BENEFITS AND CONSTRAINTS OF CONSERVATION AGRICULTURE IN MARGINAL RAINFALL AREAS

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Introduction

Conservation agriculture leads to sustainable soil resources and is based on the principles of avoiding mechanical soil disturbance, maintaining a permanent soil cover, and crop rotation. Conservation agriculture is practiced on 45 million ha, mostly in South and North America. This accounts for only about 3 percent of the 15 billion ha of arable land worldwide. Conservation agriculture is practiced from the humid tropics to almost the Arctic Circle and on all kinds of soils (FAO, 2002). FAO stated "So far the only area where the concept has not been successfully adapted is the arid areas with extreme water shortage and low production of organic matter. In these areas both humans and animals compete with the soil for crop residues."

Stewart et al. (1991) presented a conceptual model that also showed the sustainability of a soil resource base becomes increasingly difficult with increasing temperatures and decreasing precipitation. The basis for their concept is that when grassland or forestland is converted to cropland there are soil degradation processes immediately set into motion. These can include wind and water erosion, soil organic matter loss, compaction and others. These degradation processes occur to some degree in all climates and all soils. The soil resource base cannot be sustained over the long term unless soil conservation practices are implemented to offset the degradation processes. The relation of soil quality to soil degradation processes and soil conservation practices is presented in Figure 1. Stewart et al. (1991) proposed in their conceptual model that the soil resource base of cropland can be sustained in all climates, but that it becomes more difficult with increasing temperature or decreasing precipitation, and exceedingly more difficult in areas of both high temperature and low precipitation (Figure 2). The reason is that many of the soil degradation processes shown in Figure 1 occur more rapidly in hot, dry regions and the soil conservation practices needed to offset these losses become more difficult or impossible to carry out in hot, dry locales. For example, soil organic matter is inherently low in soils located in hot, dry areas and when these soils are cultivated, soil organic matter can decline rapidly leading to wind and water erosion and reduced water holding capacities. Replenishing soil organic matter in these regions is exceedingly difficult because the low precipitation limits biomass production and high temperatures accelerate decomposition rates. Loss of soil organic matter in dryland regions makes these regions even drier because it reduces the infiltration of precipitation and reduces the amount of plant available water that the soil can hold.

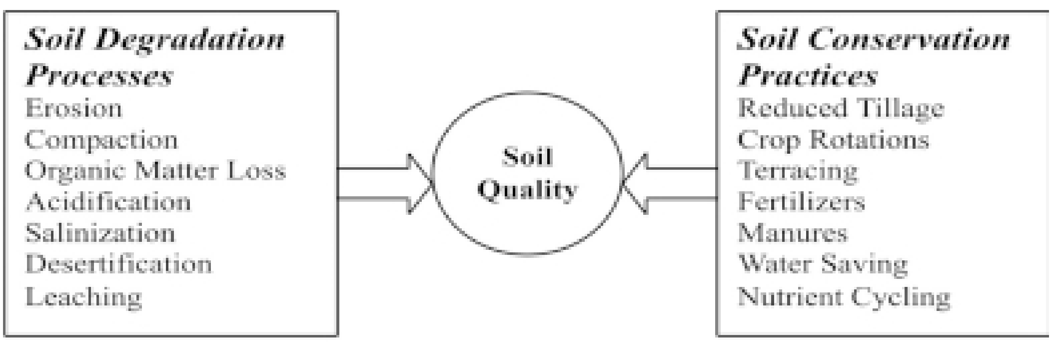

Figure 1. Relation of soil quality to soil degradation processes and soil conservation practices.

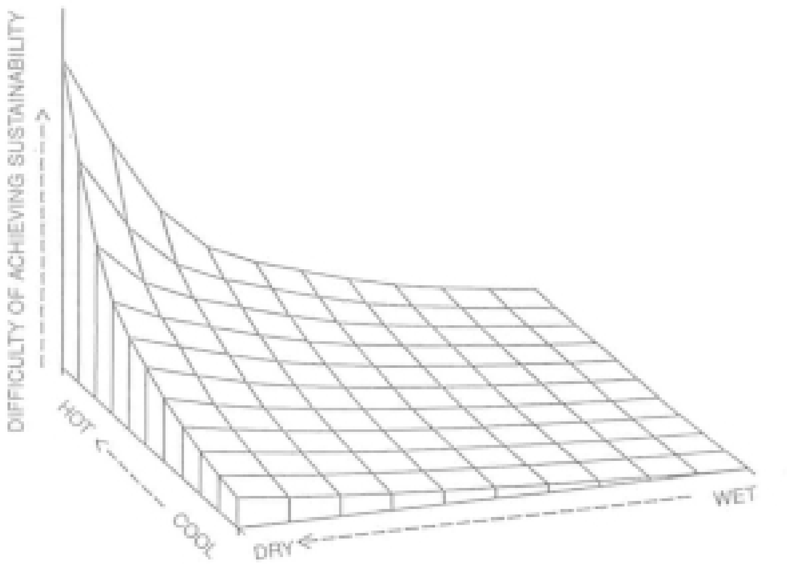

Figure 2. Generalized representation of the difficulty of developing sustainable agroecosystems in regions of increasing temperature and decreasing precipitation (from Stewart et al., 1991).

Conservation Agriculture in Dryland Areas

Although there are serious constraints to applying conservation agriculture principles in dryland regions, they should be applied to the fullest extent feasible because there are significant benefits. In the semiarid Great Plains of the United States, reduced tillage and no-tillage are becoming more and more common. Stubble-mulch tillage was introduced ias a means of controlling wind erosion that was devastating much of the area during the infamous "Dust Bowl" of the 1930s that was one of the greatest ecological disasters ever caused by the activities of man. Stubble-mulch tillage involves the use of v-shaped sweeps pulled about 10 cm below the soil surface to cut the roots of undesired vegetation. The soil is not inverted and approximately 80 percent of the crop residues remain on the surface. The crop residues remaining on the soil surface greatly reduce wind erosion and even after three or four cultivations, enough crop residues often remain on the surface to control wind erosion. Although stubble mulch tillage was initiated to control wind erosion, it was soon observed and later researched that the surface residues were also having a significant effect on soil water storage. It was later found that no-tillage resulted in even greater gains in both erosion control and water conservation. The greatest benefits in the U.S. Great Plains have resulted from using residues from wheat as mulch on the soil surface. Wheat residue is much more effective as a mulch than residues from sorghum, maize, or cotton because of the greater surface area. The use of mulch is in most cases the most effective way to minimize evaporation of soil water. There are two reasons. The first is the mulch breaks the capillary movement of water to the surface where it is evaporated. The second is that maintaining mulch on the surface minimizes tillage that dries the soil. In dryland regions, soil quickly dries to the depth of tillage. The water that is lost from below the permanent wilting percentage must then be replenished before plants can utilize any of the water from subsequent precipitation. Thus, the more often and deeper that tillage is imposed in the cropping system, the less the amount of the limited precipitation that will be available for growing crops.

An example of benefits that can accrue from improved water management practices is shown in Figure 3. These data are farmer yields of wheat grown in Deaf Smith County, Texas where the average precipitation is about 450 mm and the annual potential evapotranspiration is about 1800 mm. Therefore, drought is a common occurrence and severe water stress occurs every year. The yearly precipitation amounts show a range from less than 200 mm to more than 800 mm. A 10-yr moving average (each yearly point is the average precipitation amount for the year shown plus the nine previous years) line of annual precipitation is also shown and although there is some variation, the average annual amount has remained relatively stable. The county average wheat yields for each year are also shown along with a line showing the 10-yr moving averages. It is noteworthy that the moving yield average and moving precipitation average closely paralleled each other until the early 1970s. Since that time, the moving average grain yield increased essentially every year and the average yield has more than doubled. No single factor is responsible but it clearly shows that the use efficiency of the precipitation has dramatically increased. Water management is the first factor that must be addressed in dryland regions because other technologies such as improved cultivars and fertilizers are usually not beneficial without improved water management. The early 1970s were when the cost of oil and other energy sources increased rapidly and there was a concerted effort by researchers and extension personnel to promote less tillage and more herbicide usage. This increased the amounts of crop residues remaining on the soil surface resulting in more soil water storage during fallow periods.

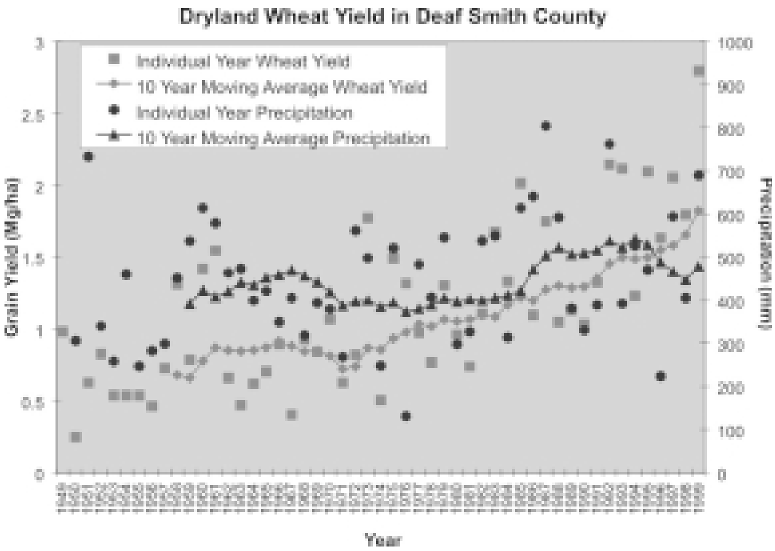

Figure 3. Relationship of annual precipitation and wheat yields showing improved water use efficiency (unpublished data, Zhen Wu, A.W. Colette and B.A. Stewart, West Texas A&M University).

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