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This article traces the emergence of the basic paradigm for early diffusion research created by two rural sociologists at Iowa State University, Bryce Ryan and Neal C. Gross. The diffusion paradigm spread to an invisible college of midwestern rural sociological researchers in the 1950s and 1960s, and then to a larger, interdisciplinary field of diffusion scholars. By the late 1960s, rural sociologists lost interest in diffusion studies, not because it was ineffective scientifically, but because of lack of support for such study as a consequence of farm overproduction and because most of the interesting research questions were thought to be answered.

The Origins and Development of the Diffusion of Innovations Paradigm as an Example of Scientific Growth

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The diffusion of innovations paradigm began more than fifty years ago when Ryan and Gross (1943) published the results of their hybrid seed corn study. Since then, more than 4,000 research publications have appeared, and diffu-

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242

sion research has become a widely practiced variety of scholarly study in sociology and other social sciences (Rogers forthcoming). This article describes some of the history of rural sociological research on the diffusion of agricultural innovations, in order to understand how this research tradition emerged and to determine how it influenced the larger body of diffusion research conducted later by scholars in other disciplinary specialties. We show how diffusion of innovations research followed, and deviated from, the Kuhnian concept of paradigm development.

"Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1983, 5). The diffusion of innovations is a communication theory that has laid the groundwork for behavior change models across the social sciences, representing a widely applicable perspective. Consequently, it is valuable to know the origins and development of this theory, and valuable to know the ways in which it does, and does not, conform to the Kuhnian model of scientific development.

Stages in a Scientific Advance

Our framework for the present analysis of the rise and fall of rural sociological diffusion research is based on (1) Thomas Kuhn's (1962 [1970]) *The Structure of Scientific Revolutions*, (2) Diana Crane's (1972) *Invisible Colleges*, and (3) Derek de Sola Price's (1963 [1986]) *Little Science, Big Science*. This model of the development of a scientific front argues that scientists in a field are first attracted to a new paradigm, but eventually discard it in favor of a yet newer paradigm. A *paradigm* is a scientific approach to some phenomenon that provides model problems and solutions for a community of scholars (Kuhn 1962 [1970], viii). According to Kuhn, a scientific specialty advances not only in a series of small incremental steps, as hypotheses are proposed, tested, and then revised, but more often moves forward in major jumps and starts (see also Price 1963 [1986]). Pronounced discontinuities occur as a revolutionary paradigm is proposed, offering an entirely new way of looking at some scientific problem. Well-known examples are Copernicus's solar-centered universe, Einstein's relativity theory, Darwinian evolution, and so forth. Paradigms vary widely in their scope and impact, but most have much less impact than the paradigms of Copernicus, Einstein, and Darwin.

Each new paradigm initially attracts a furious amount of intellectual activity as scientists seek to test the new conceptualization, either to advance the new theory or to disprove it. Gradually, over a period of time, an

intellectual consensus about the new paradigm develops among scientists in the field. Scientific interest eventually declines as fewer findings of an exciting nature are reported during a "mopping up" era of research. Kuhn (1962 [1970]) calls this stage "normal science," during which consequential changes continue to occur in work on the research front. At this stage, the research results are incorporated in textbooks in the scientific field. Eventually, however, a yet-newer paradigm may be proposed, setting off another scientific revolution, when anomalies in the existing paradigm are recognized by the "invisible college"¹ of scholars investigating the scientific problem of study, causing a crisis for the older paradigm (Kuhn 1962 [1970], ix).

Here we describe the institutions and scholars who influenced the directions taken by rural sociological research on the diffusion of innovations during the past five decades. Today, diffusion study continues as an active research front, although not in rural sociology. We give particular attention to the role played by (1) two rural sociologists at Iowa State University, Bryce Ryan and Neal C. Gross, and (2) the Subcommittee for the Study of Diffusion of Farm Practices, of the North Central Rural Sociology Committee (hereafter referred to as the "Subcommittee"). The Subcommittee played an important role in helping form an invisible college of rural sociological diffusion researchers in the midwestern state universities in the 1950s and 1960s (Crane 1972). Out of this core of early diffusion scholars grew an expanding set of investigations in various disciplines.

Past studies of the sociology of science generally have focused on a physical or a biological science (Chubin 1983) such as molecular biologists (Mullins 1972), high-energy physicists (Zaltman and Kohler 1972), or biomedical researchers (Lievrouw, Rogers, Lowe, and Nadel 1987). Here we apply the Kuhnian perspective to the case of an important *social* science research front. Prior social studies of science have been conducted (Cole and Zuckerman 1975; Mullins 1973a, 1973b), but Kuhn based his book entirely on physical science examples; he developed his concept of paradigm while he was in regular contact with social scientists at the Center for Advanced Study in the Behavior Sciences at Stanford, California, in 1958-1959. Kuhn (1962 [1970], vii-viii) says that he was impressed with the greater extent of disagreement among social scientists, compared to natural scientists, about the nature of legitimate scientific problems. This difference, Kuhn assumed, was because natural scientists were organized more tightly in invisible colleges, each centered on a paradigm. Does Kuhn's theory of scientific revolutions also apply to an invisible college of social scientists?

Our present study complements and updates Crane's (1972) analysis of the invisible college of rural sociological diffusion researchers, which was

conducted in the late 1960s. Crane combined data from a mailed questionnaire to diffusion scholars with a content analysis of the rural sociological diffusion literature to illuminate the social network structure of these diffusion researchers. We build upon Crane's quantitative analysis with (1) data from oral history interviews, (2) an analysis of the diffusion research literature, and (3) archival sources supplemented by one of the present authors' personal recollections.

The Context of Rural Sociology in the Late 1930s

In the 1930s, most rural sociologists in the United States were employed in the colleges of agriculture of land-grant universities, where they conducted research (funded by the state agricultural experiment stations), taught university courses, and served as subject-matter specialists for the state agricultural extension services (which were headquartered in colleges of agriculture). Rural sociological research on certain social problems, like corporation farms in California and race relations in Mississippi,² led to congressional criticism of rural sociology. Administrators of land-grant colleges of agriculture, who mainly represented a production agriculture orientation (most deans of agriculture at that time were agronomists or animal scientists), perceived rural sociology as of somewhat dubious value and perhaps even as politically dangerous. Accordingly, rural sociology usually was organized as a small and subordinate unit within a department of agricultural economics.³ In sum, the work conducted by U.S. rural sociologists did not fit well with the production agriculture norms of the colleges of agriculture in which they worked.

The new specialty of the diffusion of innovations, however, provided rural sociologists with an opportunity to alter this situation so as to gain favor and support from their university administrators. Diffusion research fit well with the dominant norm on increasing agricultural production. It allowed rural sociologists "to join the team" of their colleagues in colleges of agriculture (Fliegel 1993).

Following World War II, U.S. agriculture was characterized by a rapid rate of technological innovation: antibiotics for livestock disease control, chemical weed sprays, rodenticides, pesticides, hormonal feed additives for livestock, new seed varieties, and improved farm machinery. Consequently, U.S. agricultural production per acre and per worker increased dramatically, in part due to the successful activities of the agricultural extension service, which diffused agricultural innovations to farmers (Rogers 1988). The technology transfer process from U.S. land-grant universities to their farmer

constituents was so highly successful that by the late 1950s food surpluses became a major problem for the United States. The number of persons fed and clothed by the average American farmer increased from 14 in 1950, to 26 in 1960, and to 47 in 1970. As a result of this agricultural revolution, U.S. farms became business enterprises rather than family-subsistence units. American farmers became increasingly concerned with farm productivity, efficiency, competitiveness, and agricultural innovations.

Pre-paradigmatic Research on Diffusion

The earliest scholarly study of diffusion was conducted by Gabriel Tarde (1903), a French lawyer, judge, and academic sociologist, who wrote the influential book *The Laws of Imitation* (note that Tarde did not use the word "diffusion," which came later from anthropologists). Tarde identified the S-shaped curve of the rate of adoption of an innovation, the role of social status, and opinion leadership in the diffusion process. An anthropological and sociological tradition of empirical studies of the diffusion of cultural traits then got under way in the 1920s and 1930s. For example, Pemberton (1936a, 1936b, 1937, 1938) investigated the diffusion of postage stamps and other new ideas. Bowers (1937, 1938) and McVoy (1940) conducted diffusion research on other consumer innovations, but the diffusion paradigm did not form until a few years later—in the 1940s.

Meanwhile, the U.S. Department of Agriculture (USDA) Federal Extension Service conducted evaluation research to determine the relative effectiveness of agricultural bulletins in communicating research results to farmers (Wilson 1927). The USDA research initially did not prompt rural sociologists to begin studying the diffusion of farm innovations—but it did indicate that interest in diffusion was beginning.

Edwin Losey, a rural sociologist at Iowa State University in the 1930s, conducted a community survey of technological innovations in growing watermelon by personally interviewing farmers on Watermelon Island, located in the Mississippi River near Davenport, Iowa. This early diffusion study was never published, although several midwestern rural sociologists were aware of its methodology and findings, and it may have influenced the Ryan and Gross (1943) hybrid seed corn study conducted at Iowa State University a few years later.⁴

Charles R. Hoffer (1942), a rural sociologist at Michigan State University, investigated the adoption of farm innovations by celery growers of Dutch descent in Michigan. He found that bulletins about celery-growing innova-

tions in the Dutch language had no particular advantage in diffusing innovations over such bulletins published in English.

These early studies mainly concerned the role of certain communication channels in the diffusion of agricultural innovations to farmers. They did not explore the nature of the adoption or diffusion processes. The early studies were consistent with the production orientation of colleges of agriculture, and with the desire of agricultural experiment stations to transfer their research findings to farmers via the cooperative extension service. However, these early studies were mainly evaluation researches that lacked a theoretical framework. This preparadigmatic era ended in the early 1940s when Ryan and Gross conducted their noted study of the diffusion of hybrid seed corn in two Iowa communities.

The Iowa Hybrid Seed Corn Study

In the late 1930s, Iowa State University had a particularly outstanding Department of Economics and Sociology under the chairmanship of Theodore Schultz.⁵ Bryce Ryan joined the faculty of this department in 1938 as an "ABD" (he completed his Ph.D. dissertation at Harvard University in 1940). Ryan came to Iowa State with an intellectual interest in nonrational aspects of economic decision making, influenced by the work of Vilfredo Pareto, and by R. B. Dixon (1928) and other scholars of cultural change, through what he refers to as a "quasi-minor" in anthropology at Harvard (Ryan interview, 17 May 1991). Ryan did not have a farm background, and was somewhat ill at ease in the Iowa State environment of studying down-to-earth agricultural problems. Ryan designed the hybrid corn study so as to accommodate his theoretical interests in sociology, with the practical concerns of boosting agricultural production at Iowa State University's College of Agriculture. Ryan chose hybrid seed corn as an innovation of study because "The development of a genetically and economically superior seed type was a scientific achievement of great economic consequence" (Ryan and Gross 1950, 667). Hybrid corn was the most important innovation then diffusing among midwestern farmers, and it had spread very rapidly in the previous ten years.

The new seed was developed at the University of Connecticut agricultural experiment station and at other federally funded research sites around the country, and was then produced and distributed by private seed companies to farmers (Crabb 1948). The hybrid seed had to be purchased anew each year by farmers, unlike the open-pollinated seed that it replaced (which farmers

selected themselves). Planting hybrid seed generally produced a 20 percent yield increase over open-pollinated seed. Hybrid seed also was bred to be more drought resistant, a particularly important quality in the severe droughts of the mid-1930s.

As the hybrid corn study was being designed,⁶ Ryan learned that he was to be assigned a research assistant, Neal C. Gross, a recent graduate of the University of Milwaukee. Ryan invited Gross to arrive at Iowa State University several months early, during the summer of 1941, in order to interview personally the sample of Iowa farmers about their adoption of hybrid corn. Ryan told Gross that in return he could use the data in his master's thesis (Ryan interview, 9 April 1988).

Ryan selected the two communities of Jefferson and Grand Junction, Iowa, about 40 and 50 miles, respectively, west of Ames, as sites for the hybrid corn study. The exact reasons for picking these two communities is unclear today, but they probably were selected because they had been studied previously by C. Arnold Anderson and Ryan in a study of farm tenancy (Ryan interview, 17 May 1991). Jefferson and Grand Junction were considered to be representative of midwestern commercialized farming.

Data for the hybrid seed corn study were gathered by personal interviews conducted by Gross with 345 farmers during that summer. Twelve farmers with less than 20 acres were discarded from the analysis, as were 74 respondents who started farming after hybrid corn began to diffuse. Thus the data analysis was based on 259 respondents; all but two of these farmers had adopted hybrid seed by the time of the interviews in 1941. One important contribution of the Ryan and Gross study was methodological; they pioneered the use of a survey interview approach to measure an individual's innovativeness and certain independent variables related to innovativeness.

The Ryan and Gross hybrid seed corn study laid the basic groundwork for the diffusion paradigm. Unlike the preparadigmatic studies, the Ryan and Gross study advanced theoretical exploration of the diffusion process. The Iowa study was driven by scholarly interest in the relative influence of economic versus social factors in the adoption of a technological innovation. The hybrid corn study established diffusion as essentially a social process. A farmer typically adopted the innovation because of interpersonal communication with other farmers who already had adopted it (Ryan and Gross 1943). Although hybrid corn was a highly profitable innovation for Iowa farmers, most farmers did not adopt the seed when they first heard about it. Instead, a period of 14 years was required from the time at which the first few farmers planted hybrid seed corn (in 1927) until almost everyone in the two Iowa communities adopted it (1941). Almost none of the farmers planted 100 percent of their corn acreage to hybrid seed the first year that they tried it.

The general picture that emerged from the Ryan and Gross study was one of considerable farmer reluctance to adopt this highly profitable innovation, a resistance that was very gradually overcome as a farmer talked with his neighbors who already were satisfied adopters. Thus diffusion appeared to be a social process through which subjective evaluations of an innovation spread from earlier to later adopters rather than one of rational, economic decision making.⁷

Forming the Diffusion Paradigm

Ryan and Gross (1950, 665-666) investigated four main aspects of diffusion, which were to form the heart of the new paradigm: (1) the innovation-decision process for an individual farmer, including the sequential stages of awareness, trial, and adoption; (2) the roles of information sources/channels about the innovation; (3) the S-shaped rate of adoption, a curve that was tested as to whether it fit a normal distribution; and (4) the personal, economic, and social characteristics of various adopter categories (i.e., classification of individuals on the basis of their relative earliness in adopting an innovation).

Awareness precedes adoption of an innovation, by definition, in the innovation-decision process postulated by Ryan and Gross. Iowa farmers averaged five years between their date of awareness and their date of trial adoption of hybrid seed corn. In other words, a farmer generally waited five years after first hearing about the innovation of hybrid corn before planting even a small percentage of his cropland with the new seed. So the innovation-decision process consisted of learning-from-doing.

Ryan and Gross found that farmers initially planted only a small percentage of their corn acreage in the new seed.⁸ This process of small-scale trial before complete adoption occurred for both earlier and later adopters, although later-adopting farmers moved more rapidly from first trial to 100 percent adoption. "In a sense the early acceptors provided a community laboratory from which neighbors could gain some vicarious experience with the new seed over a period of some years" (Ryan and Gross 1943, 18). However, each farmer typically insisted on his own trial before complete acceptance, despite his neighbors' prior use of hybrid seed corn.

Ryan and Gross also determined farmers' sources or channels of information about the innovation. Their respondents often first heard of hybrid seed from seed corn company salesmen (reported by 49 percent of the farmers of study), but neighbors were the most influential source or channel (reported by 46 percent of the respondents) in persuading a farmer to adopt it. The Iowa farmers who were earlier adopters of the innovation typically heard of hybrid

seed from salesmen, while later adopters first heard of hybrid seed from neighbors (as would be expected from the notion of diffusion as a social process).⁹

These differences in communication sources/channels suggested that an individual farmer passed through several stages in the innovation-decision process. The modal time at which the 257 Iowa farmers reached awareness of hybrid seed was in 1935, seven years after it was first introduced; the modal time for beginning adoption (i.e., trial) was ten years after hybrid seed was first introduced. The rate of awareness was faster than the rate of adoption; the awareness curve took off more rapidly than did the adoption curve. Presumably, farmers had a stronger resistance to adopting the innovation than to gaining awareness-knowledge of the new idea.

Ryan and Gross (1943) plotted the distribution of the number of adopters of the innovation over time, and tested whether this curve was normal¹⁰ (with a chi-square goodness-of-fit test). They concluded that the actual rate of hybrid seed adoption differed significantly from the rate of adoption that would be predicted if it had followed a normal distribution. The differences in the distributions were (1) that the total range of times of adoption was four years less than expected; (2) that the predicted number of adopters per year was greater than the actual number in the early years and less than the actual number in the later years of the diffusion process; and (3) that the actual years of adoption were more concentrated around the mean (Ryan and Gross 1943). Nevertheless, the rate of adoption, when plotted cumulatively, formed an S-curve.¹¹

Finally, Ryan and Gross classified farmers into four adopter categories based on their time-of-adoption of hybrid seed. These adopter categories were reported in Gross's master's thesis (1942) and in an Iowa Agricultural Experiment Station Bulletin (Ryan and Gross 1950).¹² The four adopter categories consisted of farmers who adopted: (1) prior to 1933, (2) between 1934 and 1936, (3) between 1937 and 1939, and (4) after 1940 (1937 was the modal year of adoption for the total sample of Iowa farmers). The adopter categories differed on such variables as cosmopolitanness (measured as their number of trips to Des Moines, Iowa's largest city, located about 75 miles from the communities of study), organizational participation, commercial recreation behavior, and so forth (Table 1), but they did not differ on such economic variables as farm tenure. Ryan and Gross (1950) concluded that cosmopolitanness was positively related to innovativeness:

Our most significant observation is in the many evidences that wide social contact is associated with a psychological climate conducive to technological change. This is not to be deemed simply a product of integration of the

TABLE 1
Economic and Social Characteristics of Four Adopter Categories
in the Adoption of Hybrid Seed Corn by Iowa Farmers

<i>The adopter categories differed significantly regarding:</i>	<i>The adopter categories did not differ significantly regarding:</i>
1. Age	1. National ethnicity
2. Formal education	2. Farm tenure
3. Size of farm	3. Mobility
4. Organizational participation	
5. Attendance at organization meetings	
6. Participation in the government farm program	
7. Cosmopolitaness (trips to Des Moines)	
8. Commercial recreation behavior	
9. Reading bulletins	4. Reading books
10. Reading magazines and journals	

SOURCE: Ryan and Gross (1943 and 1950).

individual in his local community. Many of the particular variables apply to extra-community activities. (p. 706)

The Ryan and Gross study was extremely influential, as is indicated by the fact that their 1943 article is the most widely cited publication among the 4,000 diffusion publications today (Rogers forthcoming). The classic study by Ryan and Gross directed later diffusion scholars toward pursuing such research questions as:

1. What variables are related to innovativeness? In other words, what are the different characteristics of adopter categories?
2. What is the rate of adoption of an innovation, and what factors, like the perceived attributes of the innovation, explain this rate?
3. What role do different communication source/channels play at various stages in the innovation-decision process?

These research directions have dominated almost all diffusion studies since 1943.

The research paradigm created by the Ryan and Gross investigation became the academic template that was to be mimicked, first by other rural sociologists in their agricultural diffusion researches, and then by almost all other diffusion research traditions (whether they knew it or not). (Rogers 1983, 56).

Ryan and Gross could have improved their research by gathering sociometric data about network links among their sample of farmers. After all, the complete enumeration of all farmers in the two communities of study is

ideally suited to network analysis. But no sociometric questions were asked of the Iowa respondents (Gross 1942, 168-169). A network analysis could have enabled the two rural sociologists to better understand the flows of interpersonal influences about hybrid corn during the diffusion process. However, when these scholars designed the hybrid corn study, they did not understand the degree to which diffusion was a social process, and so they failed to gather the data that would have more fully illuminated such interactions. Nor did Ryan and Gross collect or incorporate spatial data in their analysis (Hägerstrand 1967), although a farmer's physical location may have affected his/her communication behavior.

The Lag in Forming an Invisible College

The Ryan and Gross hybrid seed corn study established the paradigm for diffusion research, but it did not lead immediately to conduct of diffusion researches by other rural sociologists. Fifteen more years went by before diffusion researchers developed an invisible college. This time lag following the Ryan and Gross study is an exception to Crane's (1972) model of scientific progress in which an invisible college is expected to form quickly around a new paradigm. Possible reasons for the delay in the case of diffusion research are:

1. Gross left for service in the U.S. Navy in 1942 during World War II, shortly after completing his master's thesis at Iowa State, based on the hybrid corn diffusion data (Gross 1942). He returned to the United States in late 1945 to complete some further data analysis and to assist Ryan, then at Rutgers University, in rewriting his master's thesis into Iowa Agricultural Experiment Station Research Bulletin 372 (Ryan and Gross 1950), a research monograph reporting the hybrid corn study in more detail than the Ryan and Gross (1943) article in the journal *Rural Sociology*. "As I recall, I wrote the Bulletin while at Rutgers, except for statistical tests and sent it to Neal Gross—now back in Ames." (Ryan interview, 17 May 1991)¹³
2. Funding for diffusion research from state agricultural experiment stations did not begin on a widespread basis until the early 1950s. Iowa State's George M. Beal and Joe M. Bohlen popularized rural sociological diffusion research, starting in 1954, which led to funding for numerous rural sociology diffusion researches (as will be discussed below).
3. The North Central Rural Sociology Subcommittee for the Study of Diffusion of Farm Practices was not yet established. So there was no formal mechanism for bringing together the few scattered diffusion researchers. After 1954, the Midwest Sociological Society began to include papers about diffusion in its annual conference programs, as did the Rural Sociological Society.

TABLE 2
The Rise and Fall of the Diffusion Paradigm among Rural Sociologists

<i>Stages in the Development of a Scientific Paradigm^a</i>	<i>Main Events in the Development of the Diffusion Paradigm by Rural Sociologists</i>
1. The paradigm appears.	The Ryan and Gross (1943) study of the diffusion of hybrid seed corn in two Iowa communities.
2. Normal science: An invisible college forms around the paradigm.	Beal and Bohlen (1955) popularize the diffusion paradigm, and the North Central Subcommittee facilitates the formation of an invisible college of diffusion scholars, who were mainly located in midwestern land-grant universities.
3. A decline in scholarly interest begins as the major research problems are solved, anomalies appear, and controversy occurs.	Fewer new scholars are attracted to the diffusion paradigm after 1960, and few innovations occur in diffusion research. The number of U.S. diffusion publications per year declines after 1958, and the number in developing nations declines after 1964 (see Figure 2). However, the diffusion paradigm spreads widely to other social science disciplines after about 1960.
4. Exhaustion	The number of diffusion publications by rural sociologists dies out after 1967 (except for a few post-1975 studies of the diffusion of conservation innovations), due to farm surpluses since about 1960, and to the farm crises of the 1980s.

a. SOURCES: Kuhn (1962; 1970) and Crane (1972, 172).

The Ryan and Gross study established the basic elements of the diffusion paradigm, both for rural sociologists and for other, later diffusion scholars. A content analysis of the 403 diffusion publications by rural sociologists from 1941 to mid-1966 shows that the Ryan and Gross (1943) article contained 15 of the 18 most widely used research innovations.¹⁴ A research innovation consisted of the first use of an independent or dependent variable by a diffusion scholar. For example, Ryan and Gross (1943) reported a relationship between cosmopolitanism (measured by the number of trips to Des Moines) and innovativeness (a farmer's earliness or lateness in adopting hybrid corn). This relationship represents two innovations in Crane's (1972) analysis: The independent variable of cosmopolitanism and the dependent variable of innovativeness.¹⁵ The next several decades of diffusion research were largely committed to filling in the details of the basic paradigm, through conduct of what Kuhn (1962 [1970]) calls "normal science" (Table 2).

Forming the Invisible College for Diffusion Research

Crane's (1972, 153) study of the network of 221 diffusion scholars in rural sociology in 1967 disclosed ten cliques that were highly integrated into an

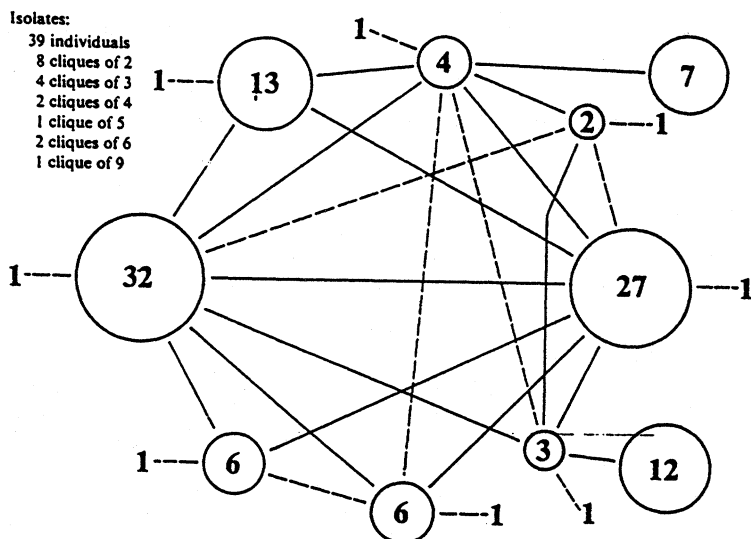


Figure 1: The invisible college of diffusion scholars in rural sociology in 1967.

SOURCES: Rogers (1983, 58) and Crane (1972, 188-189).

NOTE: Each circle represents a clique, and the number indicates how many scholars are members of each clique. The solid lines represent direct collaboration, and the dotted lines show indirect collaboration. The two largest cliques of 32 and 27 members serve to integrate the invisible college of rural sociology diffusion researchers.

invisible college. Each clique centered on a high-producing diffusion scholar: Eugene A. Wilkening at the University of Wisconsin, Herbert F. Lionberger at the University of Missouri, A. Lee Coleman at the University of Kentucky, and others (Figure 1). Six percent of the 221 diffusion scholars received 58 percent of the network choices as (1) a teacher, (2) a discussion partner about research, (3) an influencer about choice of research problems and methodology, and (4) having collaborative work in progress (Crane 1972, 50).

The integration of this network of scholars was facilitated by the North Central Subcommittee for the Study of Diffusion of Farm Practices. The North Central Rural Sociology Committee, which established the Subcommittee, was a coordinating body for rural sociology with representatives from each of the sixteen midwestern states—from Kansas to Kentucky, and from North Dakota to Ohio. The Subcommittee, usually composed of five or six professors who were leading diffusion scholars,¹⁶ was funded by the Farm Foundation (a private foundation supported by the International Harvester Company, a major manufacturer of farm machinery). The Farm Foundation,

headquartered in downtown Chicago, provided a meeting venue for the Subcommittee's twice-a-year, two-day meetings, and paid the members' travel expenses. At the Subcommittee's meetings, the rural sociologists exchanged ideas about their diffusion research in a discussion that was lively and in which criticism was direct but helpful. The meetings were small and informal, and usually continued over luncheon meals at Berghoff's and dinner at George Diamonds' Steakhouse.

The first, and most influential, report by the North Central Subcommittee was a synthesis of diffusion studies to date by George M. Beal and Joe M. Bohlen (1955): *How Farm People Accept New Ideas*.¹⁷ Five stages in the innovation-decision process were postulated: (1) awareness, (2) interest, (3) evaluation, (4) trial, and (5) adoption (also see Beal, Rogers, and Bohlen 1957). This Subcommittee publication also discussed the role of various sources/channels of communication at these five stages, establishing a more general case for the social nature of the diffusion process that Ryan and Gross (1943) had established earlier. The 1955 Subcommittee report also discussed the role of opinion leaders, community norms, and the compatibility of an innovation in relation to rate of adoption.

Beal and Bohlen (1957) also wrote North Central Report Number 18, *The Diffusion Process*, a follow-up publication that appeared two years after Report Number 15. The 1957 report classified adopters as (1) innovators, (2) early adopters, (3) early majority, (4) majority, and (5) non-adopters.

The main pioneers in agricultural diffusion research, members of the Subcommittee at one time or another, include:

1. Eugene A. Wilkening received his Ph.D. degree from the University of Chicago in 1950. His dissertation was a study of the adoption of farm innovations in North Carolina. Wilkening found that sources/channels of communication about farm innovations depended on (1) a farmer's socioeconomic status and (2) the attributes of the farm innovation of study. Higher socioeconomic farmers were more likely to use mass media communication channels, such as agricultural extension publications and farm magazines. Lower socioeconomic farmers depended more heavily on such interpersonal sources/channels of communication as neighbors, relatives, friends, and commercial dealers of farm products (Wilkening 1950; 1952a; 1952b; 1952c). In 1952, Wilkening moved from the University of North Carolina to the University of Wisconsin, where he: (1) conducted research on family factors and on individuals' values in adoption (Wilkening 1953; 1958a; 1958b), and (2) trained a cadre of diffusion scholars. Wilkening is the senior scholar in the large clique with thirty-two members shown in Figure 1, which included James Copp and Frederick Fliegel.
2. Copp received his Ph.D. degree at the University of Wisconsin where Wilkening was his dissertation advisor, and then joined the faculty at Kansas State

- University, where he studied the diffusion of innovations among cattlemen (Copp 1956, 1958; Copp, Sill, and Brown 1958). In 1956, Copp moved to Pennsylvania State University and eventually out of active participation in diffusion research.
3. Frederick "Fritz" Fliegel also received his Ph.D. degree in 1956 (Fliegel 1957) at the University of Wisconsin under Wilkening. He then joined the faculty at Pennsylvania State University, where he pioneered research on how farmers' perceived attributes of an innovation are related to its rate of adoption (Fliegel and Kivlin 1962a, 1962b). Fliegel also conducted diffusion research in India for Michigan State University, after which he moved to the University of Illinois, where his activity as a diffusion scholar wound down.
 4. Herbert F. Lionberger received his Ph.D. degree from the University of Missouri in 1950, where he then served as a faculty member in rural sociology for the rest of his career. He studied farmers' sources/channels of communication in their innovation-adoption decisions, particularly focusing on low-income farmers (Lionberger 1949, 1951, 1953, 1955, 1956; Lionberger and Hassinger 1954). Lionberger (1960) published the first book, *Adoption of New Ideas and Practices*, based on rural sociology diffusion research. He explored the role of socioeconomic status and prestige in the interpersonal networks of diffusion in a more progressive, and a less progressive, Missouri community. Like Wilkening, Lionberger helped train a future generation of diffusion researchers.
 5. A. Lee Coleman conducted survey research for the U.S. Army during World War II as part of *The American Soldier* studies directed by Samuel A. Stouffer. After returning to civilian life in 1945, Coleman studied the diffusion of soil conservation innovations in Stephenson County, Illinois, for the U.S. Department of Agriculture. Coleman (1946) drew on the diffusion paradigm formulated by Ryan and Gross (1943), but pioneered in gathering sociometric data to identify farmer opinion leaders in the diffusion of such conservation innovations as strip-cropping, terracing, contouring, and building grassed waterways. Because water runs downhill from one farm to another, soil conservation is a community-level diffusion problem. Coleman earned his Ph.D. degree at Cornell University, and in 1949 accepted a faculty position at the University of Kentucky, where he initiated a diffusion project in Washington County, Kentucky, on how neighborhood norms affected farmers' innovation adoption decisions (Coleman 1951, 1982).
 6. C. Paul Marsh joined the Kentucky faculty in 1952, and became an active collaborator with Coleman (Coleman and Marsh 1955a, 1955b; Marsh and Coleman 1954a, 1954b, 1954c, 1956). Coleman and Marsh found that communities with more innovative norms tended to have innovative opinion leaders, whereas leaders in communities that were less innovative were also less innovative. Thus leaders highly conformed to the norms of their system, and helped establish the community norms on innovativeness. Here was evidence not only that diffusion was a social process but that a system's social structure (e.g., its norms and leaders) affected the diffusion process.
 7. C. Milton Coughenour received his Ph.D. degree in 1953 from the University of Missouri, where Lionberger guided his dissertation. Coughenour then

continued his diffusion research at Missouri, until he joined the faculty of the University of Kentucky, when Paul Marsh moved to the University of North Carolina in the mid-1950s. Coughenour completed the diffusion project initiated by Coleman and Marsh in Washington County, showing that patterns of communication relationships led to differences in neighborhood norms on innovativeness (Coughenour 1960, 1964, 1991).

8. George M. Beal and Joe M. Bohlen earned their Ph.D. degrees at Iowa State University and began conducting diffusion research there in 1954, picking up where Ryan and Gross had left off a dozen years earlier. A key turning point occurred in December 1954, when Beal and Bohlen were invited to address the Iowa Extension Service's annual conference in Ames about the diffusion process.¹⁸ Their presentation (and the Subcommittee's 1955 report summarizing it) popularized diffusion research, and clarified the two main elements in the diffusion paradigm (as we discuss below).
9. Everett M. Rogers returned in 1954 from military service to graduate work at Iowa State University. His advisor, Beal, was then planning a diffusion study in Collins, Iowa, a farm community located about 20 miles southeast of Ames, in order to investigate the diffusion of several farm innovations rather than a single innovation (like hybrid corn). Beal and Rogers collected sociometric data from the Collins respondents about the networks in which they discussed agricultural innovations. Rogers's Ph.D. dissertation in 1957 at Iowa State was based on the Collins study (Rogers 1957) as were several other publications (Rogers 1958; Beal and Rogers 1957a, 1957b, 1958; Rogers and Beal 1958a; 1958b). Then Rogers joined the faculty in rural sociology at Ohio State University and began studying the diffusion of farm innovations in Ohio (Rogers and Burdge 1961). He synthesized diffusion work in *Diffusion of Innovations* (Rogers 1962).

These influential scholars in the invisible college of diffusion research led in producing diffusion publications, in training younger investigators, and in advancing the research front by means of new variables of study and new research designs. Ten "high producers" (each of whom had authored more than 10 publications) were identified by Crane (1972, 49) among the rural sociologists who had studied diffusion by 1967. Each such scholar led one of the invisible college cliques, and served to connect that clique via network links to the larger invisible college (see Figure 1).

Popularizing the Diffusion Paradigm

Beal and Bohlen created a 32-foot-long flannel-board for their presentation of the diffusion model at the 1954 Iowa Extension Service annual conference. This flannel-board presentation came to symbolize diffusion research in rural sociology during its normal science stage (see Table 2). The

presentation synthesized the research findings of Wilson, Hoffer, Ryan and Gross, Lionberger, Wilkening, Coleman and Marsh, and others. Two main dimensions were emphasized: (1) stages in the individual-level innovation-decision process and (2) the characteristics of adopter categories.¹⁹

C. R. "Dutch" Elder, Director of Information in the Iowa Extension Service, was influential in arranging the Beal-Bohlen presentation at the 1954 Extension Service conference. Elder said:

"If you guys [Beal and Bohlen] know so much about how farmers accept new technology . . . put it together and I'll give you a shot at our annual conference." (Quoted by Beal in an interview, 11 May 1991).

Elder was chairman of the American Association of Agriculture Editors (AACE), and was responsible for their annual conference in Omaha, held on 24 July 1955. Beal and Bohlen's flannel-board presentation, originally developed for their earlier presentation at Iowa State University, also was well-received in Omaha, and led directly to invitations to Beal and Bohlen to make their presentation at more than thirty state annual extension conferences during the following year or two. Beal and Bohlen also made their diffusion presentation to professional meetings of farmer cooperative leaders and to agricultural companies like Dow Chemical Company and Monsanto.

The Beal and Bohlen presentation generated funding for their diffusion research at Iowa State. For example, the National Plant Food Association (the trade association of the agricultural fertilizer industry) provided \$50,000 to support graduate students and facilities in the diffusion research "shop" in the Department of Sociology at Iowa State University.²⁰ Beal and Bohlen repeated their flannel-board presentation for the next fifteen years, from 1954 to 1969, making an estimated 600 presentations (Beal interview, 11 May 1991). The Beal and Bohlen flannel-board presentation had a strong impact for a number of reasons:

1. The attractive visual display made the complexity of the diffusion process understandable to professional audiences.
2. The duo of Beal and Bohlen became a polished act with one presenter occasionally finishing a sentence for the other. Such a two-person presentation was unique, and helped attract and hold attention, as did the 32-foot-long flannel-board.
3. The content of their diffusion presentation was highly relevant in an era of rapid advances in agricultural technology, especially to professional change agents responsible for diffusing agricultural innovations.

4. Beal and Bohlen were leading researchers in the diffusion field. To supplement their synthesis of the Ryan and Gross and other diffusion studies, they included their own research findings in their presentations.

As mentioned above, Beal and Bohlen published their flannel-board presentation as a Subcommittee report,²¹ *How Farm People Accept New Ideas*, and also as a magazine article in *Agricultural Leaders Digest* (Beal and Bohlen 1955). The Beal-Bohlen presentations created an audience for the Subcommittee report, which was very widely distributed in answer to requests. The main elements of the diffusion paradigm represented in the Beal and Bohlen flannel-board presentation and in the publications based on it were:

1. The innovation-decision process, conceptualized as an over-time sequence of five stages for an individual: (1) awareness, (2) interest, (3) evaluation, (4) trial, and (5) adoption.²²
2. The role of different communication sources/channels at various stages in the innovation-decision process. The mass media were relatively more important in creating awareness-knowledge of an innovation, while interpersonal sources or channels were more important at the evaluation stage, when the individual decides whether or not to adopt the innovation.
3. The characteristics of adopter categories, classified on the basis of time-of-adoption (i.e., innovativeness), were described. Ryan and Gross (1943) were the first to classify adopters based on time-of-adoption, a technique also used by Wilkening, Lionberger, Beal and Bohlen, and others. Adopter categories provided the basis for audience segmentation: Each adopter category had certain characteristics (cosmopolitanism, socioeconomic status, mass media exposure, extension service contact, etc.), which were used to improve communication strategies for diffusion. So diffusion research findings on the attributes of adopter categories were actionable by policymakers and by change agents.

Thomas Kuhn's conceptualization of a scientific revolution did not specify the role of popularizers of a new paradigm, other than the spontaneous spread of the paradigm among scientists in the specialty area. But in the case at hand, Beal and Bohlen carried the notion of the diffusion process to wide audiences of potential research funders, to administrators and officials in colleges of agriculture and in the Cooperative Extension Service, and to professional change agents who used diffusion research findings. Thus the popularization of diffusion research was very important in the expansion of the invisible college of rural sociological scholars of diffusion. Populariza-

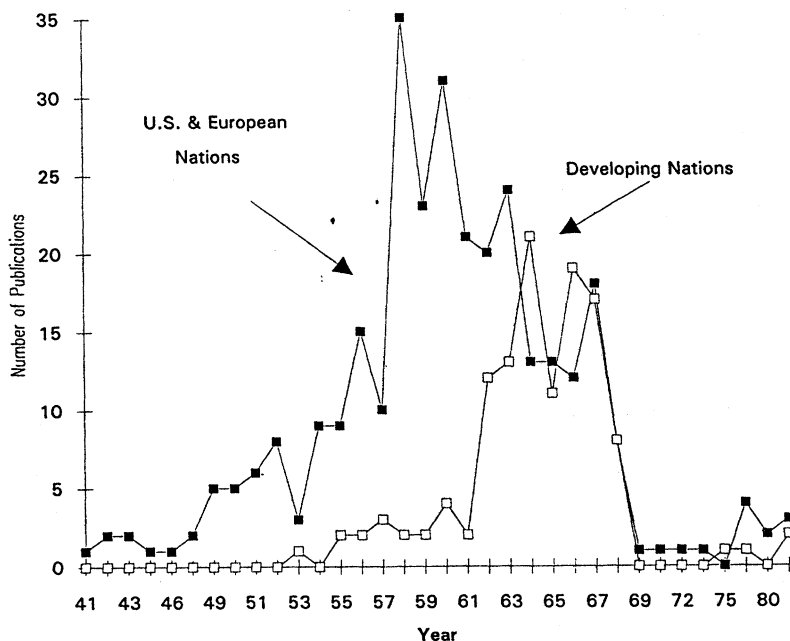


Figure 2: The number of diffusion publications by rural sociologists, by year, for the United States and Europe versus the developing nations of Latin America, Africa, and Asia.

SOURCES: Rogers and Shoemaker (1971) and Rogers (1983).

NOTE: A total of 434 rural sociology publications on diffusion appeared from 1941 to 1981. Of the 331 U.S. and European diffusion publications, thirty-six (13 percent) were European and one was Australian. A total of 103 publications reported diffusion research in Latin America, Africa, and Asia. The location of each diffusion study is determined on the basis of where the data were gathered, not where the research was published.

tion remains an understudied aspect of the social study of science (Lievrouw and Carley 1991).

Growth and Decline of Rural Sociological Interest in Diffusion

Diffusion research by rural sociologists underwent a rapid spurt after 1955, first in the United States and Europe, and then in the developing nations

of Latin America, Africa, and Asia (Figure 2). Virtually all of the diffusion publications until 1960 were published with data from U.S. farmers; however, from the mid-1960s, about as many studies were published from data collected in developing countries.²³

The spread of diffusion research to developing nations after 1960 occurred through (1) U.S. rural sociologists who conducted studies in Latin America, Africa, and Asia, and (2) two particularly influential studies: one in East Pakistan (now Bangladesh) by Syed Rahim (1961) and one in Colombia by Paul Deutschmann and Orlando Falls Borda (1962). Developing nations in the 1960s were trying to increase food production through the spread of agricultural innovations, and the diffusion paradigm seemed to offer helpful solutions. However, the number of diffusion publications in the United States declined dramatically after 1958, and after 1967 in developing nations.²⁴ Thereafter, relatively few diffusion publications were authored by rural sociologists. The major research problems had been solved, and controversies arose (see Table 2). Intellectual criticism of diffusion research arose during the late 1960s and early 1970s (Rogers 1983). The diffusion paradigm, which was developed by rural sociologists in the U.S. midwestern states during the 1940s and 1950s, spread internationally among rural sociologists during the 1960s, and then died out almost completely after 1968 among rural sociologists (although not among other scholars). So the subfield of rural sociological diffusion researchers fell, but not the diffusion paradigm, which has gradually been modified in response to critique as it spread to other fields.

The decline of research interest in diffusion research by rural sociologists resulted in part from the fact that the paradigm had been successful in answering the major theoretical questions. Crane (1972, 67) concluded:

"In the rural sociology area, a significant proportion of the innovative work in the area had already been done by the time [around 1960] the field began to acquire a significant number of new members."

Few interesting intellectual questions remained to pursue, the number of new scholars attracted to the invisible college declined (Crane 1972, 161), and several of the leading diffusion scholars left the field.

The relative lack of interesting new research questions after the mid-1950s is demonstrated in Figure 3, which shows that during the 25-year period from 1941 to 1966, the number of research innovations averaged about forty for each of the five 5-year periods. During this 25-year period, the number of diffusion publications increased spectacularly from 6 to 187, with the takeoff occurring more than a decade after publication of the Ryan and Gross (1943) study. Hence the ratio of research innovations in rural sociological diffusion research (i.e., the introduction of a new variable of analysis) decreased

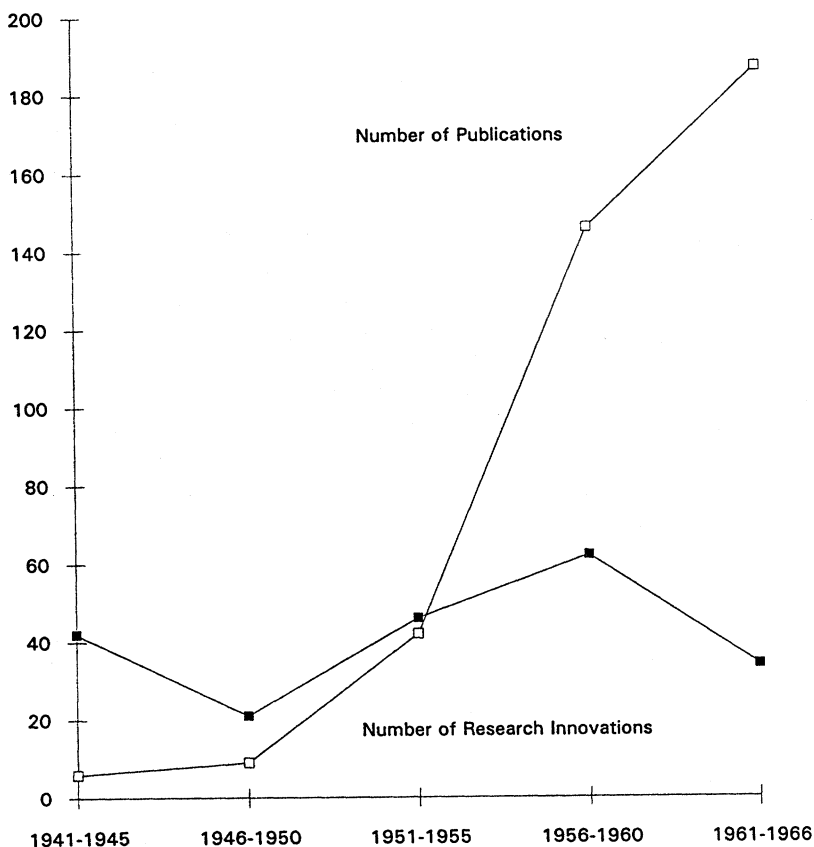


Figure 3: The number of diffusion research innovations and number of publications by five-year intervals, for the invisible college of rural sociological diffusion researchers.

SOURCE: Crane (1972, 161).

NOTE: Ratio: 7.0; 2.3; 1.1; 0.42; 0.18. The ratio of research innovations to publications drastically decreased after the mid-1950s, indicating a lack of new ideas but a continuing growth in the publication activities of invisible college of rural sociological diffusion investigators.

drastically during the 25-year period, dropping almost to 0 in the two final 5-year intervals. This decrease meant that the diffusion research front grew stale as the scholarly literature consisted mainly of replications.

When a paradigm faces such a crisis, the rate of further research activity is expected to drop (Kuhn 1962 [1970]; Price 1963). Thus, in this particular

case, the paradigm was not found inadequate in its explanatory power; rather, it became boring and stale as the main research questions were answered. Unlike the general case described by Kuhn and others, the Ryan and Gross paradigm was not replaced by an alternative paradigm to explain the diffusion of innovations.

Further, in this particular case, the mounting food surpluses produced by U.S. farmers led policymakers to question the previous value on raising agricultural production by diffusing farm innovations. Instead, rural sociologists turned their attention to finding solutions to the farm crisis caused by agricultural overproduction. So not only did the intellectual excitement of agricultural diffusion research burn out in the mid-1950s, but policymakers in agriculture (and rural sociologists themselves) began to see that the original conditions creating a need for diffusion research in agriculture had changed. Diffusion study by rural sociologists no longer promised to contribute toward solving a social problem; instead, it could possibly worsen the problem of farm overproduction.

During the late 1960s and early 1970s, diffusion researchers in rural sociology began to assess their body of accumulated research more critically (Rogers 1983). For instance, the anticipated and unanticipated consequences of diffusion were explored (Goss 1979; Havens 1975), and scholarly work by rural sociologists began to analyze the issue of whether the impacts of technological innovations were universally beneficial. Questions were raised about the environmental consequences of pesticides and other agricultural chemicals on the health of farmers and on the consumers of farm products. Several agricultural innovations like 2,4-D weed spray and diethyl stilbestrol for cattle feeding were banned by federal agencies because of their carcinogenic consequences. Such controversy and criticisms of a paradigm are typical (1) when the intellectual attraction of an invisible college is exhausted and (2) when external conditions change (see Table 2).

After 1975, several U.S. rural sociologists turned their scholarly attention to studying the diffusion of conservation and other ecology-related innovations as the result of growing national concerns with environmental problems. This new type of diffusion study by U.S. rural sociologists accounts for the completion of several diffusion publications per year in the late 1970s and early 1980s (see Figure 2), and which has continued in the years since the end of our time series in 1981. While the 1950s were years of achieving greater farm productivity in the U.S., and the 1960s were years of attempts at increasing farm productivity in Latin America, Africa, and Asia via the Green Revolution,²⁵ the 1980s and early 1990s were a time of concern the conservation of natural resources. The nature of rural sociological research

on the diffusion of innovations, which continued at a very low level of activity from 1969 to 1975, then changed to suit these contextual conditions.

The Diffusion Paradigm's Spread to Other Scientific Specialties

The diffusion paradigm was confined largely to rural sociologists throughout the 1950s. However, during the 1960s, the diffusion paradigm spread to other scientific specialties, such as public health, economics, geography, marketing, political science, and communication. One reason was publication of Rogers's (1962) *Diffusion of Innovations*, which made research results in rural sociology (and in education, anthropology, and other fields) more easily accessible to scholars. This book argued that the diffusion of innovations was a general process—whether the individuals adopting were farmers, medical doctors, or others.

An important turning point in the broadening of diffusion study beyond rural sociology was the Coleman, Menzel, and Katz (1957; Coleman, Katz, and Menzel 1966) study of the diffusion of a new antibiotic drug, tetracycline, among physicians in four Illinois communities. This study by scholars at Columbia University's Bureau of Applied Social Research was conducted in the mid-1950s. It was published in various journal articles and eventually as a book (Coleman, Katz, and Menzel 1966). The Columbia University drug study used network analysis to further specify the social process at the heart of the diffusion of innovations. The drug study showed that opinion leaders adopted the new drug relatively earlier, and shared their personal experiences with other physicians, which then accelerated the innovation's rate of adoption.²⁶

Katz, Levine, and Hamilton (1963) detailed the basic similarities among diffusion researches in medical sociology, rural sociology, and anthropology. Findings from the drug study were strikingly similar to the rural sociological diffusion findings, despite the fact that the Columbia University sociologists were unaware of the rural sociology tradition of diffusion research when they began their study (Rogers 1962). So the hybrid corn study and the drug study represent an illustration of independent invention (Merton 1973).

Finally, during the 1960s, hundreds of departments of communication were created at U.S. universities (Rogers 1994), and—since the diffusion of innovations was a special kind of communication process—diffusion studies soon began to be conducted by the new communication scholars. For example, Deutschmann and Danielson (1960) published an influential study of the diffusion of major news events among the U.S. public.

Diffusion research thus became an interdisciplinary field, rather than one centered in rural sociology. During the 1960s and 1970s, the diffusion paradigm spread to each of the social science disciplines. Each of these new subinvisible colleges followed the Ryan and Gross paradigm, while making some modifications to it.

Conclusions

The rise of rural sociological research on the diffusion of innovations generally fits the model for a scientific revolution (see Table 2) proposed by Kuhn and others, but with several important exceptions.

A few diffusion studies were completed before the paradigm was formulated by Ryan and Gross (1943), but these pre-paradigmatic studies added little to accumulated knowledge because these fact-finding investigations did not form a coherent scholarly tradition. The Ryan and Gross study (1943) created the paradigm for studying the diffusion of innovations. Then, a period of 15 years occurred before the Ryan and Gross paradigm began to attract an invisible college. This considerable time lag is not consistent with the usual stages in the growth of a scientific paradigm (Kuhn 1962 [1970]). We think that this delay was mainly due to the interruption of World War II. Here we see how external conditions affect the growth of a scientific paradigm.

The normal science stage of diffusion research was then led by scholars like Beal, Bohlen, Wilkening, Lionberger, Coleman, Marsh, Copp, Fliegel, Coughenour, and Rogers. These researchers participated in the North Central Subcommittee meetings, which facilitated their collaboration in an invisible college. They shared research results, instruments, terminology, and applications of the diffusion paradigm, advancing it through a series of relatively minor scientific innovations until about 1960. Iowa State University played a particularly key role in the rise of rural sociological diffusion research, not only as the site of the early diffusion study by Ryan and Gross, but also for the Beal and Bohlen synthesis of available research findings, leading to popularization of the diffusion paradigm. Iowa State then attracted additional scholars and funding, and made useful applications of diffusion, as did other midwestern land-grant universities like Wisconsin, Missouri, and Kentucky.

Popularization of the diffusion paradigm by Beal and Bohlen to important relevant publics in the task environment of rural sociology helped attract funds and other support, thus facilitating expansion of the invisible college. The Kuhnian conceptualization of scientific growth does not recognize the role of popularizers of a scientific paradigm, which in the present case was very important.

Eventually, shortly after the demise of the diffusion paradigm in rural sociology began about 1960, the paradigm spread widely to other social science disciplines after the paradigm was published in book form (Rogers 1962). So the diffusion paradigm itself did not decline—just the original invisible college of rural sociologists who followed this paradigm. Such exporting of a scientific paradigm to other invisible colleges was not anticipated by Kuhn and others who assumed that a paradigm would only spread in a single discipline.

After six years (from 1954 to 1960) of active research by rural sociologists during the stage of normal science, the number of publications about diffusion by rural sociologists began to decrease gradually, first in the United States and then, after 1964, in developing nations. This decline was not caused by the lack of explanatory power of the Ryan and Gross paradigm and its replacement by an alternative conceptualization. Instead, for the applied field of rural sociology, the changing policy environment (from highly valuing increased agricultural production to a greater concern about farm surpluses) contributed to the decline of rural sociological research on diffusion. Here we go beyond the Kuhnian conception of scientific revolutions to suggest that the policy environment for a scientific specialty is a crucial dimension of its growth and decline. After 1969, the excitement of scientific puzzle-solving had decreased; in the face of crisis and criticism, the invisible college of rural sociologists studying agricultural diffusion was exhausted.

Thus, for this case of a social science paradigm, we have pointed out important exceptions to the Kuhnian model. These deviations from normal paradigm growth should be explored in other research specialties, especially those in the social sciences. Moreover, these deviations have important implications for how knowledge is generated and communicated to other specialists and publics. Particularly relevant is the finding that diffusion research in rural sociology died out not because of the theory's lack of explanatory power, but rather because of the changing climate in which rural sociology operated. Research fronts may emerge to meet economic and political needs and die out when this backdrop changes.

Notes

1. An *invisible college* is the informal network of researchers who form around an intellectual paradigm to study a common topic. This definition is based on Price (1963 [1986]), who coined the term, and Crane (1972). See Lievrouw (1990) for a critique of the concept.

2. These studies were conducted as part of a series of rural community studies in different regions of the U.S., under the general direction of Carl C. Taylor, in the Division of Population and Rural Life, U.S. Department of Agriculture.

3. Rural sociology had department status, however, at Cornell University and the University of Wisconsin.

4. George Beal, who was a student and later a faculty member at Iowa State University soon after the Ryan and Gross research was conducted, thinks that the hybrid corn study was influenced by the Losey study of Watermelon Island (Beal interview, 11 May 1991).

5. Schultz later won the Nobel Prize in Economics while he was a faculty member at the University of Chicago. He resigned from Iowa State University (ISU) in 1939 as the result of a controversy about the economics of margarine versus butter. In response to pressures from the powerful dairy interests in the state, ISU President Charles Friley blocked the publication of research evidence that margarine was nutritionally equivalent to butter and a much better buy.

6. Professor C. Arnold Anderson, a sociologist at Iowa State, advised Ryan on the design of the hybrid corn study, as did agricultural statistics professors George Snedecor, Ray J. Jensen, and Paul G. Homemeyer. Ryan's colleagues, professors Ramon Schickele and A. C. Bunce, economists in ISU's Department of Economics and Sociology, also contributed ideas to the hybrid corn study (Ryan and Gross 1950; Ryan interview, 17 May 1991).

7. This conclusion by Ryan and Gross was later to be disputed by economist Zvi Griliches (1957) on the basis of his analysis of aggregate data about the diffusion of hybrid corn in the United States.

8. The widespread trial of this innovation by Iowa farmers was encouraged by the hybrid seed corn companies, who often gave each farmer a free packet of the new seed. To facilitate comparison with the farmer's open-pollinated corn growing in the rest of the field, the packet typically contained enough seed to plant several rows across a farmer's cornfield.

9. After the original hybrid corn study, Ryan gathered data in 1942 from a statewide sample of 438 Iowa farmers. Ryan found that regions of the state that started adopting hybrid seed later had a faster rate of adoption of the innovation. Ryan (1948, 281) stated, "The shortening of the acceptance process for later adopters surely testified to some breaking down of the cautions exemplified by earlier adopters." Again, as in the Ryan and Gross (1943) two-community study, evidence was found of the social nature of the diffusion process in which Iowa farmers evaluated the innovation through the opinions of their peers.

10. Ryan and Gross (1943) cited Chapin (1928) and Pemberton (1936a; 1937) for postulating an S-shaped, and presumably normal, rate of adoption for an innovation.

11. Ryan and Gross did not use the logistic curve as a model for the rate of adoption (in fact, they argued against it). The logistic curve later proved useful to Davis (1941); Hart (1945); Dodd (1955); Coleman, Katz, and Menzel (1966); Hamblin, Jacobsen, and Miller (1973); Mahajan and Peterson (1985); Valente (1993); and other diffusion scholars.

12. The 1950 bulletin was an expanded version of the Gross (1942) thesis and of their 1943 *Rural Sociology* journal article, and provided a comparison of the influence of economic variables and social variables in the diffusion of hybrid seed corn. Gross later used data about the adoption of other farm innovations than hybrid corn, collected in his interviews with the Iowa farmers in a paper with Marvin Taves, his colleague in rural sociology at the University of Minnesota (Gross and Taves 1952).

13. Ryan resigned from the ISU Department of Economics and Sociology following the oleo margarine research crisis in 1942, worked for a federal government agency in Washington during World War II, and then was employed by the United Nations Relief and Rehabilitation Agency in Germany until 1945, when he joined the faculty at Rutgers University.

14. These research innovations were used twenty or more times in other publications in the rural sociology diffusion tradition (Crane 1972, 74).

15. This has become the most widely studied dependent variable in diffusion research (Rogers 1983).

16. The original members of the North Central Subcommittee were (1) Joe M. Bohlen, Iowa State University, Chair; (2) A. Lee Coleman, University of Kentucky; (3) Robert M. Dimit, South Dakota State College; and (4) Herbert F. Lionberger, University of Missouri.

17. This report was so popular that the Subcommittee charged ten cents per copy to cover the costs of publication and handling, resulting in a considerable "profit" that was earned over the next several years.

18. This presentation was suggested by Neal C. Radabaugh, a professor of extension education at Iowa State, who had participated in a diffusion seminar taught by Beal in spring 1954. Also in the seminar, possibly the first university course taught on diffusion, was Everett Rogers.

19. The flannel-board presentation is reproduced in Cooperative Extension Service Report Number 15 (Beal and Bohlen 1955).

20. By this point in the late 1950s, the ISU Department of Sociology had split off from the Department of Economics and Sociology.

21. Although authorship of the subcommittee report was not specified, the preface stated, "The original draft was integrated by George M. Beal and Joe M. Bohlen of Iowa State University as a flannelgraph presentation entitled *The Diffusion Process*."

22. Rogers (1962; 1983) later reconceptualized this five-stage adoption-decision process as consisting of five stages: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. The innovation-decision process is directly based on the reflex arc concept of Wilhelm Wundt, John Dewey, and George Herbert Mead (Rogers 1994).

23. These conclusions about the locations in which diffusion studies were conducted are based on our analysis of the bibliographies in Rogers (1966), Rogers and Shoemaker (1971), and Rogers (1983).

24. The decline of rural sociological interest in diffusion research in developing nations occurred in part because scholars in these locales had not formed an invisible college. Crane (1972, 59) found that half of all the isolates in the invisible college of rural sociologists resided outside of the United States. These scholars typically conducted just one diffusion study, often for their thesis or dissertation, and then left the field. Here is strong evidence for the crucial importance of how participation in an invisible college (informal communication with like-minded scientists) seems to be essential for continued interest in a research front.

25. The Green Revolution resulted from the rapid diffusion of high-yielding rice and wheat varieties, bred at agricultural research institutes near Manila and Mexico City, respectively.

26. These findings have been challenged by new network models of the diffusion of innovations (Valente 1994).

References

- Beal, G. M. Interview with Thomas W. Valente and Everett M. Rogers. Kailua, Hawaii, 11 May 1991.
- Beal, G. M., and J. M. Bohlen. 1955. *How farm people accept new ideas*. Ames: Iowa Cooperative Extension Service Report 15.
- . 1957. *The diffusion process*. Ames: Iowa Cooperative Extension Service Report 18.
- Beal, G. M., and E. M. Rogers. 1957a. *The adoption of two farm practices in a central Iowa community*. Ames: Iowa Agricultural Experiment Station Report 26.
- . 1957b. Informational sources in the adoption process of new fabrics. *Journal of Home Economics* 49(8): 630-634.

- . 1958. The scientist as a referent in the communication of new technology. *Public Opinion Quarterly* 22(4): 555-563.
- Beal, G. M., E. M. Rogers, and J. M. Bohlen. 1957. Validity of the concept of stages in the adoption process. *Rural Sociology* 22(2): 166-168.
- Bowers, R. V. 1937. The direction of intra-societal diffusion. *American Sociological Review* 2:826-836.
- . 1938. Διφφερεντιαλ ιντενσιτυ οφ ιντρα-σοχιεταλ διφφυσιον. *American Sociological Review* 3:21-31.
- Chapin, F. S. 1928. *Cultural Change*. New York: Century.
- Chubin, D. E., 1983. *Sociology of sciences: An annotated bibliography on invisible colleges, 1972-1981*. New York: Garland.
- Cole, J. R., and H. Zuckerman. 1975. The emergence of a scientific specialty: The self-exemplifying case of the sociology of science. In *The idea of social structure: Papers in Honor of Robert K. Merton*, edited by Lewis A. Coser, 139-174. New York: Harcourt Brace Jovanovich.
- Coleman, A. L. 1946. *Some aspects of human relations in soil conservation*. Washington, DC: U.S. Department of Agriculture. Unpublished report to the Soil Conservation Service.
- . 1951. Differential contact with extension work in a New York rural community. *Rural Sociology* 16:207-216.
- . 1982. Some personal recollections concerning my part, and that of the University of Kentucky, in the early research on the diffusion of innovations in agriculture and rural life. Unpublished paper prepared for George Beal at the East-West Communication Institute, Honolulu, Hawaii.
- Coleman, A. L., and C. P. Marsh. 1955a. Differential communication among farmers in a Kentucky county. *Rural Sociology* 20(2): 93-101.
- . 1955b. The relation of farmer characteristics to the adoption of recommended farm practices. *Rural Sociology* 20(3-4): 289-296.
- Coleman, J., E. Katz, and H. Menzel. 1966. *Medical innovation: The diffusion of an innovation among physicians*. New York: Bobbs-Merrill.
- Coleman, J., H. Menzel, and E. Katz. 1957. The diffusion of an innovation among physicians. *Sociometry* 20:253-270.
- Copp, J. H. 1956. *Personal and social factors associated with the adoption of recommended farm practices among cattlemen*. Manhattan: Kansas Agricultural Experiment Station Report 236.
- . 1958. Toward generalization in farm practice research. *Rural Sociology* 23(2): 103-111.
- Copp, J. H., M. L. Sill, and E. J. Brown. 1958. The function of information sources in the farm practice adoption process. *Rural Sociology* 23(2): 146-157.
- Coughenour, C. M. 1960. The functioning of farmers' characteristics in relation to contact with media and practice adoption. *Rural Sociology* 25(3): 283-297.
- . 1964. The rate of technological diffusion among locality groups. *American Journal of Sociology* 69(4): 325-339.
- . Interview with Thomas W. Valente and Everett M. Rogers. Columbus, Ohio, 19 August 1991.
- Crabb, R. 1948. *The hybrid corn makers: Prophets of plenty*. New Brunswick, NJ: Rutgers University Press.
- Crane, D. 1972. *Invisible colleges: Diffusion of knowledge in scientific communities*. Chicago: University of Chicago Press.
- Davis, A. 1941. Time and the technicways. *Social Forces* 19(1): 175-189.

- Deutschmann, P. J., and W. A. Danielson. 1960. Diffusion of knowledge of the major news story. *Journalism Quarterly* 37:345-355.
- Deutschmann, P. J., and O. Falls Borda. 1962. *Communication and adoption in an Andean Village*. San Jose, Costa Rica: Programa Interamericano de Información Popular.
- Dixon, R. B. 1928. *The building of culture*. New York: Scribner.
- Dodd, S. C. 1955. Diffusion is predictable: Testing probability models for laws of interaction. *American Sociological Review* 20(4): 392-401.
- Fliegel, F. C. 1957. Farm income and the adoption of farm practices. *Rural Sociology* 22(2): 159-161.
- . 1993. *Diffusion research in rural sociology: The record and prospects for the future*. Westport, CT: Greenwood.
- Fliegel, F. C., and F. E. Kivlin. 1962a. *Differences among improved farm practices as related to rates of adoption*. State College: Pennsylvania Agricultural Experiment Station Bulletin 691.
- . 1962b. Farm practice attributes and adoption rates. *Social Forces* 40(4): 364-369.
- Goss, K. F. 1979. Consequences of diffusion of innovations. *Rural Sociology* 44(4): 754-772.
- Griliches, Z. 1957. Hybrid corn: An exploration in the economics of technical change. *Econometrica* 25:501.
- Gross, N. C. 1942. *The diffusion of a cultural trait in two Iowa townships*. Unpublished master's thesis. Ames: Iowa State University.
- Gross, N. C., and M. J. Taves. 1952. Characteristics associated with acceptance of recommended farm practices. *Rural Sociology* 17(4): 321-327.
- Hägerstrand, T. 1967. *Innovation diffusion as a spatial process*. Translated by A. Pred. Chicago: University of Chicago Press.
- Hamblin, R. L., R. B. Jacobsen, and J. L. L. Miller. 1973. *A mathematical theory of social change*. New York: Wiley.
- Hart, H. 1945. Logistic social trends. *American Journal of Sociology* 50(3): 337-352.
- Havens, A. E. 1975. Diffusion of new seed varieties and its consequences: A Colombian case. In *Problems of rural development: Case studies and multi-disciplinary perspectives*, edited by R. E. Dumett, and L. J. Brainard. Leiden, 93-111. The Netherlands: E. J. Brill.
- Hoffer, C. R. 1942. *Acceptance of approved farming practices among farmers of Dutch descent*. East Lansing: Michigan Agricultural Experiment Station Special Bulletin 316.
- Katz, E., M. L. Levine, and H. Hamilton. 1963. Traditions of research on the diffusion of innovation. *American Sociological Review* 28(2): 237-253.
- Kuhn, T. S. 1962 [1970]. *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Lievrouw, L. A. 1990. Reconciling structure and process in the study of scholarly communication. In *Scholarly Communication and Bibliometrics*, edited by C. L. Borgman, 59-69. Newbury Park: Sage.
- Lievrouw, L. A., and K. Carley. 1991. Changing patterns of communications among scientists in an era of "telescience." *Technology in Society* 12:457-477.
- Lievrouw, L. A., E. M. Rogers, C. U. Lowe, and E. Nadel. 1987. Triangulation as a research strategy for identifying invisible colleges among biomedical scientists. *Social Networks* 9:217-248.
- Lionberger, H. F. 1949. *Low-income farmers in Missouri: Their contacts with potential sources of farm and home information*. Columbia: Missouri Agricultural Experiment Station Research Bulletin 441.
- . 1951. *Sources and use of farm and home information by low-income farmers in Missouri*. Columbia: Missouri Agricultural Experiment Station Research 472.

- . 1953. Some characteristics of farm operators sought as sources of farm information in a Missouri community. *Rural Sociology* 18(4): 327-338.
- . 1955. *Information seeking habits and characteristics of farm operators*. Columbia: Missouri Agricultural Experiment Station 581.
- . 1956. The relation of informal social groups to the diffusion of farm information in a northeastern Missouri farm community. *Rural Sociology* 19(3): 233-243.
- . 1960. *Adoption of new ideas and practices*. Ames: Iowa State University Press.
- Lionberger, H. F., and E. Hassinger. 1954. *Neighborhoods as a factor in the diffusion of farm information in a northeastern Missouri farming community*. Unpublished document. Columbia: University of Missouri, Department of Rural Sociology.
- Mahajan, V., and R. A. Peterson. 1985. *Models for innovation diffusion*. Thousand Oaks, CA: Sage.
- Marsh, C. P., and A. L. Coleman. 1954a. Farmers' practice-adoption rates in relation to adoption rates of "leaders." *Rural Sociology* 19(2): 1-2.
- . 1954b. The relation of kinship, exchanging work, and visiting to the adoption of farm practices. *Rural Sociology* 19(3): 1-2.
- . 1954c. The relation of neighborhood of residence to adoption of recommended farm practices. *Rural Sociology* 19(4): 385-389.
- . 1956. Group influences and agricultural innovations: Some tentative findings and hypotheses. *American Journal of Sociology* 61(6): 588-594.
- Merton, R. K. 1973. *The sociology of science*. Chicago: University of Chicago Press.
- McVoy, E. C. 1940. Patterns of diffusion in the United States. *American Sociological Review* 5:219-227.
- Mullins, N. 1972. The development of a scientific specialty: The phage group and the origins of molecular biology. *Minerva* 10:52-82.
- . 1973a. *Theory and theory groups in contemporary sociology*. New York: Harper & Row.
- . 1973b. The development of specialties in social science: The case of ethnomethodology. *Science Studies* 3:245-273.
- Pemberton, H. E. 1936a. The curve of culture diffusion rate. *American Sociological Review* 1:546-547.
- . 1936b. Culture-diffusion gradients. *American Journal of Sociology* 42:226-233.
- . 1937. The effect of a social crisis on the curve of diffusion. *American Sociological Review* 2:55-61.
- . 1938. Spatial order of cultural diffusion. *Sociology and Social Research* 22:246-251.
- Price, D. J. deS. 1963 [1986]. *Little science, big science*. New York: Columbia University Press.
- Rahim, S. 1961. The diffusion and adoption of agricultural practices: A study in a village in East Pakistan. Comilla: Pakistan Academy for Rural Development.
- Rogers, E. M. 1957. Personality correlates of the adoption of technological practices. *Rural Sociology* 22(3): 1-2.
- . 1958. Categorizing the adopters of agricultural practices. *Rural Sociology* 23(4): 345-354.
- . 1962. *Diffusion of innovations*, first edition. New York: Free Press.
- . 1966. *Bibliography of the diffusion of innovation*. Unpublished document. Department of Communication, Michigan State University, East Lansing, MI.
- . 1983. *Diffusion of innovations*, third edition. New York: Free Press.
- . 1988. The intellectual foundation and history of the agricultural extension model. *Knowledge: Creation, Utilization, Diffusion* 9(4): 492-510.

- . 1994. *A history of communication study: A biographical approach*. New York: Free Press.
- . Forthcoming. *Diffusion of innovations*, fourth edition. New York: Free Press.
- Rogers, E. M., and G. M. Beal 1958a. *Reference group influences in the adoption of agricultural technology*. (Report to Foundation for Research on Human Behavior) Department of Economics and Sociology. Ames: Iowa State University.
- . 1958b. The importance of personal influence in the adoption of technological changes. *Social Forces* 36(4): 329-334.
- Rogers, E. M., and R. J. Burdge. 1961. *Muck vegetable growers: Diffusion of innovations among specialized farmers*. Wooster: Ohio Agricultural Experiment Station Research Circular 94.
- Rogers, E. M., and F. F. Shoemaker. 1971. *Communication of innovations: A cross-cultural approach*, second edition. New York: Free Press.
- Ryan, B. 1948. A study in technological diffusion. *Rural Sociology* 13:273-284
- . Interview with George M. Beal, 9 April 1988.
- . Interview with Everett M. Rogers, 17 May 1991.
- Ryan, B., and N. Gross. 1943. The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology* 8(1): 15-24
- . 1950. *Acceptance and diffusion of hybrid corn seed in two Iowa communities*. Ames: Iowa Agricultural Experiment Station Research Bulletin 372.
- Tarde, G. 1903. *The laws of imitation*, translated by E. C. Parson. New York: Holt.
- Valente, T. W. 1994. *Network models of the diffusion of innovations*. Cresskill, NJ: Hampton.
- . 1995. Diffusion of innovations and policy decision-making. *Journal of Communication* 43(1): 30-45.
- Wilkens, E. A. 1950. Sources of information for improved farm practices. *Rural Sociology* 15(1): 19-30.
- . 1952a. *Acceptance of improved farm practices in three coastal plain counties*. Raleigh: North Carolina Agricultural Experiment Station Bulletin 98.
- . 1952b. A sociopsychological approach to the study of the acceptance of innovations in farming. *Rural Sociology* 15(4) 352-363.
- . 1952c. Informal leaders and innovators in farm practices. *Rural Sociology* 17(3): 272-274.
- . 1953. *Adoption of improved farm practices as related to family factors*. Madison: Wisconsin Agricultural Experiment Station Research Bulletin 183.
- . 1958a. An introductory note on the social aspects of practice adoption. *Rural Sociology* 23(2): 97-102.
- . 1958b. Joint decision-making in farm families as a function of status and role. *American Sociological Review* 23(2): 187-192.
- Wilson, M. C. 1927. *Influence of bulletins, news stories, and circular letters upon farm practice adoption with particular reference to method of bulletin distribution*. Washington, DC: U.S. Department of Agriculture, Federal Extension Circular Number 57.
- Zaltman, G., and B M. Kohler. 1972. The dissemination of task and socioemotional information in an international community of scientists. *Journal of the American Society for Information Science* 23:225-236.

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