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Crop Residue Management in the United States

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Zusammenfassung

Management von Pflanzenreststoffen in den USA

In den USA hat seit Jahrzehnten das Management von Pflanzenreststoffen (MPR) zu effektiver Erosionskontrolle geführt. Zunächst war die Akzeptanz seitens der Landwirte gering, weil sie nur unwillig von intensiven Bodenbearbeitungssytsemen abgingen, die ihnen vertraut waren, und Kenntnisse dahingehend fehlten, dass Bodenerosion auf lange Sicht die Bodenfruchtbarkeit beeinflusst. Mitte der 80er Jahre jedoch begannen die Landwirte den Übergang von intensiver Bodenbearbeitung zu dem Management von Pflanzenreststoffen. Die Triebfeder dazu war mehr ökonomischer Art als die Minderung von Erosion. Mit der Einführung von MPR nahmen Arbeitsaufwand und Kraftstoffverbrauch ab. Die Landwirte konnten entweder die bewirtschaftete Fläche vergrößern oder andere Einkommensmöglichkeiten nutzen.

Die Vorteile von MPR schließen reduzierten Bodenabtrag, sauberen Oberflächenabfluss, verbesserten Bodenwasserhaushalt und Infiltration, steigende Bodenfruchtbarkeit und geringere Freisetzung von Kohlendioxyd und Luftverschmutzung ein.

Die Bereitschaft der Landwirte, Pflanzenreststoffe auf der Bodenoberfläche zu belassen, hat sich mit der Entwicklung effektiver Herbizide und Bestelltechniken, welche die Handhabung hoher Reststoffmengen ermöglichen, verbessert. Regierungsprogramme haben die Übernahme von PRM auch durch finanzielle Unterstützung erheblich gefördert. Andererseits wurden PRM-Systeme weniger als erwünscht, nämlich auf nur 37 % des Ackerlandes übernommen.

Die Gründe dafür sind verschieden. Auf bestimmten Standorten und unter gewissen klimatischen Bedingungen hat MPR keinen dauerhaften ökonomischen Nutzen gezeigt. Weitere limitierende Faktoren sind das zusätzlich erforderliche Management sowie die nötigen Investitionen in neue Technik, ökonomische Risiken und negative Einstellung zu neuen Praktiken.

Schlüsselwörter: Management für Pflanzenreststoffe, Erosionskontrolle, Bodenbearbeitungssysteme, Bodenfruchtbarkeit

Abstract

Crop residue management in the United States has been advocated for several decades as an effective means of soil erosion control. Acceptance by farmers was initially slow because farmers where reluctant to change from intensive tillage systems that had served then well and the lack of understanding that soil erosion was effecting long-term crop productivity. However, in the mid-80's farmers began the transition from intensive tillage to Crop Residue Management (CRM) systems.

The driving point was more associated with economics rather than soil erosion. With the use of CRM, labor requirements and fuel costs per land area where reduced. Farmers could either expand the total farm operation or explore other income opportunities. Benefits of CRM included reduced soil erosion, cleaner surface runoff, improved soil moisture and water infiltration, improved long-term productivity, and reduced release of carbon dioxide and air pollution.

Farmer's willingness to leave residue on the soil surface has been greatly enhanced by the development of effective herbicides and planting or seeding equipment that is capable of handling high levels of surface residue. Government programs have strongly advocated the conversion to CRM through the eligibility of farm support programs and assistance through cost sharing in developing conservation plans. Crop Residue Management systems have only been adopted on 37 percent of U.S. cropland, a figure lower than desired.

Reasons for non-adoption are varied. Some specific soils and in certain climate and/or cropping situations, CRM has not been demonstrated to consistently produce good economic returns. Further limiting factors include the need for additional management skills and capital investments in new equipment, economic risks involved with changing systems, and negative attitudes and perceptions against new practices.

Keywords: Crop residue management, erosion control, tillage systems, long-term productivity

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1 Introduction

Soil erosion by wind and water degrades our soil's crop production sustainability. Besides the outright removal of materials from fertile topsoil, large windstorms or rainstorms selectively remove material high in organic matter and nutrients. This results in surface soils depleted of plant-available nutrient with high bulk density that are low in porosity and capacity for water intake.

Any tillage and planting system that leaves all or some portion the previous crop's residue on the soil surface is described as crop residue management by the Nature Resource Conservation service (NRCS), previously known as the Soil Conservation Service (SCS) and the Conservation Technology Information Center (CTIC), West Lafayette, IN. Surface residue has been shown to greatly reduce soil erosion (Fig. 1, Laflen et al., 1985).

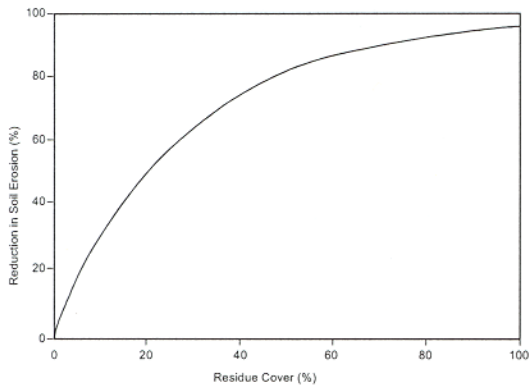

Figure 1
Predicted effect of residue cover on soil erosion (Source: Laflen et al., 1985)

As residue cover approaches 100 percent, soil erosion approaches 0 percent; with 50 percent coverage, erosion reduction is about 80 percent; when residue cover is only 10 percent, erosion reduction is still about 30 percent compared to clean tillage.

A farmer's willingness to leave residue on the soil surface has been greatly enhanced by the development of herbicides, which provided an alternative to tillage for controlling weeds. Efforts of equipment companies and innovative farmers in developing equipment that leave more residue on the surface, but have the ability to effectively plant into the residue covered surface have facilitated the availability and use of crop residue management.

Crop residue management and in particular no-till management has allowed many farmers to develop diverse crop rotational systems and in some cases to move away from the traditional fallow management used in drier climates.

Over the years, many definitions for crop residue management and tillage systems have been used, and these definitions have changed over time. The following definitions have been proposed and generally accepted for use by the Conservation Technology Information Center (Table 1, CTIC, 1996).

2 Crop Residue Management (CRM)

CRM is a year-round conservation system that usually involves a reduction in the number of passes over the field with tillage implements and/or in the intensity of tillage operations, including the elimination of plowing (inversion of the surface layer of soil). CRM begins with the selection of crops that produce sufficient quantities of residue to reduce wind and water erosion and may include the use of cover crops after low residue producing crops.

CRM includes all field operations that affect residue amounts, orientation, and distribution throughout the period requiring protection. Site specific residue cover amounts needed are usually expressed in percentage but may also be expressed as weights. Tillage systems included under CRM are conservation tillage (no-till, ridge-till, and mulch-till), and reduced tillage.

Table 1
Crop residue management and tillage definitions (CTIC, 1996)

Little or no management or residue	**Crop Residue Management (CRM)**			
Conventional Tillage	**Reduced Tillage**	**Conservation Tillage**		
		Mulch-Till	*Ridge-Till*	*No-Till*
Moldboard plow or intensive tillage used	No use of mouldboard plow and intensity of tillage reduced	Further decrease in tillage (see below)	Only ridges are tilled (see below)	No tillage performed (see below)
<15 % residue cover remaining	15-30 % residue cover remaining	30% or greater residue cover remaining		

3 Conservation Tillage

Any tillage and planting system that maintains at least 30 percent of the soil surface covered by residue after planting to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 450 kilograms per hectare flat, small grain residue equivalent on the surface throughout the critical wind erosion period. Two key factors influencing crop residues are 1) the type of crop, which establishes the initial residue amount and its fragility, and 2) the type of tillage operations prior to and including planting. Conservation tillage systems include:

2.1 No-till

The soil is left undisturbed from harvest to planting except for nutrient injection. Planting or drilling is accomplished in a narrow seedbed or slot created by coulters, row cleaners, disk openers, in-row chisels, or roto-tillers. Weed control is accomplished primarily with herbicides. Cultivation may be used for emergency weed control.

2.2 Ridge-till

The soil is left undisturbed from harvest to planting except for nutrient injection. Planting is completed in a seedbed prepared on ridges with sweeps, disk openers, coulters, or row cleaners. Residue is left on the soil surface between ridges. Weed control is accomplished with herbicides and/or cultivation. Ridges are rebuilt during cultivation.

2.3 Mulch-till

The soil is disturbed prior to planting. Tillage tools such as chisels, field cultivators, disks, sweeps, or blades are used. Weed control is accomplished with herbicides and/or cultivation.

3 Reduced Tillage (15-30 % Residue)

Tillage systems that leave 15-30 percent residue cover after planting, or 225-450 kilograms per hectare of small grain equivalent throughout the critical wind erosion period. Weed control is accomplished with herbicides and/or cultivation.

4 Intensive or Conventional Tillage (less than 15 % residue)

Tillage types that leaves less than 15 percent residue cover after planting, or less than 225 kilograms per hectare of small grain equivalent of small grain residue throughout the critical wind erosion period. Generally includes plowing with a moldboard plow and/or other intensive tillage. Weed control is accomplished with herbicides and/or cultivation.

Conservation tillage trends since 1968 are shown in Fig. 2 (CTIC, 2002; Schertz, 1988; Christensen, 1985). CTIC began a more comprehensive and consistent national survey of U.S. tillage practices in 1989. Trends from this survey are shown in Table 2 (CTIC, 2002). Conservation tillage has risen rapidly, since the 1960s. However, since 1994 total conservation tillage use has been relatively constant. Within conservation tillage, the use of no-till has continued to rise. Crop

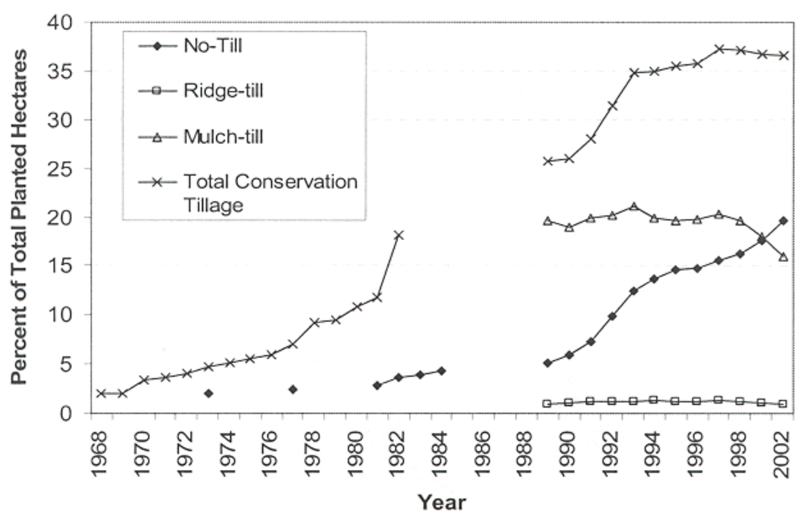

Figure 2
Conservation tillage trends in the U.S. 1968-2002

area planted with no-till has more than tripled from 6.8 to 22.4 million hectares from 1990 to 2002.

Table 2
Conservation tillage trends, 1990-2002 (Millions of Planted Cropland Hectares) (CTIC, 2002)

Tillage System	1990	1992	1994	1996	1998	2000	2002
No-Till*	6.8 (6.0 %)	11.4 (9.9 %)	15.8 (13.7 %)	17.4 (14.8) %	19.4 (16.3 %)	21.1 (17.6 %)	22.4 (19.6 %)
Ridge-Till*	1.2 (1.1 %)	1.4 (1.2 %)	1.5 (1.3 %)	1.4 (1.2 %)	1.4 (1.2 %)	1.3 (1.1 %)	1.1 (1.0 %)
Mulch-Till*	21.6 (19.0 %)	23.2 (20.2 %)	23.0 (20.0 %)	23.3 (19.8 %)	23.5 (19.7 %)	21.7 (18.0 %)	18.2 (16.0 %)
Conservation Tillage Subtotal	29.6 (26.1 %)	35.9 (31.4 %)	40.2 (35.0 %)	42.0 (35.8 %)	44.2 (37.2 %)	44.2 (36.7 %)	41.8 (36.6 %)
Reduced-Till (15-30 % cover)	28.8 (25.3)	29.7 (25.9 %)	29.6 (25.8 %)	30.3 (25.8 %)	31.6 (26.2 %)	24.8 (20.6 %)	26.0 (22.8 %)
Intensive-Till (<15 % cover)	55.4 (48.7 %)	48.8 (42.7 %)	45.1 (39.3 %)	45.2 (38.5 %)	43.0 (36.2 %)	51.5 (42.7 %)	46.3 (40.6 %)
All Planted Hectares	113.8	114.6	115.0	117.5	118.7	120.5	114.0

*No-till, ridge-till and mulch-till are considered forms of conservation tillage

In 2002, use of no-till exceeded use of mulch-till as the dominant conservation tillage practice for the first time. Some of the rise in no-till use occurred as farmers implemented conservation compliance plans in order to remain eligible for farm program benefits under government programs. Also, some of the expansion in no-till usage likely comes from farmers switching from mulch-till systems.

Corn (Zea mays L.) and soybeans (Glycine max L.) show the highest use of conservation tillage (Table 3, CTIC, 2002). Data from CTIC shows that over 56 percent of planted soybean and 36 percent of corn were conservation tilled. This contrasts with only 18 percent for cotton (Gossypium hirsutum L.). CTIC data also shows higher use of conservation tillage in double-crop fields with nearly 70 percent of double-crop soybeans conservation tilled. The greater use of conservation tillage in double-crop fields has been attributed to faster planting and conservation of moisture in the seedbed enhancing germination of the second crop (Sandretto and Bull, 1996).

Crop residue management (CRM) can improve environmental performance of crop production while maintaining economic viability. However, the benefits of CRM and economic performance are site specific. CRM maintains crop residue on the soil surface through fewer and/or less intensive tillage operations. Potential benefits of CRM include: reduced soil erosion, cleaner surface water runoff, higher soil moisture and water infiltration, improved long term productivity, and reduced release of carbon dioxide and air pollution (USDA-ERS, 2003).

Fewer and/or less intensive tillage operations can lead to direct economic savings in terms of reduced fuel and labor use and lower maintenance costs. Additionally, fewer tillage operations can lead to improved timeliness of operations, improving crop production.

However, the economic feasibility of CRM is determined by whether these benefits are offset by reductions in crop yield or increases in other production costs (e.g. pesticides, fertilizers, or equipment ownership costs).

Table 3
Tillage management by major crops in the United States, 2002 (CTIC, 2002)

Crop	Total Planted Hectares	Conservation Tillage			Conservation Tillage Total	Other Tillage Practices	
		No-Till	Ridge-Till	Mulch-Till		Reduced-Till (15-30 %) Residue	Conventional-Till (0-15 %) Residue
Corn	31.8	6.1	0.5	4.9	11.5	7.7	12.6
Small Grain	30.7	3.6	<0.1	5.2	8.8	8.4	13.5
Soybeans	30.2	10.5	0.2	6.2	17.0	6.1	7.1
Cotton	5.9	0.8	0.2	0.1	1.1	0.6	4.2
Grain Sorhum	3.9	0.6	0.1	0.6	1.2	9.3	1.8
Forage	2.8	0.4	N/A	0.3	0.7	0.6	1.5
Other	8.7	0.5	0.1	0.9	1.5	1.6	5.6
Total	114.0	22.4	1.1	18.2	41.7	26.0	46.3

Yield performance of CRM compared to conventional tillage systems are site-specific depending on soil characteristics, other cropping practices, and local climatic conditions. In general, crop yield have been shown to be poorer under CRM on poorly drained soils. Yields improve under CRM on better-drained soils, particularly with crop rotations, and tend to exceed conventional tillage yields on excessively drained coarse-textured soils (Daniel et al. 1986; Hudson and Bradley, 1995; Uri, 2000). In Northern states, cool-wet conditions under CRM can lead to delayed plantings, uneven emergence, and reduced yields. However, in more arid areas, CRM conserves moisture increasing crop yields, and reduces the need for fallow in traditional crop-fallow areas (Nielsen et al., 2002). Yields under CRM can also be lower in areas where the presence of a 'hardpan' necessitates the use of tillage to loosen the soil and allow proper root development (Raper et al., 1994).

Since one function of tillage is weed control, reduced tillage can lead to greater use of herbicides. In 1997, herbicides were at higher annual rates on corn, soybean, wheat and cotton, for CRM than for more intensive tillage (USDA-ERS, 2003). In addition, herbicides were applied more frequently on corn under CRM, and herbicides were applied to more hectares on wheat under CRM. However, tillage adoption studies have shown that tillage practice had no signifycant effect on amount of herbicides applied by soybean producers and that a higher probability of no-till use by corn producers actually reduced herbicide applications (Caswell et al., 2001; Fuglie, 1999). Decreased tillage intensity and increased surface residues could potentially lead to greater insect pressures with CRM and increase use of insecticides. In 1997, pesticide use was generally higher for CRM than for intensive tillage on corn and soybeans (USDA-ERS, 2003).

Adoption of CRM often necessitates the purchase of new machinery. In some cases, some of the old machinery would not be needed and could be sold to offset the cost of new equipment. However, in transitioning to new systems producers often keep their old equipment, sometimes because it may have limited salvage value, but often 'just in case the new system fails'. In 1993 and 1994 across much of the Midwest and in 1996 in much of Indiana, conservation tillage declined in the region due to adverse weather conditions and producers reverting to conventional tillage (Uri, 1999). As a result, even though CRM systems may require less equipment and lower equipment ownership costs in the long run, equipment ownership costs may increase during conversion from conventional tillage.

Even in situations where CRM is more profitable than conventional tillage, producers may not adopt CRM. This might be due to both real and perceived risks. Several studies have shown CRM to be more profitable but more risky than conventional tillage (Williams et al., 1989; Mikesell et al., 1988; Weersink et al., 1992). Kurkalova et al. (2001) showed even though conservation tillage provides a higher payoff than conventional tillage in Iowa, producers may require a premium to adopt conservation tillage. In addition to the price and yield risks of a well-managed CRM system are the risks inherent in learning how to manage a new system.

The 1985 Food Security Act gave farmers an additional incentive to adopt CRM on highly erodible land. Under the program, farmers who produced crops on highly erodible (HEL) land that failed to implement an approved conservation plan would forfeit eligibility for most United States Department of Agriculture (USDA) farm program benefits. CRM was the key component in conservation plans for around 75 % of the cultivated highly erodible land subject to compliance (USDA-ERS, 2003). These provisions have been continued in the 1990, 1996 and 2002 Farm Acts.

As a result of the requirements for producers to implement an approved conservation plan on HEL land, CRM use is higher on HEL land than on non-highly erodible land. The 1996 Farm Act established the Environmental Quality Incentives Program (E-QIP), which was authorized to provide incentive payment to producers to adopt conservation practices including CRM. Funding for EQIP was significantly increased in the 2002 Farm Act.

The Conservation Reserve Program (CRP) was part of the 1985 Food Security Act. Under the program USDA paid participants an annual rent for 10 years, plus half the cost of establishing a conserving land cover, usually a grass-legume mix. To be eligible one had to have land that was potentially highly erodible, actually eroding at an excessive level, or environmentally sensitive. By 1993, 14.7 million hectares of highly erodible and environmentally sensitive land were enrolled in CRP.

Establishment of CRP presented an opportunity to improve soil properties related to water infiltration and percolation through increased in surface organic matter content, increased aggregation and stability, and development of a continuous network of macropores that extended to the soil surface. As the CRP contracts began to expire, several research projects were conducted to determine the best management strategies when converting back to cultivation.

Results from these studies indicated that no-till was the best management options to retain the benefits from CRP. Intensive tillage resulted in the soil degrading to prior CRP conditions in one year's time with essentially no benefits retained from the 10 years of CRP.

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