to remove obstacles to trade.

Other key areas to look at include;

- An improved marketing strategy.
- Improved agro-forestry systems.
- Improving irrigation and water harvesting systems thus enabling farmers to produce more crops per drop, and multiply their incomes through high-value products.
- An improved seed system /use of improve crop varieties. Governments and farmers would have to incorporate hybrid varieties that can enhance yields and facilitate robust vigorous growth. This would also involve the distribution of appropriate seed varieties to respective locations whereby the incidence of natural disasters or land degradation is high. These seeds could be produced via traditional breeding methods whereby traits such as increased pest resistance are key or they may be the regular varieties but with a higher quality/purity level than the stock. Partnering with commercial seed enterprises, agricultural research institutes, non governmental association (NGOs) would boost this system.
- Livestock production would also require a significant boost to meet the demand as they not only provide us with meat, dairy products and eggs, but also wool, hides and other industrial goods. Livestock production can be closely integrated into mixed farming systems as the end-users of crop by-products in addition to acting as a source of organic fertilizer, ploughing and transport. Selection and breeding, together with improved feeding regimes, could lead to faster fattening and larger animals. Practises would involve routine hormone therapy, artificial insemination through biotechnology, a deeper understanding if animal genetic make-up for improved disease control, adaptation to environmental stresses and increased production. Intensive systems of stall-feeding emerge in areas where land availability is scarce, leading to less soil damage and faster fattening. This trend too can be expected to continue and accelerate. A continued shift in production methods can be expected, away from extensive grazing systems and towards more intensive and industrial methods. Mixed farming, in which

livestock provide manure and draught power in addition to milk and meat, still predominates for cattle. As populations and economies grow, these multipurpose types of farming will tend to give way to more specialized enterprises.

Productivity Improvement in Agriculture through Biotechnology

Agriculture is expected to feed an increasing human population, forecast to reach 8 000 million by 2020, of whom 6 700 million will be in the developing countries. Although the rate of population growth is steadily decreasing, the increase in absolute numbers of people to be fed may be such that the carrying capacity of agricultural lands could soon be reached, given current technology. The technological challenge is to obtain this agricultural productivity improvement without destroying the global natural resource base. New technologies, such as biotechnology, if properly focused, offer a responsible way to enhance agricultural crop productivity for now and the future.

The main biotechnological applications in crop biotechnology include tissue culture, marker-assisted selection and transgenic technology. Tissue culture includes micropropagation; embryo rescue; plant regeneration from callus and cell suspension; and protoplast, anther and microspore culture, which are used particularly for large-scale plant multiplication. Micropropagation has proved especially useful in producing high quality, disease-free planting material of a wide range of crops. Tissue culture also provides the means to overcome reproductive isolating barriers between distantly related wild relatives to crops through embryo rescue and *in vitro* fertilisation or plant protoplast fusions.

Molecular marker technology is useful for assisting and speeding up selection through conventional breeding. It is a powerful method for identifying the genetic basis of traits and is used to construct linkage maps to locate particular genes that determine beneficial traits. Using molecular markers, genetic maps of great detail and accuracy have been developed for many crop species. Markers are particularly useful for analysing the influence of complex traits like plant productivity and stress tolerance and are being employed to develop suitable cultivars of the major crops.

Generation of genetically modified trangenic plants with a range of added traits, uses advanced recombinant DNA techniques including genetic engineering and cloning.

Several transgenic cultivars of major food crops, such as soybeans, maize, canola, potatoes and papayas, have been commercially released incorporating genes for resistance to herbicides, insects and viruses. It is estimated that the global area planted with transgenic crops has risen from 1.7 million hectares in 1996 to 44.2 million hectares in 2000 (ISAAA, 2000).

Crop improvement continues to benefit from advances in plant molecular biology and genomics. The completion of the genome sequence of the mustard (*Arabidopsis thaliana)* and rice and the continuing work on functional genomics has tremendous direct benefits both for dicotyledons and monocotyledons. The increase in understanding of gene regulation and expression will allow crops to be modified to provide food, fiber, medicine and fuel as well as tolerance to environmental stresses. The tools are in place to meet future food demand through increases in crop productivity with less land and water to meet the demand of the population increase.

It is however, important to recognise that possible environmental risks can be caused by transgenic gene escape and genetic erosion and new products of biotechnology, mainly involving genetically modified crops, have raised such concerns. Adequate biosafety regulations, risk assessment of transgenic crops and establishment and compliance with appropriate mechanisms and instruments for monitoring use are needed to ensure that there will be no harmful effects on the environment or for the users.

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