Innovating Conservation Agriculture: The Case of No-Till Cropping

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Abstract The extensive sociological studies of conservation agriculture have provided considerable understanding of farmers’ use of conservation practices, but attempts to develop predictive models have failed. Reviews of research findings question the utility of the conceptual and methodological perspectives of prior research. The argument advanced here is that actor-network theory is useful in analyzing conservation agriculture as a radically different agriculture: a new paradigm with new beliefs about soils, plants, the environment, and farmers themselves as well as new crop production systems. The new indigenous cultures of conservation tillage and cropping are innovative products of social networks that join farmland, farmers, farm advisors, and farm supply representatives in new ways. The spread of conservation agriculture has occurred as the result both of new agricultural science of conservation tillage and cropping and the spread of these new networks and their innovative cropping systems.

During the past half century the spread of no-tillage cropping in particular, and conservation tillage agriculture generally, constitutes a qualitative change in cropping agriculture in the United States and temperate zones around the world (Carter 1994). In 1998, more than 50 million acres of cropland were no-tilled or ridge-tilled, one-sixth of the nation’s cropland. In 36 of the 50 states and Puerto Rico, five percent or more of the cropland was no-tilled or ridge-tilled (CTIC 1998). This change is part of a broad shift to conservation cropping that in 1998 was practiced on 109 million acres (39%) of the cropland in the United States.

Rural sociologists have had difficulties explaining this socio-technical change. The early discovery that the classic form of the innovation-diffusion model (Rogers 1983) did not provide a good fit with farmers’ adoption (or nonadoption) of conservation methods (Pampel and vanEs 1977; Taylor and Miller 1978) led to development of a number of improved conceptual models (e.g., Nowak 1984, 1987; van Es 1984;...

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1 In ten of these states more than 50 percent of the cropland was managed with conservation tillage. For discussion of the worldwide reach of conservation agriculture, including no-tillage, see Carter (1994) and Napier et al. (1994).
Napier et al. 1988; Napier et al. 2000). Despite varied revisions of the conceptual model, the identification of a large number of factors related to the adoption of conservation practices, as well as a wide range of constraints thereto, the explanation of farmers’ conservation behavior has proved elusive. After reviewing social and economic studies of conservation behavior, William Lockeretz (1990:523) concluded that researchers were “not even close” to predicting “farmers’ conservation behavior from their personal characteristics, the characteristics of their farms, or their linkages to institutions and information sources.” Building on Lockeretz’s evaluation, Nowak and Korsching (1998:170) conclude that the “continuing and pervasive criticisms [of the research record] call into question the utility of this whole line of research.”

The purpose of this paper is three fold. The first is to briefly review conceptual issues involved in the lack of fit of the classic innovation-diffusion model with the innovation of no-tillage cropping. The main argument, drawing upon actor-network theory (ANT), is that the innovation of no-tillage cropping agriculture led to and was created and sustained by new networks and relationships involving farmland, farmers, farm advisors, farm supply agents, new techniques, and agricultural scientists. Moreover, the innovation of conservation cropping systems created through these networks constitutes a new cropping agriculture that includes both new indigenous systems of agricultural practice and a new technoscience of conservation tillage agriculture. The second purpose of this paper is to give substance to the theoretical argument by analyzing data on the innovation of no-till cropping in Kentucky. Finally, the paper ends with a discussion of the significance of the data analysis.

Theoretical Perspective

The difficulties encountered in explaining the innovation and “adoption” of conservation cropping agriculture indicates the need to consider a different conceptual perspective (Nowak and Korsching 1998). From the vantage point of the traditional innovation-diffusion paradigm, the central problem is: Why is the farmer (as key actor) using or not using various appropriate conservation practices? With this conceptual orientation, other actors, agencies, organizations, the biophysical environment, and the farmer’s relationships with these are considered as causal sources, resources, or constraints. Although this perspective has been quite useful in explaining the innovation-adoption of individual techniques, it is both partial and limited. On the one hand, conservation tillage agriculture encompasses a different orientation to agriculture and the environment as well as the employ-
ment of various new practices. Moreover, a more balanced analytical perspective would not privilege or uncritically accept one set of actors or social relationships as central, but instead accord the same problematic status to all. Such a perspective is especially appropriate for present purposes because no-tillage cropping (and conservation tillage agriculture in general) entails a qualitative change (e.g., Kuhn 1970) in agriculture that engages multiple actors, agencies, institutions, and farming environments in a long process of social construction of new techniques that are loosely coupled tillage and cropping systems and new institutional structures.

ANT is an analytical perspective that focuses on actor(s)-networks as the central problem in all social phenomena. The fundamental principle of ANT is that “entities take their form and acquire their attributes as a result of their relations with other entities” (Law 1999:3). One of the meta-theoretical tenets of ANT is a “generalized agnosticism” with respect to actors or entities ([Callon 1986] Michael 1996). That is, relational systems include nonhuman as well as human “entities,” i.e., soils, plants, animals and human beings. Moreover, “relations” refers to human-to-nonhuman relationships as well as inter-human relationships. Entities and actors take on or are ascribed meanings as a result of social interaction. Consequently, distinctions among or qualities of entities, including social divisions (e.g., classes, agency, and power) are understood as effects or outcomes of relationships. Or, otherwise stated, all entities, regardless of their materiality, are produced in relations. But this means that entities—actors, groups, landscapes, etc.—“are performed in, by, and through those relations . . .” in which they are embedded (Law 1999:4). Finally, exploration of the socially created distinctions, relationships, meanings, etc. of entities requires strict neutrality by the analyst and the use of an abstract and neutral vocabulary that does not privilege any one set of actors/entities.

There have been several studies using this perspective. Callon (1986, 1987) has shown how scientist innovators in constructing innovations also construct actor-networks and identities for themselves and other network members. The “others” may accept the innovation and embrace the constructed network, or they may subvert the constructed identities, refuse to participate in the constructed network, and cause the constructed system to fail. Bijker (1987) has shown that in the process of creating an innovation, the innovators construct both a new technical frame—knowledge, methods, routines—for the innovation and an actor-network embracing the new technical frame. The process by which new socio-technical systems embodying various “entities” in new relationships vis-à-vis the environment are created is a process of
"heterogenous engineering" (Law 1987). Juska and Busch (1994), Busch and Juska (1997), and de Sousa and Busch (1998) have used this theoretical perspective to analyze the development of rapeseed as technoscience, a commodity, and soybean production in Brazil, respectively.

Constant (1987) conceptualizes technoscience as a sociocultural complex with three analytic components: (a) the practitioners and their traditions of technical practice, (b) the scientists and engineers that produce knowledge and technical artifacts, and (c) the system of technological knowledge (Fig. 1). These analytic components do not exist in isolation, but rather develop in a favorable socio-political and institutional environment. The mirror image of these overlapping systems of knowledge are the networks of relationships among practitioners, scientists, agency representatives, and non-human entities that make it a functioning society.²

This perspective forms the central hypothesis of this paper: no-tillage and cropping agriculture, in its various forms—indigenous practices by farmers, new farm landscapes and identities of farmers, applied science, commodities, and instrumentalities—is a product of new social networks among farmers, cropland, agricultural advisors, company representatives, and agricultural scientists. Moreover, farmers, agricultural advisors, landscapes, etc. acquired new identities that are products of the performances of the interacting actors.

**Conceptualizing Cropping Systems**

In no-till (and strip-till) cropping “the soil is left undisturbed from harvest to planting except strips up to 1/3 of the row width (strips may involve only residue disturbance or soil disturbance). Planting is accomplished using disc openers, coulter(s), row cleaners, in-row chisels or roto-tillers. Weed control is accomplished primarily with crop protection products. Cultivation may be used for emergency weed control” (CTIC 1998:18). Initially, one may notice that the definition of no-tillage includes not merely tillage per se but also planting and that the combination constitutes a new or different “tillage and planting system” (e.g., D’Ittri 1985; Sprague and Triplett 1986) rather than merely either a new tillage or planting technique(s). Thus, in the spread of conservation tillage and planting, we are dealing with something qualitatively different than, for example, the adoption of new techniques, such as 2,4-D (Beal and Rogers 1960), or hybrid corn seed (Ryan and

²See Figure 2 in Juska and Busch (1994:592) for a more elaborate representation of these relationships applying to the development of rapeseed as a commodity.
Gross 1943; Ryan 1948), which required only relatively minor adaptations of the existing tillage and cropping system at the farm level.\(^3\)

No-tillage is one of the systems used in the Midwest and Upper Plains in planting corn, soybeans, sorghum, and small grain crops. The emphasis is on limiting land (surface) disturbance. There is no single method or technique of planting a crop. Instead, there are multiple alternatives. In addition, the Conservation Tillage Information Center (CTIC 1998:18) makes explicit the concept that conservation tillage, including no-tillage, is necessarily part of “a year-around conservation tillage system beginning with the selection of crops that produce sufficient quantities of residue,” including cover crops, and “includes all field operations that affect residue amounts, orientation and distribution throughout the period requiring protection.” The farmer must make choices among crops, tillage, and/or planting methods and the like that may vary from field to field and year to year. Therefore, a no-tillage planting system is a loosely-coupled system (Aldrich 1979) with a primary goal of saving soil and moisture while producing a crop that is “satisfyingly” profitable.

By contrast, for example, a technique of using a no-till wheat drill is a

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\(^3\)The distinction between technical change and agro-system change is admittedly a matter of degree and, hence, relative. This is because new techniques, such as hybrid corn seed and rapeseed, involve many complex changes in seed production, distribution, and utilization but also because in themselves the adoption of some individual technical systems, e.g., the tractor or the pipeline milker, resulted in substantial qualitative change in farming systems.
tightly-coupled system (Aldrich 1979). With tightly-coupled technical systems, the functional interdependence of the system components (e.g., opening coulters, planting shear, grain and fertilizer boxes, press wheels, human operator, etc.) is relatively high, and most of the systemic relationships, excepting the operations of the human operator, are designed (socially constructed) in the artifact itself. Even the activities of a human agent who uses the technique are prescribed; i.e., the operator follows a technical script for use of the particular implement. With loosely-coupled systems, however, the “structures and activities . . . [of the system] are only weakly connected to each other and, therefore, are free to vary independently” (Aldrich 1979:76–77). In loosely-coupled systems, the connection, or relationships, among system components is “thematic” as well as “functional” (Fivush 1987). The theme (goals) of a no-till corn system, for example, is the maintenance of a covered landscape and the successful planting of a corn crop in untilled ground. The more loosely (less tightly) coupled the system that a person constructs, the more the system operator engages in its construction and operation.

Although tightly-coupled techniques are distinguished from loosely-coupled cropping systems, socio-technical systems admittedly vary along a tight-loose continuum. Tillage and cropping systems (which include tightly-coupled components) are intermediate in this respect between relatively tightly-coupled techniques on one end and very loosely-coupled farming systems at the other end. As van Es et al. (1986:60) recognized, “no-till is a . . . complex practice without a standard procedure, requiring more in the way of management skills, experimentation and risks.” More recently, Carter (1994:Preface) has put it: “There is . . . no universal prescription for the adoption of conservation tillage to any one location or region.” In other words, there is no no-tillage corn system per se to be adopted. A no-till corn system for a particular farm must be designed and constructed by the system’s manager, whose capacities and resources become its principal components.

Initially, innovators constructed both a general technical frame and specific individual operating systems. As a result of decades of research and practice, a technoscience now exists that farmers can use in constructing tillage and planting systems in particular agroecosystems. The agroecosystem of a farm embraces social and economic as well as ecological dimensions (e.g., Altieri 1987). The master no-till technical frame consists of current theories of no-tillage and planting (e.g., Carter 1994; Pierce and Frye 1998; Hatfield et al. 1998), management strategies,4

\[\text{Management strategies include minimizing operational costs, maintaining plant residue and/or plant cover, providing sufficient fertilizer, minimizing pest-plant competition, timely planting, and varied problem-solving and adaptive learning routines.}\]
technical scripts for particular implements, and models of operational systems by varied tillage and cropping system innovators.\textsuperscript{5} It is the shared, and therefore cultural, knowledge of agricultural scientists, professional soil conservation and agricultural workers, agribusiness technicians and agents, and farmers engaged in conservation tillage and planting. In Constant’s (1987) terms, these comprise the social organizations, institutions, and practitioners of no-tillage planting practice.

The implications of this conceptualization of conservation tillage and planting are substantial. First, failure to recognize the fundamental, systemic differences between the tightly-coupled technical components (e.g., the pre-plant application of Roundup, or no-till planting) of a no-till cropping system and the loosely-coupled tillage and planting system leads to badly flawed conceptual and methodological designs. The mixing of system levels violates the principles of independence in sampling designs.\textsuperscript{6} Related to this is the fallacy of assuming that a no-tillage cropping system can be validly measured by a number of so-called no-till techniques used.

Second, in addition to the farmer, the key variables (constraints) in any loosely-coupled no-tillage planting system are the farm or agroecological setting, the supporting network, and the policy environment. The managerial and technical abilities of farmers and the dimensions of the agroecological and socioeconomic settings affect the thematic goals and management strategies undergirding the tillage and planting systems that farmers construct (Carlson and Dillman 1988; Makowski et al. 1990). Failure to recognize and account for variability in these major dimensions in research designs leads to misspecification of the research model.

Third, because the farmer and the farm are the key constraints, loosely-coupled tillage and planting systems are reconstructed, not adopted, by a farmer and a network of other entities. The reconstruction of a successful tillage and planting system in a new agroecological setting is nearly always a multi-year project, and the adaptive modification of the system continues almost indefinitely (Coughenour and Chamala 2000). Nowak and Korschching (1985) called this an evolutionary process. Failure to recognize that farmers, when surveyed, may be at different stages in this evolutionary or adaptive process can contribute to substantial interpretive errors.

\textsuperscript{5}This definition of technical frame is adapted from Bijker (1987) and following Kuhn (1970).

\textsuperscript{6}This compromises the sampling assumption that practices vary randomly (and independently) across space (i.e., regardless of agroecosystem) which Nowak and Korschching (1998) noted.
Fourth, as will be argued below, the reconstruction of a no-till cropping system, especially in areas where established no-till agriculture does not exist, is a process and product of new networking. The farmer’s task is to construct his/her own operative tillage and cropping system. This requires gaining access to the conservation tillage and cropping technical frame and repertoire of appropriate techniques through networking with agricultural advisors, farmers, company representatives, and the like. Inevitably, the operative tillage and cropping system that the farmer and his/her network constructs is the result of their collective collaboration.

Innovative Networks and No-tillage in Christian County, Kentucky: A Synopsis

Soils and climate in Christian County, located in southwestern Kentucky, are relatively favorable for cropping agriculture. The land is undulating to rolling upland plains, and the limestone soils are deep, well-drained, and with a thin loess mantle. The relatively long growing season averages 194 days with above freezing temperatures and an annual average rainfall of 50.8 inches. Forty-eight percent of the average rainfall typically occurs during the growing season. With appropriate technology, the climatic conditions are suitable for double cropping.

In 1954 Harry Young, Jr. (Extension Specialist in Farm Management) left the Kentucky Cooperative Extension Service to partner with his father and brother in operating the 1,235-acre family grain and livestock farm. With training in agronomy and in agricultural economics, Harry Young was concerned about erosion of his cropland and immediately set up a rotation that kept cropland in grass or legumes three or four years out of seven.7

His expertise in farm management also enabled him to determine that in the farm economy of the mid-1950s, the labor involved in plowing and cultivation was one of the major costs of crop production and that any reduction in this cost made land devoted to major crops progressively more profitable than land devoted to pasture and livestock production. The possibility of using herbicides to reduce field cultivation costs thus attracted his interest. Along with many other farmers at the time, Harry Young, Jr. started using 2,4-D to control broad leaf weeds and testing the effectiveness of other new herbicides as they became available.

7This rotation was consistent with widely advocated soil management recommendations. See “Land Blankets,” The Progressive Farmer Vol. 63 (August 1948):15; “Three L’s are Paying Off” (lime, legumes, livestock), The Progressive Farmer Vol. 67 (August 1952).
In 1956, Reeves Davie was transferred from Carlisle County to become the agricultural extension agent in Christian County (Davie 1996). Like Harry Young, Jr., he had been trained in agricultural economics and was interested in farm management. Having known Harry Young, Jr. as a Farm Management Specialist in the Extension Service, one of his first steps as the new Agricultural Agent was to enlist Harry Young to lead the training of a group of farmers in farm management. Their collaboration in various extension activities continued for more than 15 years.

In 1953, Shirley H. Phillips was promoted from Associate Agricultural Agent to state Specialist in Field Crops (Phillips 1992). He began working with farmers across the state in varietal trials, in the use of herbicides, and various practices to increase crop yields. In 1959, he enlisted Harry Young, Jr. in farm trials of new seed varieties. Their collaboration in new crop varietal and herbicide trials continued periodically over the following decade (Davie 1996).

**Trying the Substitution of Herbicides for Cultivators**

Particularly troublesome were wet springs that kept farmers from timely cultivation. The use of chemicals to control weeds when fields were too wet to cultivate was a way of salvaging a crop.\(^8\)

Since 1948, the use of preemergent herbicides had reportedly provided some farmers both cost savings and preemptive protection against wet weather delays of field work (Lassiter 1948). When Dalapon, labeled for the control of annual and perennial grasses in corn, became available in the 1950s, Harry Young, Jr. joined several of his neighbors in trying to substitute chemicals for all cultivation in corn. It worked well enough the first year that several farmers tried it the following year. But satisfactory control of grassy weeds was not attained, and this scheme was abandoned as impractical (van Es and Notier 1988). Both Phillips and Davie were interested observers and consultants of the failed attempt at substituting herbicides for field cultivation.

When Atrazine, labeled as a preemergent for control of weeds and grasses, became available for the 1961 cropping season, Harry Young decided to determine whether it would provide the weed control that he and other farmers had been seeking. After planting 77 acres of tilled ground with corn, Harry Young immediately broadcast Atrazine.

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\(^8\)Since 1947, publications such as *Wallaces Farmer* and *The Progressive Farmer*, periodically had appraised midwestern and southern farmers of the success in substituting chemical herbicides for cultivation in controlling weeds in corn. Throughout the 1950s increasing numbers of farmers made use of herbicides to control weeds in corn (Coughenour and Chamala 2000).
Conventionally planted corn was grown on 15 acres along side the no-till trial. Although some weeds came up despite the herbicide control, the fewer weeds and the higher grain yield in the trial than in the cultivated acreage convinced him that Atrazine and 2,4-D would provide satisfactory post-plant weed control (Young 1961). Phillips, Davie and other local farmers were interested observers of the trial.

**Serendipity: No-till Corn**

As he was concluding that Atrazine and 2,4-D provided satisfactory post-plant weed control, Harry Young decided in the late summer of 1961 to join a group of Christian County farmers led by Reeves Davie to view some of George McKibben’s experimental cropping trials at the Illinois Experiment Station (Davie 1996). One of the plots in particular—no-till corn in killed grass sod—excited special interest because the corn looked as though it would yield as well as that in the other plots. Prompted by this discovery, later in the fall Harry Young wrote to Superintendent Webb at Dawson Springs to enquire about the yield. When told that the trial plot had yielded as well as the others, he decided to set up his own trial in 1962. This decision resulted from the chance expansion of the local network focusing on reduced tillage to extra-local, if not yet “global,” interest in no-tillage. This was a radical step because until then Harry Young had accepted the conventional wisdom (and science) that the best corn yields were produced with fall plowing, plowing down fertilizer, careful plant bed preparation, and early planting, as Shirley Phillips and most scientists and advisors recommended (Phillips and Loeffel 1963). But Harry Young also had read Faulkner’s *Pilgrim’s Folly*, Rodale’s *Pay Dirt*, and other similar literature and had been successful in reducing tillage. He recognized that if McKibben’s no-tillage could be made to work on his farm, it would save a lot of field work time, speed the planting process, and probably save soil.⁹

**Trials: No-till Corn, Minimum-till Barley, and Lespedeza**

As the 1962 season approached, Harry Young decided to try no-tilling corn on killed lespedeza sod that would be sufficiently friable for a modified conventional planter to penetrate. He used Atrazine to kill 0.7 acre of lespedeza and provide preemergent weed control (Phillips and Young 1973; Davie 1996). He weighted an old planter so that the

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⁹Harry Young knew that other farmers in Kentucky and other states were experimenting with plow-plant cropping, but he also knew that this method delayed planting and left the ground rough (e.g., LaRue 1962; Barksdale 1962).
planting shear would cut a trough to plant corn in the killed lespedeza sod. The planter left some seed uncovered, so Harry Young ran the wheels of his tractor over the rows to cover them. Although complete weed control was not attained, the yield of the no-till corn was comparable to that in the conventionally planted field alongside.10 Reeves Davie, Shirley Phillips as well as Harry Young were quite interested in, even surprised and informed by, the outcome of this experiment. As its success became evident, Davie arranged a field day for interested local farmers and others to view the trial. After the corn was harvested, Harry Young disced the field twice and broadcast and disced in barley.

The next spring (1963) lespedeza was seeded into the barley and the crops were harvested in the fall and summer, respectively. Another trial of no-till corn in killed lespedeza sod was established in a different field. Meanwhile, the success of the previous year’s trial persuaded two neighboring farmers to join in trying to no-till corn, thereby expanding the local innovative network (Figure 2). One farmer came up with a novel solution to the planting problem (Davie 1999). He mounted a coulter on the front-mounted, hydraulic row-cultivator of his tractor to cut a slot in the ground into which the planter trailing behind the tractor placed the corn seed. Again, Harry Young’s yields of no-till corn were comparable to that in the conventionally-tilled field (Phillips and Young 1973), and that fall Reeves Davie held another field day for local farmers and interested extension workers. Equally important, Shirley Phillips became more than an interested observer and began taking a more active role in evaluating the advantages of no-tillage and discussing the new system with extension workers and agricultural scientists.

Despite the satisfactory yields of no-till corn, the trials had not been problem free. Harry Young discovered in the 1962 trial that the residual from the high rate of Atrazine used, which was necessary to kill lespedeza sod and control grasses, adversely affected germination of the barley planted after the corn harvest. Fortunately, Harry Young and the local innovative network soon found an effective solution to this problem. On returning to Dawson Springs in summer of 1963 to see the no-tillage trials, Harry Young found that George McKibben had used Paraquat to knock down plant growth prior to planting, whereby less Atrazine was needed for post-plant weed control. On returning to Christian County, Harry Young persuaded several other farmers also trying no-till corn to join in ordering Paraquat for their use in 1964.

10 Individual farmers reportedly had tried planting no-till corn in sod on sloping fields as early as 1955 (Shear 1968) and tried ridge-till planting in Iowa in 1954 (Buchele 1967), but these trials were not widely publicized and were unknown to Harry Young in 1962.
The rotation of no-till corn on killed lespedeza sod followed by barley and lespedeza was repeated by the expanding network of Christian County farmers in the 1964 and 1965 seasons. Despite using a farm-built planting system, Harry Young’s no-till corn plots over four seasons (1962–1965) averaged 110.3 bu. per acre compared to 102 bu. per acre on the conventionally tilled check plots (Phillips and Young 1973). Moreover, no-till planting saved field work time and seemed to save soil. These successes, and those of the expanding network of farmers trying no-tillage, also cemented Shirley Phillips and Reeves Davie as co-members in the innovative network and strong advocates of no-till cropping methods. Shirley Phillips, in particular (staunch advocate of plowing), felt challenged to gain greater understanding of the underlying processes.11

Networking

In addition to organizing field days, to which notables on no-tillage around the country were invited, Reeves Davie was centrally positioned to be an effective local advocate of the emergent indigenous culture of

11 Shirley Phillips would later recall (1992) that “we knew what was happening [e.g., that no-till corn was successful], but we couldn’t quite figure out why it was happening . . .” because plowing was thought to be essential.
conservation agriculture. As County Extension Agent for Agriculture he had wide contacts with farmers in Christian County. His personal enthusiasm gave an infectious quality to his advocacy of no-tillage, and skeptical farmers could talk to an expanding network of local innovators. Moreover, in 1964 and for several years afterwards Davie was invited by instructors of the adult farmer Vocational Agriculture courses in Christian County to teach a session on no-tillage in each of the two classes held each year. This provided an excellent opportunity to extend the message about no-till agriculture locally. Moreover, in 1964 he was appointed Pennyrile Area Extension Specialist in Farm Economics, which provided opportunities to talk to farmers about the benefits of no-tillage in a wider area.

Following corn harvest in 1965, Harry Young changed the crop rotation by minimum-tilling wheat—a more profitable crop than barley—into the corn stalks. By the spring of 1966, the innovative network in southern Christian County included twenty farmers who had managed to modify planting equipment to experiment with no-tilling corn.\textsuperscript{12}

With the support of a planning committee, Reeves Davie and Shirley Phillips organized lectures and visits to Young’s farm and three others. Farmers, extension workers, and agricultural scientists were invited, including George McKibben from the Dawson Springs Experiment Station. The field day, attended by 325 persons from 19 counties (Davie 1996), not only show-cased no-tillage in Christian County, it helped spawn local innovative networks at other locations.

\textbf{A New Cropping System: No-till Corn, Soybeans, and Wheat}

In discussions that day with Harry Young, Shirley Phillips, George McKibben and others, Reeves Davie argued that they should be experimenting with double-cropping no-till soybeans after the wheat or barley harvest (Davie 1996, 1999). Davie had seen farmers in western Kentucky try double cropping soybeans after wheat or barley with conventional tillage. The crops almost invariably failed due to the soil moisture lost and the delay in timely planting while preparing the seed bed. No-tillage would minimize both of these constraints. Harry Young and one or two other farmers, as well as George McKibben, decided to conduct trials of such a cropping system in the 1967 season.

\textsuperscript{12} Carlson and Dillman (1988) found that mechanical skill was a major factor in the success of Palouse farmers in adopting no-tillage cropping.
Network Expansion: Chemical and Machinery Companies, Research-Extension Administration

The expanding local markets for chemical herbicides attracted the interest of "global" chemical companies who sent representatives to establish linkages with the expanding local networks and to assess the emerging markets. Paraquat had been used in the western states to kill weeds in orchards and was used to a limited extent in pasture renovation in Kentucky, but the order of a large quantity of Paraquat by Christian County farmers in 1964 and 1965 prompted an Imperial Chemical Industries (ICI) sales representative to visit Shirley Phillips for an explanation of the suddenly expanded interest in this product (Phillips 1992). As the result of farmers starting to use Lasso prior to double-cropping soybeans, Monsanto sent two representatives to the 1967 Christian County no-till field day (Davie 1996).

The farmers were also aided in experimental trials of their new cropping system by the discovery that in 1966 Allis-Chalmers had developed a commercial no-till planter.15

Reeves Davie played a key role in aiding farmers' acquisition of these planters by contacting the Allis-Chalmers regional manager in Memphis, TN, to determine the availability of the new planter. Subsequently, he persuaded the local dealer that there was sufficient interest in no-tillage for him to order all the available no-till planters in Memphis, TN, for sale to Christian County farmers. (Harry Young eagerly purchased one of the new no-till planters for use in 1967.) The sale of all of the southern region planters to Christian County farmers prompted an immediate visit by the regional sales manager to determine the reason for this surprising demand. In these ways, the local networks enrolled new (national) actors that delivered new technical resources and advisory assistance; and the companies became willing sponsors of field days.

As Field Crops Specialist, Shirley Phillips carried the news of the success of the new conservation cropping system to skeptical extension and research workers in the Department of Agronomy and the College of Agriculture at the University of Kentucky. He also began tracking experiments with no-till cropping at other research stations. While the latter linkages enabled him to become an increasingly knowledgeable advisor and local advocate of no-till cropping, his feedback to a skeptical agricultural faculty and extension administration was equally signif-

15 When farmers began to reduce tillage in the early 1950s, small machinery companies began developing various types of planters to plant in minimum tilled soils, but Allis-Chalmers was the first to develop and market a planter for untilled ground.
icant. As a result of the evident success of no-till planting in Christian County, the expanding interest in the system, and Phillips’ effective missionary work, in 1966 the extension administration officially endorsed the no-till planting of corn in killed sod as a successful system (Biennial Report of Cooperative Extension, 1966–1967). This had the important result of leading to the formation of an extension task force to promote no-till cropping throughout the state with Phillips as leader.14

In 1968, Phillips’ influence within research and extension circles in the College of Agriculture was increased by his promotion to Assistant Extension Director for Agriculture. This position enabled him to direct extension work on no-tillage and to become more effective in persuading researchers to expand studies of no-till and soil relationships.

Cropping System Development

For Harry Young and the other farmers trying double cropping, the 1967 season was pivotal, as it marked the initial trial of a new cropping system: no-till corn followed by minimum-tilled wheat and no-till soybeans after harvesting wheat the following year (Davie 1996). In the fall after the soybean harvest, a minimum-till rye cover crop was planted then killed in spring to plant no-till corn. This rotation of three crops in two years was repeated in 1968 and 1969. There were numerous questions, however, which took several years of trials to answer satisfactorily: what was the best variety of soybeans in double cropping; how best to handle heavy straw stubble; and what herbicides gave the best weed control? Under Phillips’ active leadership, statewide varietal and herbicide trials were organized. Harry Young played an active role in these studies by participating in state herbicide trials with soybeans in the 1967 to 1972 cropping seasons and in soybean varietal trials from 1968 to 1970.

Meanwhile, Harry Young continued keeping systematic records of trials of the new no-tillage cropping system first started in 1962 with no-till corn in killed lespedeza sod followed by small grain and intercropped lespedeza (Phillips and Young 1973). The small grain was seeded by a grain drill in the minimum tilled corn field. This cropping system was continued for five years. Then for the next three years double-crop soybeans after small-grain harvest was substituted for the lespedeza. For the eight-year trial period, no-till corn averaged 103.4 bu/ac compared to 99.8 bu/ac on the conventionally-tilled plots. Dur-

14Initially, the task force consisted of specialists in field crops (Shirley Phillips), weeds (James Herron), soil fertility (Harold Miller), and agricultural engineering (Robert Stewart).
ing the three years of the corn-wheat-soybean system, the wheat averaged 48.3 bu/ac and the soybeans averaged 45.5 bu/ac. On the basis of Young’s data, Phillips and Young (1973) estimated savings in tillage costs of $4.00 per acre for no-tillage over conventional tillage. While comparative costs varied by year, kind of equipment used, and relative costs of chemicals and tractor fuel, in the late sixties no-till corn had a total cost advantage of $3.00 to $4.00 per acre over conventionally tilled corn.

Apart from successful crop production, Shirley Phillips’ particular interest was in the soil saving aspect of no-tillage and in determining the kinds of soils in which no-tillage could be used successfully. Again, both the experiences of farmers in using the system with different soils as well as the studies by experiment station scientists provided useful guidelines (Phillips 1969). The soil-saving aspect of no-tillage was quickly confirmed, but the no-till techniques that worked well in the finely-textured soils of Christian County did not work well in heavy clay soils for which new techniques had to be developed (Phillips and Young 1973). Farmers and researchers discovered that differences in soil texture required changes in planters and altered the effectiveness of herbicides. Soil moisture levels at planting time also affected stands.

Mobilizing the Networks: The Take-off of No-till Cropping

The field days organized by Reeves Davie and his planning committees in 1967 and 1968 attracted even greater interest than had the 1966 field day (Davie 1996). In 1967, 725 people from 18 states registered; and more than 800 attended the 1968 field day, helping spread information about the success of no-tillage nationwide. The no-tillers in Christian County, and the Young farm in particular, had become a social networking magnet. Over the ensuing decade or so, more than 13,000 persons visited the Young farm alone to see and consult with the innovative leader (Davie 1996).

The field days provided an opportunity for intense discussion among professional workers. The night before each of the field days extension workers, agricultural scientists, and sponsoring commercial company representatives gathered for dinner followed by a discussion of no-tillage cropping. The discussion was led by Shirley Phillips (Davie

15 Difficulties in adapting no-tillage planting to different soils, climates, and weed and pest regimes slowed the spread of no-till planting and required decades of research to solve (Blevins and Thomas 1978). In studies of the innovation and development of other systems, these types of difficulties are referred to as “reverse salients” (Hughes 1987) or functional failures (Bijker 1987) requiring new innovation.
1996), who had broad familiarity with both the experiences of local farmers and research from around the country. These events, along with the field day lectures and discussions, provided opportunities for sharing both research and practical information on current problems with no-tillage cropping and for planning future experiments.

The successes of the new cropping systems that farmers were constructing, which had the potential of increasing land efficiency by 150 percent, convinced many farmers to make it their conventional tillage and cropping system. As one person who began participating in the innovative networks in 1967 later recalled: after 1967, the economic data favoring the new cropping system was "overwhelming" (Teeter 1992):

We were grossing $300 an acre in 1969, 1970, and 1971 . . . [nearly] as much as the land was worth . . . [at that time]. By 1968, the people [farmers] that were quick adapters had access to [innovators and] information and were quick changers. . . . By 1969, if you weren't double cropping all your acreage . . . no-till . . ., with all the herbicides (Atrazine, Lorox, Lasso, Paraquat), planters, and all that [available], you had been left at the station. . . . This entire region, some of the best land in the state, . . . in a period of three years went from no double cropping and no no-tillage to it being the standard practice.

Spurred by the favorable markets, the acreage planted to soybeans in Christian County, for example, increased more than 12 fold between 1966 and 1971.

However, the first flush of no-till adoption could not be sustained. The inability to control noxious weeds and grasses and difficulties in planting into wetter and cooler soils caused some farmers to reduce or to discontinue no-tillage and others to hesitate in trying it (Choi 1981).

**New Value-Orientations and Identities**

Gradually, practitioners of the new no-till cropping came to recognize their soils as a "living dynamic organism that functions in a holistic way depending on its condition or state, rather than as an inanimate mixture of sand, silt, and clay" (Doran et al. 1999:22). Their soils were no longer either good or bad, as they previously had thought, but rather were either healthy or unhealthy (Harwood 1990). Healthy soils “have the capacity . . . to function as a vital living system, within ecosystem and land use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health” (Doran et al. 1999:22). Doran et al. (1999) emphasize that although the practice of conservation tillage and cropping
contributes to substantially better soil health, relative to the practice of plow culture, the potential magnitude of the effects are largely dependent on climate, landscape position, and soil characteristics.

Farmers increasingly recognized that soil health could be managed, but not engineered. These conservation-minded farmers endeavored to understand the components of this complex ecosystem and its interactions, processes, balances, plant regimes, and products. More fundamentally, these farmers became better managers of an agroecosystem (Altieri 1987) composed of social and economic as well as biotic or environmental systems. Water quality; soil biota, moisture, fertility, temperature, and structure; as well as weeds, pests, and diseases of crops; costs of inputs; and crop prices became factors to be considered by farmers in attempting to maintain soil health and attain profitable and sustainable production. No-till farmers quickly discovered that there is not one way of doing this. Instead they learned to continually monitor social, economic, and environmental factors and select the most appropriate technique(s) from a repertoire of techniques to attain no-till cropping system goals (Coughenour and Chamala 2000). In so doing, they gained knowledge and developed greater management skills than they had used with conventional (plow) tillage.

The process of constructing new social networks, which resulted in a new agri-landscape and agri-society, also constructs new social identities for its actors (Greider and Garkovich 1994; Michael 1996). The old images of the plowman, powerfully turning the sod and controlling nature, have become archaic. Instead, Harry Young and others have become practical agro-ecologists working with the soil and plant environments, trying to balance or harmonize varied factors in such a way as to achieve satisfying production and profit while sustaining the environment. Harry Young, and now his son, proudly show fields that have not seen a plow in over four decades. Professional workers, like Shirley Phillips, have changed their professional identities as well. As Shirley Phillips (1992), who became recognized internationally for his work in no-tillage, put it: "I spent half my career telling people how to prepare seed beds . . . and the equivalent in backing off [from those ideas] and [in getting] into minimum tillage . . ." to save and improve the quality of soils and crop production.

The New Technoscience Society of No-Till Agriculture

Through their interaction, innovative actors construct a new technical frame that provides a new “grammar” of shared meanings which in turn defines, or identifies, the innovative social group (Bijker 1987). As local networks enroll more and more nonlocal actors who operate with
the expanding new technical system and additional, supporting technical frames and networks develop, a new society is established (Callon 1987). In the case of no-tillage and conservation tillage cropping more generally, the processes of social construction initiated in Agricultural Experiment Stations, Christian County, and in many other local networks resulted in a new technoscience society of no-tillage cropping. Claims that conservation tillage was revolutionary were made early for stubble mulching (Bennett 1942) and later for no-till farming (Gersmehl 1978). Other early proponents of no-till referred to it more modestly as a “new” tillage technology system (Phillips and Young 1973:20). Regardless, the critical point is that no-tillage agriculture denotes the presence of new agricultural systems; i.e., new value-orientations, including soil and cropping goals, new knowledge, and a new repertoire of cropping techniques.

Van Es and Notier (1988) analyzed the evolutionary development of no-tillage agriculture in terms of Anderson and Hardaker’s (1979) concepts of the notional, preliminary, and developed stages of an innovation. In summary: immediately following World War II, agricultural scientists and farmers began to “experiment” with various notions of direct planting, e.g., stubble-mulch planting, to save field work time and costs. Most ended in failure. Taking a cue from the success of direct drilling in renovating pastures, however, Dow Chemical Company researchers in Michigan experimented in the early 1950s with the “slit-planting of corn and soybeans” (van Es and Notier 1988:98). Later in the decade, researchers in Indiana and North Carolina tried the notion; and, as noted earlier, several Christian County farmers tried unsuccessfully to substitute herbicide weed control for post-plant cultivation.

The preliminary stage of the experimental development of no-till planting was inaugurated at several experiment stations with the manufacture and distribution of Atrazine and Paraquat in the late 1950s. Particularly notable were experiments in growing corn in killed sod at the Dixon Springs Experiment Station, Illinois, and the fortuitous linkages with the innovative group in Christian County but also with networks in southern Illinois (van Es et al. 1986). Researchers at the Ohio and Virginia experiment stations also began experimenting with no-till techniques.

When the Allis-Chalmers no-till planter became available in 1966, agricultural scientists felt that they had a developed no-till row cropping system that could be diffused to farmers (van Es and Notier 1988). The operational systems, however, had been developed by the local innovative networks in southwestern Kentucky that, as van Es and Notier (1988) acknowledge, faced difficult problems. The difficulties arose be-
cause the system was not fully developed; moreover, would-be innovators had to reconstruct a system suitable for their farm and available resources.

The infant technoscience of no-till cropping in 1960 developed rapidly in the succeeding decades. While only 4.5 percent of total public and private research funding for agriculture in 1960 went to support research on weeds, insects, and plant nutrition, by 1984 this had increased to 26.1 percent (Coughenour and Chamala 2000). At land-grant universities and the Agricultural Research Service, USDA research on soil-related problems, cropping structures and inputs, as well as management-related research on corn and soybeans, increased substantially during the same period. By the mid-1980s, research and publication had reached the point that agricultural scientists began publishing books on no-till cropping, e.g., Phillips and Phillips (1984), D'Itri (1985), Sprague and Triplett (1986). More recent publications illustrate the progressive expansion of conservation-tillage technoscience of weeds (Hatfield et al. 1998), soil quality (Lal 1999), crop residue management (Unger 1994), and conservation tillage systems (Pierce and Frye 1998; Carter 1994).

As the technoscience has developed, new machines and chemical herbicides were developed and marketed by commercial agribusinesses. Moreover, at the organizational level the institutions and professional advisory services and agencies responsible for the promotion and advocacy of conservation tillage have become more effective. Notably, in the mid-1980s the policy position of the Soil Conservation Service (now Natural Resource Conservation Service) shifted from passive acceptance to active promotion of conservation tillage systems as a means of attaining the goal of soil conservation.

Research has shown that conservation tillage methods overwhelmingly accomplish the intended purpose of minimizing soil erosion and runoff of water (Sims et al. 1994). Moreover, the reduced runoff generally reduces the off-site movement of nutrients and pesticides. Unfortunately, the greater use of herbicides for weed control with less tillage may result in increased movement of chemicals into streams and bodies of water. Even so, after reviewing the literature, Fawcett et al. (1994) concluded that herbicide movement on highly erodible fields was less when any type of conservation tillage method was used compared to plow tillage.

The New Agriculture: Social Movements and Public Policy

This technoscience complex has been and still is powerfully impacted by the surrounding sociopolitical culture—conservation and market
policies, agencies, and environmental movements (cf. Coughenour and Chamala 2000). The soil conservation movement that developed in the 1930s heightened farmers’ concerns with soil erosion (Held and Clawson 1967; Christensen and Norris 1983; Nowak 1984; Swanson et al. 1986), even though many were slow to recognize the amount of erosion on their own farm. While farmers and rural residents were early laggards in their concern with environmental quality (Buttel and Flinn 1974; Marsh and Christenson 1977; Jones and Dunlap 1992), the gap was never very large and gradually narrowed over time as more farmers and rural residents became engaged in debating environmental issues (Lowe and Pinhey 1982; Buttel 1987; Jones and Dunlap 1992; Arcury and Christenson 1993).\footnote{Jones and Dunlap (1992:44) conclude that there was no evidence of a widening of the social bases of environmental concern. They made comparisons of the bivariate correlations and standardized regression coefficients for 1973 to 1982 and for 1983 to 1990 for “Residence at 16” and for “Current residence” with environmental concern. Results reported in their Table 2 indicate a substantial decline in the magnitudes of these coefficients from the first to the second decade, which is consistent with a broadening of the social bases of environmental concern.
\footnote{Studies of adaptive innovation of conservation tillage and cropping in Australia bolster the conclusion that networks of farmers and farm advisors are the central innovative structures in spreading conservation agriculture (Coughenour and Chamala 2000).}
 Initially, progress toward the policy goal of soil conservation was handicapped by agricultural production policies that encouraged cultivation of erosion-prone farmland (Held and Clawson 1965). A change in the rule of what qualified as a cost-sharing practice in the Agriculture, Rural Development and Related Agencies Appropriation Act of 1979, began to change the situation. But the policy conflict between production and conservation goals was not completely eliminated until the Food Security Act of 1985 (Coughenour and Chamala 2000). It provided for the support of farm incomes by targeted commodity prices and deficiency payments while retiring erosion prone land from production through the Conservation Reserve Program (CRP) and requiring farmers to develop and use approved farm conservation plans.

**Discussion and Conclusions**

The successful innovation of no-till cropping was not an individual creation; it was a network product.\footnote{Studies of adaptive innovation of conservation tillage and cropping in Australia bolster the conclusion that networks of farmers and farm advisors are the central innovative structures in spreading conservation agriculture (Coughenour and Chamala 2000).} Doubtless, the common backgrounds of the central figures in the Christian County network had much to do with the readiness with which they became an innovative group. The fortuitous combination of complementary roles—professionals and
farmer experimenters—also were important in the farmers' innovative construction of loosely-coupled, no-till cropping systems. But this does not detract from the central conclusion that the new conservation tillage and cropping frame that emerged was a product not of any one person but rather of multiple individuals, including critical inputs from other farmers, scientists, and commercial companies. Continued research and farmer testing expanded and developed the knowledge of no-tillage cropping into a radically new technoscience society of conservation tillage generally.

On the one hand, the conclusion that the innovation of no-tillage is a product of networking is hardly new. The role of social networks in the process of technological innovation has been explored for a wide range of technologies (e.g., Latour 1987; Bijker et al. 1987; Bijker and Law 1992; Juska and Busch 1994; de Sousa and Busch 1998). In this respect, the innovative network in no-tillage cropping represents simply another case that further confirms the utility of this particular theoretical perspective of the innovative process.

The more important issue is the general applicability of this model of an innovative network to the innovation of no-tillage agriculture in new areas, and to new, loosely-coupled agricultural systems generally. It is necessary to begin this assessment by acknowledging that the model is incomplete in several respects. On the one hand, neither this study nor the excellent article by van Es and Notier (1988) provide a complete analysis of the development of the technoscience of no-till cropping, especially from an actor-network perspective. Similarly, the specific impacts of policy and market changes on no-till innovation require more thorough research than has been provided thus far (e.g., Coughenour and Chamala 2000). Second, the social construction of the techniques—herbicides and tillage and planting machines (without which broadly successful no-tillage systems could not have been constructed)—has not been detailed (e.g., see Peterson 1967). Consequently, at present we have only a partial model of the innovation of no-tillage agriculture.

Nevertheless, the issue of the extent to which the part-model applies to the spread of no-till agriculture is germane. Clearly, a single case study is not sufficient to develop confidence in a new conceptual model of agricultural system change. Confidence in the model is bolstered in some degree by studies in the farming-systems-research tradition (e.g., Cernea et al. 1985; Chambers et al. 1989). Many studies in this tradition emphasize the critical importance of farmer-led research and coordination of off-farm and on-farm research in developing new agricultural systems. This model differs from farming system models in
its focus on the importance of developing local networks and in the emphasis on the change in social identities. It also differs in its emphasis on the importance of development of extra-local linkages and, in the longer time perspective, which paradigmatic change necessarily takes.

The most direct support for the model is provided by the parallel research on conservation tillage innovation in Australia (Coughenour and Chamala 2000). In Queensland, Australia, innovative networks involving agricultural advisors and farmers conducting on-farm research were critical to the construction of new tillage-cropping systems by farmers. One contribution to the model of this companion study is that no-tillage innovation progressed in several steps: minimum tillage or stubble mulching came first; then herbicides were progressively substituted for tillage; until finally changes in economic and/or environmental conditions impelled the adaptive construction of no-tillage cropping as an alternative (Coughenour and Chamala 2000). It is likely that a similar process occurred in the United States in areas in which a substantial increase in no-till cropping occurred during the 1990s. But this is a matter requiring further research.

There is a notable difference between the network model of innovation and the traditional model of innovation-diffusion. The difference is that the focus on predicting system change shifts from the efficacy of the farmer in learning a new technique to the efficacy of farmers, scientists, and advisors in collaborating to reconstruct operative tillage and cropping systems from extant no-till cropping frames. Successful collaborative networks depend on the initiatives of each member. As this research suggests, professional advisors must be committed to the task of working with farmers over a period of several years while successes and failures lead to the construction of new systems adapted to the local agroecology.18

Finally, an issue in the spread of no-tillage cropping is what concepts best describe the processes? The accounts of different innovators (Coughenour and Chamala 2000) make evident that one farmer rarely, if ever, copies another farmer's no-till system. Instead, because the farmer and his farm are the key constraints, a farmer through networking reconstructs19 a no-till cropping system for the farm from

18 When the focus is on the formation of innovative networks, rather than individual farmers, the structure of the network and the different roles individuals play in constructing a new indigenous tillage frame become important. But the notions of innovators and laggards loses meaning and significance.

19 In his discussion of reinvention, Rogers (1983:179) notes that it "may reduce mistakes and encourage customization of the innovation to fit it more appropriately to local and/or changing conditions."
model(s) of successful no-till systems in the general no-till cropping frame. Because the new system entails new value-orientations and goals as well as new relationships, the farmer's identity is reconstructed in the process. This process of culture and identity formation proceeds with tentative ideas, many trials, successive evaluations, and tentative conclusions. For innovators, it is a sequence of trials and evaluations in a slow process of adaptive, or evolutionary, development. For social networks, it is the search and discovery of needed resources, commitments, value-assessments, and new indigenous knowledge.

References


Innovating Conservation Agriculture — Coughenour


