The 'Second Wave': The Expansion of Soybeans Across Southern Ontario, 1951-96

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The expansion of soybeans across Southern Ontario is documented and described. Three sets of factors are explored in a discussion of the changing nature of the decision environment that facilitated the crop's adoption and expansion: the development of improved cultivars and other technological innovations, the link with the earlier expansion of grain corn, and the competitive position of soybeans for use of the cropland resource. These developments altered the decision environment such that the share of cropland in soybeans in Ontario increased from 1.9 percent (62,715 ha) in 1951 to 22.8 percent (776,171 ha) in 1996, by which date they were the leading cash crop. Soybean expansion, along with that of grain corn, is, in turn, linked to an increased cash cropping orientation of the agricultural system. The two crops have also been instrumental in the intensification of the use of the farmland resource with the conversion of improved pasture and woodland to cropland. Across Southern Ontario change in the use of the cropland resource has been a fundamental part of the ongoing transformation of agriculture.

Key words: Soybeans, cultivars, innovation, crop complementarity, cash-cropping, comparative advantage

Robinson (1990, 129) observes that "changes affecting agriculture throughout the Developed World since 1945 can be described as 'revolutionary' in that farming in the 1980s is a vastly different proposition from that just forty years earlier." Troughton (1984, 379) sees this revolutionary change as "the process whereby agriculture (farming) is being transformed from an activity generally carried out at a relatively small scale and at a low level of capital intensity to one in which the major portion of production comes from a reduced number of large scale and/or highly capitalized units". Bowler (1992) uses the term 'industrialization of agriculture' to describe the processes of change in the most recent transformation of agriculture and identifies intensification, concentration and specialization as the key structural dimensions of the industrialization process. Troughton (1992) provides an overview of these processes in a Canadian context.

Across Southern Ontario these transformations have been manifested in a diversity of ways and have given rise to a range of concerns (e.g. Special Committee on Farm Income in Ontario, 1969; Clemenson, 1985; Johnston and Smit, 1985; Mage, 1985; Troughton, 1985;

Dickinson et al., 1987; Keddie and Mage, 1991; Smit and Smithers, 1991). One aspect of these transformations has been a dramatic change in the use of Southern Ontario's cropland resource.

The 'first wave' in this transformation occurred with the expansion of grain corn. In the period from 1951 to 1981 the area in grain corn increased from 117,000 to nearly 879,000 ha and by 1981 it occupied just over 25 percent of Southern Ontario's cropland area. The two decades from 1961 to 1981 were the period of the crop's rapid expansion from a southwestern hearth.

The 'second wave' in this transformation occurred with the expansion of soybeans. In 1951 about 63,000 ha of soybeans were reported in Southern Ontario, while by 1996 over 776,000 ha were reported and the crop occupied about 23 percent of the cropland area. The years 1976 to 1996 marked the rapid expansion of soybeans from a southwestern hearth in a fashion similar to grain corn, but about 15 years later.

The expansion of these two crops has been a fundamental part of the transformation of Southern Ontario agriculture. The adoption and expansion of grain corn has been documented and described in a number of earlier studies (Joseph and Keddie, 1981 and 1985; Keddie, 1983). This paper traces the expansion of soybeans across Southern Ontario and subsequently discusses this expansion as both a cause and consequence of other changes.

Purpose and Objectives

The purpose of this paper is to document, describe and explain the expansion of soybeans, the 'second wave' in the transformation of the use of Southern Ontario's cropland resource. This purpose is achieved through pursuit of the following objectives:

Objective 1: To document and describe the expansion of soybeans across Southern Ontario from 1951 to 1996.

Expansion of the crop is the joint consequence of two processes: an increase in the number of farms reporting the crop's production (adoption) and an increase in the scale of production per farm reporting production. Consequently, the expansion of soybeans is documented by identifying adoption and scale of production over time for Southern Ontario for the census years from 1951 to 1996. The data on agricultural land use used for this documentation and elsewhere in this study, unless otherwise credited, are from Statistics Canada, Census of Canada, Agriculture, Ontario, for the census years 1951 to 1996 inclusive.

Objective 2: To provide insights into the changing nature of the decision environment that in turn facilitated the crop's adoption and expansion.

An examination of the changing nature of the decision environment includes the exploration of three sets of factors: the development of improved cultivars (varieties) and other technological developments, the link with the earlier expansion of grain corn across the study area, and the competitive position of soybeans.

Brown (1981, 185) claims that "generally a new technology cannot fulfill its potential without complementary technologies which relax or bypass constraints that develop." In the context of soybeans in Southern Ontario, these constraints are chiefly biophysical conditions, but also include production issues such as weed control, inoculation and technological efficiency. This paper thus discusses the development of technologies that address the constraints posed by Southern Ontario's climate as well as improvements in chemical weed control, soybean inoculation and improvements in production machinery and equipment.

Rogers (1962) and Hartman and Brown (1970) note that compatibility is one of the key characteristics of innovations that relates to their rate of adoption. Rogers (1962, 126-127) defines compatibility as "the degree to which an innovation is consistent with existing values and past experiences of adopters" and notes that "an innovation may be compatible not only with cultural values but also with previously adopted ideas." This paper explores the compatibility between a cash cropping culture established with grain corn and the adoption of soybeans. It also explores the complementarities between grain corn and soybeans noted by Fisher (1981).

The third factor that contributed to the changing decision environment that facilitated the expansion of soybeans across Southern Ontario is that of the crop's competitive position. Regardless of the development of technology that overcomes production constraints and compatibility with an existing innovation, profitability is a key attribute of innovations that relates to their rate of adoption (Rogers, 1962) and producers

will not adopt soybeans unless they perceive the crop as a profitable use of their resources (Meilke, 1983). This paper thus investigates the comparative advantage of soybeans in a system where a number of crops with different roles in the farming systems of Southern Ontario compete for the use of the cropland resource.

The Expansion of Soybeans Across Southern Ontario

In 1951 about 63,000 ha were cultivated with soybeans in Southern Ontario and 6,778 farms (5.3% of those reporting cropland) reported the crop's production. Soybeans occupied less than two percent of the total cropland area and ranked eighth in cropland area. In contrast, by 1996 the area in soybeans was over 776,000 ha and production was reported on 18,738 farms (33.0% of those reporting cropland). By this date it was the second leading crop in Southern Ontario, exceeded only by hay, and it occupied nearly 23 percent of the total cropland area.

Table 1 documents the change in soybean area, number of farms reporting production and hectares per farm reporting. From these data it is possible to identify two phases or stages in the crop's expansion, the period from 1951 to 1976 and that from 1976 to 1996.

In the first phase (1951 to 1976) the area devoted to the crop increased from about 63,000 to over 151,000 ha, but the number of farms reporting production increased only marginally (6,778 to 6,990). The expansion in area was largely a consequence of an increase in scale of production per farm reporting the crop, from 9.3 to 21.6 ha. Furthermore, as is evident in Figure 1, the crop remained highly concentrated in the southwest with the four CDs (Census Divisions) of Essex, Kent, Lambton and Elgin (the southwestern core) accounting for 94 percent of the crop's area and 91 percent of the producers, both values marginally higher than in 1951. By 1976 soybeans were well established in the southwestern core where they occupied over 23 percent of the cropland area and were reported on nearly 56 percent of farms with cropland. In contrast, only about one percent of farms with cropland outside the southwestern core reported soybeans and the crop accounted for only 0.3 percent of the cropland area.

A number of features are evident in the second phase of the crop's expansion from 1976 to 1996. Firstly, while the share of area and producers accounted for by the southwestern core

Table 1: Southern Ontario, Soybeans

Year	Hectares (% of cropland)		Farms Reporting (% of farms with cropland)		Hectares per Farm Reporting
1951	62,715	(1.9)	6,778	(5.3)	9.3
1956	96,923	(3.1)	8,900	(7.3)	10.9
1961	85,731	(2.8)	7,466	(6.9)	11.5
1966	112,846	(3.5)	7,651	(7.8)	14.7
1971	148,582	(4.9)	7,634	(9.2)	19.5
1976	151,100	(4.6)	6,990	(10.0)	21.6
1981	278,839	(8.0)	10,338	(14.2)	27.0
1986	380,245	(11.5)	12,118	(19.2)	31.4
1991	570,113	(17.4)	14,671	(24.9)	38.9
1996	776,171	(22.8)	18,738	(33.0)	41.4

Source: *Statistics Canada, Census of Canada, Agriculture, Ontario,* 1951, 1956, 1961, 1966, 1971, 1976, 1981, 1986, 1991 and 1996.

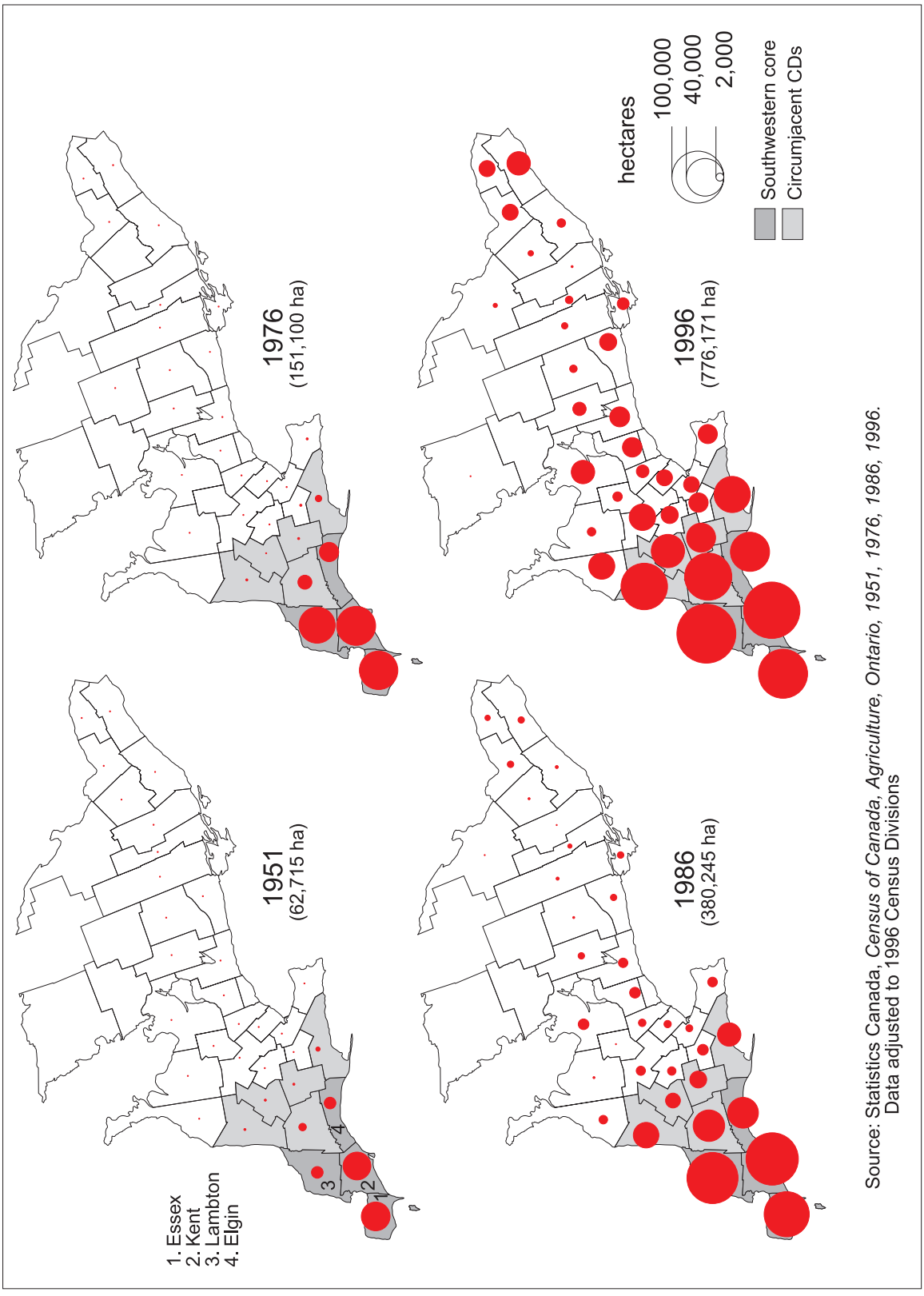


Figure 1. Total Area of Soybeans by Census Division, Southern Ontario

declined to 42 percent and 36 percent respectively, as is evident from Figure 1 the crop continued to increase in importance, from 142,000 to nearly 326,000 ha. Furthermore, by 1996 soybeans occupied nearly 49 percent of cropland area, compared to 23 percent in 1976, and nearly 78 percent of farms with cropland reported soybeans, up substantially from 56 percent in 1976.

While the ongoing expansion of the crop in the southwestern core is impressive, the second and outstanding feature of the period is the expansion of soybeans to the east and north (Figure 1). In 1976 only 630 farms reported just under 8,900 ha of soybeans in the 34 CDs beyond the southwestern core. By 1996 the number of farms reporting the crop had increased to 11,936 (25% of farms with cropland) and they reported over 450,000 ha of soybeans (16% of total cropland area). Thus the number of farmers outside the southwestern core who grow soybeans increased by almost 1900 percent from 1976 to 1996, and the total area increased by over 5000 percent.

Figure 1 reveals additional features of the expansion beyond the southwestern core. In the first decade, from 1976 to 1986, most of this expansion (65%) occurred in five CDs circumjacent to the core. In contrast, from 1986 to 1996, while expansion continued in the five circumjacent CDs their share of total growth beyond the core was reduced to 48 percent as growth was more rapid in CDs further east and north.

In the final decade of greatest growth all CDs experienced an expansion of soybeans. In relative terms, however, the area under the crop grew 1.3 fold in the four CDs of the southwestern core, 2.8 fold in the five CDs circumjacent to the core and 5.0 fold across the remainder of the study area. By 1996 soybeans were widely distributed across Southern Ontario (Figure 1).

The expansion of soybeans from 1976 to 1996 was a joint consequence of two processes. As is evident from Table 1, across these two decades the number of farms reporting production increased from 6,990 to 18,738. Nearly all of this increase (96%) occurred in CDs to the east and north of the southwestern core. In addition, the scale of production at the individual farm level increased from 21.6 to 41.4 ha. The growth in hectares per farm occurred across the entire study area, from 22.4 to 47.9 ha in the southwestern core and from 14.1 to 37.7 ha for the remainder of the study area.

The adoption and expansion documented above can be explained with reference to the changing nature of the decision environment that facilitated it. This is done through consideration of the three factors outlined earlier: technological developments, compatibility with grain corn, and the competitive position of soybeans.

Improved Cultivars and Other Technological Developments

The definitive history of the remarkable achievements in the development of cultivars that have made it possible for soybeans to achieve their present status across Southern Ontario has yet to be written. A brief review by Beversdorf et al. (1995), however, provides a series of key insights. Developments in chemical weed control, inoculants and field equipment and machinery have also made significant contributions.

Cultivars are developed to enhance various plant attributes (Beversdorf et al., 1995). The key attributes that have been the focus in the development of improved cultivars for Southern Ontario include yield, heat rating (time to maturity), cold tolerance, lodging resistance, resistance to Phytophthora root rot and herbicide tolerance. The development of Phytophthora root rot resistance is of particular importance for southwestern Ontario. Outside the southwestern core, the range of climatic conditions posed particular barriers to soybeans with respect to short growing seasons and cold weather at flowering time. Thus the development of short season varieties (earlier maturing cultivars) with cold tolerance without sacrificing yield potential are the key developments in making possible the expansion of the crop across Southern Ontario beyond the initial area of concentration in the extreme southwest.

Producers are kept informed regarding the development of new soybean varieties and their comparative attributes in a number of ways. Until 1988, the Field Crop Recommendations Guide, an annual publication of the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), listed recommended soybean varieties (cultivars) with their appropriate heat unit designations (HU ratings). Since 1988 annual reports of the Ontario Oil and Protein Seed Crop Committee titled Ontario Soybean Variety Trials have been the source for this detailed listing of recommended varieties. Over the years the

number of recommended varieties has increased enormously (e.g. 11 in 1959 to 134 in 1997), as has the range and sophistication of the data made available from the trials conducted before a variety makes the recommended list.

As discussed earlier, by 1951 soybeans were already well established as a crop in the four CDs of southwestern Ontario, particularly in Essex and Kent. By this date, the major cash crops of grain corn, winter wheat and soybeans together accounted for about 60 percent of cropland use (soybeans 18%) here. These three crops were reported on the majority of farms with 75, 65 and 44 percent of farms with cropland respectively reporting grain corn, winter wheat and soybeans. In that same year the cultivar Harosoy, with a HU rating of 3100, was released by the Harrow Research Station. This variety was arguably the most successful soybean cultivar ever developed in North America (Tanner pers com, 1998). By 1959 it occupied 75 percent of the soybean area in Ontario (Durance, 1987) and was the dominant variety across Ohio, Indiana and Illinois (Tanner pers com, 1998).

Harosoy's relatively high HU rating meant that it was most suited to the warmer conditions of Ontario's extreme southwest. However, it faced other barriers, among them its susceptibility to Phytophthora root rot, which by the mid-1950s was present on many of the area's heavier soils (Beverdorf et al., 1995). In 1963, Harosoy 63 was released. It had been developed for greater Phytophthora root rot resistance while remaining similar to Harosoy in all other respects. Harosoy 63 rapidly replaced Harosoy as the dominant cultivar (Beversdorf et al., 1995) and Harosoy was removed from the recommended list just two years after Harosoy 63's release.

Phytophthora root rot continued to be an issue in southwestern Ontario due in part to the development of new races of the disease that Harosoy 63 was not resistant to. This led to the development of Harcor and Corsoy 79, which first appeared on the recommended list in 1977 and 1982 respectively (Durance, 1987). Although the Phytophthora organism is not generally a problem beyond southwestern Ontario, all new cultivars (including short season varieties) are routinely tested for resistance to the disease, and the Ontario Soybean Variety Trials currently identify cultivars that are resistant to most or all races of the Phytophthora root rot organism in Ontario. Thus technological development in Phytophthora resistance facilitated the early expansion of soybeans in southwestern Ontario, and ongoing development of new cultivars has ensured the crop's continued success in areas where it is susceptible to the disease.

Although Phytophthora root rot has not been a problem beyond southwestern Ontario, the relatively short growing season posed a barrier to the crop's early adoption and expansion. Although a number of cultivars were available for the shorter growing season areas of Southern Ontario, they lacked the necessary cold tolerance, the ability of the plant to withstand cold night temperatures in the flowering stage without the abortion of the flowers (Tanner pers com, 1998). According to Blay-Palmer (1999) any temperature below 10 degrees Celsius caused soybeans to abort their flowers, resulting in fewer pods and significantly reduced yields.

This barrier was overcome with the appearance of Maple Arrow on the recommended list in 1978. This cultivar, rated at 2550 HUs, was developed at the Ottawa Research Station by crossing Swedish breeding material with Harosoy (Jenkinson, 1980), which resulted in vastly superior cold tolerance over the short season varieties available earlier. Maple Arrow remained on the recommended list until 1994, and it has been widely used as an adapted parental source of cold tolerance for many of the improved short-season cultivars developed since 1978 (Voldeng et al., 1997). These include Maple Glen (2575 HUs) in 1988, which is less susceptible to shattering, and OAC Bayfield in 1994 (initially rated at 2650 HUs but changed to 2725), which accounts for a yield improvement of approximately 10 percent over other short-season varieties. OAC Bayfield accounted for about 160,000 ha of Ontario soybean production in 1998 (Blay-Palmer, 1999).

The development of cultivars that addressed problems with Phyotphthora root rot in southwestern Ontario and had the necessary cold tolerance for the areas with short growing seasons facilitated the crop's adoption and expansion. These developments were complemented by the introduction of further innovations that allowed higher yields. Prior to effective chemical weed control for soybeans, wide spacing was necessary to make inter-row cultivation possible. Early short season cultivars produced small plants that would not grow sufficiently in size to give acceptable yields if planted with the needed spacing for effective mechanical cultivation (Tanner pers com, 1998).

Progress in chemical weed control since the 1960s has contributed to higher yields in the lower HU areas of Southern Ontario.

Finally, soybeans in Ontario initially faced some problems in establishing the appropriate rhizobium bacteria in the soil. The rhizobia cause nodules to form on legume roots and then fix nitrogen in the nodules. Different legume crops require separate groups of rhizobia to nodulate (Hume 1978), and the presence or absence of the specific wild rhizobia required to nodulate soybeans in the soil is a matter of chance. This problem can be overcome through inoculation (the introduction of bacteria at seeding time to ensure nodulation). Inoculants are applied routinely year after year as insurance in fields where soybeans have been grown previously and may be particularly critical on first time soybean fields. The development of granular inoculants during the mid 1970s proved significant. Experimental results from Woodstock in 1976 and 1977 showed 20 percent yield advantages for fields seeded to soybeans for the first time with granular inoculants over the powdered peat types (Hume, 1978). Across much of the short season area the granular inoculant 532 C played an important role in the successful establishment of soybeans (Tanner pers com, 1998). As of 1994, the soybean rhizobia strain 532 C was the established strain across about 20 percent of the soybean soils in Southern Ontario, especially in the newer short season production area (Hume, 1994). It has supported average yields about nine percent higher than the next best strain available, though it is not able to displace populations of other strains established in older soybean soils. The higher yields associated with its use in the newer production areas has undoubtedly been an important factor in helping to establish the competitive position of the crop.

There have also been developments in the area of field equipment and machinery. The development of innovations that improved labour efficiency and crop yields includes numerous types of machinery. Of particular importance to the production of soybeans are the floating cutter bar that helped to reduce harvest losses (Stone, 1975), and depth precision planters that improved germination rates (Tanner pers com, 1998). The depth precision planter was of particular importance for farmers using or wishing to use conservation tillage practices (Blay-Palmer, 1999).

In this brief review the key cultivars have been identified and other important developments noted. The development of Harosoy and Harosoy 63 were of particular importance to the crop's early expansion in the southwestern core from 1951 to 1976. In time, many of the other developments occurred across the last few decades corresponding to the period of the crop's expansion beyond the southwestern core. While many factors played a role in facilitating this, the release of Maple Arrow in 1978 with its cold tolerance trait was probably the most important breakthrough. Beversdorf et al. (1995) refer to it along with Harosoy as milestone cultivars. Furthermore, the development of improved cultivars is complemented by advances in chemical weed control, inoculation and machinery (Voldeng et al., 1997; Hume, 1994). These factors combine to allow narrow-row, high population production systems in all of Southern Ontario, and average soybean yields increased by about 67 percent from 1950 to 1996.

The development of improved cultivars and a range of other developments constitute necessary, but not of themselves sufficient, conditions to account for the enormous expansion of soybeans across Southern Ontario. Further explanation of the changing nature of the decision environment that facilitated the expansion of soybeans can be found in a consideration of the crop's complementarity with grain corn.

The Link with Grain Corn

The prior expansion of grain corn across the study area facilitated the adoption and expansion of soybeans in two related ways. Firstly, it developed a cash cropping culture in areas where previously little or no such culture existed. The adoption and production of soybeans was in turn compatible with the cash cropping culture established with grain corn. This compatibility was reinforced by the complementarities between the two crops.

The period from 1961 to 1981 was one of rapid expansion of grain corn north and east from the southwestern core. Across these two decades the area in grain corn beyond the southwestern core increased from 41,000 ha to over 668,000 ha. By 1981 grain corn was spread across the CDs of Southern Ontario in a manner similar to the distribution of the cropland resource (Keddie and Mage, 1985).

Over the same period the number of farms classified as grain and oil seed enterprises (a type of cash cropping enterprise) beyond the southwestern core increased from 768 to 7,629. The coefficient of correlation between change in the number of grain and oil seed enterprises across the 1961-81 period and change in the area of grain corn for the 34 CDs beyond the southwestern core is 0.926 (significant at the 0.01 level of confidence). Furthermore, there are no other land use changes across the area substantial enough to account for the huge increase in the number of grain and oil seed enterprises across the period in question.

Further evidence of the importance of grain corn to grain and oil seed enterprises is available if one consults land use data for farms classified by enterprise type. Grain corn occupied over 43 percent of the cropland on grain and oil seed enterprises in 1981 and its production was reported on 66 percent of such enterprises. Soybeans and wheat accounted for 22 percent and 11 percent of the cropland use and in turn were reported respectively on 48 percent and 46 percent of grain and oil seed enterprises.

These data include the four CDs of the southwestern core where 44 percent of grain and oil seed enterprises were located in 1981. These four CDs also accounted for 81 percent of the area in soybeans, 40 percent of the wheat, but only 24 percent of the grain corn. A reasonable interpretation of these contrasts is that, beyond the four CDs of the southwest, grain corn played an even more substantial role on grain and oil seed enterprises than that suggested by the aggregate data. This lends further weight to the claim that grain corn played a key role in the development of cash crop enterprises, where, prior to its introduction, relatively few such enterprises existed.

One can reasonably argue that the establishment of grain and oil seed enterprises, initially based largely on grain corn production, facilitated the subsequent adoption of soybeans by helping to establish a cash cropping culture in areas where little cash cropping previously existed. Fisher (1981, p. 29) highlights the complementarity between the two crops:

> Many farmers find that soybeans and corn are complementary crops in the farm operation. The same equipment can be used for both, and their growing and harvesting seasons usually occur at different times: in the spring, corn can be planted first, followed by the soybean planting; and in the fall, the soybean crop is harvested first, followed by corn. Thus, the use and costs of both labour and equipment can be spread out over time and over the area under cultivation.

Risk spreading, both with respect to fluctuating crop prices and production risks due to disease and pest outbreaks, provides an additional incentive for farmers who are cash cropping grain corn to incorporate soybeans into their production systems. Crop rotations are generally associated with a decrease in the incidence of pests associated with a particular crop (Blay-Palmer, 1999). Thus rotating grain corn with soybeans decreased the production risk for both.

There were other advantages of soybean production coupled with grain corn, particularly in the early years of soybean expansion north and east. Farmers were able to achieve very effective chemical weed control with grain corn early on (Keddie, 1983). Soybeans produced in rotation with grain corn, provided herbicide residuals were not too high, benefitted from this at a time when chemical weed control for soybeans was not well developed (Tanner pers com, 1998). In addition, although soybeans are noted as not being responsive to applied fertilizer, they are very responsive to the high residual fertility associated with the production of grain corn (Tanner pers com, 1998). Furthermore, grain corn's expansion was associated with an increased incidence of tile drainage (Blay-Palmer, 1999). Well-drained fields not only produce higher soybeans yields but also help to control Phytophthora root rot.

A strong continuing association between soybean and grain corn production is evident. In 1996, about 33 percent of study area farms with cropland reported soybeans and 37 percent reported grain corn. However, about two thirds of farms reporting soybean production also reported grain corn, and such farms accounted for about 75 percent of the total area in soybeans (Statistics Canada, 1998). Across the 35 CDs of the study area for which data were available, the proportion of soybean area on farms also reporting grain corn ranged from a high of 89 percent to a low of 53 percent, and 24 of the 35 CDs recorded values above 70 percent.

Data for 1996 on farms classified by enterprise type are also confirmatory of an ongoing substantial role for both crops

on farms classified as grain and oil seed enterprises. At this date soybeans occupied about 44 percent of the cropland on grain and oil seed farms (up from 22% in 1981) and the crop's production was reported on 85 percent of them (up from 48% in 1981). Grain corn was now the second leading crop, occupying about 31 percent of the cropland (down from 43% in 1981). Its production was, however, still reported on 66 percent of the grain and oil seed enterprises, the same value as recorded in 1981.

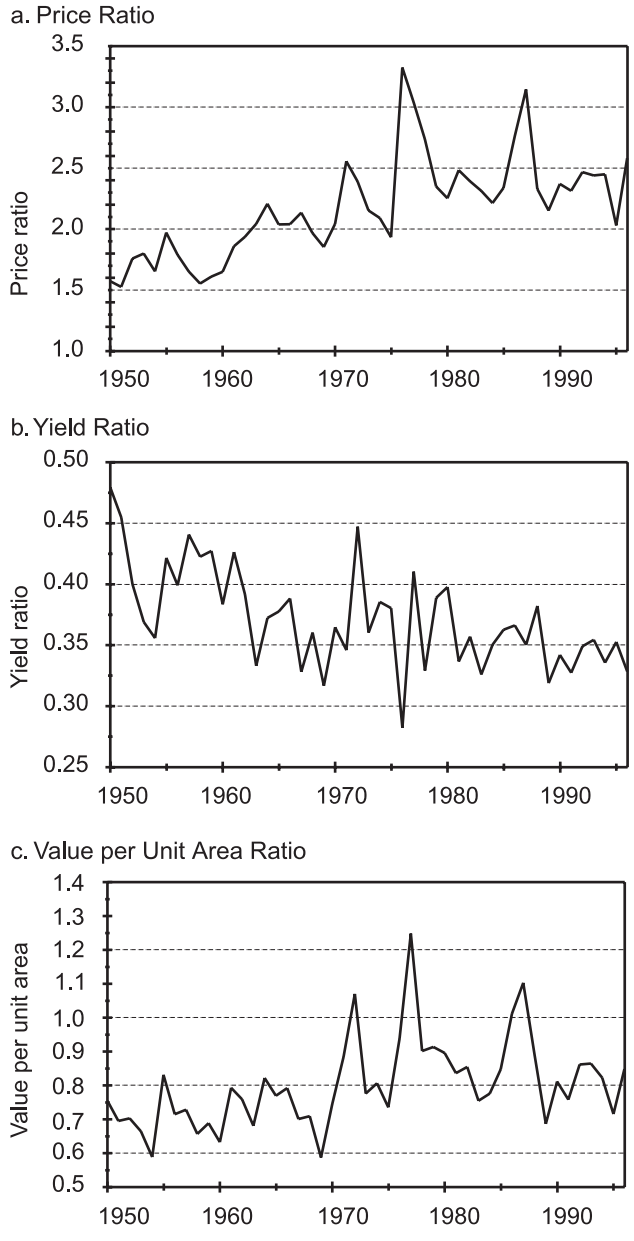
As discussed above, the expansion of grain corn across the study area contributed to the development of cash cropping enterprises. This in turn facilitated the establishment of a cash cropping culture compatible with the adoption and production of soybeans. This compatibility was reinforced by the complementarities between grain corn and soybeans. Thus it is reasonable to conclude that the prior expansion of grain corn across the study area facilitated the adoption and expansion of soybeans.

The Competitive Position of Soybeans

In a commercial agricultural environment like Southern Ontario's, it would be surprising if the competitive position of soybeans vis-à-vis alternative crops was not a key factor in explaining the crop's adoption and expansion. Relative advantage, often expressed as economic profitability, is seen as a key attribute of innovations that relates to their rate of adoption (Rogers, 1962). It is discussed here as the third factor that contributed to changes in the decision environment that facilitated the adoption and expansion of soybeans across Southern Ontario from 1951 to 1996.

Two aspects of the competitive position of soybeans for use of the cropland resource are explored here: a direct comparison of soybeans vis-à-vis grain, and a more general consideration of changes in cropland use across the study area.

Figure 2 shows aspects of the competitive position of soybeans vis-à-vis grain corn for the use of Southern Ontario's cropland resource. As is evident from Figure 2a, the soybean/grain corn price ratio from 1950 to 1996 shows an improved competitive position for soybeans. Meilke (1983, 1) notes that "soybeans compete most directly with grain corn for land and the price of soybeans relative to corn is a key factor determining which crop a farmer will grow." In a subsequent analysis Meilke concludes that soybean/grain corn price ratios above 3.0 result in large increases in soybean area, while ratios of 2.0 or less result in area declines.



Source: Ontario Ministry of Agriculture, Food and Rural Affairs, *Agricultural Statistics for Ontario*, Annual, 1950 to 1996.

Figure 2. Soybean/Grain Corn Ratios, 1950 - 1996.

Smithers (1994) investigated this proposition in detail for Kent and Essex, the heart of cash cropping in southwestern Ontario, for the period 1960 to 1992. He found that changes in

area planted in soybeans were positively associated with an increase in the price ratio, while changes in grain corn area had a negative association. However, while annual changes in soybean area had a statistically significant association (r^2=0.25) with the price ratio, annual changes in grain corn area did not. This investigation led Smithers to conclude that most of the variation in year-to-year changes in area remained unexplained by the soybean/grain corn price ratios.

Across the same period, while yields for both crops increased, the soybean/grain corn yield ratio moved in favour of grain corn (Figure 2b). This may in part help explain the relatively weak association between changes in the area of both crops and the soybean/grain corn price ratio. By combining price and yield, one can derive a soybean/grain corn value per unit area ratio (Figure 2c). Since production costs are higher for grain corn than soybeans, ratios less than 1.0 would yield similar gross margins (gross income minus total variable costs). For example, across the period 1984 to 1989, crop-budget data (Economics and Policy Coordination Branch, OMAF) suggest that a ratio of about 0.75 would result in similar gross margins. In contrast, data for 1980 from a study by Fisher (1981) yield a ratio of 0.85 for similar gross margins. These contrasts illustrate that, since input costs are not constant, the break even point is more than a function of price and yield and varies not only from year to year but from producer to producer.

Figure 2c illustrates that, regardless of the appropriate ratio, the competitive position of soybeans vis-à-vis grain corn has improved. Across the years from 1951 to 1975 inclusive, the soybean/grain corn value per unit area ratio averaged just over 0.74. It was below 0.75 in 15 of the 25 years and above 0.85 on only two occasions. By way of contrast, from 1976 to 1995 inclusive, the ratio averaged over 0.87. It was below 0.75 in only two of the 20 years, but above 0.85 on 11 occasions.

Bearing these ratios in mind along with Meilke's claim that soybeans compete most directly with grain corn for land, it is instructive to investigate the relative position of the two crops in the traditional cash cropping heartland of the study area, the four CDs of the southwestern core. In 1961 (the first year for which data by farm type are available) they contained nearly 83 percent of the study area's grain and oil seed enterprises.

In 1951 these four CDs contained about 93 percent of the study area's soybeans and 75 percent of the grain corn. From 1951 to 1976 nearly the entire increase of 84,000 ha (143%) of soybeans in Ontario occurred in these four CDs. Over the same period, however, the area in grain corn increased by about 118,000 ha (132%). Both crops were almost equally effective competitors for the use of the cropland resource, and by 1976 together they occupied 57 percent of the cropland, up from 31 percent in 1951. It should be noted that the area under crops also increased by 135,000 ha (29%), testimony to an intensification in the use of the farmland resource.

In the period from 1976 to 1996 the soybean/grain corn value per unit area ratio moved in favour of soybeans. Across these two decades, the area in soybeans increased by about 184,000 ha while grain corn declined by about 27,000 ha, but together they occupied 75 percent of the cropland area (which had in turn increased by another 63,000 ha). While grain corn declined, other cropland uses declined even more substantially (94,000 ha). Even in the cash cropping heartland, the question of soybeans as a competitor for the use of cropland resource is more complex than its competitive position vis-à-vis grain corn alone.

Since the expansion of soybeans after 1976 was not restricted to the four CDs of the southwestern core it is necessary to extend our consideration of soybeans, grain corn and competition for the use of the cropland resource more broadly. Across the study area grain corn achieved its maximum census year area in 1981. So here the focus is on the time period from 1981 to 1996.

Between 1981 and 1996 the area in grain corn across the study area declined by about 112,000 ha while the area in soybeans increased by over 497,000 ha. Thus the decline in grain corn will accommodate about 23 percent of the increase in soybeans. This comparison is, however, complicated by a decline of total cropland across the study area. An alternative method is to undertake a shift share analysis. The procedure for using this method is to calculate 'expected' values for 1996 based on each crop's share of total cropland in 1981 multiplied by the cropland total in 1996, and to compare these values against the 'actual' values in 1996. Using this method for the study area as a whole,

the decline in grain corn accommodates about 19 percent of the increase in soybeans across the 1981 to 1996 period.

It is likely that grain corn and soybeans experience the most direct head-to-head competition for the use of the cropland resource on enterprises where both crops are produced as cash crops. Given limitations on available data, this type of analysis can best be done by comparing the use of the cropland resource across time for enterprises classified by product type as grain and oil seed farms. These data are only available for Ontario as a whole, and are only for farms with sales of $2,500 or more.

Table 2a provides these data for grain and oil seed farms using the same shift share procedure as outlined above. In this analysis, the decline in grain corn accommodates about 58 percent of the increase in soybeans while other crops collectively accommodate 42 percent. Since the area in grain corn on such farms in 1981 was about 43 percent of cropland, compared to 35 percent for other crops (excluding soybeans), grain corn's relative decline was not much more pronounced than that of all other crops together (this was the case despite a marked increase in the cropland under wheat on such farms between 1981 and 1996).

As is evident from Table 2a, by 1996 soybeans had assumed the leading position on grain and oil seed enterprises. The crop occupied nearly 44 percent of the cropland on such enterprises and its production was reported on nearly 85 percent of them. The cropland area and the number reporting production translates into nearly 53 ha in soybeans per farm reporting production. Clearly by 1996 soybeans were the premier cash crop on grain and oil seed enterprises.

Interestingly, despite the absolute and relative decline of grain corn on grain and oil seed farms across the 1981-96 period, the proportion of farms reporting its production, as noted in the previous section, remained virtually constant at about 66 percent. So, while cash crop farmers may have reduced the area in grain corn to accommodate soybeans, the same proportion retained it as part of the cropping system. This may reflect a

Table 2: Cropland and Selected Cropland Uses on Farms Classified by Farm Type, 1981 and 1996 (hectares)

	Actual 1981	Actual 1996	'Expected' 1996[1]	Gain or Loss [2]
A. GRAIN AND OIL SEED FARMS				
Cropland	999,782	1,256,148		
Soybeans	217,223	546,878	272,924	+273,954
Grain Corn	432,984	384,286	544,010	-159,724
Other Crops	349,575	324,984	439,214	-114,230
B. ALL OTHER FARMS CLASSIFIED BY FARM TYPE				
Cropland	2,474,440	2,213,494		
Soybeans	58,824	224,573	52,621	+171,952
Grain Corn	434,902	379,329	389,039	-9,710
Other Crops	1,980,714	1,609,592	1,771,834	-162,242

1. Expected' 1996 is based on each crop's share of total cropland in 1981 multiplied by the total cropland in 1996.
2. Gain or loss is calculated as Actual 1996 minus 'Expected' 1996.

Sources: *Statistics Canada, Census of Canada, Agriculture, Ontario,* 1981 and 1996. Data for soybeans in 1996 from special tabulations purchased from Statistics Canada as it was not included among the crops on the table of data for farms with sales of $2,500 or more classified by product type.

desire to spread risk, and possibly also reflects other complementarities between the two crops. Figure 2c demonstrates that the competitive position of soybeans vis-à-vis grain corn has improved. It also, however, demonstrates the variability of the ratios from year to year. This short term variability suggests the advantage, from a risk perspective, for cash crop operators to produce both crops. Crop frequency data (the number of farms reporting each crop) indicate that on average about 2.7 crops were produced on grain and oil seed farms in both 1981 and 1996.

In Southern Ontario overall, the decline in grain corn from 1981 to 1996 accommodates only 19 percent of the increase in soybeans, while on grain and oil seed enterprises its decline accommodates about 58 percent of the increase in soybeans. This discrepancy reflects the complexity of the land use changes that have occurred as the area in soybeans has expanded. As indicated in Table 2b, for all other farms classified by type (excludes grain and oil seed farms), the decline in grain corn accommodates under six percent of the increase in soybeans while other crops collectively accommodate over 94 percent. The role of grain corn as a feed on many livestock enterprises probably accounts in part for the modest role its decline had in accommodating soybeans on farms other than grain and oil seed enterprises.

As is indicated on Table 2b, by 1996 nearly 225,000 ha of soybeans were reported on farms other than grain and oil seed enterprises, nearly a four fold increase since 1981. These 225,000 ha represent about 10 percent of the cropland on such farms, and about 17 percent of them reported soybean production. This translates into about 28 ha of soybeans per farm reporting production. Soybeans on such enterprises are in all likelihood produced largely as a cash crop. On these farms soybeans seemingly have found a place as a cash crop sideline to the main enterprise, at the expense of a range of other crops.

Table 3 allows further insights in exploring the role of soybeans as a competitor for the use of the cropland resource

Table 3: Southern Ontario, Use of the Cropland Resource (1000s ha)

	Actual 1951	Actual 1996	'Expected' 1996[1]	Gain or Loss [2]
A. GRAIN AND OIL SEED FARMS				
Cropland	3,273	3,403		
Hay	1,224	912	1,273	-361
Soybeans	63	776	66	+710
Grain Corn	117	767	122	+645
Winter Wheat	284	291	295	-4
Barley	74	120	77	+43
Silage Corn	114	119	119	–
Mixed Grain	425	108	442	-334
Field Beans	23	44	24	+20
Oats	668	34	695	-661
Tobacco	44	28	46	-18
Other	237	204	246	-42

1. 'Expected' 1996 is based on each crop's share of total cropland in 1951 multiplied by the total cropland in 1996.
2. Gain or loss is calculated as Actual 1996 minus 'Expected' 1996.

Sources: *Statistics Canada, Census of Canada, Agriculture, Ontario,* 1981 and 1996.

and the role of grain corn along with other crops in accommodating the increase in soybean production. It provides an overview of the use of the cropland resource across the entire study period from 1951 to 1996. From this broad perspective it becomes apparent that three crops have experienced large absolute declines (oats, mixed grain, and hay) while two crops experienced substantial gains (soybeans and grain corn). Thus, although some portion of soybeans' increase has been accommodated by the grain corn's decline since 1981, both crops hold pride of place as competitors for the use of Southern Ontario's cropland resource.

By 1996 soybeans had surpassed grain corn as the premier cash crop. Grain corn, however, also holds an important role as a feed grain on livestock enterprises. In a commercial agricultural environment such as in Southern Ontario, profitability or the competitive position of a crop vis-à-vis alternative crops is probably the most important factor in accounting for its adoption and expansion. The best evidence for this is found in the changing use of the cropland resource. It is important, however, to bear in mind that this is in turn facilitated and constrained by a host of other considerations.

Conclusions

This paper has provided a documentation and description of the expansion of soybeans across Southern Ontario from 1951 to 1996. The crop's adoption and expansion reflects ongoing decisions made by thousands of individual farmers. Three sets of factors were advanced to provide an understanding of the changing nature of the decision environment in which these individual decisions were made. Collectively they constitute in large part the necessary and sufficient conditions that led to the adoption and/or expansion of soybeans by farmers across the study area.

One factor was the development of cultivars suitable for the range of bio-physical conditions found across Southern Ontario, coupled with other technological developments favourable to the crop's production. Despite the linked and multi-faceted nature of technological development, it is important to recognize the key role played by a handful of cultivars that helped to overcome specific constraints to soybean production. In the extreme southwest of the study area Harosoy, which dominated production by the late 1950s, and the Phytophthora root rot resistant Harosoy 63, which dominated production by the late 1960s, were of great importance to the modest expansion of soybeans in the period from 1951-1976. Maple Arrow, both directly and as a parental source of cold tolerance, was of major importance in the expansion of soybeans after 1976 east and north into shorter season areas. These developments constitute necessary but not of themselves sufficient conditions for the widespread adoption and expansion of the crop across Southern Ontario.

A second factor of importance to the adoption and expansion of soybeans was the prior establishment of grain corn across the study area. Soybeans as a cash crop were compatible with the cash cropping culture established in large part as a consequence of the adoption and expansion of grain corn. This compatibility was in turn reinforced by the complementarity between the two crops. This complementarity was reflected by such features as timeliness in the use of both labour and equipment, risk spreading, weed control with corn particularly prior to effective herbicides for soybeans, and the response of soybeans to the high residual fertility associated with grain corn production. This compatibility and complementarity facilitated the crop's adoption and expansion and thus impacted upon the rate with which both occurred.

The position of soybeans as a competitor for the use of the cropland resource was the third factor explored in investigating the crop's adoption and expansion. The years after 1976 were the period of the rapid expansion of soybeans, and this was the case in the southwestern core as well as across the remainder of the study area. This was explained by the improved competitive position of soybeans vis-à-vis grain corn.

The expansion of soybeans was only in part at the expense of grain corn, the decline of which accommodated only 19 percent of the expansion of soybeans across the period from 1981 to 1996. The majority of this decline occurred on grain and oil seed farms, where grain corn and soybeans are in direct competition with one another. On all other farms classified by type, the substantial increase in soybeans was accommodated by a decline of crops other than grain corn. This provides evidence that soybeans have found a place, probably largely as a sideline

cash crop, across a range of farm types other than grain and oil seed enterprises. This, in a commercial agricultural environment like that found in Southern Ontario, is testimony to the fact that many farmers across Southern Ontario (not just cash crop farmers) perceive the production of soybeans as a profitable use of their resources.

The crop's production and role on farm enterprises however, has to be seen in context. On cash crop enterprises, risk spreading and other benefits that accrue from the production of a number of cash crops seemingly constrain the proportion of cropland producers will devote to a single crop, even if it is most profitable most years. For farmers operating other types of enterprises, short of fundamental change in orientation, there are other constraints. For example, on livestock enterprises such as dairy farms, the feed and forage crop requirements of the enterprise place practical limits on the area devoted to soybeans, if they are produced at all.

By 1996 soybeans had surpassed grain corn to rank second (after hay) in the use of Southern Ontario's cropland resource. It also had become the leading crop in terms of farm cash receipts (Statistics Canada, 1997). In 1996 soybeans accounted for 20.7 percent of farm cash receipts from all crops compared to 18.6 percent for grain corn. This rises to 32.4 percent of receipts from field crops (excluding fruit, vegetable, floriculture and nursery receipts).

More generally, the expansion of soybeans and grain corn are part of a change in the orientation of Ontario agriculture. In 1951, crop receipts accounted for about 20 percent of farm cash income from farming operations, and receipts from grain corn accounted for about 1.5 percent of the total (Statistics Canada, 1952). In that year receipts from soybeans were not listed. By 1996 receipts from crops constituted 43 percent of farm cash receipts with soybeans and grain corn accounting for 17 percent (Statistics Canada, 1997).

Further evidence of the contribution of grain corn and soybeans to a shift in the orientation of Ontario agriculture is available from data on farms classified by product type. In 1961 grain and oil seed farms (numbering 4,436) constituted 5.1 percent of the farms classified by product type in Ontario and accounted for 6.9 percent (197,000 ha) of the land under crops. Grain corn and soybean occupied 46.6 percent of the cropland on such farms, which were in turn concentrated in the four CDs of the southwestern core (82%). By way of contrast, in 1996 grain and oil seed enterprises (numbering 12,250) constituted 20.5 percent of farms classified by type and accounted for 36.2 percent (1,256,00 ha) of land under crops. Soybeans and grain corn occupied 74.1 percent of the cropland on such farms, which were in turn well represented across the study area although most concentrated in the four CDs of the southwestern core (44%).

The expansion of grain corn and soybeans also represent an intensification in the use of Southern Ontario's farmland resource. Across the period from 1951 to 1996 farmland declined by over 30 percent, a joint consequence of losses to urban generated demands and the removal of marginal land from agriculture (Xu, 1993). Across the same period, however, the area of cropland increased by four percent. This increase is largely a consequence of the conversion of improved pasture to cropland, although the loss of woodland also played a role.

The net gain of cropland (130,000 ha) is a consequence of a gain of about 508,000 ha across 12 contiguous CDs in the southwestern part of the study area, but a loss of about 378,000 ha across the remaining 26 CDs. The share of study area cropland in the 12 CDs that gained cropland increased from about 44 percent in 1951 to nearly 57 percent in 1996. In 1996 these 12 CDs also accounted for about 80 percent of the study area's soybeans and 67 percent of the grain corn. These two crops jointly occupied nearly 59 percent of the cropland across the 12 CDs. It is this portion of the study area that epitomizes the intensification in the use of Southern Ontario's farmland resource, an intensification that can be seen as a response to economic pressures on farmers to gain larger economic returns per unit land area. It is also this part of the study area, the agricultural heartland of Ontario, that has been the focus of studies concerned with the negative environmental effects of this intensification and their remediation (e.g. Miller et al. 1982; Troughton, 1985; Coleman and Roberts, 1987; Dickinson et al., 1987; Smit and Smithers, 1991; Wandel and Smithers, 2000).

By 1996 grain corn and soybeans had jointly transformed the use of the cropland resource across Southern Ontario. Grain corn represented the 'first wave' in this transformation while soybeans constituted the 'second wave'. In 1951 they jointly occupied about 5.5 percent of the total cropland area but in

1996 the value stood at 45.3 percent. This change, as we have seen, is in turn both a cause and a consequence of other changes or transformations in the system. Across Southern Ontario change in the use of the cropland resource has been a fundamental part of the ongoing transformation of its agriculture.

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