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Potential Effect of Conservation Tillage on Sustainable Land Use: A Review of Global Long-Term Studies*[1]

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ABSTRACT

Although understood differently in different parts of the world, conservation tillage usually includes leaving crop residues on the soil surface to reduce tillage. Through a global review of long-term conservation tillage research, this paper discusses the long-term effect of conservation tillage on sustainable land use, nutrient availability and crop yield response. Research has shown several potential benefits associated with conservation tillage, such as potential carbon sequestration, nutrient availability, and yield response. This research would provide a better perspective of the role of soil conservation tillage and hold promise in promoting application of practical technologies for dryland farming systems in China.

Key Words: conservation tillage, no-till, reduced tillage, residue management

INTRODUCTION

Conservation tillage generally refers to "methods of tillage that maintain a cover of crop residues on the soil surface and either reduce the amount of tilling (reduced tillage or minimal tillage) or eliminate it altogether (no-till)" (Acton and Gregorich, 1995). However, due to regional, technical, economical and institutional differences, the term "conservation tillage" is understood differently in various parts of the world. The US Conservation Technology Information Center developed the first widely accepted definition of conservation tillage as "any tillage and planting system that covers at least 30 percent of the soil surface with crop residue, after planting, in order to reduce soil erosion by water" (CTIC, 1999). Mannering and Fenster (1983) suggested that "a common characteristic of any conservation tillage is its potential to reduce soil and water loss relative to conventional tillage". Conservation agriculture in Europe refers to "several practices, which permit the management of the soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from degradation processes (such as soil erosion and compaction) and generally it includes any practice, which reduces, changes or eliminates soil tillage and avoids residue burning to maintain enough surface residue throughout the year" (ECAF, 1999).

Thus, conservation tillage may be interpreted as "any system that promotes good crop yields while at the same time maintaining soil fertility, minimizing soil and nutrient loss, and saving energy/fuel inputs". For example, in Scandinavia conservation tillage normally involves some form of reduced tillage, which covers alternatives ranging from systems that include thorough stubble cultivation in autumn followed

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by harrowing in spring to direct drilling systems with no cultivation at all prior to sowing (Riley *et al.*, 1994). Concerning the different climate conditions, soil types and cropping systems, conservation tillage does not necessarily mean less tillage; rather it needs to be suited to local agroecosystems in both space and time (Carter, 1994), where it serves to reduce soil and water loss as well as conserve natural resources relative to conventional tillage. A broad definition of conservation tillage given by Wittmus *et al.* (1973), namely "conservation tillage includes tillage systems that create as good an environment as possible for the growing crop and that optimize the conservation of soil and water resources, consistent with sound economic practices," seems to be well recognized and accepted.

This research, then, is aimed at gaining an improved understanding of the long-term impacts of conservation tillage practices on sustainable land use, nutrient availability and yield response through a global review of long-term conservation tillage research. This would provide a better perception of the role of soil conservation tillage and may promote application of practical technologies for dryland farming systems in China.

BACKGROUND AND BENEFITS OF CONSERVATION TILLAGE

Recent conferences (Tullberg and Hoogmoed, 2003; Wang and Gao, 2004) have illustrated large interest in conservation tillage. Yet, long-term research on conservation tillage has been carried out for at least 30 years, especially in the semiarid and semi-humid regions with dryland farming, where it was concerned with crop production without supplemental irrigation. Several benefits from conservation tillage systems have been reported: 1) economical benefits (such as labor, energy, machinery cost, and time saved) (Uri *et al.*, 1998; Uri, 2000; Stonehouse, 1997), 2) positive effects from erosion protection and soil and water conservation, and 3) increases in soil organic matter.

On the other hand, due to different weather and soil conditions, research has also reported low nutrient availability and inconsistent yield response with conservation tillage. For example, research in the United States for areas with low annual rainfall and on soils with low water holding capacity, such as light, well-drained silty loam soils, has suggested that the positive aspects of conservation tillage outweigh the negative aspects. On land with drought stress and serious erosion problems, the added water should increase yield potential in more southern latitudes. Meanwhile moldboard plowing or chiseling often has the highest rating on dark, poorly drained silty clay loams in northern latitudes, where the extra water may delay planting and reduce yield potential; and the lower temperature early in the growing season with surface residue systems could delay growth in the northern United States (Griffith *et al.*, 1986).

A review from Riley *et al.* (1994) indicated that in Norway, some adverse effects of straw residues were found on poorly drained soils, and poor results were found after early sowing on silt soil with reduced tillage, probably due to waterlogging at germination. Better results were often observed in dry years than in wet years. Plowless tillage has been most successful in silty clay soils in Sweden. Long-term trials in Norway have had no negative trend in yields over a period of 15 years. Long-term research also documented several potential benefits associated with conservation tillage, such as potential carbon sequestration (Uri *et al.*, 1998), potential nutrient availability (Rasmussen, 1999), and potential yield response (Guérif *et al.*, 2001) from sustainable land use.

The introduction of mechanized plowing and other farming operations to meet the increase in food demand dates back to the early part of the twentieth century (Lal, 2001). During the 1950s the focus of soil tillage was on plowing, mechanization, and power requirements. The development of mechanized farming technology resulted in great increases in yields per unit of land and labor. This made it possible to expand production concurrent with the increase in food demand for an increasing global population. However, excessive plowing brought about undesirable effects, *e.g.*, drastic soil disturbance exacerbated risks of wind and water soil erosion, and soil compaction that led to the development of hard pans and poor soil tilth. In addition, the combination of inversive soil tilling and more intensive cropping methods increased the rate of soil degradation, *e.g.*, deterioration of soil structure, accelerated erosion,