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The Economic and Environmental Revolution in Semi-arid Cropping in North America

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Abstract: semi-arid annual cropping has traditionally been identified with highly variable yields and returns and soil degradation due to wind erosion. Cropping systems in the semi-arid regions of North America have changed to make more efficient use of limited precipitation. American and Canadian farmers in the western plains have sharply reduced summer fallow, the practice of idling land for a growing season, and increased use of no-tillage farming. These two production systems are complementary because no-till conserves soil moisture allowing more frequent cropping (less fallow), and less fallow with diverse rotations increases the relative profitability of no-till. Less summer fallow and increased no-till provide potentially revolutionary environmental and economic benefits in the American and Canadian plains. Research efforts and policies would be wise to reinforce these trends.

Keywords: North American agriculture, semi-arid, economic, cropping systems, no-till, summer fallow.

The vast Great Plains of North America from the Rocky Mountains in the west to the Corn Belt in the east supply a substantial portion of the world's small grains and oil seeds. This region also conjures up images of human suffering and resource degradation from the devastating 1930s Dust Bowl when most cultivated soils in the plains were severely eroded by wind. However, the last three decades have witnessed a largely unheralded revolution in farming methods which have the potential for improving soil and air quality in the American plains and Canadian prairies. A key barometer of this revolution has been a sharp reduction in summer fallow, a practice in which fields are periodically tilled or sprayed with a non-selective herbicide, but not cropped. Reduced tillage and alternative annual spring crops including pulse crops and canola (*Brassica rapa* L. and *B. napus* L.) have been critical allies in this revolution.

Annual cropping in semi-arid and arid regions provides an economic challenge for producers. Low and variable precipitation leads to low and variable crop yields and farm income. Production systems must be geared to managing scarce moisture efficiently. For over a hundred years, Canadian and American plains farmers have used summer fallow as a key moisture and

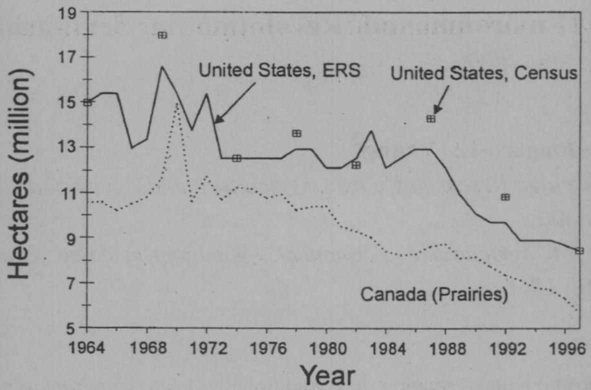

Fig. 1. Yearly and census year summer fallow area in the United States and Canada, 1964-1997.

risk management tool. Summer fallow conserves soil moisture, provides economical weed and disease control, increases available nitrogen, and smooths labour and machinery requirements throughout the year. These features stabilize crop yields and income over time. Our objective is to examine the underlying economic and technological factors which may explain, at least in part, the decline of summer fallow and the growth of new soil conserving annual cropping systems in semi-arid North America. Specific emphasis will be placed on world markets, national policies, risk management, and new technology supporting crop rotation changes and tillage reductions.

Summer Fallow Trends and Environmental Benefits

The western portion of the American Great Plains is semi-arid. This region encompasses western Texas, Oklahoma, Kansas, Nebraska, North Dakota, South Dakota, and eastern New Mexico, Colorado, Wyoming, and Montana. The Canadian semi-arid prairies include south-eastern Alberta and south-western Saskatchewan. While the Pacific states of California, Oregon and Washington contain substantial semi-arid farmlands, primarily leeward of mountain ranges, these regions fall outside the Great Plains. Most of the studies cited below are from the Great Plains, but similar conditions and principles apply to semi-arid zones of the Pacific states.

As illustrated in Fig. 1, between the 1964 and 1997 agricultural census years, US farmers reduced summer fallow by 43%, or 6.5 million ha. (The next two sections draw on a recent popular article by the authors (Smith and Young, 2000a)). USDA-ERS (1997) data, also plotted in Figure 1, show similar declines, with minor variations. Summer fallow fell from a peak of 17% of cropland in the western US in 1969 to 8% in 1997. Farmers in the three Canadian prairie provinces (Alberta, Saskatchewan, and Manitoba) cut summer fallow by 46%, or by 4.9 million ha, from 1964 to 1997. In Canada, summer fallow declined from 40% of cropland used for crops in 1969 to 19% in 1997. Figure 2

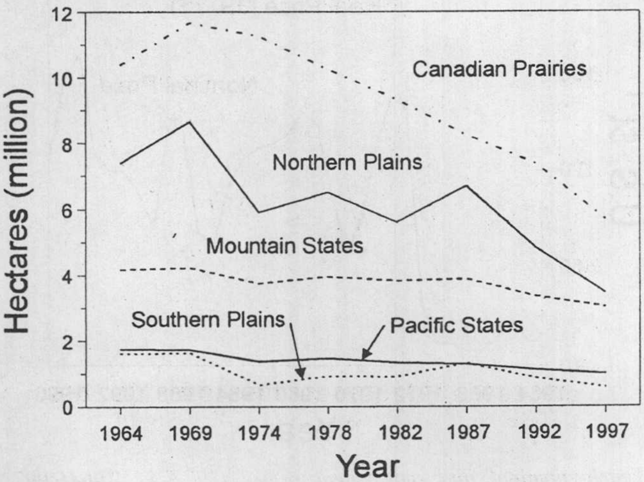

Fig. 2. Census year summer fallow area by North American region, 1964-1997.

shows that the decline in summer fallow area, with some regional variation, has occurred throughout the Canadian prairies, the US northern plains, and mountain states. Summer fallow areas in the US southern plains and Pacific states are smaller and have declined by lesser amounts.

Long term wind erosion degrades soil productivity and contributes to airborne particulates which harm human health, industrial and residential hygiene, and traffic safety. Improved cropping systems can sharply reduce wind erosion and improve air quality. Using conventional summer fallow as the base for dust emissions, Lee (1999) estimated that improved conservation tillage fallow would reduce dust emissions by 54% and continuous annual grain cropping would reduce dust emissions by an impressive 95%. The predictions by Lee (1999) are also consistent with measured differences in residue cover at a study site with average precipitation of 280 mm y^{-1}. Crop residue cover fell to 20% of surface area after minimum tillage fallow, but no-till continuous hard red spring wheat (*Triticum aestivum* L.) maintained 57 to 90% of surface covered with residue throughout the production period (Young *et al.*, 1999). Cultivated summer fallow also increases the breakdown of soil organic matter, increases atmospheric carbon, intensifies nitrate leaching, and decreases water-use efficiency. The long-term economic costs of soil erosion and soil degradation in semi-arid environments can be high (Smith *et al.*, 2000a; Williams *et al.*, 1993).

Markets and Policies

Are the declines in summer fallow in western North America a short-term response to transitory world grain prices and national agricultural policies? During 1964-72, US agricultural census (USDC) and US Department of Agriculture (USDA-ERS, 1997) statistics show summer

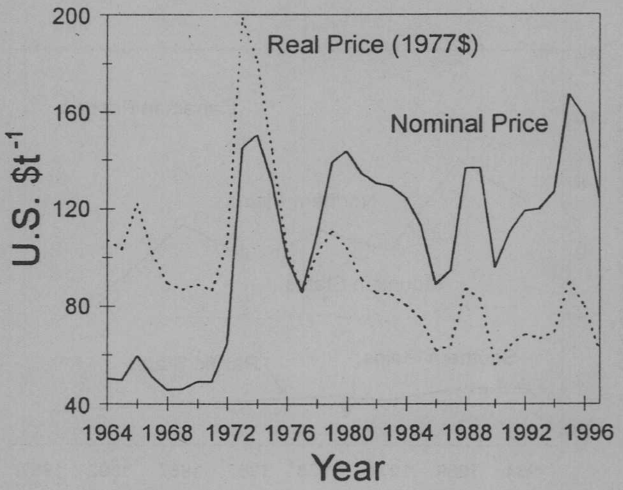

Fig. 3. Yearly nominal and real wheat prices (1977 $), 1964-1997.

fallow acreage fluctuated between 13 and 16.6 million ha (Fig. 1). This was an era of relatively low nominal wheat prices (Fig. 3) and large grain stocks. With low grain prices, a grain-fallow rotation was probably the optimal risk management strategy for many farmers in the Great Plains. US farm programs idled an additional 15 to 25.5 million ha y^{-1} during 1964-72, but these acreage reductions did not "crowd out" summer fallow (Figs. 1 and 4). Canadian provincial statistics showed farmers fallowed 10.5 to 11.7 million ha during 1964-80, except for 1970 when a program to reduce wheat stocks cut grain planting and increased summer fallow.

During 1973-74, following the depletion of wheat stocks by Russian purchases and by production shortfalls, nominal wheat prices rose to about US\$150 t^{-1}, an unprecedented spike in real grain prices (Fig. 3). US summer fallow plummeted from 15.4 to 12.6 million ha from 1972 to 1973, a likely response to the higher grain prices.

Nominal US wheat prices varied from \$85 to \$140 t^{-1} from 1976 to 1988, but national summer fallow area remained remarkably stable at 12.1 to 13 million ha, except for 13.8 million during 1983, the "Payment in Kind" program year. US summer fallow acreage changed little while area idled in farm programs rose from zero in 1980 and 1981 to nearly 31.5 million ha in 1983, 1987, and 1988 (Fig. 4). In contrast, summer fallow area started to decline during this period in the Canadian Prairies. The coupling of wheat and barley (*Hordeum vulgare* L.) subsidies to historical base areas in the US, but not Canada, may have discouraged US farmers from deviating from customary grain-fallow rotations in this period.

In sharp contrast to the previous decade, during 1989-97 summer fallow area in the US began a sharp decline (Fig. 1). Between the 1987 and 1997 census years, summer fallow fell from 14.3 to 8.5 million ha, or 41%. USDA-ERS (1997) reports a

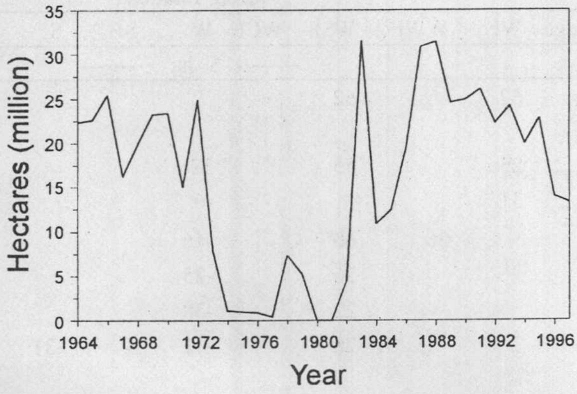

Fig. 4. Land idled yearly in the United States by government programs, 1964-1997.

reduction from 13 to 8.9 million ha from 1987 to 1995, or 31%. Figure 2 reveals that the continuing reduction in summer fallow during the 1990s occurred primarily in the northern plains of the US and the Canadian prairies. It is difficult to explain the large decrease in summer fallow during the 1990s based on market and policy forces alone. Contrary to most expectations, the recent decline in US summer fallow began during a period of traditional coupled grain subsidies and low real grain prices during 1990-92 (Figs. 1 and 3). The decline continued, as might be expected, during the higher real grain prices of 1995-97 and the decoupled US subsidies of 1996-97. Surprisingly, summer fallow declined persistently in the US as area idled by all farm programs declined from a peak of 31.5 million ha in 1988 to 13.3 million in 1997 (Fig. 4). The reduction in idled area included releases from the Conservation Reserve Program (CRP) which was heavily concentrated in the northern plains, the dominant location for US summer fallow. In partial explanation, the 1996 US farm bill, which eliminated wheat supply control based on historical plantings, plus the high grain prices of 1995-97, probably precluded some previous CRP and other idled land from returning to fallow.

While Canada did not have explicit wheat supply controls based on historical plantings before or after the 1990s, summer fallow area fell by about 30% during the decade. As discussed below, technological developments available to farmers on both sides of the border probably contributed strongly to the decline in summer fallow. The steady decline in fallow despite varying market price and policy trends suggest prices and policy were not dominant in determining the trend.

Crop Rotations

The traditional cropping system in the semi-arid portion of the North American plains has been a two-year rotation of wheat and summer fallow (Ford and Krall, 1979). There are many reasons farmers fallow, but one of the main reasons is to accumulate

Table 1. Economic returns for semiarid dryland crop rotations[1].

Author	Crop rotation[2]										
	Tillage	WF	WWF	WSF	WCF	W	SF	S	LW	PW	KW
					-------- $\$ ha^{-1}$ --------						
Schlegel *et al.*, 1999	RT	67		62							
	NT	25		55		32					
Smith *et al.*, 1994	CT	31				-6					
Wiese *et al.*, 1994	CT		30	60		-16					
	RT			26		-25					
	NT			22		-38					
Williams *et al.*, 1990	CT	2		28		-11	4	-31			
	NT	4		27		-5	-9	-25			
Zentner and Campbell, 1988	CT	16	17			-28					
Zentner *et al.*, 1984	CT	67	87			65					
Zentner *et al.*, 2000	CT		30			8			121	50	11
	NT		14			-1			100	41	103

[1] Values reported in local currency and can differ from values reported by the authors due to combining treatments together and excluding government programs.

[2] Crop rotations are: WF is wheat-fallow, WWF is wheat-wheat-fallow, WSF is wheat-sorghum-fallow, WCF is wheat-corn-fallow, W is continuous wheat, SF is sorghum-fallow, S is continuous sorghum, LW is lentil-wheat, PW is field pea-wheat, and KW is chick pea (*Cicer arietinum* L.)-wheat. Tillages are: CT is conventional tillage, RT is reduced tillage, and NT is no tillage.

adequate soil moisture to ensure a crop yield. Direct costs of weed control in semi-arid fallow systems are low because there is often inadequate moisture for weed germination during much of the fallow period. Fallow systems are not, however, a particularly efficient user of water. Of the precipitation received during the fallow period, only about 20% is stored as soil moisture for the following crop (Campbell, *et al.*, 1987; Jones and Popham, 1997; Larney and Lindwall, 1995; Peterson *et al.*, 1996). The per cent of moisture stored is generally lower in the southern Plains and higher with reduced tillage practices. Soil moisture at the time of winter wheat planting was found to be similar for conventional tillage and chemical fallow (Dalrymple *et al.*, 1993). Rotation alternatives using less frequent fallow have utilized sorghum (*Sorghum bicolor* L.), corn (*Zea mays* L.) and more frequent wheat in the central and southern Plains (Anderson *et al.*, 1999; Jones and Popham, 1997; Norwood and Currie, 1998; Norwood and Dhuyvetter, 1993; Peterson *et al.*, 1996; Schlegel *et al.*, 1999; Wiese *et al.*, 1994; Williams *et al.*, 1990), and more frequent

Table 2. Economic returns for semiarid tillage systems[1]

Author	Rotation	Tillage System[2] ($\$ ha^{-1}$)			
		CT	RT	MT	NT
Halvorson *et al.*, 1994	WF	87	93		84
Norwood and Currie, 1998	WSF	66	42		36
	WCF	78	75		63
Norwood and Dhuyvetter, 1993	WF	-6	-1	-11	-20
	WSF	-2	11		9
Smith *et al.*, 1996 - exp. 1	WF	52	25		-2
Smith *et al.*, 1996 - exp. 2	WF	46	51		31
Zentner *et al.*, 1991 - silt loam	WF	40		25	5
	W	29			0
Zentner *et al.*, 1991 - sandy loam	WF	-16			-21
	W	-84			-108
- clay	WF			29	20
	W	-46			-52
Zentner *et al.*, 1996	WF	59		45	11
	W	77			53

[1] Values reported in local currency and can differ from values reported by the authors due to combining treatments together and excluding government programs.

[2] Tillages are: CT is conventional tillage, RT is reduced tillage, MT is minimum tillage, and NT is no tillage. Crop rotations are: WF is wheat-fallow, WSF is wheat-sorghum-fallow, and WCF is wheat-corn-fallow.

cereal and pulse crops in the northern Plains (Campbell *et al*., 1987, 1988; Zentner and Campbell, 1988; Zentner *et al*., 1997). These studies have determined that more output can be produced with less frequent fallow, increasing the efficiency of water use. Recognition of increased water- use efficiency with annual cropping have likely contributed to the decline in fallow in the North American plains.

The impact on economic returns with decreased fallow remains mixed (Tables 1 and 2). Direct comparisons across the studies in Tables 1 and 2 are not definitive because prices and other conditions vary. Nonetheless, results from the central and southern Plains show that rotations with wheat, sorghum, and fallow tend to be more profitable than wheat-fallow, continuous wheat, or continuous sorghum (Dhuyvetter *et al*., 1996; Norwood and Currie, 1998; Norwood and Dhuyvetter, 1993; Schlegel *et al*., 1999; Williams *et al*., 1990). In the northern Plains, wheat-wheat-fallow tends to be at least as profitable as wheat-fallow, and both of these rotations are more profitable than continuous wheat (Smith *et al*., 1994; Zentner and Campbell, 1988; Zentner *et al*., 1984). Wheat-pulse crop rotations in the northern Plains, however, are more profitable than conventional wheat-fallow rotations and reduced fallow (Zentner *et al*., 2000). These results show that cropping economics in the North American plains may favour a partial reduction of fallow in the rotation rather than a complete switch from wheat-fallow to annual cropping. It is also important to have increased crop diversity to profitably extend crop rotations and reduce summer fallow.

Not surprisingly, production costs per ha of wheat-fallow systems tend to be lower than for systems with less fallow (Dhuyvetter *et al.*, 1996; Norwood and Dhuyvetter, 1993; Smith *et al.*, 1994; Zentner *et al.*, 2000). Because production costs and output per unit area both rise with less fallow, crop prices will be a key factor in determining the benefits of more intensive crop rotations. In the northern Plains, research has shown low grain prices result in the wheat-fallow system being the most profitable, but as grain prices rise it becomes profitable to reduce fallow and increase the proportion of crop (Smith *et al.*, 1994; Zentner and Campbell, 1988; Zentner *et al.*, 1984). Reducing the frequency of fallow also increases annual variability of returns due to very low yields in dry years from recropped land.

There are a number of technological innovations over the past three decades that have increased the economic competitiveness of annual cropping in semi-arid North America. Increased herbicide options and declining real prices of key nonselective herbicides have decreased the need for fallow as a weed control practice. New larger equipment, such as no-till air seeder drills, can complete field operations in a timely manner. New equipment has also increased precision in seeding, weed control, and fertilizer placement. The recognition that fallow conserves a low per cent of precipitation and that no-till annual cropping is more efficient in storing precipitation has increased recropping utilizing no-till. Commercial inorganic nitrogen fertilizer has been readily available at stable prices, reducing the need for fallow. The decline in soil organic matter in fallow systems has reduced the short-term benefit of nitrogen release from fallow. With depleted soils, nitrogen is generally required for a crop on fallow. Improved cultivars have increased the drought tolerance of many small grains and oil seeds and widened the selection of crops to grow in rotation.

With limited and variable moisture, a management strategy of measuring soil moisture in the spring has been proposed for fertilizing and cropping decisions. An economic benefit was found in the Canadian prairies to adjusting fertilizer rates based on spring soil moisture (Zentner and Read, 1977). With "flex cropping", if soil moisture is above a critical level, a crop is planted, otherwise the land is fallowed. Flexible cropping has been found to improve profitability and reduce income variability in both American and Canadian studies (Young and van Kooten, 1989; Zentner *et al.*, 1993). The adoption of a flexible cropping system will reduce fallow compared with traditional crop-fallow. It will also contribute to increased soil conservation and soil quality (Young and van Kooten, 1989; Clark and Furtan, 1983).

Fallow has many environmental disadvantages, including the increased potential for soil erosion. Cover crops on fallow have been tested to determine their impact on residue cover and subsequent crop yield (Unger and Vigil, 1998). Annual legumes for a green manure were found to reduce the following year yield and reduce returns compared to a conventional fallow system (Zentner *et al.*, 1996a). Moisture use by cover crops late into the fallow season plus no direct economic return from the cover crop resulted in annual decreased economic competitiveness. Cover crops on fallow could have greater economic potential if fall seeded or biennial (sweet clover) crops are used as a cover because growth can be terminated earlier in the season to allow for moisture to accumulate in the soil, and in the case of sweet clover there can be revenue from hay (Smith *et al.*, 1999).

While reducing fallow, Canadian prairie farmers have increased cropping of broadleaf crops, and a similar trend is occurring in the northern US since base area for farm programs was eliminated in the 1996 farm bill (Smith and Young, 2000b). In the moist regions, canola seeding has increased. In the semi-arid regions, seeding of mustard (*Brassica juncea* L.) and annual legumes, primarily field pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medic.), has increased. The inclusion of non cereal crops in the rotation has had economic and agronomic benefits. The returns and prices of the alternate crops have been favourable and have not moved in the same direction as wheat. Agronomic benefits include disease control, nitrogen fixation by legumes and lower fertilizer costs, and long-term weed control because of the ability to rotate herbicide families and prevent the buildup of specific weeds or herbicide resistant weeds.

Tillage

A major environmental problem of summer fallow is that it leaves the soil exposed and increases wind erosion. No-till chemical fallow can eliminate most of the wind erosion associated with summer fallow (Larney *et al.*, 1994). While yearly on-farm losses due to soil erosion often appear to be small, the long-term costs can be high (Pimentel *et al.*, 1995). Societal costs of soil erosion off the farm often exceed on-farm costs (Colacicco *et al.*, 1989). Lost productivity in semi-arid regions can not be restored economically with the use of inorganic fertilizers (Smith and Shaykewich, 1990; Smith *et al.*, 2000b; Williams and Tanaka, 1996). Research in North America has also shown erosion can increase the variability of returns (Williams *et al.*, 1993). Reduced and no-till tillage systems on fallow can reduce soil erosion (Smith *et al.*, 2000a) and increase soil moisture storage (Peterson *et al.*, 1996; Smika, 1990). Spring soil moisture for no-till on loam and clay soils in the northern Plains was found to be at least as high as for conventional tillage, though this did not translate into consistently higher yields (McConkey *et al.*, 1996).

Tillage is a primary factor in controlling wind erosion. The tillage studies listed in Tables 1 and 2 evaluate the direct benefits and costs of alternate tillage systems. The long-term indirect impact of tillage systems on productivity through soil erosion should be included. In a whole farm optimization model, Smith *et al.* (2000a) determined the long-term costs of soil erosion from intensive tillage practices were high enough to overcome the lower short-term profitability disadvantage of no-till. Had long-term erosion costs not been taken into account, reduced tillage would have been more profitable than no-till. Chemical fallow and less frequent fallow can be optimal for Saskatchewan producers concerned about soil quality (van Kooten *et al.*, 1990).

Reduced tillage systems offer many agronomic benefits, but the economic benefits for North American plains farmers are not as clear (Tables 1 and 2). In many past studies no-till systems have been shown to be less profitable than conventional tillage in semi-arid regions because of increased weed control costs. Inexpensive tillage weed control is replaced with expensive herbicides when converting to no-till. Production costs for no-till have been found to be higher than those for conventional or reduced tillage in some studies (Norwood and Currie, 1998; Norwood and Dhuyvetter, 1993; Zentner *et al*., 1991, 1996b, 2000). When difficult-to-control weeds are present herbicide costs for no-till systems can be many times more costly than tillage, which results in lower net returns for no-till (Smith *et al*., 1996). In contrast, Norwood and Dhuyvetter (1993) found higher returns for reduced and no-till tillage with sorghum included in the crop rotation, but Wiese *et al*. (1994) found the opposite. The crop rotation will influence the relative profitability of tillage systems. However, recent case studies of farmers in a 200 to 330 mm y^{-1} precipitation zone in eastern Washington state showed no-till production costs per unit output for wheat and barley were lower than for conventional tillage (Camara *et al*., 1999). Case study farmers also reported the relative profitability advantage of no-till was gaining over time due to improved technology and management.

Worldwide, a gradual improvement in the relative profitability of no-till has resulted in an expansion of area planted by no-till. For several years, no-till soybean and corn production has been shown to be less costly in North and South America than conventional tillage (Hebblethwaite and Towery, 1998). Aggregate world statistics show an estimated 6 million ha no-tilled in 1987, 10 million in 1990, and 45 million in 1997 (Hebblethwaite and Towery, 1998). Approximately 28% of the land in Argentina, 18% in Canada, 16% in the United States and 15% in Brazil was no-tilled in 1997. Almost all of the no-till adoption in Argentina (Peiretti, 1999), Brazil (Denardin, 1999), and Western Australia (Crabtree, 2000) has been since the early to mid 1990s. No-till adoption by country is not reported by climate region, so adoption in semi-arid regions could be different. The economic benefit from no-till would appear to be more difficult to attain in semi-arid regions, where summer fallow has been a major use of land compared with moist regions (Lafond *et al*., 1993; Zentner *et al*., 1991). However, a higher per cent of land was no-tilled prior to planting in the semi-arid region of the Canadian prairies than in the prairies as a whole (Statistics Canada, 1997). Data on cropping system, summer fallow, and tillage system would be required to determine whether no-till and reduced use of summer fallow are correlated.

No-till provides managerial benefits including fewer field passes, timeliness of field operations, reduced labour use, and the ability to manage an increase in crop area. While some past studies indicate no-till decreases profitability in semi-arid environments, there can exist field-scale and farm-level operational benefits that result in higher farm returns with no-till. A longer planting window with adequate surface soil moisture because of reduced evaporation can influence optimal equipment and farm size.

Total labour and machine requirements could allow the producer to farm additional land, either owned, rented, or custom, that would increase total farm returns. More emphasis on conservation incentives in recent farm programs in the US and Canada have also likely fostered adoption of conservation tillage practices (Helms *et al*., 1987; Williams *et al*., 1990). The adoption of no-till tillage systems has been found to be enhanced by educational campaigns which highlight the health and soil productivity costs of soil erosion and technical information on potentially profitable conservation systems (Wang *et al*., 2000).

Risk

Income variability in crop production arises from yield and price risk. Price risk can be managed, to some extent, by diversifying into crops with weakly correlated prices (Weisensel and Schoney, 1989). However, cropping opportunities are limited in semi-arid regions and prices of substitute crops are often strongly positively correlated. Yield risk in semi-arid environments often dominates price risk due to precipitation variability. Summer fallow has historically been used to reduce yield variability. Yield risk has also been reduced with the use of crop rotations to break disease cycles and to enhance nutrient cycling. Yield risk has also been managed with use of tillage practices to increase soil moisture and conserve soil, and flexible cropping to gear the frequency of summer fallow to available soil moisture (Young and van Kooten, 1989; Zentner *et al*., 1993). Income variability can also be reduced with the use of insurance, including yield insurance and single event catastrophic loss insurance such as that for hail.

Decision making in risky environments usually involves a trade-off between average net earnings and the variability of earnings. The optimum cropping system will depend on each individual grower's ability and willingness to bear risk. Producers very averse to risk will use a cropping system that has low income variability and accept lower average returns. Producers less averse to risk will accept higher income variability for a higher average return. In the northern Plains, wheat-fallow has the lowest income variability, but also has lower average net returns when compared with some crop rotations with less frequent fallow and additional crops in the rotation (Brown, 1987; Zentner and Campbell, 1988; Zentner *et al*., 1984). Weisensel and Schoney (1989) determined the adoption of lentil production required a producer willing to accept additional risk. Tillage practices will also be influenced by risk preferences (Williams *et al*., 1993) and through government program effects on risk (Williams *et al*., 1990).

US and Canadian programs to stabilize farm incomes have recently strengthened the safety net for producers to intensify rotations. Crop insurance has been expanded to include more crops and premium subsidies have been increased (Schoney, 1995; Williams, 1988; Zentner and Campbell, 1988). Zentner and Campbell (1988) found crop insurance reduced the variability of net returns over time for most rotations. Insurance actually reduced average net returns for wheat-fallow because over time indemnities were less than premiums for this rotation, but average net returns for rotations with less fallow were increased with insurance.

Future Challenges and Directions

While summer fallow has declined by over 40% in western North America in the past 35 years, it is likely summer fallow will persist in some arid farming regions. In the early 1970s, these reductions appear to have been responses to high grain prices, but the declines persisted even when grain prices declined. New farming technology appears to be pushing summer fallow area to a lower plateau. Future refinement and adoption of these technologies - especially reduced tillage and new crop cultivars for arid environments - will continue to eliminate fallow.

In the short run, summer fallow will still fluctuate modestly in response to weather cycles, market forces, and policy changes. The very low grain prices of 1998 through 2000 could increase summer fallow from the record 1997 lows of 8.5 million ha in the US and 5.7 million ha in Canada.

If semi-arid cropping systems are to remain profitable and sustainable, there are many technology and economic issues that need to be addressed. American and Canadian farmers in semi-arid regions have adopted systems with increased cropping diversity, less fallow, and reduced tillage. These systems have agronomic, environmental and economic benefits. However, the economic benefits of these systems are always changing and there is no guarantee these systems will continue to be the most profitable. New technologies to enhance the cropping system revolution need to be developed and the economics of the new technologies evaluated. Cropping system development and evaluation will require the input of many disciplines, including soils, crops, and economics. Multi disciplinary research can greatly assist in problem solving, though research teams can be difficult to assemble and maintain because unidisciplinary research is often more rewarding professionally (Young, 1995).

Cropping systems need to be constantly refined in North America to respond to current and future conditions. Government incentives to increase carbon sequestration to slow global warming could benefit semi-arid regions. Cropping and tillage systems will change in response to emerging technologies and supply and demand balances in global grain and oilseed markets. Potential large adjustments in energy, herbicide, and fertilizer prices in response to geopolitical and technological developments will influence choice of land use and farming practices in semi-arid areas in North America and elsewhere. Output price changes will also alter the production system. While magnitudes and timing of changes are uncertain, alternatives need to be developed and researched so options are available to increase average net returns and reduce variability.

The reduction in summer fallow and adoption of more soil conserving farming systems in semi-arid Canada and the US over the last three decades represents a rare "win-win" development where both farm profits and the environment have benefited. Policy makers and scientists would be wise to reinforce the incentives for this trend throughout the world.

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