Chapter 10

Conclusions: research and development priorities

Tillage is an important technique by which farmers influence soil and micro-climate with the objective of improving production. Ever since primitive societies learned to manipulate soil by simple tools, cultivation has been an essential component of farming and its usefulness has never been questioned. It is only recently that tillage and its consequences have been a concern to the scientific community. Since the 1950s mechanized tillage operations with their sometimes drastic effects on soil and environments have been widely used. Their large energy requirements have led to a closer examination of the need for such expensive, time-consuming and potentially degradative techniques.

The consequences of tillage on soils and environments are hard to generalize. The effects vary among soils, climates, initial conditions and subsequent management. The short-term effects often differ from the long-term effects, about which little is known for the tropics

Conservation tillage can be an important low input component of sustainable agricultural systems. It is aimed at preserving the productive potential of soil and maintaining environmental quality. It emphasizes the use and improvement of the natural resource rather than its exploitation for economic gains. Conservation tillage is synonymous with good farming.

PAST ACHIEVEMENTS

In the humid and sub-humid tropics, mechanical tillage often has more adverse than beneficial effects. Ploughing exposes structurally unstable soil to raindrop impact, decreases infiltration rate, increases runoff and soil erosion, increases the maximum soil temperature, increases evaporation, and often reduces crop yield. Where there is an adequate quantity of crop residue mulch and chemical weed control is feasible, mechanical tillage is economically wasteful and ecologically incompatible. For most soils and for grain crops, the intensity and frequency of tillage operations can be substantially reduced.

In the arid and semi-arid tropics, mechanical loosening of soil is often beneficial. Plough-till systems are needed where soils are easily compacted and there is little crop residue or stubble mulch to protect the soil. Although the beneficial effects are short lived and disappear by the end of the first cropping cycle, deep ploughing and soil inversion often improve porosity and infiltration, decrease runoff and erosion, and improve soil-water storage and crop yield. The beneficial effects of tillage are less marked where crop residue mulch is available.

Tied-ridge systems are useful and effective on soils with a stable structure where the capacity of the ridge-furrow system is adequate to accept the rainfall. They are appropriate for shallow soils of low-water holding capacity, soils of low inherent fertility, and for marginal ecoregions. The ridge furrow system is useful on sandy soils prone to wind erosion and sandblasting.

Vertisols can be intensively managed using appropriate tillage methods. Deep ploughing, incorporation of stubble mulch, and the use of lime and chemical fertilizers are essential. The broadbed and furrow system or a graded ridge furrow system is useful for providing surface drainage. Deep ploughing and the application of gypsum are needed for the reclamation of sodic soils.

Crop yields on sandy soils of low water holding capacity are often improved by moderate compaction. Compaction increases seed-soil contact and improves water retention properties. Compaction in the seed zone and application of residue mulches or compost often improves crop stand and yield.

KNOWLEDGE GAPS

Tillage research in the tropics is still in its infancy. Many of the contradictory results arise from the lack of systematic investigations. The results of tillage research should always be supported by detailed analyses of soil properties, environmental factors and crop characteristics. The results from tillage experiments are not comparable without such supporting data.

To describe and quantify the ecologic, economic and anthropologic or social effects of tillage is challenging. Such information is not available for tropical ecosystems. By strengthening our knowledge, tillage needs can be specified to deal with weed control and soil compaction alleviation. Developing soil-specific tillage methods is necessitated by the high costs of fuel and increased risks of soil erosion on ploughed lands in humid and sub-humid environments. So far, the development of sophisticated tillage tools has been misdirected. Rather than curing the disease by understanding causes, scientists have been misled by the symptoms. With an understanding of the soil limitations and soil potential, and crop requirements, it is possible to avoid excessive, expensive and often ecologically-harmful tillage. This does not mean ploughless agriculture on all soils and crops, but unnecessary soil manipulation and wasteful use of energy and resources can be minimized.

Tillage research hitherto conducted in the tropics lacks a holistic approach. A systems approach is essential for the wide adaptation of conservation tillage. For conservation tillage systems to be adopted successfully in a wide range of soils and environments, they must fit into the overall scheme of present and future trends in the farming systems of a region and must meet the rising social and economic aspirations of the farming community. Conservation tillage has become controversial because of its effects on the transport of herbicides and nutrients in surface and subsurface waters. Long-term and large-scale ecosystem studies are necessary to assess the effectiveness of various conservation tillage systems in reducing pollution of natural waters by sediments, nutrients and pesticides.

RESEARCH PRIORITIES

To minimize tillage inputs and to reduce risks of soil degradation, it is important to: (i) develop alternate systems for weed control, (ii) provide sources of mulch through appropriate cropping systems, (iii) alleviate soil compaction by biological means, (iv) develop suitable tools to sow through mulch and on uneven ground, and (v) develop effective drainage and erosion control systems for soils prone to waterlogging and susceptible to erosion. In addition, important research topics include the following:

Developing a soil guide

Impressive progress has been made by soil scientists in assessing the nutritional status of soils and recommending the rates of fertilizers for meeting crop requirements. There are no similar schemes for routinely measurable soil properties to diagnose soil tilth-related constraints to crop production and recommend the appropriate conservation tillage systems to achieve and maintain the desired seedbed. Soil structure and tilth continue to be elusive properties difficult to diagnose and assess. There is a need to develop soil-based guidelines for tillage requirements for sustainable management of soil and water resources for the principal soils, ecoregions and crops of the tropics.

Reducing inputs

Minimizing inputs of tillage effort, fertilizers and pesticides are major objectives that deserve high priority. The aim is to sustain optimum economic returns while minimizing dependence on those inputs that are not available or are based on non-renewable resources. In the tropics and subtropics herbicides and farm chemicals are not easily or economically available and high rates of application are neither ecologically nor environmentally compatible. Pathways of pesticides and other chemicals are not known for the tropics. Dependence on herbicides as a preferred mode of weed control should be minimized. Allelopathic effects of cover crops and biological methods of weed control should be evaluated. Regenerative cropping systems must, therefore, be studied with the aim of reducing dependence on potentially hazardous chemicals.

Crop stand establishment

Poor seedling establishment results in a sparse crop stand and low yields especially in the arid and semi-arid tropics. This may be due to poor seed quality, low soil moisture, unfavourable microclimate in the seed zone or to heavy pest infestation. There are many aspects that need investigating, including time of sowing, seed rate, seed placement, seed-soil contact, row orientation and integrated pest management. The role of appropriate cultivars and of seed characteristics (such as size, hardiness) cannot be overemphasized. Also important are allelopathic effects related to anaerobic decomposition of crop residues, particularly in the humid tropics. Suitable cultivars should be screened for the specific environments in the seedbed created by different tillage systems.

Diverse farming and cropping systems

Diversification is a key to ecological stability. Appropriate tillage methods should be developed for systems of row crop production so that they can be integrated with livestock raising and with the growing of perennial crops.

Techniques of management of pastures or of woody plants and shrubs should be devised that are compatible with the specific requirements of proposed tillage systems for row crop production.

Agricultural sustainability

The issues of sustainability and of environmental quality will remain a major challenge to agriculture for generations. What are a system's performance indicators that can be used to assess sustainability and its ability to preserve the resource base? Should the agronomic returns be assessed in terms of production (i) per unit area; (ii) per unit time; (iii) per unit loss of soil property that plays a vital role in maintaining soil's life support processes such as organic matter content; (iv) per unit loss of soil's effective rooting depth (e.g. kilogrammes of grain produced per kilogramme of soil erosion); (v) output:input ratio evaluated in terms of calories; (vi) or per unit increment of major pollutants to first order streams or groundwater? Assessing the suitability of tillage methods in terms of the economics of crop production on a seasonal or annual basis alone is not enough. Appropriate system performance indicators, to assess sustainability as influenced by tillage methods and soil management are not yet established.

The holistic approach

Conservation tillage is an approach in which long-term sustainability and preservation of environmental quality and the resource base are given priority over short-term economic returns. It may not always yield the highest economic returns in the short-term. It is also soil- and site-specific and no single blueprint of cultural practices is universally applicable. It includes no-till, minimum-till, ridge tillage, chisel ploughing, zonal tillage, and a range of other cultural practices developed to overcome specific constraints. The appropriate type of conservation tillage depends on both biophysical and socio-economic factors and on the interactions between them. The most beneficial tillage practice is the one that creates or maintains favourable porosity for water and air movement and root growth. This is site-specific and needs to be validated, adapted and fine-tuned to local environments.

The effectiveness of conservation tillage can be vastly improved by adopting other supporting practices based on principles of good farming. These include crop rotations, cover crops, mixed farming, agroforestry and summer fallowing. The slow adoption of conservation tillage is due to the lack of suitable supporting practices that would enhance its effectiveness.

Socio-economic factors

Although the basic principles of sound soil and environmental management are well known, subtle adjustments to the package of cultural practices are commonly needed to optimize the use of limited resources and to alleviate soil and environment related limitations to crop production due to differences in socio-economic factors. Such adjustments depend on differences in climate, soil, erosion risks, availability of commercial inputs, infrastructure, farm size, and socio-economic factors. Up to now socio-economic, cultural and ethnic factors have not been given the attention they deserve. Economic profitability and social acceptability are important considerations.

Soil degradation

Soil degradation is a serious problem in the tropics, so the main justification for conservation tillage is to prevent soil erosion, provide favourable soil and microclimate environments, reduce risks of environmental pollution, decrease the risks of soil salinity and sodicity, and enhance productivity of the soil. Conservation tillage is a risk-avoiding and a problem solving approach, geared to providing satisfactory yield under poor conditions rather than the highest yield under the best conditions. It is also aimed at alleviating specific constraints, e.g., accelerated erosion, drought stress, surface sealing and crusting, subsoil compaction, unfavourable soil temperature regimes, anaerobic conditions in the root zone, and other factors responsible for low soil fertility.

Weed control measures

Conservation tillage has become controversial because it depends on herbicides. The herbicides used pollute natural waters. The pathways, biodegradation and transport processes in different systems of soil and crop management are not fully understood. Long-term and ecologically oriented field experiments are needed. Development of alternative methods of weed control is a high priority.

Alleviating drudgery

Replacing the back-breaking hoe with improved tools remains a challenge. Human suffering and subsistence agriculture in the tropics are synonymous. Why has animal traction not been adopted in several parts of Africa, even though tractorized tillage implements are out of reach of most farmers? A multi-disciplinary approach is needed to address the complex but important issues of alleviating the drudgery associated with farming in the tropics.