No-Till in the Lowland Humid Tropics

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ABSTRACT

The adaptation of no-till farming in the humid tropics is expected to be useful for soils that are susceptible to accelerated erosion, drought prone due to low plant available water reserves and shallow effective rooting depth, subject to supra-optimal soil temperatures during crop establishment periods, and for those that are of low inherent fertility. The system is adaptable for small- or large-sized farms and has the additional benefits of saving labor and energy, and facilitating multiple cropping. This report reviewssoil and environmental factors that favor the adaptation of no-till system for food crop production.

INTRODUCTION

The total area covered by the lowland humid tropics is about 2600 million ha. Major soils of this ecology are Alfisols, Ultisols and Oxisols. Together these soil orders occupy a vast area of the subhumid and humid tropics. In West Africa, for example, the majority of low activity clay soils are Oxic Alfisols and Ultisols especially in regidns where rainfall exceeds about 1200 mm per annum. The percent surface area in the tropics covered hy Alfisols, Ultisols and Oxisols is 16.2, 11.2 and 22.5 corresponding to 800, 550 and 1100 million hectares, respectively. These soils predominantly contain low activity clays i.e. the clay fraction comprises mostly kaolinite and halloysite with hydrous oxides of iron and aluminum. While in Oxic Alfisols and Ultisols a part of the clay fraction is readily dispersible that in Oxisols is relatively resistant to dispersion.

Constraints to intensive landuse in Alfisols are predominantly physical and comprise low available water holding capacity, and susceptibility to erosion and soil compaction. The drought stress frequently experienced by crops grown on Alfisols is due to low available water reserves and high surface soil temperatures. Accelerated soil erosion is caused partly by the development of crust or an impermeable surface seal. Easily dispersible Oxic Alfisols are particularly vulnerable to crusting and hard setting following extremes of temperature and moisture conditions. Surface custing is further aggravated by the low level of soil organic matter content. In addition to soil physical factors, nitrogen deficiency is also a major problem in Alfisols. In comparison the acidic Ultisols and Oxisols have additional constraints of nutritional disorders due to low pH, deficiencies of major nutrients, and A1 and Mn toxicity. When nutrient imbalance is corrected, however, soil physical constraints limit crop production.

There are two major consequences of severe physical and/or nutritional constraints i.e rapid deterioration in soil properties following new arable land development, and decline in crop yields. These consequences are particularly severe following mechanical land clearing and mechanized farming based on motorized plowing and harrowing and combine harvesting that involve considerable vehicular traffic.

SOIL SURFACE MANAGEMENT

Appropriate soil surface management practices are those that curtail the deterioration in soil properties. Providing a protective vegetation cover on the soil surface and minimizing exposure of soil are obviously desirable. No-till is a system of soil management that, while eliminating all preplanting seedbed preparation, achieves these conditions of minimizing soil exposure and providing crop residue mulch. The more the surface area covered by the crop residue mulch the better the protection it gives to easily dispersible soil beneath. The benefits of mulch farming techniques in relation to plow-based system for these easily dispersed and hard-setting soils are well established. These include improved soil and water conservation, reduced soil compaction, and savings in labor and fuel costs.

Crop response to no-till farming is soil and crop specific. Soil properties that favor the adaptation of no-till farming include the followings:

(i) Coarse-textured surface horizons and in soils with high initial porosity,

(ii) High biological activity of soil fauna e.g. earthworms,

(iii) Friable consistency over a wide range of soil-water contents.

In addition, no-till is naturally suited for those problem soils that are highly susceptible to erosion. With an adequate quantity of crop residue mulch, no-till is an effective measure in reducing soil erosion. The most important consideration is the development of agronomic packages that ensure adequate quantity of crop residue mulch. Some viable systems to procure residue mulch for no-till farming are:

(i) Crop residue mulch:

The use of previous crop residue as mulch is a viable alternative for those rotations and cropping systems where at least one crop produces enough biomass. The use of a grain cereal e.g. maize in rotation with cowpea or'soybean is a workable system for soils where maize can be grown.

(ii) Cover crops and integration with livestock:

A quick growing crop, preferably a legume, is grown to restore soil and to produce mulch in situ. Grain crops are seeded through the chemically or mechanically suppressed mulch without plowing. The practice of growing a food crop through the unsuppressed cover, called live mulch, is feasible only if the latter does not compete for moisture and nutrients and does not smother the grain crop. The desirable characteristics of an appropriate cover crop are (i) ease of establishment, (ii) vigorous growth and rapid establishment of surface cover, (iii) deep rooted, (iv) determinate growth that naturally dies during the dry season, (v) no interference with the crop grown in the following season, and (vi) some economic returns. Ley farming, whereever feasible, is the obvious answer.

(iii) Mixed cropping and integration with woody perennials:

Growing perennial shrubs in associations with food crops and growing more than one crop in the same field simultaneously are also effective conservation measures and preduce the required mulch material. Cropping systems with multicanopy structure and those that provide continuous vegetative cover throughout the year protect the soil against raindrop impact. The cropping systems involving alley cropping, strip cropping, and alternate strips of woody perennilas and annuals, and of mixed cropping are important components of no-till farming.

CROP RESPONSE TO NO-TILL FARMING

Different crops respond differently to the no-till system depending on differences in initial soil conditions, quantity and quality of crop residue mulch, effective rooting depth, and prevalent micro- and meso-climate. On high-fertility Alfisols crop yield with the no-till system is often equivalent or better than in the plow-based system if there is adequate amount of residue mulch, weeds are effectively controlled, and seedling establishment is satisfactory. Grain yields are often high in favor of no-till for soils of low available water holding capacity. Fertilizer response of maize and other cereals is often different than that of the plowed system because of the microbial immobilization, and due to differential losses by leaching and in water runoff. Grain legumes e.g. cowpea and soybean grown on ridges and plowed seedbed suffer more from drought stress and high soil temperature than those grown in an untilled seedbed. Soybean emergence is particularly sensitive to fluctuations in soil temperature and moisture regimes. In contrast to grain crops, root tubers require large "root room" for adequate development. Similar to soybean, however, yam seedlings are very sensitive to high soil temperatures. Crop residue mulch is, therefore, equally beneficial for root crops as well.

Because Ultisols have lower chemical fertility than Alfisols and are acidic, the choice of crops to be grown is an important aspect that affects yield response to no-till farming. For example, regardless of the tillage methods maize does not grow well on unlimed Ultisol. The no-till system on acidic Ultisols and Oxisols is, therefore, better suited to those crops that are relatively tolerant to low soil pH e.g. upland rice, cowpea and tropical root crops. Similar to Alfisols, however, crop response to no-till on Ultisols is also influenced by mulching. Mulching alters physical, nutritional and biological environments and enhances crop growth and yields.

Oxisols are similar to Ultisols in chemical and physical soil properties. Oxisols of the Amazon Basin and those in central Brazil are susceptible to accelerated soil erosion, and have low plant available water reserves. Experiments conducted in Brazilian Oxisols have shown that no-till system results in significant improvements in soil structural properties and in crop yields. High yields of soybeans have been reported with no-till system on Brazilian Oxisols.

SOIL CHARACTERISTICS UNSUITABLE FOR NO-TILL SYSTEM

A no-till system is usually unsatisfactory if its requirements are not met. Soil surface conditions which cause negative response to no-till farming are:

(i) Soil compaction:

Seedling establishment and crop growth with the no-till system are often unsatisfactory in soil with compacted surface layer. Soil structure must be restored prior to adapting the no-till system.

(ii) Eroded and degraded lands:

Severely eroded and degraded soils due to prior mismanagement do not respond to no-till unless the physical, nutritional, and soil biological properties are restored.

(iii) Micro-relief:

An uneven ground surface is an obstacle in uniform crop establishment with motorized farm operations. Lack of seed-soil contact caused by smearing of a clayey soil also results in poor crop stand.

(iv) Residue mulch:

Both too much and too little crop residue mulch are problems in no-till system. Seed-soil contact is often poor and inadequate in soils with too much residue especially if the residue is moist. Pest and rodent problems are also more severe on an untilled and mulched soil than in plowed and clean seedbed.

(v) Perennial and rhizomatous weeds:

Some rhizomatous (e.g. Imperata and Talinum) and other perennial weeds are difficult to control with contact herbicides. Inadequate weed control can severely reduce crop yields with the no-till system.

Successful adaptation of the no-till system under the conditions listed above require alleviation of these constraints. Practicing no-till farming is based on the use of herbicides. The herbicides are often not available, and the dynamics of herbicides and their by-products in tropical soils have not been extensively studied. Surface application of fertilizers, soil amendments, herbicides, and pesticides has implications for environmental pollution. Regrettably there is little information about the fate and pathways of these chemicals. Use of Furadan insecticides in no-till plots nay result in elimination of soil macro-fauna e.g. earthworms. A biologically inactive soil is easily degraded in harsh environments of the tropics.

NO-TILL FARMING ON GRAVELLY SOILS

A common feature of many soils in the tropics, especially those derived from Basement Complex rocks, is the existence of subsurface gravel layer. These layers can inhibit root growth of annuals depending on the size and concentraction of gravels and on the texture and packing of the intergravel material. For utilization of water and nutrients present in the layers beneath, it is imperative to increase the proportion of root-sized pores in the gravel layer. An increase in macroporosity of the compacted gravelly horizon may be brought about through mechanical or biological means. Experiments conducted at IITA have shown some beneficial effects of sub-soiling by chisel or paraplow without soil inversion. Because loosening by paraplow is beneficial temporarily, this high energy treatment is frequently required to promote deep root penetration. Vertical mulching has also been tried to preserve the macroporosity created by mechanical loosening. The second alternative is to utilise the greater root penetration ability of tap-rooted perennials. Macroporosity of compacted subsoil layers can be increased by growing deep-rooted shrubs and woody perennials. The following shallow-rooted maize or soybean can use the bio-channels thus created to avail soil water and nutrient reserves in the layers beneath provided that soil is not disturbed. The continuity and stability of biochannels is ascertained through a no-till system. Biological methods of facilitating root extension such as appropriate cropping sequences, crop combinations and no-till farming are promising alternatives for management of soils with stone-lines.

NO-TILL FARMING ON ACID SOILS

In addition to unfavorable soil physical conditions root growth and proliferation in acidic subsoils is restricted due to A1 and/or Mn toxicity and deficiency of some essential nutrients. Addition of lime to replace A1 and Mn by Ca and Mg is one approach to overcome the problem if lime is locally available at economic rates. Surface application of lime as is done with a no-till system is less efficient than when incorporated by plowing. The need for incorporation of lime must be weighed against the erosion and compaction hazard on plowed land.

Experiments conducted in tropical America on management of acid soils have demonstrated the benefits of using large amounts of organic matter and crop residue. Procuring mulch in situ by growing an appropriate cover crop is a practical method of obtaining the desired quantity of residue mulch. Growing crops through the mulch by no-till system is an obvious choice especially if it can be combined with the species and varieties of crops which are tolerant to low pH.

UTILIZATION OF WETLANDS WITH A NO-TILL SYSTEM

Constraints to intensive utilization of wetlands for food crop production include trafficability and water control. Experiments conducted at IITA and elsewhere have shown the benefits of no-till farming for growing rice on wetlands during the rainy season and upland crops e.g. cowpea during the dry season.

CONCLUSIONS

Fragile ecosystems and easily degraded soils of the humid tropics can be used for intensive food crop production with mulch farming and no-till systems. No-till farming, however, is a system of soil and crop management that must fit into the overall framework of the soil's constraints and its potential and the socioeconomic conditions. Agronomic and cultural practices to seed through crop residue mulch without plowing are different than those needed in plow-based systems. The success of no-till system, therefore, depends on the availability of these agronomic packages for major soils, ecologies and crops to be grown. Since productivity of soils of the tropics declines rapidly with erosion and other ecological constraints, it is important to develop packages of agronomic practices that will facilitate adaptation of no-till farming techniques. Some of the researchable items that will facilitate rapid adaptation of no-till farming are:

(i) Integrated weed control methods need to be developed for plowless agriculture in the tropics. It is important to develop alternate weed control strategies especially for the regions where herbicides are not available.

(ii) Cropping systems should be designed to meet crop residue requirement for no-till system. There should be enough residue available to meet needs for alternate uses and for mulch. Cover crops and woody perennials are important components of appropriate cropping systems for no-till farming. Integration of livestock with crops and the use of animal traction are research priorities for addressing the problems of small-holders of the tropics.

(iii) Restoration of eroded and degraded lands is necessary prior to implementation of a no-till system.

(iv) Environmental protection in relation to the use of herbicides and other chemicals should be given a high priority. There is little research information regarding the fate of these chemicals in tropical environments. Research should be conducted to assess the movement of these chemicals in surface runoff, with eroded soil, and in percolation water.

These research needs emphasize the importance of a team approach involving a coordinated effort by soil and plant scientists, biologists, engineers and social scientists.