ABSTRACT

A SPACE PREFERENCE APPROACH TO THE DETERMINATION OF INDIVIDUAL CONTACT FIELDS IN THE SPATIAL DIFFUSION OF HARVESTORE SYSTEMS IN NORTHEAST IOWA

by David James DeTemple

The purpose of this research is to explore the implications of hypothesized relationship between spatial behavior and spatial diffusion of innovation processes. The focus of the research is on (1) the derivation of a rule of spatial behavior to account for movement from place to place in the spatial diffusion of rural innovations and (2) on the construction of a spatial diffusion simulation model employing the empirically derived rule of spatial behavior.

A basic premise in the conceptualization of the spatial diffusion of innovations is that adoption is primarily the result of a learning process, where an individual adopts an innovation as soon as he has accumulated sufficient information to overcome resistance to adopt. This premise implies that spatial diffusion theory should be concerned with those factors which relate to the spatial pattern of information flow. Thus, fundamental to modelling the spatial aspects of innovation-adoption has been the manner in which

information movement from one location to another has been explained.

There are two information sources identified as being relevant to the learning-adoption process. The first source, mass media, is considered important in the initial introduction of an innovation to an individual, but after awareness of the innovation, this source becomes less significant in persuading adoption. The second source, interpersonal contact with others who have either (1) previously adopted the innovation or who have (2) relevant information and are regarded as reliable sources, is considered more significant in persuading final adoption. Thus, the research focuses exclusively on the spatial mechanisms of interpersonal contact.

The transition mechanisms accounting for information movement from place to place have varied considerably from model to model. The view taken by many is that the intensity of information flow between individuals is a continuous function of intervening distance; however, it is shown statistically that for northeast Iowa distance is not as important a factor as previously assumed.

The approach developed in this research is an attempt to clarify the spatial interaction mechanism which controls movement of innovation-adoption from one location to another. Two movement factors are hypothesized as controlling the flow of relevant information. The first movement factor is individual interaction with the central place system through which diffusion occurs. A rule of spatial behavior to account for individual interaction with the central place system is empirically derived by employing the method of paired-comparisons. From consistent statements of choice by decision-makers residing at different locations a probabilistic behavioral rule of preferred alternatives is obtained. This rule of spatial behavior is defined such that when applied to a distribution of central place alternatives it is capable of generating the probability of individual contact with each central place, or individual contact fields.

The second movement factor is interpersonal contact within a central place. Not being able to discover the explicit structure of interpersonal contact, a simple random bias model is employed to model this movement factor. The model regards every individual that interacts with a central place as having an equal chance of contacting every other individual who interacts with that place.

Thus, communication between individuals is hypothesized as being dependent on the probability of individual interaction with the central place system and on the probability of interpersonal contact within a central place. Both movement factors are modelled separately, and linked together to provide the transition mechanisms in the spatial diffusion simulation model.

The constructed simulation model is run and evaluated against the actual diffusion of Harvestore Systems (silos) in northeast Iowa. Visual and statistical analysis of actual and simulated patterns of diffusion show that both patterns could have been the result of the same real-world diffusion process. Based on evaluation criteria for judging the validity of a simulation model, it is concluded that the model is a plausible representation of the spatial diffusion process studied.

The diffusion model is an improvement over previous models in that (1) it is sensitive to the spatial structure of the central place system through which diffusion occurs; (2) distance is not regarded as an unchangeable force emanating from all points equally in all directions, but is considered as only one of several attributes of a spatial alternative evaluated by a decision-maker; and (3) the exact residential location of individual decision-makers is maintained. The behavioral approach and the alternative representation of the spatial diffusion process are the major contributions of this research.

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by

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CHAPTER I

CONTEXT OF THE RESEARCH PROBLEM

Introduction

One of the fundamental concerns of human geography has been with the description and explanation of spatial patterns. In efforts to provide adequate explanation for rather complex spatial-temporal patterns, geographers have traditionally considered the spatial behavior of aggregate populations, and have regarded the spatial behavior of individuals as both unique and unpredictable.[1] Some have felt that individual variations in space and time preferences are so great as to preclude any rationalization of individual spatial behavior.[2] However, Hägerstrand's work in migration and in spatial diffusion of innovations has demonstrated the possibility of focusing geographic research at the level of the individual. His work has shown that even though the individual's exact decisions may not be precisely determined, the probability of making a range of decisions can be determined.[3]

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[1] Richard L. Morrill and Forrest R. Pitts, "Marriage, Migration, and the Mean Information Field: A Study in Uniqueness and Generality," <u>Annals of the Association of American Geographers</u>, LVII (1967), p. 402.

[2] Walter Isard, <u>Location and Space Economy</u> (Cambridge, Mass.: The M.I.T. Press, 1956), pp. 84-85.

[3] For the reader who is unacquainted with Hägerstrand's spatial diffusion of innovation research, see Torsten Hägerstrand, <u>The Propagation of Innovation Waves</u>, Lund Studies in Geography: Series B, Human Geography No. 4 (Lund, Sweden:

Spatial diffusion has long been a subject of geographic inquiry, but Hägerstrand's pioneering work in the early 1950's on spatial diffusion of innovations provided the initial stimulus for the development of a strong theoretical research tradition.[4] His spatial diffusion work was clearly an attempt to capture in a diffusion model the spatial structure of the innovation-adoption process and characteristics of individual behavior in space. Since the highly complex processes preclude true analytic solutions, Monte Carlo simulation techniques were selected to model the processes which generate spatial patterns of innovation-adoption. The

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Gleerup, 1952); Torsten Hägerstrand, "Migration and Area," in _Migration in Sweden: A Symposium_, ed. by David Hannerberg, Torsten Hägerstrand, and Bruno Odeving, Lund Studies in Geography: Series B, Human Geography No. 13 (Lund, Sweden: Gleerup, 1957), pp. 25-158; Torsten Hägerstrand, "A Monte Carlo Approach to Diffusion," Archives of _Europeennes De Sociologie_, VI (1965), pp. 43-67; Torsten Hägerstrand, "Aspects of the Spatial Structure of Social Communication and the Diffusion of Information," _Papers of the Regional Science Association_, XVI (1966), pp. 27-42; Torsten Hägerstrand, "On Monte Carlo Simulation of Diffusion," in _Quantitative Geography, Part I: Economic and Cultural Topics_, ed. by William L. Garrison and Duane F. Marble, Northwestern University, Department of Geography, Studies in Geography No. 13 (1967), pp. 1-32; Torsten Hägerstrand, _Innovation Diffusion as a Spatial Process_, translated by Allan Pred (Chicago: University of Chicago Press, 1967); Torsten Hägerstrand, "Quantitative Techniques for Analysis of the Spread of Information and Technology," in _Education and Economic Development_, ed. by C. A. Anderson and M. J. Bowman (Chicago: Aldine, 1965), pp. 244-280.

[4]Whenever the term "spatial diffusion" is used in this study, unless otherwise noted, reference is specifically to the "spatial diffusion of innovations". For a general review of spatial diffusion research in geography, see L. A. Brown and E. G. Moore, "Diffusion Research in Geography: A Perspective," in _Progress in Geography: International Reviews of Current Research_, Vol. 1, ed. by Christopher Board, _et al_. (New York: St. Martin's Press, 1969), pp. 119-157.

simulation model was designed as a pseudo-experiment in real space, and an analog for abstract decision-making processes.[5] As Hägerstrand notes:[6]

> "The simulation technique makes it possible to create imagined societies of different structure, to endow individuals with various behavior probabilities and rules of action, and finally to let random numbers infuse life into the system."

Conceptualization of the Spatial Diffusion of Innovation Processes

Hägerstrand's conceptualization of the spatial diffusion processes are most explicit in his simulation models. These models consider specific empirical examples--the spread of agricultural innovations through a rural landscape.

Innovation Adoption as a Learning Process

The basic premise in Hägerstrand's conceptualization is that the adoption of an innovation is primarily the result of a learning process, where an individual adopts an innovation as soon as he has accumulated sufficient information to overcome resistance to adopt. This premise implies that spatial diffusion theory should be concerned with those factors which relate to the spatial pattern of information flow, e.g., the characteristics which influence the spatial pattern of communication and resistances to adopt and the relationship

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[5] J. Wolpert and D. Zillmann, "The Sequential Expansion of a Decision Model in a Spatial Context," Environment and Planning, I (1969), p. 91.

[6] Hägerstrand, "Quantitative Techniques," p. 266.

between exposure to relevant information and the reduction of resistances to adopt.[7]

Information Factors

Hägerstrand identifies two information sources relevant to the individual's learning-adoption process. The first source, mass media, is considered significant in the initial introduction of an innovation to an individual, but after awareness of the innovation, this source becomes less significant in persuading adoption. The second source, interpersonal contact with others who have either (1) previously adopted the innovation or who have (2) relevant information and are regarded as reliable sources, is considered more significant in persuading final adoption.[8] Hence, Hägerstrand focuses his simulation model exclusively on the mechanisms of interpersonal contact.

The Neighborhood Effect

Hägerstrand hypothesizes that the destination of personal messages depends on the configuration of an individual's network of interpersonal contact, and that this network is

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[7]Lawrence A. Brown, "Diffusion Dynamics: A Review and Revision of the Quantitative Theory of the Spatial Diffusion of Innovation," (unpublished Ph.D. dissertation, Northwestern University, 1966), pp. 7-10; Hägerstrand, Innovation Diffusion as a Spatial Process, pp. 138-140.

[8]For a brief review of the significance of interpersonal contact in the learning-adoption process, see Everett M. Rogers, Diffusion of Innovation (New York: The Free Press, 1962), pp. 138-140.

dependent on the presence of various barriers. Initial focus is primarily on the spatial ramification of physical barriers which impede contact, such as lakes, rivers, and mountains, and on geographical distance which separates potential communicants. This distance factor plays a major role in Hägerstrand's diffusion model and has been termed the neighborhood effect.

A Hierarchy of Networks of Communication

Hägerstrand, also, recognized the importance of hierarchy of networks of communication:[9]

> "As a demonstration and entirely arbitrary, we can make three groups operating in international, regional, and local ranges. Some individuals are wholly bound to the local plane, others operate on the regional and local plane, and still others operate more or less on all three."

At the local level innovations spread through a communication network linking individuals directly to one another through interpersonal contact. However, at the regional level a different network of communication comes into play, one tied closely to the spatial pattern of linkages between central places.

As Hägerstrand notes, diffusion over a landscape of central places tends to follow the structure of the central place hierarchy. Urban places tend to adopt certain innovations before rural; and larger, relatively more

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[9] Hägerstrand, "On the Monte Carlo Simulation of Diffusion," p. 8.

important places at greater distances tend to adopt before smaller places that are nearby. Hägerstrand observes that:[10]

> "The urban hierarchy canalizes the course of diffusion. In addition to the influence from a neighboring center on the neighboring districts we find short circuits to more important places at greater distance."

Brown has suggested that diffusion may be viewed at two levels, local and regional, and that "these two levels may be superimposed to provide a more comprehensive picture of diffusion within a large region--in other words, among central places and then to individual farmers."[11]

Market Factors

In identifying patterns of diffusion of commercial and manufactured items not adequately explained by spatial diffusion theory, Brown postulated that the deviations may be the result of (1) marketing decisions by distributors and (2) the shopping trip behavior of potential adopters. These additional factors have been termed market factors, as opposed to the previously identified information factors.[12]

Market factors are important in determining the hierarchical pattern of diffusion through a central place landscape. In the case of a dispersed farm population, consumers are not residing in central places. Therefore, their shopping

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[10] Hägerstrand, The Propagation of Innovation Waves; Brown, "Diffusion Dynamics," pp. 33-42.

[11] Brown and Moore, "Diffusion Research," p. 125.

[12] Brown, "Diffusion Dynamics," pp. 2-4, 42-49.

trip behavior strongly influences both the frequency and the set of central places with which they interact. The type of innovation and the distribution of the propagators of that innovation determine the set of central places through which relevant information circulates. Thus the central place system is extremely important in focusing the spatial pattern of innovation diffusion.

Modelling the Spatial Diffusion Process

One of the challenges for diffusion research has been to combine individual behavior with the structure of the spatial system to develop process theories from which spatial diffusion patterns can be deduced. Hägerstrand's research goal was to simulate the spatial diffusion process and eventually make predictions achievable.[13] Unfortunately, even though information factors, market factors, and the central place system were recognized as basic elements of the spatial diffusion process, Hägerstrand was only able to incorporate a portion of his conceptualization into a diffusion model. In part, the reason the model included only a portion of his conceptualization of the diffusion process was that the nature of many of the basic relationships, such as that of the central place hierarchy, simply were not known.

Geographic diffusion studies following the Hägerstrand approach are either concerned with refinements of the original

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[13] Hägerstrand, "On Monte Carlo Simulation of Diffusion," p. 7.

simulation model[14] or focus upon the processes which generate the observed spatial pattern of innovation-adoption. These latter studies have been successful in identifying critical elements relevant to diffusion in a specific study area. However, in modelling diffusion processes many of these studies have applied the structure of Hägerstrand's simulation model directly to their own problem without appropriate modifications.[15] The result has been that relatively little

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[14]Refinements of Hägerstrand's original Monte Carlo simulation model have focused on (1) experimentation with various mathematical distance-decay functions (see, Richard L. Morrill, "The Distribution of Migration Distances," Papers of the Regional Science Association, XI (1963), pp. 75-84; Morrill and Pitts, "Uniqueness and Generality," pp. 401-422), (2) derivation of both biased and unbiased mean information fields (see, Duane F. Marble and John D. Nysteun, "An Approach to the Direct Measurement of Community Mean Information Fields," Papers of the Regional Science Association, XI (1963), pp. 99-109; Morrill and Pitts, "Uniqueness and Generality," pp. 401-422; Lawrence A. Brown, Eric G. Moore, and William Moultrie, TRANSMAP: A Program for Planar Transformation of Point Distributions, Ohio State University, Department of Geography, Discussion Paper No. 3, pp. 26; Forrest R. Pitts, MIFCAL and NONCEL: Two Computer Programs for the Generalization of the Hägerstrand Model to an Irregular Lattice, Northwestern University, Department of Geography, Technical Paper No. 23 (1967), pp. 33), and (3) the construction of computer programs (see, Forrest R. Pitts, "Problems in Computer Simulation of Diffusion," Papers of the Regional Science Association, XI (1963), pp. 111-122; Forrest R. Pitts, HAGER III and HAGER IV: Two Monte Carlo Computer Programs for the Study of Spatial Diffusion Problems, Northwestern University, Department of Geography, Research Report No. 12 (1965), pp. 42; Pitts, MIFCAL and NONCEL; Brown, Moore, and Moultrie, TRANSMAP).

[15]For examples where the Hägerstrand model has been applied see, Leonard W. Bowden, Diffusion of the Decision to Irrigate, University of Chicago, Department of Geography, Research Paper No. 97 (1965), pp. 89-120; and Burton O. Witthuhn, "The Spatial Integration of Uganda as Shown by the Diffusion of Postal Agencies, 1900-1965," The East Lakes Geographer, IV (1968), pp. 5-20.

insight has been gained in either understanding individual spatial behavior or explaining general spatial diffusion processes.[16]

A Behavioral Aspect of Spatial Diffusion Theory

Many existing theories in human geography, including spatial diffusion theory, have at least implicit behavioral assumptions in their structure. The spatial patterns of the diffusion of phenomena, ideas, and techniques through a region are spatial expression of many individual decisions. The basic geographic elements of distance, direction, and spatial variation are evident in diffusion patterns. But if the processes which generate diffusion patterns are to be explained, then notions of human decision-making must be incorporated into geographic diffusion theory.[17] As King has noted:[18]

> ". . . existing theoretical statements in geography appear weak on at least two accounts. First, it usually is the case with statements that the basic spatial structure appears as given, rather than as a logical consequence of theory. . . . A second weakness . . . is that the behavioral

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[16]Brown and Moore, "Diffusion Research," pp. 143-144.

[17]David Harvey, "Conceptual and Measurement Problems in the Cognitive-Behavioral Approach to Location Theory," in *Behavioral Problems in Geography: A Symposium*, ed. by Kevin R. Cox and Reginald G. Golledge, Northwestern University, Department of Geography, Studies in Geography No. 17 (1969), p. 35.

[18]Leslie J. King, "The Analysis of Spatial Form and Its Relation to Geographic Theory," *Annals of the Association of American Geographers*, LIX (1969), pp. 593-595.

> underpinnings of these statements have seldom been made explicit . . . much of geographical analysis has been pursued on highly aggregative levels with considerable emphasis upon techniques and too little attention upon possible behavioral mechanisms."

Thus, to understand processes that evolve spatial patterns, concern should be for building geographic theory and models on the basis of postulates regarding human behavior. One approach to the search for relevant behavioral postulates relates parameters describing actual behavior patterns in an area to specified spatial structures in the same area. Hägerstrand's use of the mean information field is an excellent example of this type of approach. The parameters of the information field are based upon interaction data for the area under study. The parameters are *place dependent*, in that they are tied directly to the spatial structure of the system for which they are calibrated and say little about the characteristics of parameters for different places or spatial systems.[19] This form of description of overt behavior is no more a process type of explanation than is the description of the diffusion pattern itself.[20]

A second approach to the search for relevant behavioral postulates consists of a description of behavioral processes irrespective of the spatial system in which the behaviors are

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[19] Kevin R. Cox and Reginald G. Golledge, "Editorial Introduction: Behavioral Models in Geography," in *Behavioral Problems in Geography*, pp. 2-3.

[20] Leslie Curry, "Central Places in the Random Spatial Economy," *Journal of Regional Science*, VII (Supplement, 1967), p. 219.

found. This approach involves a search for postulates or rules of spatial choice, movement, and interactions which are <u>place independent</u> of the spatial system in which they operate. In support of this type of approach Curry argues that:[21]

> "A postulate on spatial behavior should not directly describe the behavior occurring within a central place system, since it is obvious that the system can then be directly derived without providing any insight. The behavior postulate must allow a central place system to be erected on it in a sufficiently indirect manner that a measure of initial surprise is occasioned by the results, and this postulate must still describe behavior after the system has been derived."

Moreover, Rushton states that:[22]

> " . . . the essential feature of a useful postulate is that it should describe the rules by which alternative locations are evaluated and choices consequently made. This procedure we may call spatial behavior, reserving the term 'behavior in space' for the description of the actual spatial choices made in a particular system. Since behavior in space is in part determined by the particular spatial system in which it has been observed, it is not admissable as a behavioral postulate in any theory. In short, such behavior is not independent of the particular system in which it has been studied. On the other hand, a postulate which describes the rules of spatial behavior is capable of generating a variety of behavior patterns in space as the system . . . to which the rules are applied, is allowed to change."

Thus, postulates of spatial behavior should mirror individual decisions and be able to deduce "behavior in space" where each individual decision-maker, encompassed in his own

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[21]Curry, "Central Places," p. 219.

[22]Gerard Rushton, "Analysis of Spatial Behavior by Revealed Space Preferences," <u>Annals of the Association of American Geographers</u>, LIX (1969), p. 392.

spatial environment, reaches decisions which maximize some satisfaction or preference function.[23]

Statement of the Research Problem

The primary purpose of this study is to pursue the implications of the hypothesized relationships between spatial behavior and spatial processes that appear to have been present in virtually every conceptualization of spatial diffusion processes. The focus of the research is on (1) the derivation of a rule of spatial behavior to account for movement from one location to another in the spatial diffusion of rural innovations[24] and (2) on the construction of a spatial diffusion simulation model employing the empirically derived rule of spatial behavior. The proposed model is an improvement over previous diffusion models in that (1) it is sensitive to the spatial structure of the central place system through which diffusion occurs; (2) distance is not regarded as an unchangeable force emanating from all points equally in all directions, but is considered as one of several characteristics of a spatial alternative to be evaluated by decision-makers; and (3) the exact residential location of the individual decision-maker is maintained.

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[23] Harvey, "Conceptual and Measurement Problems," p. 36.

[24] A rule of spatial behavior is defined so as to describe behavioral processes irrespective of the spatial structure of the system in which behaviors are found.

The first objective of this study (Chapter II) is to clarify the role of movement in spatial diffusion of innovation models. In this chapter a simple conceptual model is proposed that offers an alternative to transition mechanisms[25] proposed in previous diffusion models. The model considers both individual interaction with the central place system and interpersonel contact at the central place as important determinants of the spatial pattern of innovation adoption. Both determinants can be modelled separately and then linked together to account for movement.

The next objective of the study (Chapter III) is to model individual interaction with the central place system by defining a procedure for deriving a rule of spatial behavior. The spatial behavioral rule when applied against a set of alternative central places will give the probability of individual contact with each central place. This *individual contact field* is defined such that, given the location of a decision-maker and the locations of alternative central places, the behavioral rule can generate the probability of the decision-maker interacting with each central place.

Finally, the third objective is to incorporate aspects of existing diffusion theory, central place theory, and behaviorally determined individual contact fields into a spatial diffusion of innovation model. In Chapter IV the

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[25]In construction of spatial diffusion models the transition mechanism is the modelling approach employed to account for movement from one location to another.

simulation model is constructed and in Chapter V it is run and evaluated against the actual diffusion of Harvestore Systems in northeast Iowa (See Map 1).[26] Chapter VI includes a brief summary and critique of the research and proposals for future research.

[26]The Harvestore System, a special type of farm silo manufactured by A. O. Smith Harvestore Products, Inc., is a unique feed-crop storage innovation in that it does three things of which no other silo is capable; (1) it resists corrosion from feed acids, (2) it provides maximum protection from oxygen to preserve feed nutrients, and (3) it unloads from the bottom.

CHAPTER II

THE TRANSITION MECHANISM IN THE SPATIAL DIFFUSION OF INNOVATION MODEL

The Neighborhood Effect

Fundamental to modelling the spatial aspects of the innovation-adoption processes has been the manner in which movement from place to place has been explained. The transition mechanisms accounting for movement have varied considerably from model to model.[1] The view taken by Hägerstrand is that the intensity of movement is a continuous function of geographic distance. This particular transition mechanism has been termed the neighborhood effect and has been widely accepted as a basic premise of geographic diffusion theory.

In empirical investigation Hägerstrand noted the spatial cluster-like pattern of adopters of rural innovations. He concluded that as information about an innovation spreads these clusters of adopters tend to expand step-by-step in a manner that suggests the probability of adopting an innovation is higher among those potential adopters who reside near individuals having previously adopted the innovation than among those potential adopters whose nearest neighbors have not yet adopted the innovation. This observation based on visual inspection has been widely accepted with little questioning of either its validity or relevance. Yet, in extensive

[1]See, Brown and Moore, "Diffusion Research," pp. 140-141.

sociological reviews of innovation diffusion, neither distance nor the neighborhood effect is mentioned as one of the crucial elements in the analysis of innovation diffusion.[2] This lack of recognition of the neighborhood effect suggests that it may not be as relevant as hypothesized. If the neighborhood effect is a dominant feature of the diffusion process, then it seems apparent that with an appropriate statistical test the relevance of this transition mechanism can be evaluated.

Statistical Evaluation of the Neighborhood Effect

To evaluate the neighborhood effect Barnard and Pearson's 2 x 2 Comparative Time Trial is selected as an appropriate statistical model to determine whether the probability of adoption is higher among those potential adopters who reside near an individual who has previously adopted the innovation than among those potential adopters whose nearest neighbors have not adopted the innovation.[3] This test is appropriate because nearest neighbors can be measured as direct geographic

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[2] Rogers, *Diffusion of Innovations*, pp. 12-20; Elihu Katz, "The Social Itinerary of Technical Change: Two Studies on the Diffusion of Innovation," *Human Organization*, XX (1961), pp. 72-80.

[3] G. A. Barnard, "Significance Tests for 2 x 2 Tables," *Biometrika*, XXXIV (1947), pp. 123-138; E. S. Pearson, "The Choice of Statistical Tests Illustrated on the Interpretation of Data Classed in a 2 x 2 Table," *Biometrika*, XXXIV (1947), pp. 139-167; A. D. Cliff, "The Neighbourhood Effect in the Diffusion of Innovations," *Transaction of the Institute of British Geographers*, XLIV (1968), pp. 75-84.

distance and does not depend upon an arbitrary lattice structure.[4]

The 2 x 2 Comparative Time Trial is used to determine whether non-adopters of an innovation who have some neighbors who have adopted the innovation are more likely to accept the new farm practice than those non-adopters whose nearest neighbors are all non-adopters. Table 1 contains the contingency table format to test this research hypothesis.

TABLE 1

2 x 2 COMPARATIVE TIME TRIAL CONTINGENCY TABLE TO TEST THE NEIGHBORHOOD EFFECT[5]

Neighbors at "t"	Individuals at "t+1" who were non-adopters at "t"		
	Adopters	Non-adopters	Total
Some adopters	c	c	m
All non-adopters	d	b	n
Total	s	r	N

The statistic, $u = ((cb-da)/N) \div ((m\ n\ r\ s)/(N^2(N-1))^{1/2}$, associated with the time trial is normally distributed with unit variance. If "u" exceeds the established significance

[4]A number of statistical models have been used to evaluate actual and simulated patterns of spatial diffusion, for a short review of these models see Brown and Moore, "Diffusion Research," pp. 128-130.

[5]A. D. Cliff, "The Neighbourhood Effect in the Diffusion of Innovations," Transactions of the Institute of British Geographers, XLIV (1968), p. 79.

level the null hypothesis can be rejected and the research hypothesis, the neighborhood effect, can with a certain risk of error be accepted.

The neighborhood effect is empirically tested for the diffusion of 2,4D weed spray among 148 farm operators residing in the Collins, Iowa, trade area (See Map 1 in Appendix A). This innovation was first available to the Iowa farmer in 1945, and adoption by each farm operator in the Collins area is recorded for each year through 1955.[6]

The test is repeated four times for every year, 1946 through 1955 inclusive, with the form of the time trial varying such that neighbors at time "t" are defined as (1) the first nearest neighbor only, (2) the first two nearest neighbors, (3) the first three nearest neighbors, and finally (4) the first four nearest neighbors. By varying the form of the test and repeating over the 1946-1955 time span of 2,4D adoption, precaution is taken to insure that if the neighborhood effect was operating that it be detected.[7]

To reject the null hypothesis at the 0.05 level of significance the calculated "u" statistics needs to exceed

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[6]George M. Beal and Everett M. Rogers, The Adoption of Two Farm Practices in a Central Iowa Community, Iowa State University, Agricultural and Home Economics Experimental Station, Special Report No. 26 (1960), pp. 20; For a listing of Collins, Iowa 2,4D diffusion data see Appendix D.

[7]See Appendix C for a description and listing of computer program TWOBY used to calculate this test, and Appendix D for a listing of the Collins, Iowa 2,4D diffusion data.

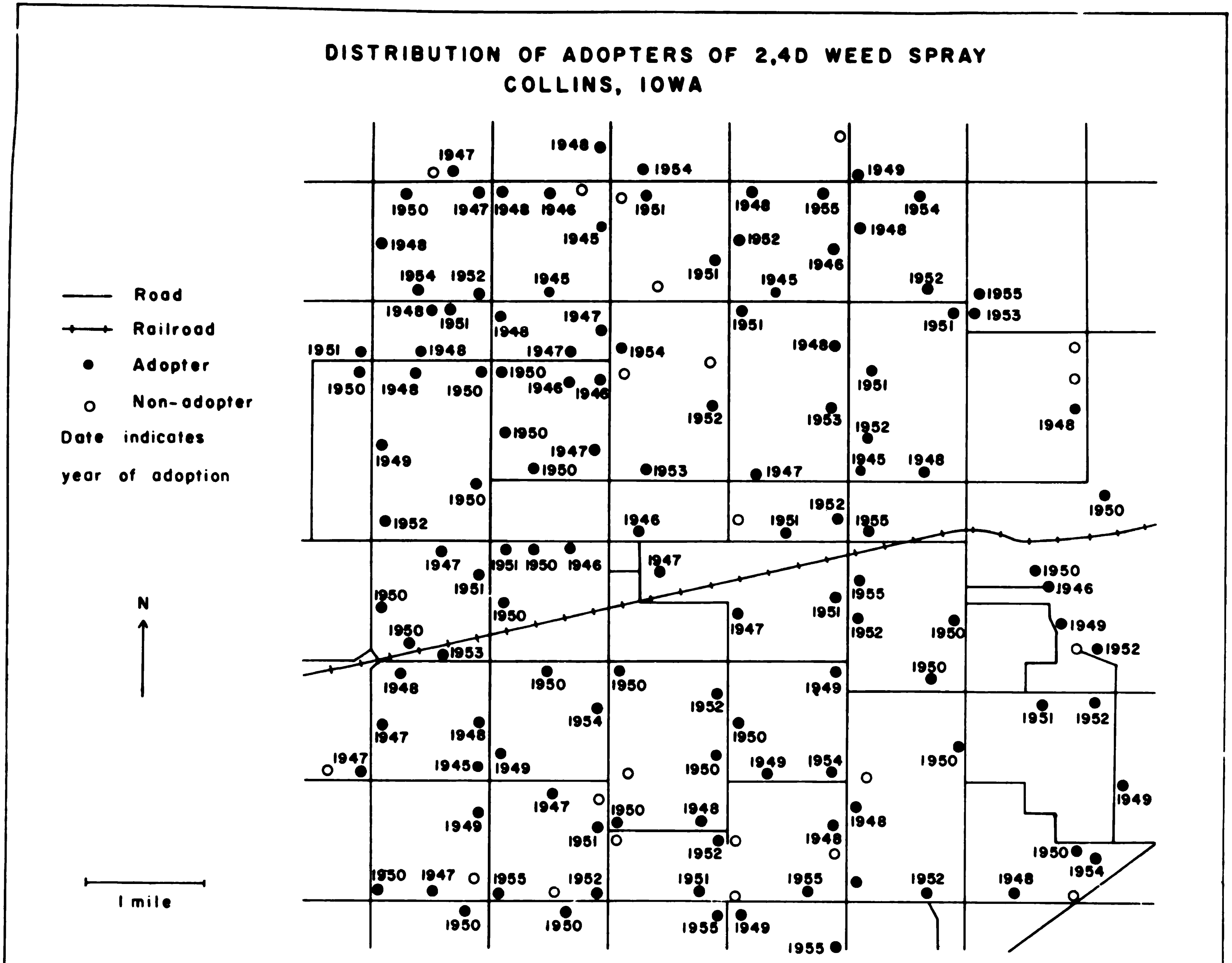
DISTRIBUTION OF ADOPTERS OF 2,4D WEED SPRAY
COLLINS, IOWA
Road
Railroad
Adopter
Non-adopter
Date indicates
year of adoption
N
1 mile

Figure 1

TABLE 2

RESULTS FROM THE 2 x 2 COMPARATIVE TIME TRIAL CONTINGENCY TEST OF THE COLLINS, IOWA 2,4D DIFFUSION DATA (1946-1955)

YEAR	"u" STATISTIC FOR NUMBER OF NEAREST NEIGHBORS			
	1	1,2	1,2,3	1,2,3,4
1946	-0.515	-0.566	-0.960	+0.080
1947	+0.847	+1.150	+1.709	+1.317
1948	+1.419	+0.432	+0.433	-0.134
1949	+1.254	-0.283	-0.644	-0.827
1950	-0.248	-0.063	-0.668	-0.766
1951	+0.949	-0.928	-0.595	+1.170
1952	-0.451	+0.310	+0.843	----
1953	-0.628	-0.820	+0.631	----
1954	-0.670	----	----	----
1955	+0.122			

SOURCE: Calculated by the Author.

± 1.96. In the 2,4D case the null hypothesis could not be statistically rejected (See results in Table 2). There is no evidence to indicate that the neighborhood effect was operating as hypothesized. Therefore, the neighborhood effect, as a relevant transition mechanism in the diffusion of 2,4D weed spray must be rejected for the Collins, Iowa area.

The results of the test are not entirely unexpected since Cliff has previously tested the hypothesis using Hägerstrand's original Asby, Sweden, data. Cliff's results, using both a contiguity ratio test and the comparative time trial, confirmed the results of the Collins, Iowa, analysis. In support of both of these studies, one of Hägerstrand's students used "nearest neighbor analysis" to test the same hypothesis and concluded that he was unable to detect the neighborhood effect.[8] If the results of these three separate analyzes of spatial diffusion patterns are accepted, then the only conclusion possible is that at the scale tested the simple neighborhood effect is not as relevant a transition mechanism as previously assumed.

A Socio-economic Bias

One reason the neighborhood effect proved invalid at the scale tested is that geographic distance is biased by

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[8]Cliff, "The Neighbourhood Effect," p. 80.

the socio-economic characteristics of the resident population.[9] Evidence indicates that continued interpersonal contact between individuals is a function of perceived cultural, social, economic, and political rewards associated with interaction. These features tend to dominate the distance factor in determining the structure of an individual's network of interpersonal contact.[10] Tornqvist notes that:[11]

> "The probability of contact between different households did not depend on the physical distance between them. The information was spread in a complicated network of social relations which we were unable to survey . . . we assume in conclusion that the factor of distance is more or less inoperative in a small region."

Thus, a more complex approach to modelling the transition mechanism needs to include biases other than distance, e.g., acquaintanceship circle biases, force field biases, and reciprocity biases.[12]

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[9]There is a large literature in the social sciences which suggests that interpersonal contact is greatly influenced by such variables as age, occupation, and educational level; see, Cliff, "The Neighbourhood Effect," pp. 80-81; and Georg Karlsson, _Social Mechanisms: Studies in Sociological Theory_ (New York: The Free Press, 1958), pp. 18-55.

[10]Kevin R. Cox, "The Genesis of Acquaintance Field Spatial Structures: A Conceptual Model and Empirical Tests," in _Behavioral Problems in Geography: A Symposium_, ed. by Kevin R. Cox and Reginald G. Golledge (Evanston, Illinois: Northwestern University, Department of Geography, Studies in Geography No. 17, 1969), pp. 146-168.

[11]G. Tornqvist, _TV Agandets Utveckling I Sverige 1956-1965_ (Stockholm: Almqvist and Wiksells, 1967), p. 222, cited in Brown and Moore, "Diffusion Research," p. 145.

[12]Brown and Moore, "Diffusion Research," pp. 140-141.

A Random Bias

Another type of transition mechanism, found in the random net model, logistic curve model, and a variety of other diffusion models, treats movement as random without regard for distance or any other variable.[13] In a simple random bias model every individual is regarded as having an equal chance of interacting with every other individual. Intuitively, this type of transition mechanism is unattractive, but when one is unable to discover the explicit structure of movement in the diffusion process, it may be the only logical alternative.

A Conceptual Model

The neighborhood effect has been shown not to be as relevant a factor of spatial diffusion as previously hypothesized. However, as also noted, the structure of the central place system is recognized as being important in guiding the path of diffusion of rural innovations. Unfortunately, no spatial diffusion transition mechanism has been able to both maintain the location of the individual decision-maker and account for the influence of the central place system.[14] If transition mechanisms are going to account for

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[13]R. Solomonoff and A. Rapoport, "Connectivity of Random Nets," Bulletin of Mathematical Biophysics, XIII (1951), pp. 107-118; The logistic curve model implies movement, but it does not explicitly account for it. Thus, movement must be considered random.

[14]Both Brown, "Diffusion Dynamics," and J. C. Hudson, "Diffusion in a Central Place System," Geographical Analysis,

movement, then it is necessary to include both interpersonal contact and individual interaction with the central place system in the same diffusion model.

Both influences can be included in a simulation model by assuming that information flow is contingent upon both the probability of individual interaction with a central place and the probability of interpersonal contact within the central place. For example, a potential adopter of an innovation may interact with a central place, contact a previous adopter, and adopt the innovation; then, in the next generation of the simulation interact with a different central place, and contact a non-adopter, who then adopts.

Thus, for each generation of the simulation, individuals that interact with each central place are grouped; then the probability of interpersonal contact within each central place group determines the spatial pattern of innovation-adoption. The model allows the central place system to guide the pattern of diffusion while retaining the permanent location of the individual decision-maker. For each generation an individual may interact with a completely different set of potential contacts.

The conceptual model includes two components: one to account for an individual's interaction with the central place system and the other to account for that individual's

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I (1969), pp. 45-68, focus on the diffusion of innovations through a central place landscape, but neither operate at a scale where the location of the individual decision-maker is maintained.

interpersonal contact at the central place. Modelling the latter has been a major focus of spatial diffusion research, but no simple transition mechanism has been found. The problem is that interpersonal contact is dependent on a variety of socio-economic factors. To model interpersonal contact it appears that a large amount of individual data are required. But there is also a need for an operational diffusion model which can generalize on the basis of a small amount of individual data. Therefore, given the present state of understanding, a simple random bias model is used to represent interpersonal contact.

The task in the remainder of this study is to model individual interaction with the central place system (Chapter III) and then link the two components together into a spatial diffusion simulation model (Chapter IV).

CHAPTER III

A SPACE PREFERENCE DETERMINATION OF INDIVIDUAL CONTACT FIELDS

As noted in the previous chapter the central place system has been excluded from the structure of transition mechanisms accounting for movement from place to place in the spatial diffusion of innovation models. The task in this chapter is to define a procedure for deriving a rule of spatial behavior such that, when applied to a distribution of central places, it is capable of generating unique, individual contact fields.[1]

Revealed Space Preferences

Consumer spatial behavior has been identified as influencing the pattern of innovation diffusion. Therefore, it is a logical surrogate for a dispersed rural population's interactions with alternative central places. A consumer's behavior over space implies that he makes a search among a finite set of alternative opportunities and chooses those which he expects will give the greatest satisfaction.[2]

[1]The actual decision-making process as performed by each individual is not duplicated. But it is possible to establish from the characteristics of preferred alternatives a behavioral rule which will permit the reproduction of decisions. The individual contact field, as defined in Chapter I, gives the probability of an individual interacting with alternative central places.

[2]Gerard Rushton, "The Scaling of Locational Preferences," in Behavioral Problems in Geography, pp. 198-201.

It is known that consumers are drawn to those places which offer a large variety of goods and services at the expense of those places which offer only a few. Given two central places with a similar number of goods and services to offer, the consumer tends to patronize the closest or most accessible central place. Thus, in making decisions which are translated into overt behavior, consumers have the problem of ordering in their minds all combinations of distance and the number of goods and services offered; of applying this ordering to actual alternative central places; and of choosing that alternative which ranks highest in expected satisfaction.

The analysis of behavior by revealed space preference has shown that it is possible, from consistent statements of preferences by consumers residing at different locations, to derive a description of the ordering of all conceivable spatial alternatives.[3] In order for individual comparison of central place alternatives to be taken out of unique spatial situations, central places are assigned to general locational type categories which are based on both the population size of the central place and distance from the decision-maker.[4] The locational types may be defined as in

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[3]Gerard Rushton, "Analysis of Spatial Behavior by Revealed Space Preference," Annals of the Association of American Geographers, LIX (1969), pp. 391-401.

[4]Population size of the central place is used as a surrogate for the number of goods and services offered.

Figure 2. Here, all towns within forty-eight miles of a farm household are assigned to one of forty-eight locational types. It is possible for any central place to be assigned to different locational types for different farms. For example, given two farms, one five miles and the other 10 miles from a central place with a population of 3,000; the central place would be classified locational type "25" for the first farm and "26" for the second farm.

A Rule of Spatial Behavior

A behavioral rule of preferred locational types can be derived by employing the method of paired-comparisons. With the method of paired-comparisons the locational type of a chosen spatial alternative is considered preferred over the locational types of all rejected alternatives. Also, choice among alternatives is assumed equivalent to choice between all paired combinations of the locational types[6] to which the alternatives belong.

In experimental situations, the method of paired-comparisons presents to an individual all possible pairs of *n* locational types for his choice. However, in non-controlled situations the implicit paired-comparisons are extracted from actual individual choice data. A consistent

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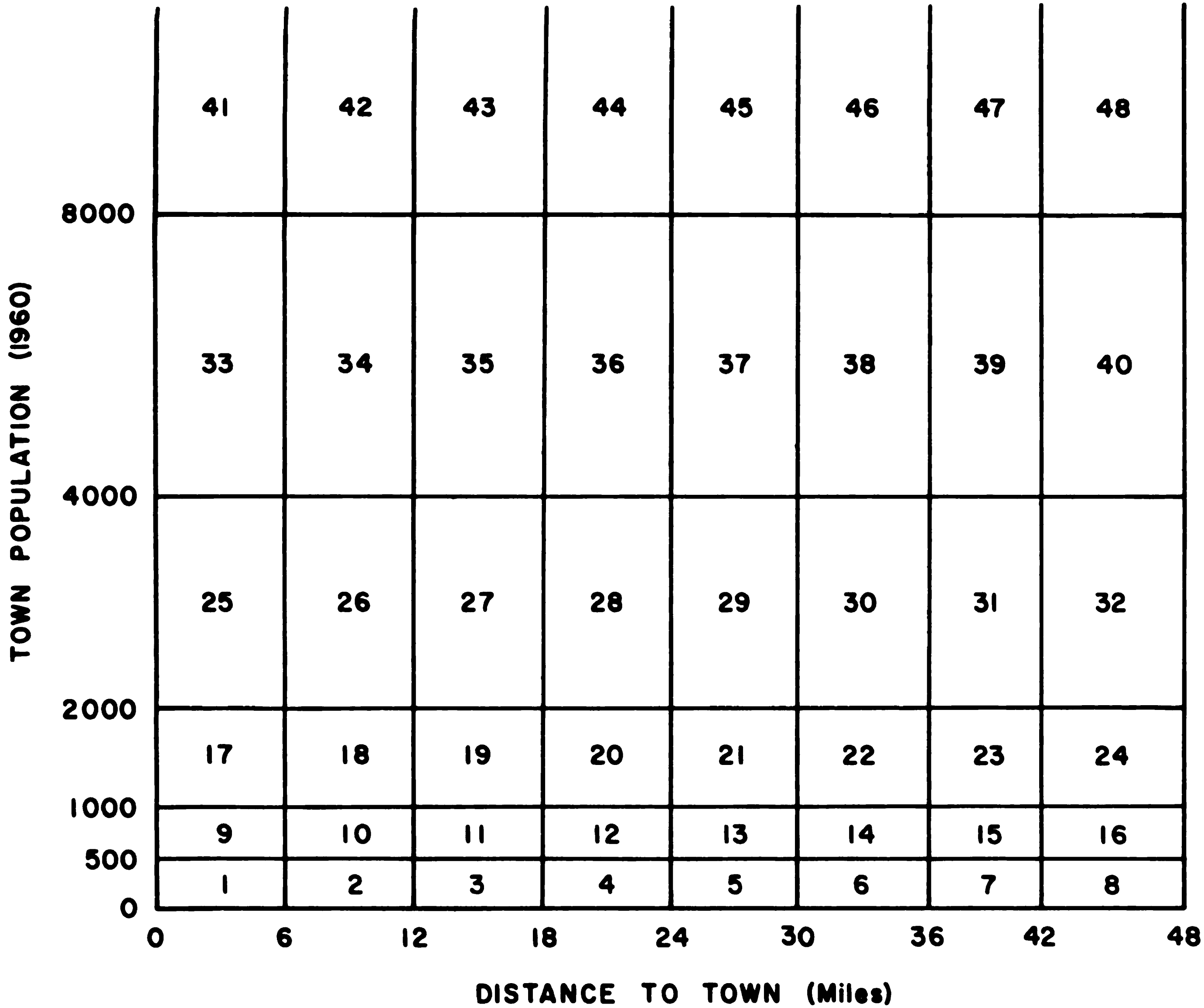
[5] Rushton, "The Scaling of Locational Preferences," pp. 202-203.

[6] Given *n* locational types, there are $n(n-1)/2$ possible paired combinations.



DEFINITION OF LOCATIONAL TYPES

Figure 2

space preference is revealed by replicating the procedure over a large enough sample to reliably estimate the proportion of times locational type *i* is chosen over *j* when the choice is between *i* and *j*. Comparisons are summarized in a n x n matrix of preference probabilities.[7]

The paired-comparison matrix of revealed space preferences is an empirically derived rule of spatial behavior. Given two central place alternatives, the rule does not directly describe behavior occurring in the system. The preference probabilities are defined independent of the spatial structure of the central place system. Therefore, the rule is capable of generating a variety of behavior patterns as the central place alternatives are allowed to change.

Multiple Alternative Situations

The behavioral rule is a probabilistic statement for spatial situations where the individual decision-maker is confronted with a choice between two locational types. In reality, spatial situations are more complex. The problem is to extend the preference rule to the more complex situations where choice is from many alternatives.

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[7]For an example of the paired-comparison matrix of revealed space preferences, see Appendix F. The complementary probabilities of the matrix sum to one $P_{ij} + P_{ji} = 1$; all probabilities below the main diagonal of the matrix can be directly derived from the probabilities above the main diagonal, and vice versa.

Each decision-maker is located in a unique spatial setting with many central place alternatives to evaluate. The classification of central places by locational types takes the alternatives out of their unique spatial context, but individual choice is still complicated by the number of alternatives available. The problem is to determine the likelihood of choosing an alternative when three or more central places are available. Direct empirical measurement of all combinations of locational types for choice situations where there are more than two central places to choose is impossible.[8]

The solution to this problem is provided by R. D. Luce's choice axiom. This axiom is a simple but powerful statement which relates to the relationship among choice probabilities as the number of alternatives change. The basic assumption is that the ratio of the likelihood of choosing one alternative to the likelihood of choosing another is constant irrespective of the number and composition of other available alternatives.[9]

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[8]For 48 locational types there are 1128 possible paired combinations; however, for spatial situations where there are three, four, and five alternative locational types to evaluate there are 17,296; 194,580; and 1,712,304 combinations. An extremely large set of data would be required to estimate probabilities by direct measurement for spatial situations where there are more than paired combinations.

[9]R. D. Luce, _Individual Choice Behavior_ (New York: John Wiley, 1959); Richard C. Atkinson, Gordon H. Bower, and Edward J. Crothers, "Choice Behavior," Chapter Four in _An Introduction to Mathematical Learning Theory_ (New York: John Wiley, 1965), pp. 135-186.

Thus, from Luce's axiom, given n-1 adjacent choice probabilities, the entire array of n(n-1)/2 choice probabilities in the paired-comparisons matrix can be predicted. Given the probability of locational type *i* being chosen over locational type *j* and the probability of locational type *j* being preferred over locational type *k*, then with the constant ratio assumption the probability of locational type *i* being chosen over locational type *k* can be determined. More importantly, implicit in the axiom is the fact that paired choices provide enough information to determine choice probabilities when three or more alternatives are considered.[10] Therefore, the simple behavior rule of space preferences can be extended to situations where the individual has more than two locational types from which to choose. Given locational types *i*, *j*, and *k*, the probability of each being selected can be determined.

Derivation of Individual Contact Fields: An Example

The individual contact field can be derived for any spatial situation where there are more than two alternatives to evaluate when the paired-comparisons matrix of revealed space preferences, the location of decision-makers, and the distribution of central place alternatives are given. As an example, consider a sample household located two miles south and four miles west of Nashua, Iowa, where the

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[10] Atkinson, Bower, and Crothers, *Mathematical Learning Theory*, pp. 146-150.

decision-maker perceives Nashua (N), Charles City (C), and Waverly (W) as the only available central place alternatives. The three alternatives and locational type categories are shown in Table 3.

TABLE 3

Central Place Alternatives and Locational Type Classification

Central Place	Miles from Household	Population (1960)	Locational Type
Nashua	6	1740	17
Charles City	13	9960	43
Waverly	21	6360	36

The likelihood of one locational type being chosen over another for all possible pairs of the three locational types 17, 43, and 36 is shown in Table 4.[11]

TABLE 4

Preference Data Matrix: Probability That Column Location Type is Preferred to Row Type

		Locational Types		
		17	43	36
Nashua (N)	17	0.50	0.37	0.04
Charles City (C)	43	0.63	0.50	0.09
Waverly (W)	36	0.96	0.91	0.50

[11]The information in Table 4 was extracted from the paired-comparisons matrix of revealed space preferences listed in Appendix F.

To predict the three-alternative probabilities from the pair data, the relevant calculations are exhibited below. The equation notation is simplified by letting the first letter of each central place name represent the probability of that alternative being chosen.

The probability of Nashua being chosen can be written as

$$P(N) = \frac{N}{N + C + W} = \frac{1}{1 + \frac{C}{N} + \frac{W}{N}}$$

Estimates of C/N and W/N may be obtained from the pair data in Table 4; they are

$$\frac{C}{N} = \frac{0.37}{0.63} = 0.5873$$

and

$$\frac{W}{N} = \frac{0.04}{0.96} = 0.0416$$

When these values are substituted into the above equation for P(N), the resulting prediction is

$$P(N) = \frac{1}{1 + 0.5873 + 0.0416} = \frac{1}{1.6289} = 0.6139$$

The predicted probabilities of the other two alternatives are readily obtained as follows:

$$P(C) = \frac{C}{N + C + W} = \frac{C/N}{1 + C/N + W/N} = \frac{0.5873}{1.6289} = 0.3606$$

and $$P(W) = \frac{W}{N + C + W} = \frac{W/N}{1 + C/N + W/N} = \frac{0.0416}{1.6289} = 0.0255$$

Thus, the individual contact field for the sample household is:

Central Place	Probability of Contact
Nashua	0.6139
Charles City	0.3606
Waverly	0.0255
	1.0000

It is possible to derive individual contact fields for as many alternatives as the decision-maker perceives. If for the sample household the decision-maker had perceived five central place alternatives then the individual contact field would have been:[12]

Central Place	Miles to Household	Population (1960)	Locational Type	Probability of Contact
Nashua	6	1740	17	0.565
Charles City	13	9960	43	0.305
Greene	12	1430	18	0.106
Waverly	21	6360	36	0.018
Clarksville	13	1330	19	0.006
				1.000

Summary

In this chapter a procedure has been outlined for deriving a rule of spatial behavior that is capable of generating unique, individual contact fields. The behavioral rule is based on revealed space preferences and is derived independently of the unique structure of any central place system. The uniqueness of both spatial choice and the characteristics of central place alternatives is removed by defining locational types. Locational types, also, allow for the analytical separation of preference and distribution of alternatives.

[12]The individual contact field was calculated using Fortran Program ALTERN on a CDC 6500 computer at Michigan State University. Program ALTERN is listed in Appendix C.

Thus, patterns of behavior in space can be predicted by taking the behavioral rule and applying it against any set of central place alternatives.

The purpose of this chapter was to derive a behavioral model of individual interaction with the central place system that could be incorporated into a spatial diffusion model. In Chapter IV the behaviorally derived individual contact field is linked to a simple random bias model to simulate the diffusion of a rural innovation in northeast Iowa.

CHAPTER IV

THE SPATIAL DIFFUSION OF HARVESTORE SYSTEMS IN NORTHEAST IOWA: THE MODEL

The Diffusion Model

The conceptual model proposed in Chapter II assumed that information flow in the innovation-adoption process is contingent upon both individual interaction with the central place system and interpersonal contact within a central place. The individual contact field construct was derived as a surrogate model for central place interaction and suggested as an alternative representation of interpersonal contact was a simple random bias model. By linking the individual contact field construct together with the simple random bias model, a spatial diffusion of innovation model is constructed which accounts for both movement factors. The operating rules of the model are:[1]

1. Individuals are either adopters or potential adopters of an innovation: at the outset there must be at least one adopter.

2. Each individual may accept the innovation but once an adopter he remains one.

3. Acceptance occurs only upon communication through interpersonal contact with an adopter.

[1]Some of the rules presented are similar to those of Hägerstrand, see, Hägerstrand, "On Monte Carlo Simulation of Diffusion," pp. 12-13.

4. An innovation is accepted upon first contact with an adopter; each communication contains sufficient influence to persuade adoption.

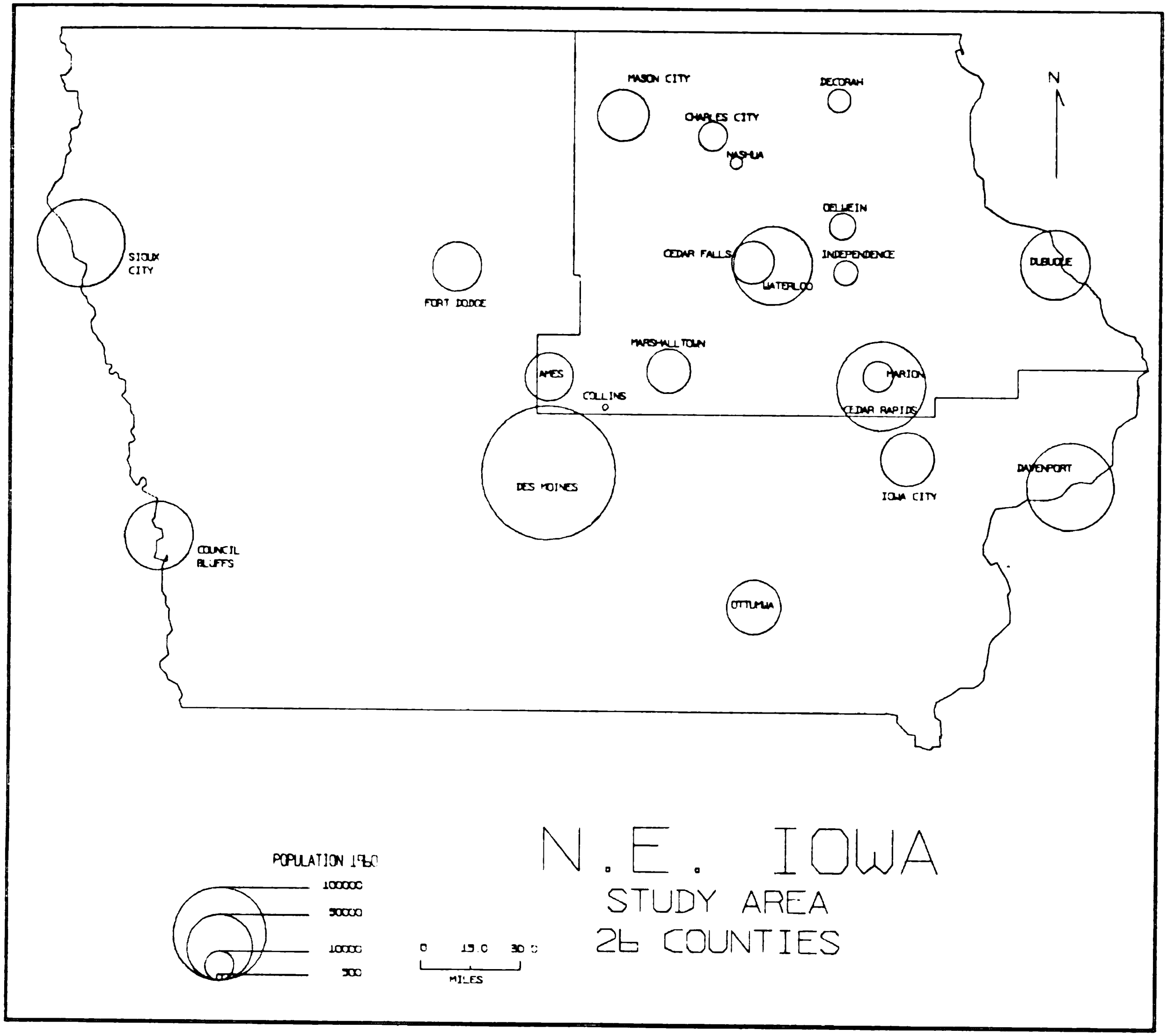
5. Interpersonal contact takes place only at certain time intervals (called generations) when every adopter contacts one other individual, adopter or potential adopter.

6. Communication between individuals depends on the probability of individual interaction with the central place system and the probability of interpersonal contact at the central place.

The model incorporates a probability distribution in which the likelihood of interpersonal contact between any two individuals is specified. Spatial patterns of innovation-adoption are simulated for each generation by obtaining a set of random numbers which are used to sample this probability distribution. A sequence of such samplings simulates the diffusion pattern through time. A range of different diffusion patterns is generated by repeating the whole procedure. To evaluate the model the correspondence between the simulated diffusion patterns and the actual diffusion of Harvestore Systems in northeast Iowa is examined.

The Study Area

The area chosen for this study includes the 26 counties in northeastern Iowa that corresponds to the exclusive market area of the Harvestore dealers located at Cedar Falls and Nashua, Iowa (see Map 1. This study area was selected primarily because of the availability of Harvestore diffusion data that corresponds to the same general area as


N
MASON CITY
DECORAH
CHARLES CITY
NASHUA
OELWEIN
CEDAR FALLS
INDEPENDENCE
WATERLOO
SIOUX CITY
FORT DODGE
DUBUQUE
MARSHALLTOWN
AMES
COLLINS
MARION
CEDAR RAPIDS
DES MOINES
IOWA CITY
DAVENPORT
COUNCIL BLUFFS
OTTUMWA
N.E. IOWA
STUDY AREA
26 COUNTIES
POPULATION 1960
100000
50000
10000
500
0 15.0 30.0
MILES

Map 1

the consumer behavior data (Iowa) and the 2,4D weed spray data (Collins, Iowa).[1a]

Harvestore Systems

The Harvestore System is a unique feed-crop storage system that has a number of advantages over ordinary farm silos. A serious problem with feed-crop storage in ordinary silos is that up to one-fourth of the feed-crop is lost through oxidation. Atmospheric temperature changes cause gases inside silos to expand and contract. This action exerts pressure on the silo structure which can not be compensated for without allowing air to enter and contact the feed-crop.

The major advantage of the Harvestore System is that it can be sealed air-tight to reduce feed-crop loss through oxidation. The Harvestore structure is constructed of glass-fused-to-steel plates that are impervious to air. Inside the structure pressure absorbing gas-bags vented to the outside compensate for changes in atmospheric temperature and pressure. With a rise in outside temperature gases inside the structure expand and push air out of the breather bags. With a fall in outside temperature gases inside contract and the breather bags are filled with air. Thus, the system, by controlling in-and-out air flow, compensates for pressure changes inside the Harvestore structure without allowing air to contact the feed-crop.

[1a]See Appendix H for a more complete description of the study area.

The obvious advantage to adopting a Harvestore System is the significant reduction in feed-crop loss through oxidation. But the system also gives the farmer greater flexibility in cropping and harvesting, and allows him to increase both the quantity and quality of animal feed. Feed-crops can be harvested early when moisture and protein content are high and stored in the Harvestore structure without the worry or cost of drying. Double-cropping with a winter crop and an early spring harvest is a possibility that allows the farmer to get an extra crop per year off the same acreage.

Harvestore structures have automatic unloading from the bottom, therefore it is not necessary to unload the structure before refilling. Ordinary silos load and unload from the top, thus they must be emptied before refilling.

With a Harvestore System a farmer can realize a savings in labor costs since harvesting takes less time, much of the heavy labor is eliminated with automatic equipment, and crops need not all be harvested at once but may be harvested when the farmer has the available labor.

The first Harvestore System recorded in northeast Iowa was installed in 1949. The initial structure was located on a farm ten miles southeast of Waterloo (see Maps 4 and 5 in Appendix A). From 1950 through 1967 there was a general increase in the number of systems adopted per year so that by the end of 1967 there were Harvestore Systems on 395 farms in northeast Iowa. The number of farms adopting and cummulative number adopted from 1950 through 1967 are recorded in Table 5 (Also, see Maps 4-39 in Appendix A).[2]

The Harvestore System is an innovation in the production of feed for dairy cattle, beef cattle, and hogs and might have spread more rapidly in northeast Iowa, but the cost of construction and the need for additional mechanized equipment impeded adoption. The large scale financing needed to install a Harvestore System requires that a farmer make a substantial financial commitment in adopting a new system of feed-crop production and storage.

The Diffusion Pattern

There are several observable trends in the spatial pattern of acceptance of Harvestore Systems in the northeast Iowa study area. The earliest trend is the development of a cluster of adopters south of Waterloo (See Maps 4-21 in Appendix A). The Waterloo cluster is most pronounced in the early 1950's; in 1952 and 1953 nearly half of all systems in

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[2]Each farm that adopted a Harvestore System and the years of adoption is listed in Appendix D. This information was obtained from Mr. Robert Lyons at A. O. Smith Harvestore Products, Inc., Arlington Heights, Illinois. The exact locations of farms adopting the systems were verified by the local dealers; Iowa Structures, Cedar Falls, Iowa, and Skyline Harvestore, Nashua, Iowa.

The diffusion of Harvestore Systems in northeast Iowa is plotted on Maps 4-39 in Appendix A. The even numbered maps record the location of each farm adopting the system in a particular year and the odd numbered maps record the location of all farms that have adopted the system up to the end of a particular year.

TABLE 5

NUMBER OF FARMS ADOPTING

HARVESTORE SYSTEMS

Year	New Adopters	Total
1950	6	7
1951	14	21
1952	21	42
1953	16	58
1954	18	76
1955	13	89
1956	9	98
1957	7	105
1958	28	133
1959	25	158
1960	11	169
1961	42	211
1962	24	235
1963	12	247
1964	19	266
1965	22	288
1966	57	345
1967	50	395

use were in this cluster. By 1955 adoption had tended to move away from this cluster.

A second trend is the development of a tight cluster of adopters west of Dubuque (See Maps 16-31 in Appendix A). Initial growth of this mode of adopters was slow until 1958. From 1958 through 1960 nearly half of all new systems adopted in the study area were installed in this cluster. After 1960 acceptance of the innovation tended to expand away from the Dubuque cluster.

A third identifiable pattern was the general tendency for adoption of Harvestore Systems to move from south to north. Throughout the study period there had been scattered growth in the number of systems adopted in the northern half of the study area. In the early 1950's there were a number of systems adopted in the northern half of the area, but from 1957 through 1962 very few systems were installed in the north area. However, after 1962 there has been a tendency for the proportion of adopters to increase. By 1967 the majority of Harvestore Systems being adopted were in the northern half of the study area (See maps 34-39 in Appendix A).

The three trends identified account for a majority of the Harvestore Systems adopted. The development of each of the three trends corresponds to peak years in the number of systems adopted. The Waterloo cluster developed early in the study period and accounts for a large proportion of the adoptions in the peak years of 1952 and 1953 (See Table 5). In the late 1950's the Dubuque cluster accounts almost totally for the number of adoptions in 1958 and 1959. Finally, the general trend for adoption to move from south to north corresponds with the increase in number of adoptions in 1966 and 1967.

In addition to the three previously identified trends is an observed general diffusion of adoption of the innovation into an area south of Mason City and west of Waterloo along the western boundary of the northeast Iowa study area. The pattern in the 1950's begins as a slow diffusion of acceptance of the innovation spreading from the east, but from 1957 through 1959 a number of adoptions occur south of Mason City which appear independent of the westward diffusion pattern (See Maps 18-23).

What is apparent in the development of the spatial diffusion pattern in northeast Iowa is that when a cluster of adopters reaches some minimum threshold size, the adoption rate increases. The adoption rate remains high in the cluster until all of the most innovative potential adopters have accepted Harvestore Systems, and then the rate decreases. With both the Waterloo and Dubuque clusters the adoption rate remained high for three or four years.

The Basic Data

Before the simulation may be run the diffusion model needs the following information:

1. The number and location of all potential adopters.
2. The number and location of all initial adopters.
3. The behavioral rule used to derive individual contact fields (paired-comparisons matrix of preferred locational types).
4. The location and population of all central places in the study area which decision-makers consider as possible alternatives.

The Population of Initial and Potential Adopters

To insure that simulation runs are not spatially biased care must be taken in selecting the distribution of potential adopters. In northeast Iowa there are over 40,000 farms.

Thus assuming that the operator of each farm could adopt a Harvestore System there are over 40,000 potential adopters in the study area. Analytically, this number of potential adopters is more than the diffusion model can handle. Therefore, the number must be reduced to something less than the total.

Both the number and the location of potential adopters can bias simulation runs. It is obvious if the sample of potential adopters considered in the diffusion model is not an unbiased sample of the total population of potential adopters that the resulting simulation patterns will be spatially biased. Also, simulation patterns will be spatially biased if the sample is not sufficiently large. For example, if in a simulation run 999 out of 1000 potential adopters accept an innovation, then the resulting spatial pattern of adopters is highly predictable.[3] In fact, the results of the simulation are determined by the distribution of potential adopters; no other mechanism in the diffusion model plays an important part in determining the spatial pattern.

---

[3]When 999 out of a sample of 1000 potential adopters accept in a simulation run it is clear that the sample is not large enough. Only 1000 different spatial patterns can occur:

$$\frac{N!}{r!\,(N-r)!} = \frac{1000!}{999!\,1!} = 1000$$

Each of the spatial patterns is almost exactly the same as all the others.

Since there are 395 adopters of the actual innovation in the study area, the sample of potential adopters must be significantly larger than this number. Arbitrarily, a stratified random sample of 1000 farms is drawn as the set of potential adopters for the diffusion simulation model (see Map 2). By stratifying the sample an unbiased estimate of the spatial distribution of the population of potential adopters is obtained; and 1000 farms are considered a sufficiently large sample for the number of actual adopters.[4] In none of the twenty-six counties in the study area does the number of Harvestore Systems accepted exceed the number of sample potential adopters (see Figure 3).

The initial set of 21 adopters selected for the simulation model correspond to the 1951 distribution of Harvestore Systems (see Map 7 in Appendix A). This distribution allows the model sufficient number of initial adopters to simulate the spatial pattern of innovation-adoption in a minimum number of generations.

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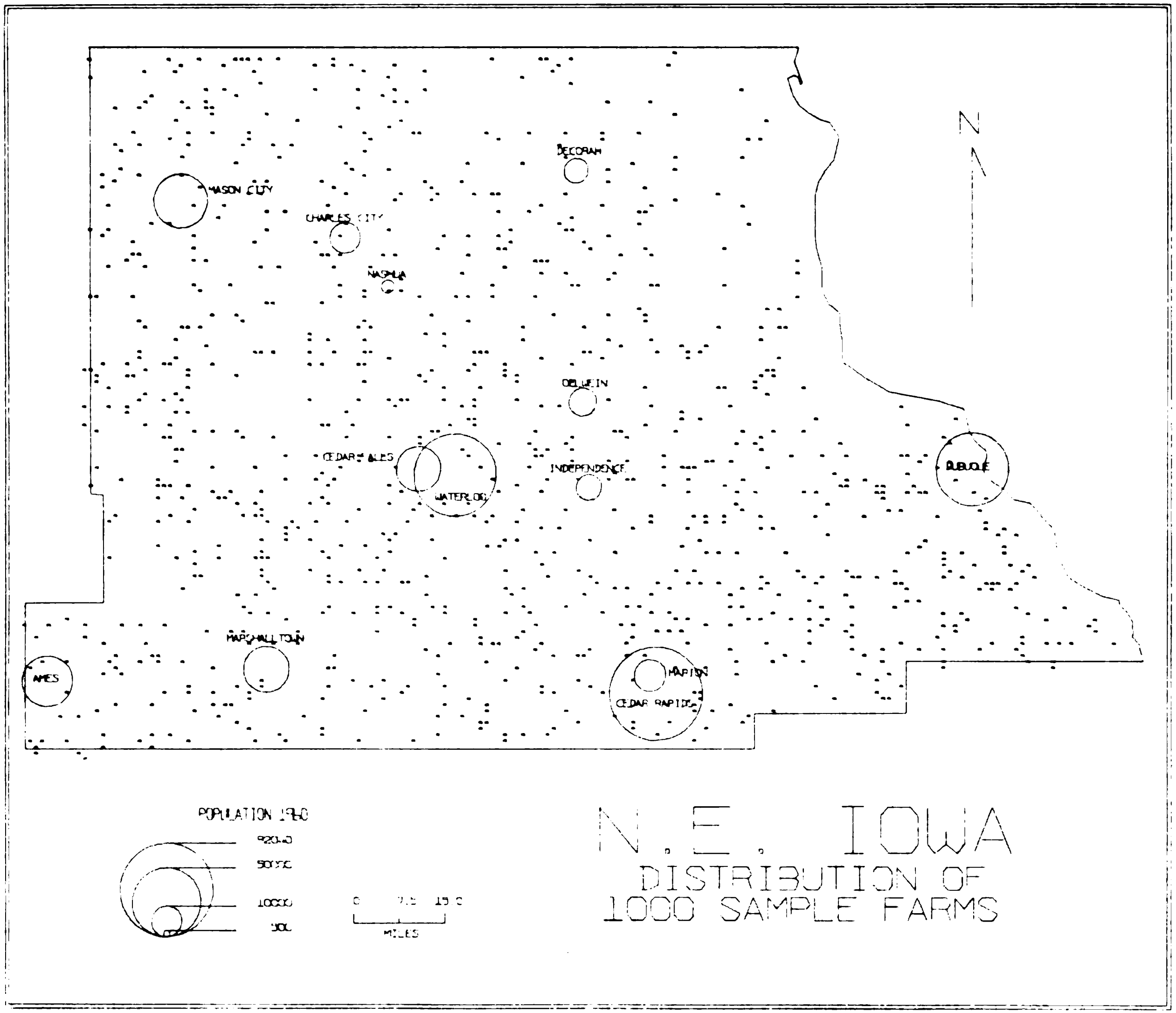
[4]The possible number of different spatial patterns that can result from a simulation where 395 out of 1000 potential adopters accept an innovation is almost infinite,

$$\frac{1000!}{395!\ 605!}$$


N
MASON CITY
CHARLES CITY
NASHUA
DECORAH
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
MILES
N.E. IOWA
DISTRIBUTION OF
1000 SAMPLE FARMS

Map 2

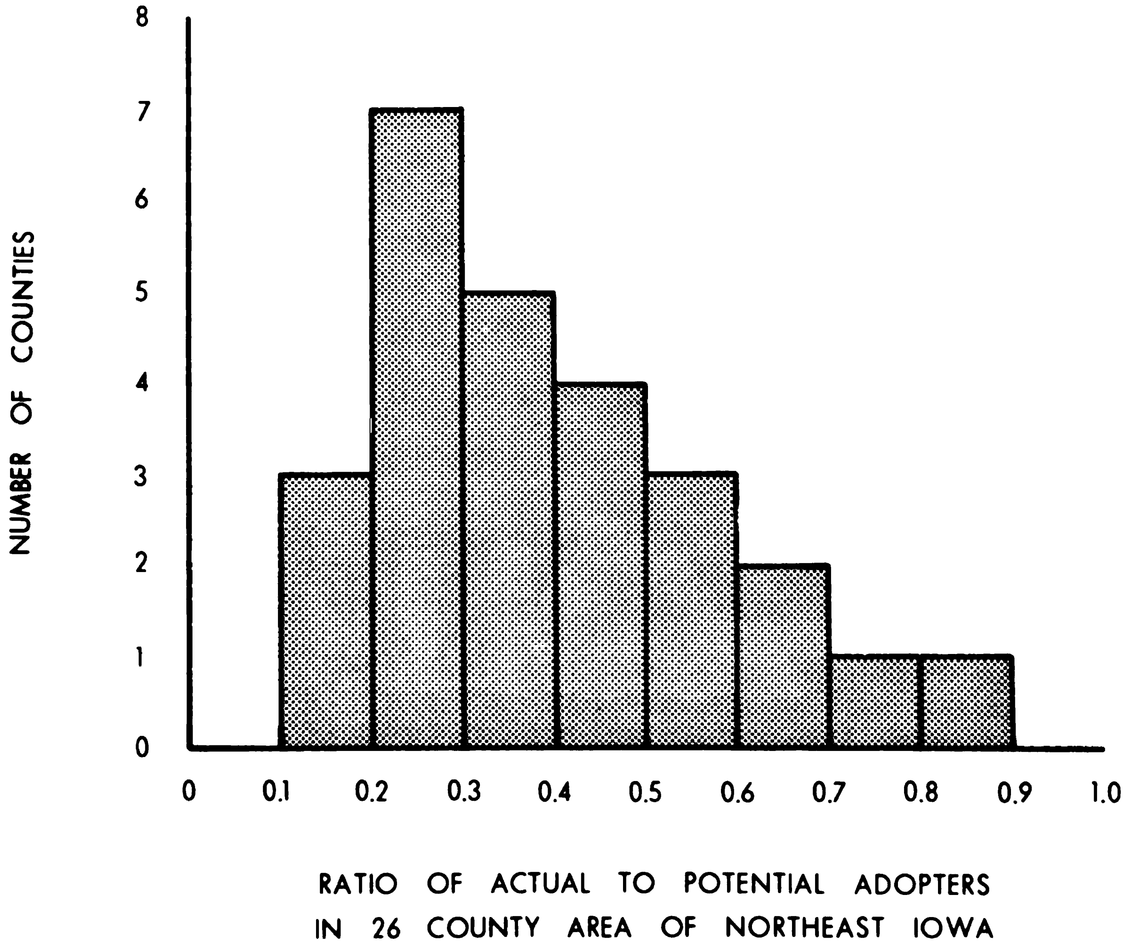

NUMBER OF COUNTIES
8
7
6
5
4
3
2
1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
RATIO OF ACTUAL TO POTENTIAL ADOPTERS
IN 26 COUNTY AREA OF NORTHEAST IOWA

Figure 3

The Behavioral Rule

Two data sets are used to generate the paired-comparisons matrix of preferred locational types.[5] The first set of data describes the consumer behavior for a random sample of dispersed farm households in Iowa. Identified in the data are the central places patronized and the total dollar value of expenditures on selected household commodities.[6] The second data set is the location and 1960 population of all Iowa central places (see Map 3).[7] These two data sets form the basis from which the behavioral rule is empirically calibrated.[8]

Available Spatial Alternatives

The distribution of central places within 48 miles of an individual defines all of his alternative opportunities

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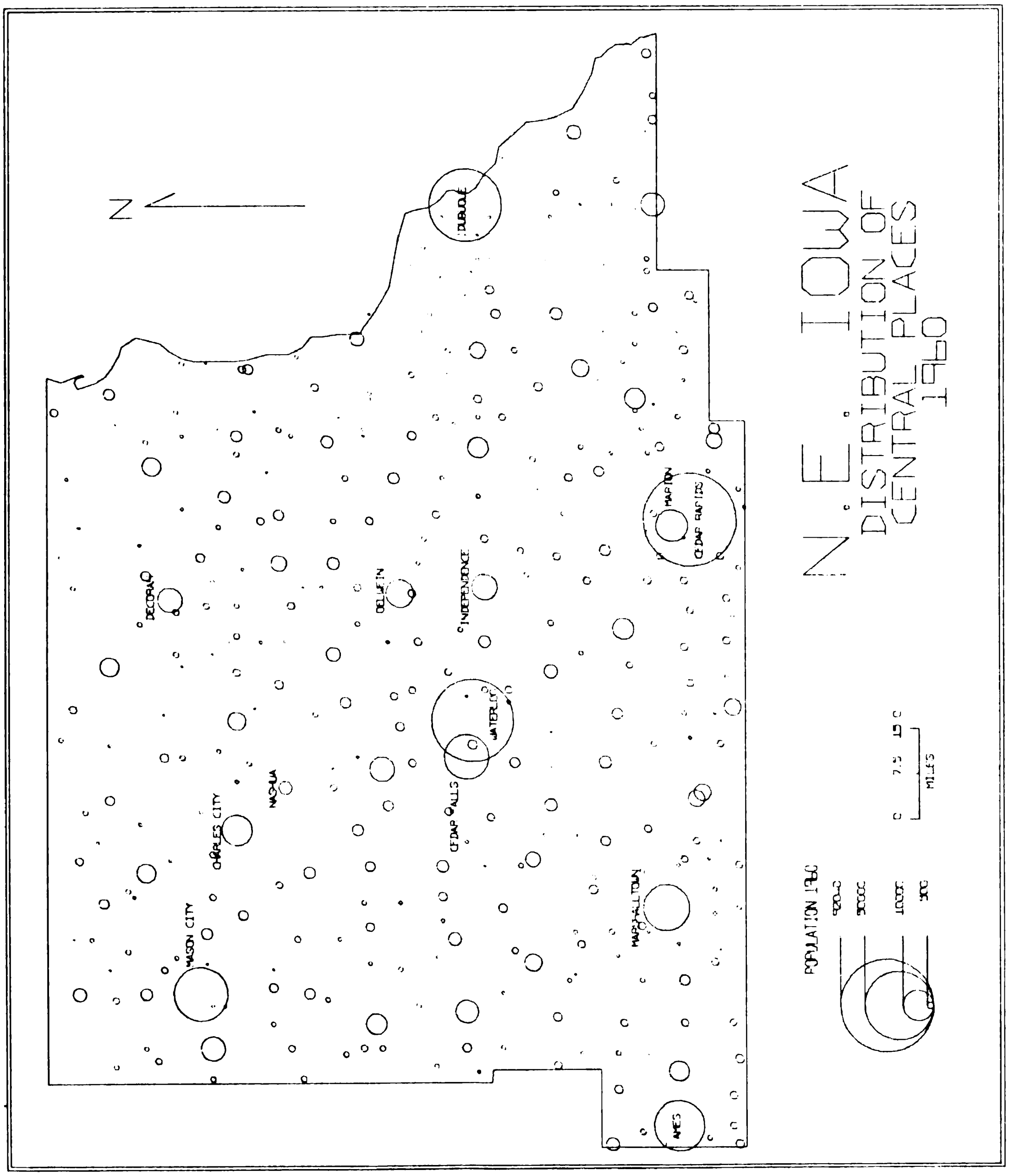
[5]The paired-comparison matrix of preferred locational types is listed in Appendix F. The locational types used to generate the matrix are the same as defined in Figure 1.

[6]The type and number of household commodities used to define the behavioral rule is fundamental to the structure of the probabilities. For a listing of the 20 commodities selected and the reason for selections, see Appendix B.

[7]This data was collected in the Spring of 1961 as part of a survey of expenditures and sales by persons living in rural Iowa. The survey was conducted by the Iowa State University Statistical Laboratory for the Iowa College-Community Research Center. For further description of this survey and the data collected, see Appendix A in Gerard Rushton, Spatial Pattern of Grocery Purchases by the Iowa Rural Population, University of Iowa, Bureau of Business and Economic Research, Studies in Business and Economics, New Series No. 9 (1966), pp. 103-109.

[8]The behavioral rule was used to generate individual contact fields for each household in the Iowa sample. The individual contact fields were successful in predicting the most preferred central place for greater than 65% of the sample.


N.E. IOWA
DISTRIBUTION OF
CENTRAL PLACES
1960
N
DUBUQUE
DECORAH
OELWEIN
INDEPENDENCE
MARION
CEDAR RAPIDS
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
POPULATION 1960
MILES

Map 3

for central place interaction.[9] For every sample farm in the study area there are well over 200 central places within 48 miles. Thus, it is obvious that a decision-maker is unable to perceive all of his alternatives and to evaluate each one. The farther away and the smaller the central place, the more likely the individual is to ignore it as an alternative.

Preferred Locational Types

Theoretically the decision-maker has access to a broad range of locational types; typically only some limited portion of the alternatives are relevant and applicable to his decision behavior.[10] In Iowa greater than 99 per cent of all dollars spent on the selected household commodities are spent at five or fewer central places. In most cases the five central places are the five with which the individual has the highest probability of interacting according to the behavioral rule. This tends to indicate that decision-makers perceive their first five preferred locational type central places as the complete set of relevant alternatives.

To model interaction with the central place system, it is necessary to only consider a decision-makers first five preferred alternatives. Thus, the individual contact

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[9] The name, location, and 1960 population of all central places in northeast Iowa are listed in Appendix H. Also, see Map 2.

[10] Julian Wolpert, "Behavioral Aspects of the Decision to Migrate," _Papers of the Regional Science Association_, XV (1965), p. 161.

field need be defined for only five central places. Identification of preferred alternatives is accomplished first by scaling the information contained in the paired-comparisons matrix to obtain a one-dimensional ranking of all locational types. Then by comparing the preference ranking to the list of locational types available to the decision-maker, the five preferred central places can be identified.

A ranking of locational types by preferences is found by scaling the information contained in the paired-comparison matrix of revealed space preferences.[11] The scaling technique used is an algorithm developed by Kruskal.[12] Table 6 shows the computed scale values and rankings on the first dimension. The stress value for the first dimension equals 0.334. In Figure 4, locational types are plotted on one dimension. The negative scale values are most preferred and the positive scale values are least preferred. In Figure 5, the scale is shown as isolines. The isolines represent a trade-off between population size and distance to a central place; the same variables used to define locational types. This surface is called an indifference surface of spatial choice and infers that a decision-maker would be indifferent between any two central places located along one of the isolines. The

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[11]For a more complete discussion of scaling of locational types, see Gerard Rushton, "The Scaling of Locational Preferences," in Cox and Golledge, Behavioral Problems in Geography, pp. 197-227.

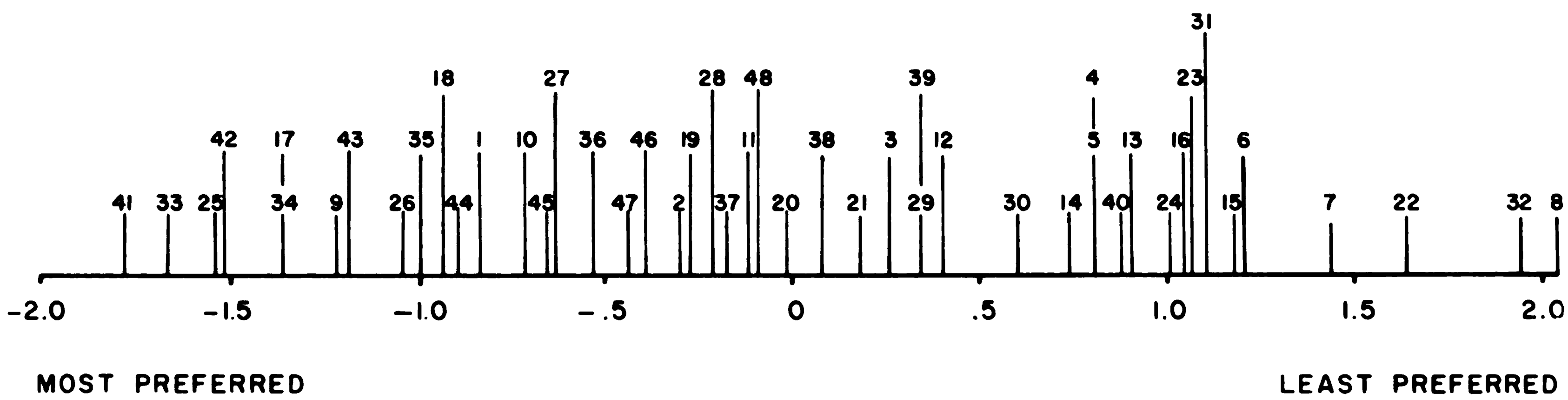
[12]J. B. Kruskal, "Non-Metric Multi-Dimensional Scaling: A Numerical Method," Psychometrika, XXIX (1964), pp. 115-129.

preferred central place lies on the highest point on the surface (upper left).

TABLE 6

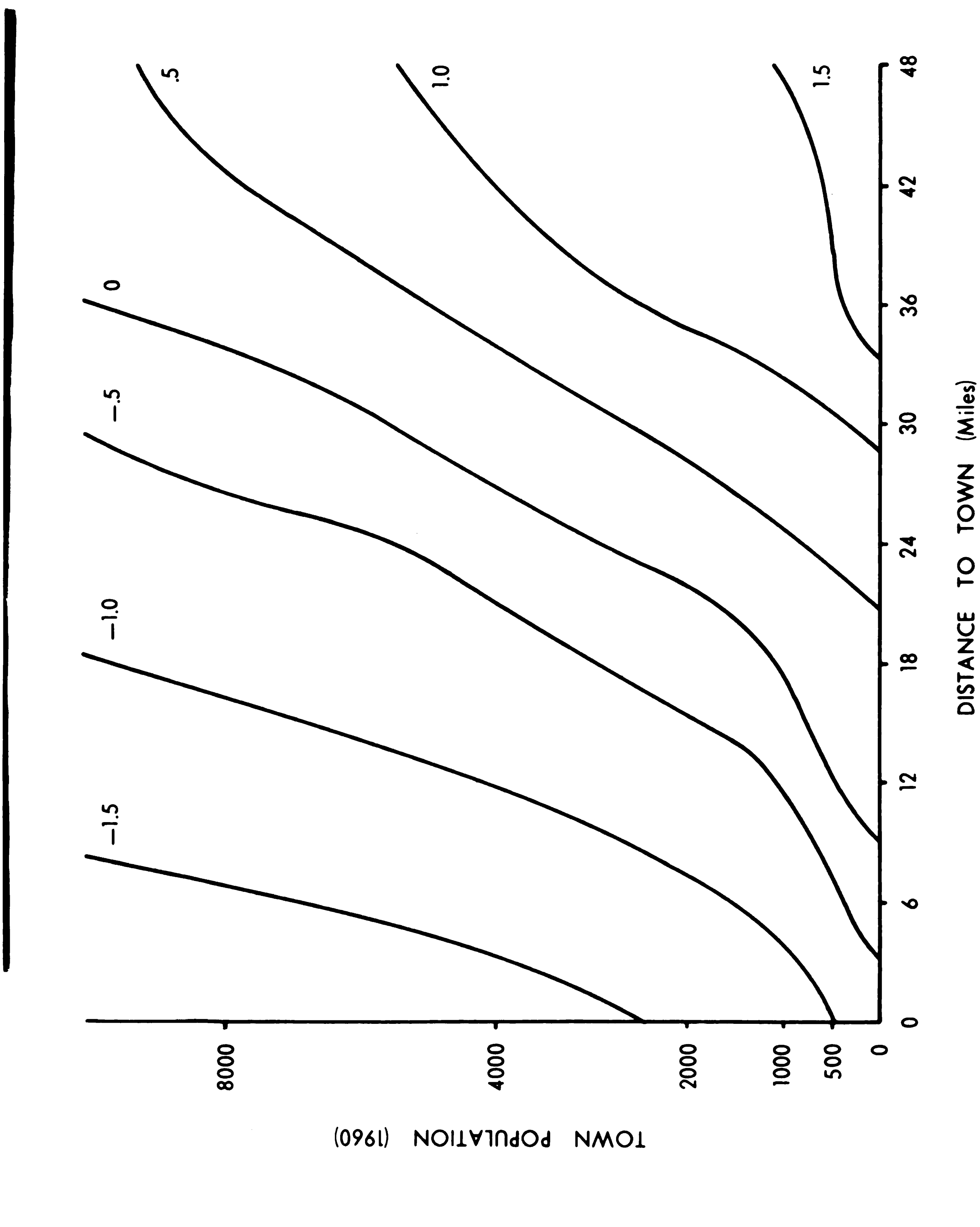
SCALE VALUES FOR THE LOCATIONAL TYPES

Locational Types	Scale Value	Rank	Locational Types	Scale Value	Rank
1	-0.821	13	25	-1.522	3
2	-0.272	20	26	-1.026	9
3	0.285	29	27	-0.622	16
4	0.821	36	28	-0.204	22
5	0.819	35	29	0.366	30
6	1.221	44	30	0.611	33
7	1.461	45	31	1.130	42
8	2.052	48	32	1.963	47
9	-1.181	7	33	-1.613	2
10	-0.702	14	34	-1.341	5
11	-0.094	24	35	-0.989	10
12	0.416	32	36	-0.521	17
13	0.928	38	37	-0.165	23
14	0.766	34	38	0.105	27
15	1.201	43	39	0.347	31
16	1.063	40	40	0.894	37
17	-1.337	6	41	-1.762	1
18	-0.931	11	42	-1.465	4
19	-0.264	21	43	-1.153	8
20	-0.012	26	44	-0.895	12
21	0.204	28	45	-0.652	15
22	1.656	46	46	-0.384	19
23	1.073	41	47	-0.426	18
24	1.017	39	48	-0.070	25



ONE DIMENSIONAL SCALE FOR LOCATIONAL TYPES

Figure 4



SPACE PREFERENCE STRUCTURE FOR FACTOR II

Figure 5

Summary

In this chapter a transition mechanism accounting for both individual interaction with the central place system and interpersonal contact within a central place has been incorporated into the rules of a diffusion simulation model. The transition mechanism links the individual contact field construct with a simple random bias model to account for place to place movement in the diffusion process.

The behavioral rule and the parameters of the model have been defined so that the model can be run through a number of simulations. In the following chapter a number of simulations are performed, and the diffusion model is evaluated against the actual diffusion of Harvestore Systems.

CHAPTER V

THE SPATIAL DIFFUSION OF HARVESTORE SYSTEMS IN NORTHEAST IOWA: THE SIMULATION AND EVALUATION

The Simulation Runs

Ten simulation runs are performed to compare with the actual diffusion of Harvestore Systems.[1] Each simulation is run through seven generations. See Tables 7 and 8 for the results of the ten simulation runs.[2]

Evaluation of the Diffusion Model

Validation is the process of determining how well a model replicates the properties of the real-world system under study. Evaluation of the validity of a Monte Carlo diffusion model is a difficult process. Since the Monte Carlo method depends on sampling from a probability distribution, each run through the model may produce a wide range of results even though the underlying spatial process is

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[1]The ten simulations are run using Program SPACDIF listed in Appendix C. The number of simulations is restricted to ten because of the time limitations on the CDC 6500 computer.

[2]Simulation 2 is also mapped, see Maps 40-53. This simulation was chosen to map because it corresponds closely to the mean for all ten simulations and appears to be what might be called an average simulation. If it had been possible all ten simulations would have been mapped.

It might be noted that on Maps 40, 42, 44, 46, 48, 50, and 52 the location of previous adopters, new adopters, and central place where interpersonal contact occurred is shown.

TABLE 7

CUMMULATIVE NUMBER OF ADOPTERS

Generation	Simulation 1	2	3	4	5	6	7	8	9	10	Mean	Standard Deviation	Observations
g_0	21	21	21	21	21	21	21	21	21	21	21.0		21 (1951)
g_1	33	33	33	35	33	35	34	36	29	35	34.6	1.90	
g_2	55	55	62	64	62	50	58	72	52	58	58.8	6.46	58 (1953)
g_3	82	98	107	120	111	75	98	129	102	95	101.7	16.22	105 (1957)
g_4	120	158	180	195	196	111	154	209	177	136	160.6	35.35	158 (1959)
g_5	178	231	260	219	305	166	225	301	267	196	242.0	50.77	247 (1963)
g_6	236	313	344	377	391	238	309	392	354	283	323.7	58.11	
g_7	315	397	437	458	472	315	396	480	432	384	408.6	59.00	395 (1967)

TABLE 8

NUMBER OF ADOPTIONS PER GENERATION

	Simulation											
Generation	1	2	3	4	5	6	7	8	9	10	Mean	Standard Deviation
g_1	12	12	12	14	12	14	13	15	8	14	12.6	1.95
g_2	22	22	29	29	29	15	24	36	23	23	25.2	5.73
g_3	27	43	45	56	49	25	40	57	50	37	42.9	10.95
g_4	38	60	73	75	85	36	56	80	75	41	64.0	18.39
g_5	58	73	80	96	109	55	71	92	90	60	78.4	18.12
g_6	58	82	84	96	86	72	84	91	87	87	81.7	9.70
g_7	79	84	93	81	81	77	87	88	78	101	84.3	7.56

constant. Mere correspondence between a single simulation or an average of all simulations with the actual diffusion of an innovation does not validate a model, but likewise lack of correspondence does not necessarily invalidate the model.[3]

If a simulated pattern is similar to the real-world diffusion pattern, one can conclude that the structure of the simulation model is a plausible explanation of the real-world process.[4] As Morrill notes:[6]

> ". . . the model was not intended to account for the exact pattern . . . The proper test was whether the simulated pattern of spread had the right extent . . . intensity . . . and solidarity . . . This similarity, rather than conformance, indicated that both the actual and the simulated patterns could have occurred according to the operation of the model. This is the crucial test of theory."

Simplification and abstraction in model building increases uncertainty of a simulation's "representativeness" and thus adds to the necessity of establishing validity. The evaluation of a simulation model is subjective and ultimately depends on the degree of satisfaction with the theoretical interpretation of the random variables. For hypothesis and theory construction the final validity criteria are defined in terms of the heuristic payoff. In this context,

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[3]See, David Harvey, "Models of the Evolution of Spatial Patterns in Human Geography," in Richard J. Chorley and Peter Haggett (eds.), Models in Geography (London: Methuen, 1967), pp. 582-588, for a general discussion of the use of Monte Carlo simulation in geographic research.

[4]Brown and Moore, "Diffusion Research," p. 143.

[5]Richard L. Morrill, "The Negro Ghetto: Problems and Alternatives," Geographical Review, LV (1965), p. 359.

Hermann has suggested five criteria for judging the validity of a simulation model: (1) event validity, (2) face validity, (3) internal validity, (4) variable-parameter validity, and (5) hypothesis validity.[6] The validity of the spatial diffusion model is discussed in terms of four of the five criteria.[7]

Event Validity

Comparing the simulated outcome with the actual diffusion of an innovation is the basis for determining the event validity of a diffusion simulation model. Checking for event validity includes the comparison between aggregate patterns of behavior in space and implies the notion of goodness-of-fit between the simulated output and the actual diffusion pattern.[8]

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[6]Charles F. Hermann, "Validation Problems in Games and Simulation with Special Reference to Models of International Politics," Behavioral Science, XII (1967), pp. 216-231.

[7]No variable-parameter sensitivity analysis was run on the diffusion model. Several simulation runs were performed with different sets of initial and potential adopters, and no obvious deviations from the expected results were noted. One reason sensitivity analysis was not employed is that the procedure is quite laborious and for a complex model almost endless. Little insight could have been gained by such an analysis since there are no fixed-value parameters, and an alteration of the theoretical justification of the variables would have invalidated the deductive model before analysis.

[8]Tom W. Carroll, SINDI 2: Simulation of Innovation Diffusion in a Rural Community of Brazil, Michigan State University, Project of the Diffusion of Innovations in Rural Societies, Technical Report No. 8 (1969), p. 192; Hermann, "Validation Problems," p. 222.

The Diffusion Pattern[9]

There are three observable spatial trends in the pattern of acceptance in Simulation 2. The first trend is the development of a cluster of adopters south of Waterloo (see Maps 42-49). The Waterloo cluster is visually evident, but is not as pronounced as in the actual diffusion of Harvestore Systems. Development of this cluster begins in the initial generations and continues throughout the simulation, however, in later generations it tends to appear rather obscured.

The second trend is the development of a cluster of adopters in an area west of Dubuque (see Maps 44-51). This trend becomes evident in the third generation. Spatially, the cluster is similar to that which develops in the diffusion of Harvestore Systems, but is neither as tightly clustered nor contains as many adopters. Both the Waterloo and Dubuque trends are visually similar to the actual diffusion pattern.

The third trend evident is the lack of the spread of innovation-adoption into a relatively large area south of Mason City along the western boundary of the study area (see Maps 50-53). Unlike the actual diffusion pattern, no adoption occurred in this area in Simulation 2. This trend indicates that there is a serious boundary problem. The model

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[9]This discussion of the diffusion pattern is based on Simulation 2. Visual inspection of Maps 40-53 provides most of the conclusions.

does not account for interaction outside of the study area and it is apparent that in the diffusion of Harvestore Systems that interaction to the west of the study area is occurring.

A trend identified in the actual diffusion pattern and not evident in the simulation is the tendency for innovation-adoption to move from the southern to the northern half of the study area. In the last generation of the simulation there is a significant increase in the proportion of adoption in the northern area. If the simulation run were allowed to continue several more generations this south to north trend may develop.

Chi-Square Analysis

Chi-square procedures are used to test whether both the actual diffusion pattern and the simulated pattern, Simulation 2, could have been the result of the same diffusion process. The results of the chi-square analysis are recorded in Table 9. The analysis of the twenty-six counties in the study area shows that three out of the four computed chi-square values are significant at the .1 probability level or higher; two at the .7 probability level or higher; and one at the .9 probability level. The analysis for Year 1967-Generation 7 with a chi-square value significant at the .03 level is the only comparison to indicate that the two spatial distributions may not be a result of the same diffusion process.

TABLE 9

CHI-SQUARE ANALYSIS BETWEEN
SIMULATION 2 AND THE ACTUAL DIFFUSION
OF HARVESTORE SYSTEMS IN NORTHEAST IOWA

Number of Counties	Chi-Square Values (with significance levels) Year and Generation Compared			
	1956-3	1959-4	1962-5	1967-7
26 (Total Study Area)	15.01 (.90)	20.34 (.70)	33.64 (.10)	38.43 (.03)
21 (Five Western Counties Deleted)	12.51 (.90)	13.84 (.80)	21.64 (.40)	21.69 (.40)

In identifying trends in the simulated pattern it was noted that the model did not account for interaction along the western boundary of the study area. Therefore, to eliminate the effect of the boundary problem the five western counties are deleted and a second chi-square analysis is performed. The computed chi-square values for the remaining twenty-one counties are all significant at the .4 or higher probability level. Thus, it is possible to conclude that both spatial distributions may be the results of the same diffusion process.

Even though there are some differences in the basic geographic elements of distance, direction, and spatial variation between the actual and simulated diffusion patterns, based on both visual similarity and chi-square analysis, there appears to be event validity to the diffusion simulation model.

Face Validity

Face validity is the plausibility of the overall structure of the simulation model.[7] The question of face validity rests on whether all important variables and processes have been logically accounted for in the model.

The focus of the constructed diffusion model is on the transition mechanism that accounts for movement from place to place in the innovation-adoption process. This

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[7]Hermann, "Validation Problems," p. 221; Carroll, SINDI 2, p. 185.

transition mechanism is based on the space preference determined individual contact fields and is designed such that it (1) is sensitive to the spatial structure of the central place system through which diffusion occurs; (2) does not regard distance as an unchangeable force emanating from all points equally in all directions, but as one of several characteristics of a spatial alternative considered by a decision-maker; and (3) maintains the exact location of each individual decision-maker. On these characteristics of the transition mechanism the spatial diffusion model seems plausible.

Incorporated into the transition mechanism as a representation of interpersonal contact within a central place is a simple random bias model. The random bias model is a simplification of a complex network of social communication, but given the level of understanding of the explicit structure of interpersonal movement it seems to be a logical alternative.

Both mass-media and interpersonal contact have been identified as important information sources in the learning-adoption process. However, where the transition mechanism accounts for information circulation by interpersonal contact, no mechanism is provided to account for the influence of mass-media information. The model assumes that each decision-maker has equal access to mass-media information. There is some indication that in the late stages of adoption mass-media information has little influence on persuading acceptance.[8]

The model meets the test of face validity to the extent that it simulates the most important subprocesses which contribute to the spatial diffusion process. For the innovation and study area to which it was applied, the model is a plausible representation of the spatial diffusion process.

Internal Validity

The critical requirement for internal validity is that between-run variations be accounted for by the identifiable relationships in the simulation.[9] If the between-run variations cannot be rationalized, then internal validity is low. However, given the complexity of the phenomenon studied and the type of stochastic model, some variation between simulation runs is expected. The means and standard deviations for new adopters and cummulative adopters by generation for the ten simulation runs are listed in Tables 5 and 6.

Even though the between-runs variations are higher than expected, the simulation runs compare favorably. There appears to be no simulation event which is not a logical consequence of the theoretical relationships incorporated

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[8]Rogers, Diffusion of Innovations, pp. 138-140.

[9]Internal validity is also dependent on the internal operations of the computer model. One check on internal validity is the close inspection of the logic of the computer

into the diffusion model. The infrequent anomalous generations, e.g., Simulation 1-Generation 3 (Sim 1-Gen 3), Sim 5-Gen 4, Sim 6-Gen 2, and Sim 8-Gen 2, can be attributed to the properties of the transition mechanism.

In Sim 1-Gen 3 the number of new adopters is below that expected. During this generation the pattern of central place interaction reduced the opportunity for inter-personal contact between adopters and potential adopters. Since the only manner in which an innovation diffuses is through inter-personal contact, and the number of propagators of the innovation is less than expected, the diffusion rate is slowed down. Because of this one generation the simulation ran about one generation behind the average. The same situation occurred in Sim 6-Gen 2.

In Sim 8-Gen 2 the number of new adopters exceeded that expected. In fact, the maximum number possible accepted the innovation. This development increased the diffusion rate and the simulation ran at least one generation ahead of the average for the rest of the run. A similar situation occurred in Sim 5-Gen 4.

Hypothesis Validity

Hypothesis validity refers to the extent that hypothesized relationships between variables in the real-world are

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program SPACDIF. During the program testing several logic errors were detected and corrected. Given the theoretical model the program is logically consistent.

present in the simulation model. Hypothesized relationships may either be explicitly programmed into the model or manifest themselves as indirect results of the complex interactions simulated by the model.[10]

Past spatial diffusion research has shown that the central place hierarchy plays an important function in guiding the spatial pattern of innovation-adoption.[11] The hypothesized relationships between individual interaction with the central place system and interpersonal contact are explicitly introduced into the simulation model. When the model was applied to the diffusion of Harvestore Systems in the study area, the output manifest these relationships. For example, in Simulation 2 the cluster of adopters west of Dubuque that was simulated was remarkably similar to the actual diffusion pattern. The cluster developed as a function of the hypothesized relationships programmed into the model; neither the set of initial adopters nor the distribution of potential adopters directly determined this event. Also, even though the short circuit phenomenon was not explicitly introduced into the model, it was manifested in the simulated outcome. On both of these counts the

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[10]Carroll, SINDI 2, p. 196; Hermann, "Validation Problems," pp. 223-224.

[11]Hägerstrand, The Propagation of Innovation Waves; Brown, "Diffusion Dynamics," pp. 33-42; Hudson, "Diffusion in a Central Place System," pp. 45-68.

hypothesized relationships operationalized in the simulation model appear to be plausible representations of the real-world.

Summary

The spatial diffusion of innovation model has been designed and applied to a real-world diffusion system. The model appears to take into account the most important aspects of the spatial diffusion process: the structure of the central place system, the mechanism of interpersonal contact, and the location and spatial choice behavior of individual decision-makers. The simulation runs compare favorably with the actual diffusion process. Based on the criteria for judging the validity of a simulation model, this model is a plausible representation of the spatial diffusion process.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The goal of this research was to explore the implications of hypothesized relationships between spatial behavior and spatial diffusion processes. The focus of the research was on (1) the derivation of a rule of spatial behavior to account for movement from place to place in the spatial diffusion of rural innovations and (2) on the construction of a spatial diffusion simulation model employing an empirically derived rule of spatial behavior.

Fundamental to modelling the spatial aspects of innovation-adoption has been the manner in which movement from one location to another has been explained. The view taken by many is that the intensity of movement is a continuous function of intervening distance; however, it was shown statistically that for northeast Iowa, distance is not as important a factor as previously assumed.

The approach developed was an attempt to clarify the spatial interaction mechanism which controls movement of innovation-adoption from one location to another. Two movement factors were hypothesized as controlling the flow of relevant information in the learning-adoption process. The first movement factor was individual interaction with the central place system through which diffusion occurs. A rule of spatial behavior to account for individual interaction with the central place system was empirically derived by employing the method of paired-comparisons. From consistent statements of choice by decision-makers residing at different locations a probabilistic behavioral rule of preferred central place alternatives was obtained. This rule of spatial behavior when applied to a distribution of central place alternatives is capable of generating unique individual contact fields.

The second movement factor was interpersonal contact at a central place. Not being able to discover the explicit structure of interpersonal contact in the spatial diffusion process, a simple random bias model was employed to account for this movement factor in the simulation model. The model regards every individual that interacts with a central place as having an equal chance of contacting every other individual who interacts with that place.

Thus, communication between individuals was hypothesized as dependent on the probability of individual interaction with the central place system and on the probability of interpersonal contact at a central place. Both movement factors were modelled separately and linked together to provide the transition mechanism in the spatial diffusion simulation model.

The constructed simulation model was run and evaluated against the actual diffusion of Harvestore Systems in northeast Iowa. Visual and statistical analysis of actual and simulated patterns of spatial diffusion showed that both patterns could have been the result of the same real-world diffusion process. Based on evaluation criteria for judging the validity of a simulation model, it was concluded that the diffusion model is a plausible representation of the spatial diffusion process studied.

The diffusion model is an improvement over previous models in that (1) it is sensitive to the spatial structure of the central place system through which diffusion occurs; (2) distance is not regarded as an unchangeable force emanating from all points equally in all directions, but is considered as only one of several attributes of a spatial alternative evaluated by a decision-maker; and (3) the exact residential location of individual decision-makers is maintained. The behavioral approach and the alternative representation of the spatial diffusion process are the major contributions of this research.

Conclusions

The diffusion model was successful in simulating a pattern that corresponded to the actual pattern of Harvestore Systems, but there were a number of obvious differences. Many of the differences between the simulated and actual diffusion patterns were a consequence of an overly simplified conceptualization of the spatial diffusion process, operationalization of hypothesized relationships, and the definition of the boundaries of the northeast Iowa study area.

Most spatial diffusion models are attempts to directly describe diffusion patterns within some spatial system by estimating parameters and adding variables until obtaining a good fit. This type of procedure is entirely unsatisfactory, especially when the added variables are manipulated by parameters until a good fit is obtained. Both the parameters and variables are tied directly to the spatial structure of the central place system for which they are calibrated and say little about the characteristics of parameters and variable for different places and spatial systems. It is obvious that with such a procedure diffusion patterns can be directly derived from the model without providing any insight into diffusion processes.

In this research an attempt was made to construct a spatial diffusion model that describes the rules by which alternatives are evaluated and choices subsequently made. Such a behavioral model is capable of generating a variety of diffusion patterns as the central place system, to which the model is applied, is allowed to change. Since there are no fixed-value parameters and the variables are not tied to the spatial structure of the central place system for which they were empirically defined, the spatial diffusion model can be applied equally well to other central place systems or study regions. In this sense the model is more general than previous diffusion models.

The model is sensitive to the spatial structure of the central place system through which diffusion occurs but physical barriers to movement, such as mountains, rivers, and lakes, are not explicitly treated. Physical barriers are relatively unimportant in the northeast Iowa study area because of the homogeneous nature of the landscape; but in a more heterogeneous landscape, physical barriers can play an important function in determining the set of central places with which an individual chooses to interact. For example, a central place may be a preferred spatial alternative except for the intervening physical barrier which greatly increases the travel distance to that central place. The increased travel distance to the central place caused by the intervening physical barrier redefines the attractiveness of the alternative. Physical barriers could be accounted for with little restructuring of the simulation model by merely redefining the measure of distance to a central place alternative. If in assigning an alternative to a locational type, distance were measured in actual travel distance, cost, or time, the physical barriers present would be implicitly considered.

The type of innovation and distribution policy of the propagator of an innovation are important aspects of spatial diffusion that were not considered in the simulation model. In the case of the diffusion of Harvestore Systems the distribution policy of the local dealers did not appear to have an effect on the spatial pattern of acceptance,[1] but for many innovations (e.g., manufactured goods) the distribution policy may be very important in defining the size and locations of central places where the item is available. Thus, further examination of the relationships between the type of innovation, distribution policy of the propagator, and the central place hierarchy should prove worthwhile in extending our comprehension of the spatial diffusion processes.

The simulation model provides an interface between the spatial and rural sociological diffusion research tradition which should prove to be a useful framework for future research. Geographers and rural sociologists have been concerned with different aspects of the diffusion of agricultural innovations; geographers have focused on the spatial dimensions of diffusion, and rural sociologists have tended

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[1]Harvestore Systems dealers are located in Cedar Falls and Nashua, Iowa. These two dealers have exclusive sales and service rights to the northeast Iowa study area. Each dealer employes a number of salesmen to contact farmers in a one or two county area. The salesmen make personal contact with potential buyers, but it appears that the salesmen have not been a significant factor in persuading final adoption of the innovation. Salesmen function more as the agents who finalize sales after the decision to adopt has been made by the farmer.

to concentrate on the sociological aspects of innovation-adoption among small groups and residents of a single community. Unfortunately, spatial and sociological research has not been linked together to account for diffusion of agricultural innovations through a landscape of central places. But, the simulation model does provide an opportunity to bring the two research traditions together. The model, though adequate, would provide a fuller recognition of the complexities of the real world if a sociological model to simulate interpersonal contact could be substituted for the simple random bias model. The framework of the simulation model provides the opportunity to integrate the spatial with the aspatial sociological traditions in diffusion research and to consider such aspatial aspects as the influence of mass-media information, psychological resistance to adoption, cultural perception, and the structure of acquaintanceship circles in a spatial diffusion model.

This research has added to the body of knowledge on individual spatial behavior and has contributed to the further understanding of spatial diffusion processes. There is still much work remaining before one fully understands the spatial mechanisms in innovation diffusion, but this research has indicated a possible approach and framework for future investigation which should lead to a more complete understanding of the spatial diffusion of innovation processes.

SELECTED BIBLIOGRAPHY

Atkinson, Richard C.; Bower, Gordon H.; and Crothers, Edward J. _An Introduction to Mathematical Learning Theory_. New York: John Wiley, 1965.

Barnard, G. A. "Significance Tests for 2 x 2 Tables." _Biometrika_, XXXIV (1947), 123-138.

Beal, George M., and Rogers, Everett M. _The Adoption of Two Farm Practices in a Central Iowa Community_. Ames, Iowa: Iowa State University, Agricultural and Home Economics Experimental Station Special Report No. 26, 1960.

Bowden, Leonard W. _Diffusion of the Decision to Irrigate_. Chicago: University of Chicago, Department of Geography, Research Paper No. 97, 1965.

Brown, Lawrence A. "Diffusion Dynamics: A Review and Revision of the Quantitative Theory of the Spatial Diffusion of Innovation." Unpublished Ph.D. dissertation, Northwestern University, 1966.

Brown, Lawrence A.; Moore, Eric G.; and Moultrie, William. _TRANSMAP: A Program for Planar Transformation of Point Distributions_. Columbus, Ohio: Ohio State University, Department of Geography, Discussion Paper No. 3.

Brown, Lawrence A., and Moore, Eric G. "Diffusion Research in Geography: A Perspective." _Progress in Geography: International Reviews of Current Research_. Vol. I. Edited by Christoper Board, _et al_. New York: St. Martin's Press, 1969.

Carroll, Tom W. _SINDI 2: Simulation of Innovation Diffusion in a Rural Community of Brazil_. East Lansing, Michigan: Michigan State University, Project of the Diffusion of Innovations in Rural Societies, Technical Report No. 8, 1969.

Cliff, A. D. "The Neighbourhood Effect in the Diffusion of Innovations." _Transactions of the Institute of British Geographers_, XLIV (1968), 75-84.

Cox, Kevin R. "The Genesis of Acquaintance Field Spatial Structures: A Conceptual Model and Empirical Tests." _Behavioral Problems in Geography: A Symposium_. Edited by Kevin R. Cox and Reginald Golledge. Evanston, Illinois: Northwestern University, Department of Geography, Studies in Geography No. 17, 1969.

Hägerstrand, Torsten. "Aspects of the Spatial Structure of Social Communication and the Diffusion of Information." Papers of the Regional Science Association, XVI (1966), 27-42.

Hägerstrand, Torsten. Innovation Diffusion as a Spatial Process. Translated by Allan Pred. Chicago: University of Chicago Press, 1967.

Hägerstrand, Torsten. "A Monte Carlo Approach to Diffusion." Archives of Europeennes De Sociologie, VI (1965), 43-67.

Hägerstrand, Torsten. "On Monte Carlo Simulation of Diffusion." Quantitative Geography, Part I: Economic and Cultural Topics. Edited by William L. Garrison and Duane F. Marble. Evanston, Illinois: Northwestern University, Department of Geography, Studies in Geography No. 13, 1967.

Hägerstrand, Torsten. The Propagation of Innovation Waves. Lund Studies in Geography: Series B, Human Geography No. 4. Lund, Sweden: Gleerup, 1952.

Hägerstrand, Torsten. "Quantitative Techniques for Analysis of the Spread of Information and Technology." Education and Economic Development. Edited by C. A. Anderson and M. J. Bowman. Chicago: Aldine, 1965.

Harvey, David. "Models of the Evolution of Spatial Pattern in Human Geography." Models in Geography. Edited by Richard J. Chorley and Peter Haggett. London: Methuen, 1967.

Hermann, Charles F. "Validation Problems in Games and Simulation with Special Reference to Models of International Politics." Behavioral Science, XII (1967), 216-231.

Hudson, John C. "Diffusion in a Central Place System." Geographical Analysis, I (1969), 45-68.

Karlsson, Georg. Social Mechanisms. New York: The Free Press, 1958.

Luce, R. D. Individual Choice Behavior. New York: John Wiley, 1959.

Marble, Duane F., and Nysteun, John D. "An Approach to the Direct Measurement of Community Mean Information Fields." Papers of the Regional Science Association, XI (1963), 99-109.

Morrill, Richard L. "The Distribution of Migration Distances." Papers of the Regional Science Association, XI (1963), 75-84.

Morrill, Richard L., and Pitts, Forrest R. "Marriage, Migration, and the Mean Information Field: A Study in Uniqueness and Generality." Annals of the Association of American Geographers, LVIII (1967), 401-422.

Morrill, Richard L. "The Negro Ghetto: Problems and Alternatives." Geographical Review, LV (1965), 339-361.

Pearson, E. S. "The Choice of Statistical Tests Illustrated on the Interpretation of Data Classed in a 2 x 2 Table." Biometrika, XXXIV (1947), 139-167.

Pitts, Forrest R. HAGER III and HAGER IV: Two Monte Carlo Computer Programs for the Study of Spatial Diffusion Problems. Evanston, Illinois: Northwestern University, Department of Geography, Research Report No. 12, 1965.

Pitts, Forrest R. MIFCAL and NONCEL: Two Computer Programs for the Generalization of the Hägerstrand Model to an Irregular Lattice. Evanston, Illinois: Northwestern University, Department of Geography, Technical Report No. 23, 1967.

Pitts, Forrest R. "Problems in Computer Simulation of Diffusion." Papers of the Regional Science Association, XI (1963), 111-122.

Rogers, Everett M. Diffusion of Innovations. New York: The Free Press, 1962.

Rushton, Gerard. "Analysis of Spatial Behavior by Revealed Space Preference." Annals of the Association of American Geographers, LIX (1969), 391-401.

Rushton, Gerard. "The Scaling of Locational Preferences." Behavioral Problems in Geography: A Symposium. Edited by Kevin Cox and Reginald Golledge. Evanston, Illinois: Northwestern University, Department of Geography, Studies in Geography No. 17, 1969.

Rushton, Gerard. Spatial Pattern of Grocery Purchases by the Iowa Rural Population. Iowa City, Iowa: University of Iowa, Bureau of Business and Economic Research, Studies in Business and Economics, New Series No. 9, 1966.

Solomonoff, R., and Rapoport, A. "Connectivity of Random Nets." Bulletin of Mathematical Biophysics XIII (1951), 107-118.

Witthuhn, Burton O. "The Spatial Integration of Uganda as Shown by the Diffusion of Postal Agencies, 1900-1965." The East Lakes Geographer, IV (1968), 5-20.

Wolpert, Julian. "Behavioral Aspects of the Decision to Migrate." Papers of the Regional Science Association, XV (1966), 159-169.

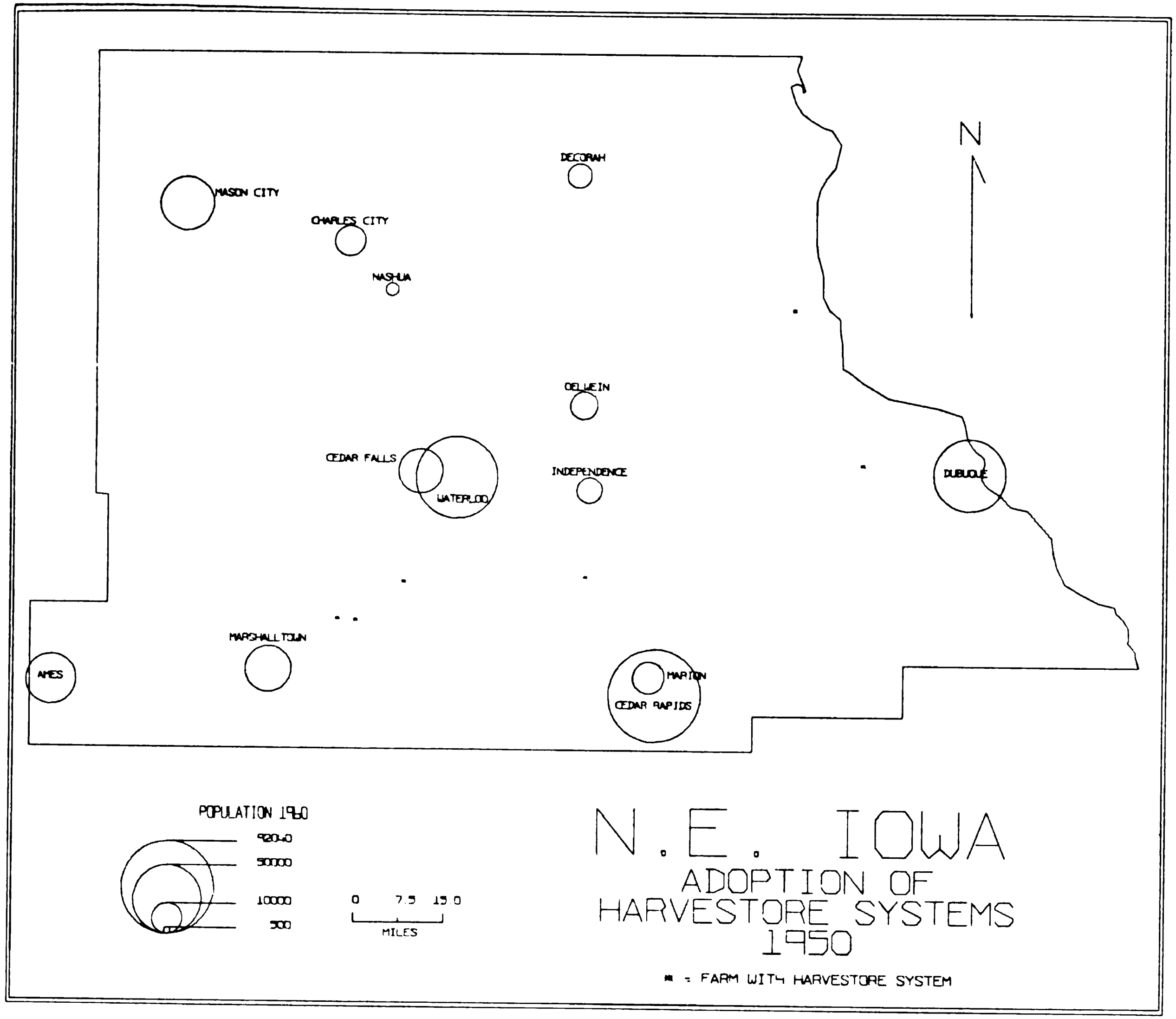
APPENDIX A

MAPS OF THE ACTUAL AND SIMULATED DIFFUSION OF HARVESTORE SYSTEMS IN NORTHEAST IOWA, 1950-1967

The maps in this dissertation were produced using Program MAPIT on a Calcomp Plotter in conjunction with a C.D.C. computer at Michigan State University. To construct the maps it was necessary to supply the population and coordinates of the central places, the coordinates of individual farms and the map outline, the title and labels with coordinates, and the size of the map. For a more complete discussion of Program MAPIT, see

> Robert Kern and Gerard Rushton, _MAPIT: A Computer Program for Producing Flow Maps, Dot Maps, and Graduated Symbol Maps_, Research Report, Computer Institute for Social Science Research, Michigan State University, East Lansing, Michigan, April 1969; and

> Robert Kern, _MAPIT: Map Drawing on the Calcomp Plotter_, Technical Report No. 87, Computer Institute for Social Science Research, Michigan State University, East Lansing, Michigan, 1969.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ADOPTION OF
HARVESTORE SYSTEMS
1950
■ = FARM WITH HARVESTORE SYSTEM
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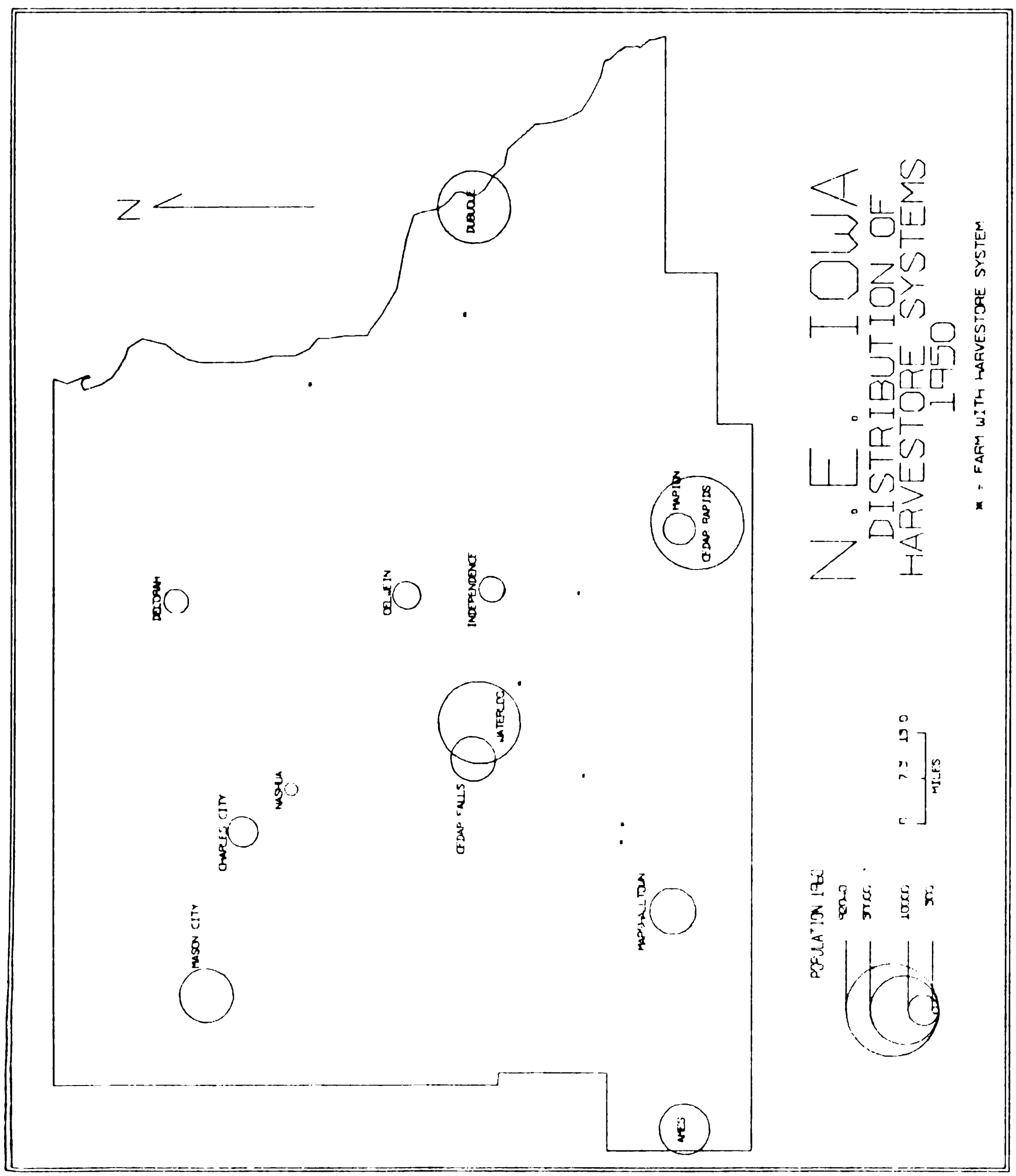
10000
500
0 7.5 15.0
MILES
N
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS

Map 4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DISTRIBUTION OF
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1950
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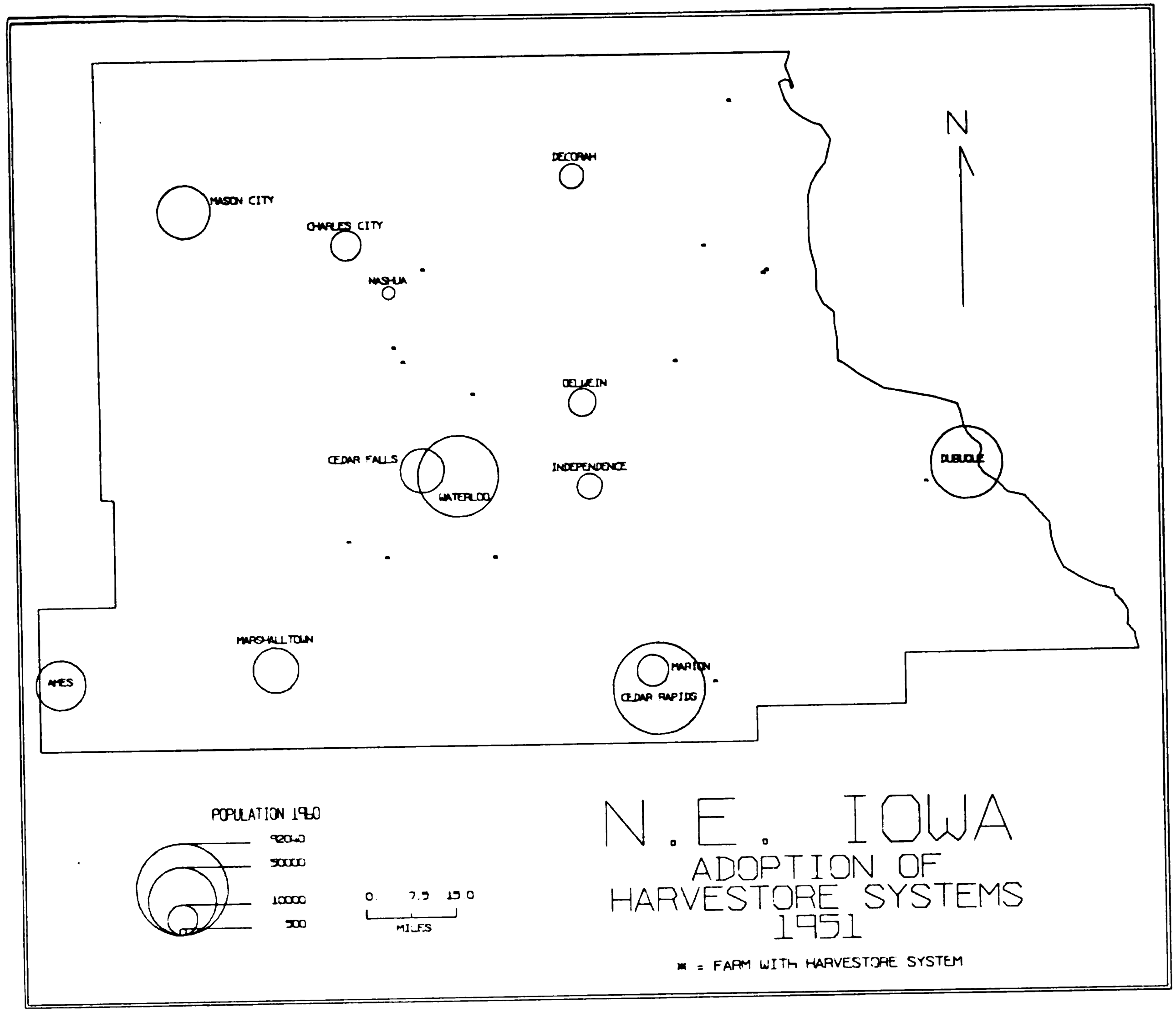
NASHUA
CEDAR FALLS
INDEPENDENCE
DECORAH
CEDAR RAPIDS
AMES
MILES

Map 5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CEDAR RAPIDS
POPULATION 1960
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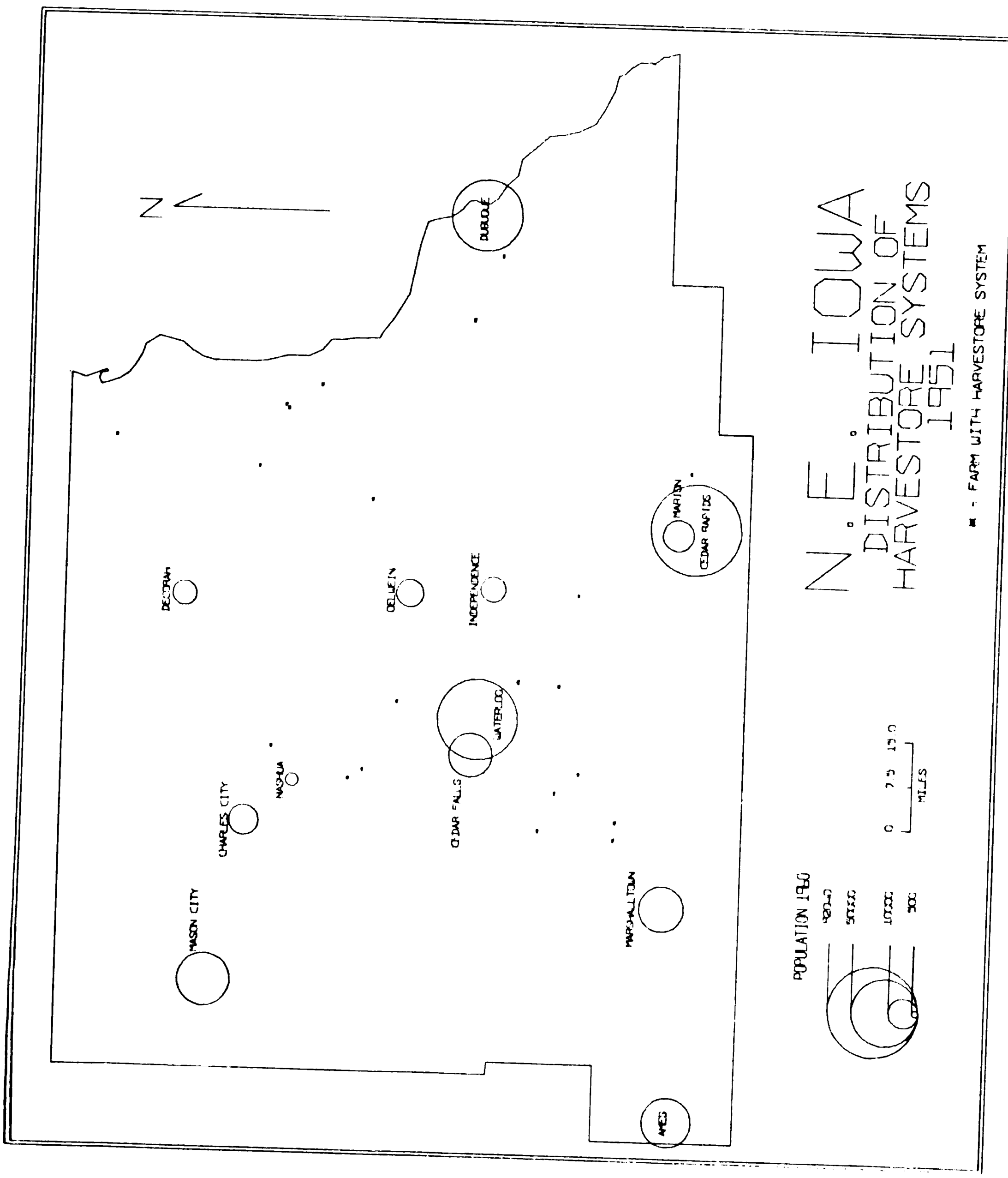
MILES
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1951
* = FARM WITH HARVESTORE SYSTEM

Map 6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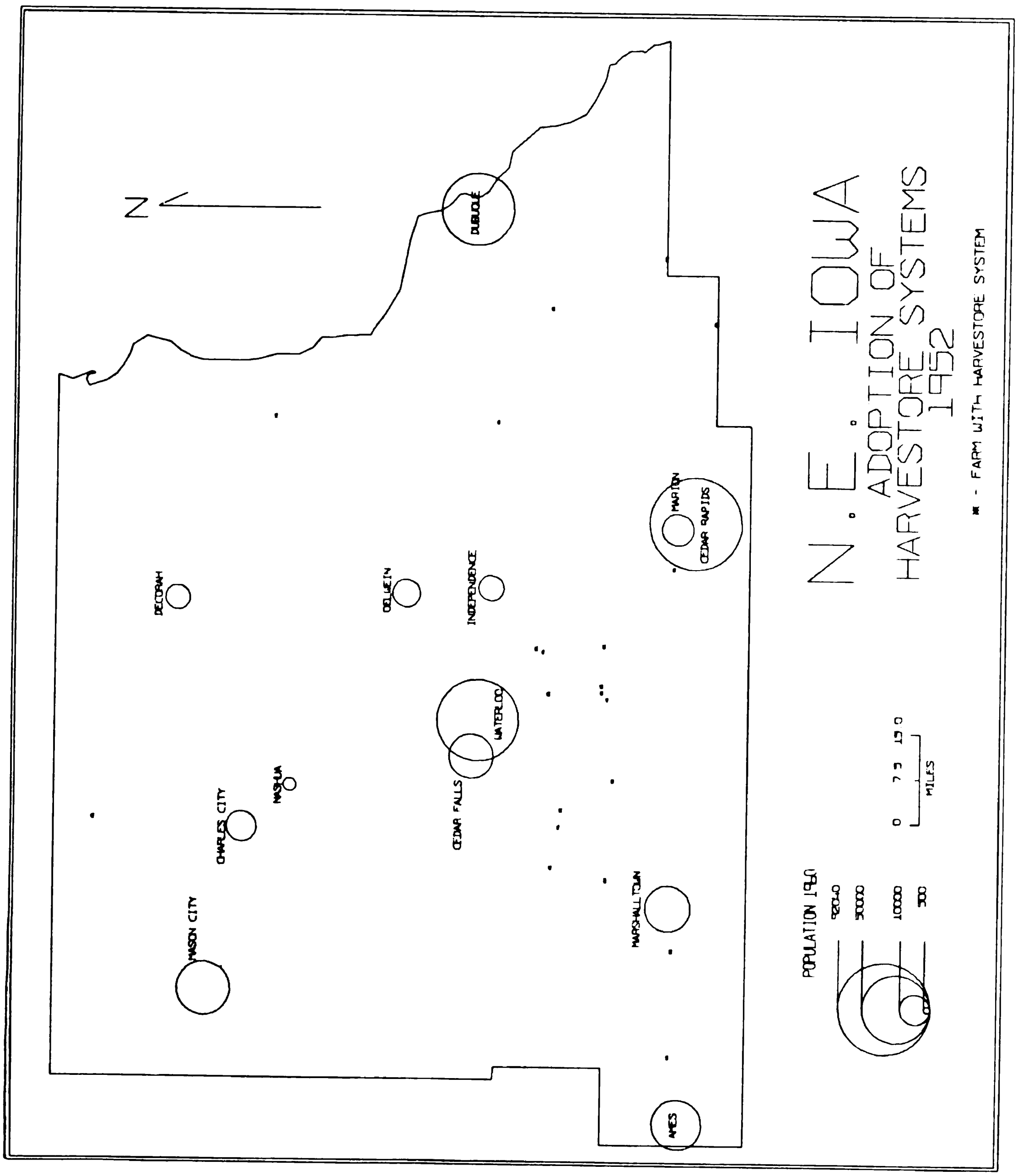
DUBUQUE
MARION
CEDAR RAPIDS
MARSHALLTOWN
AMES

Map 7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DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
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CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
POPULATION 1960
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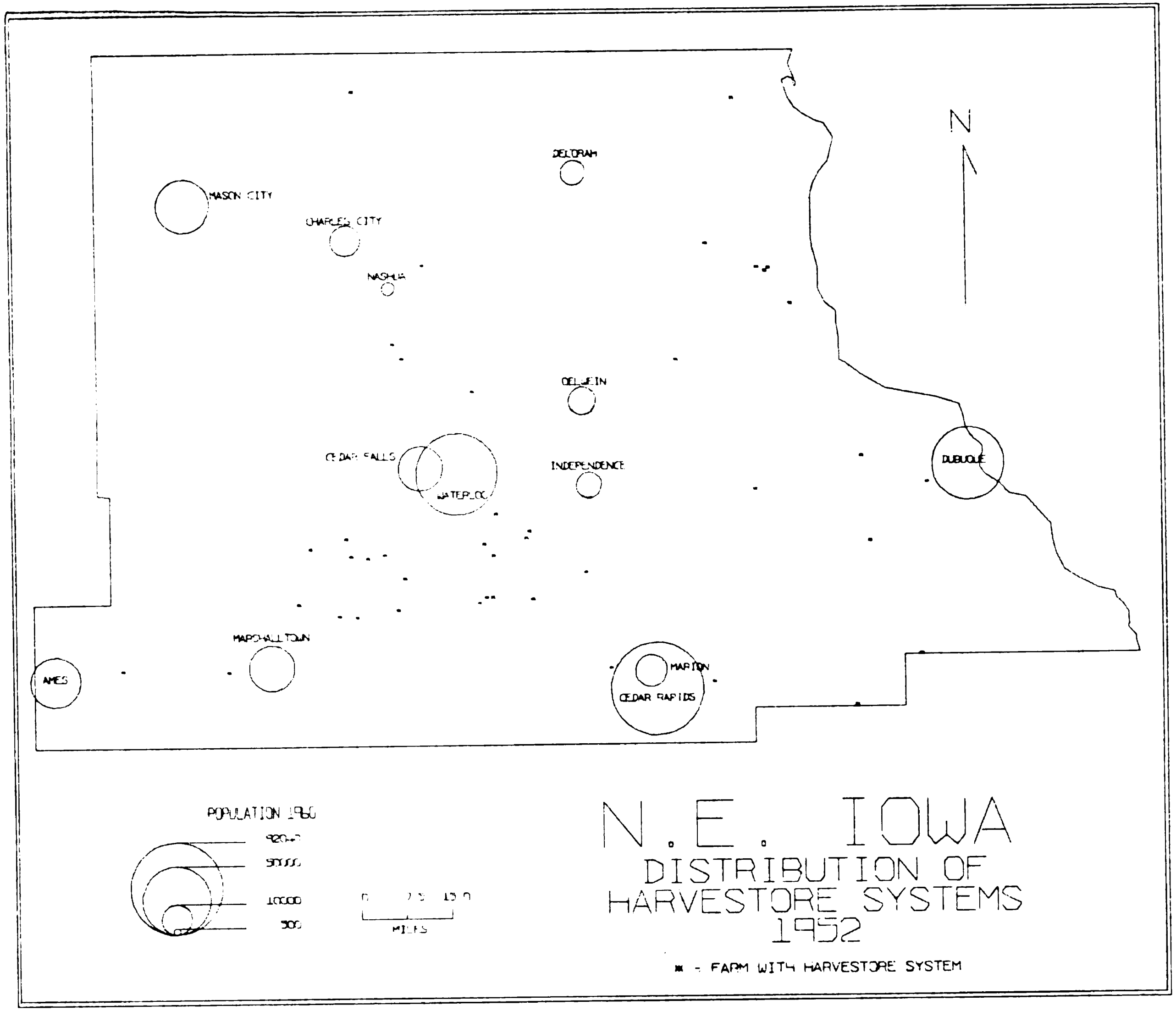
MILES

Map 8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AMES
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CEDAR RAPIDS
POPULATION 1960
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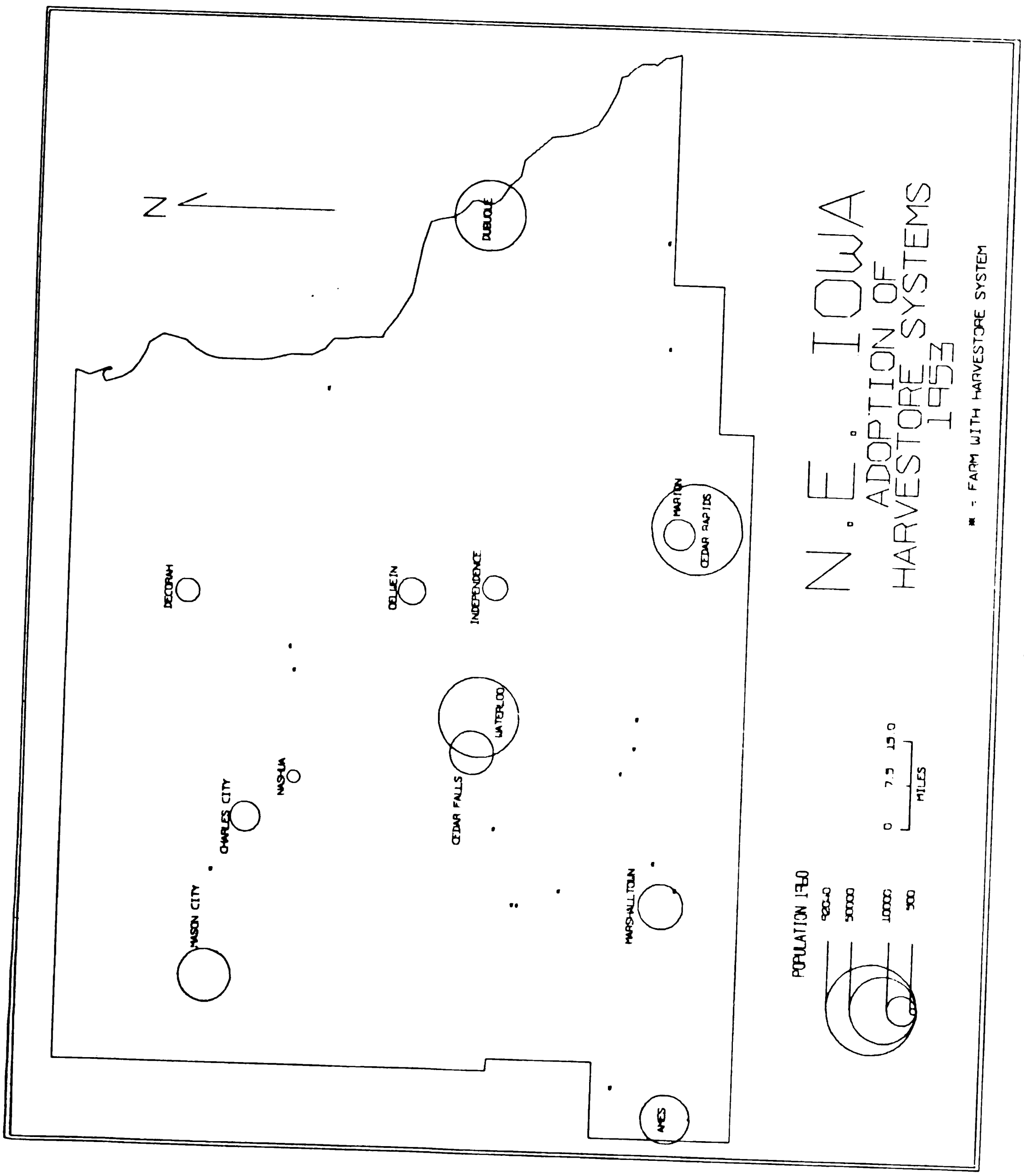
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
1952
* - FARM WITH HARVESTORE SYSTEM

Map 9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1953
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CEDAR RAPIDS
DECORAH
OELWEIN
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WATERLOO
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MASON CITY
MARSHALLTOWN
AMES
POPULATION 1960
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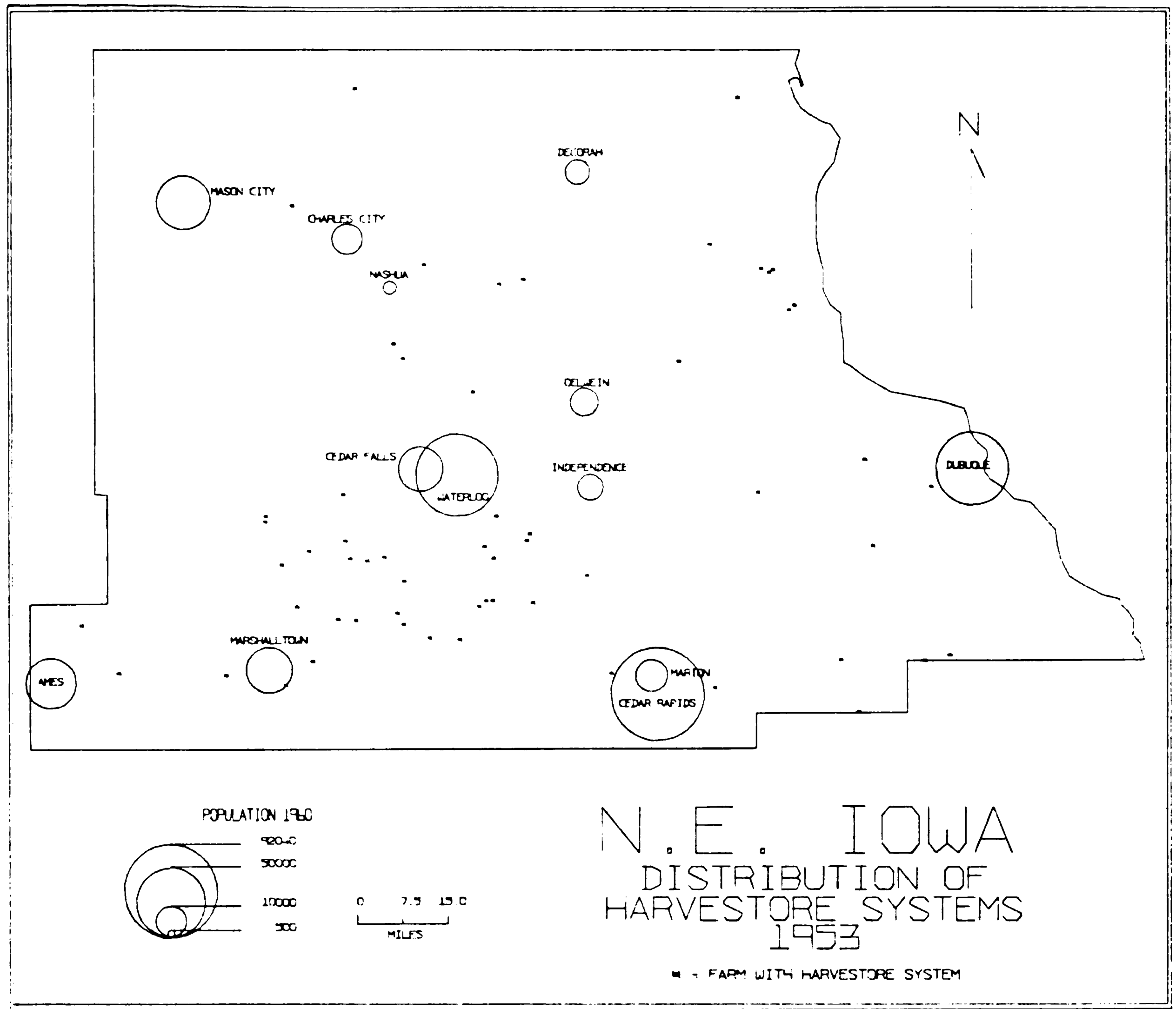
MILES

Map 10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POPULATION 1960
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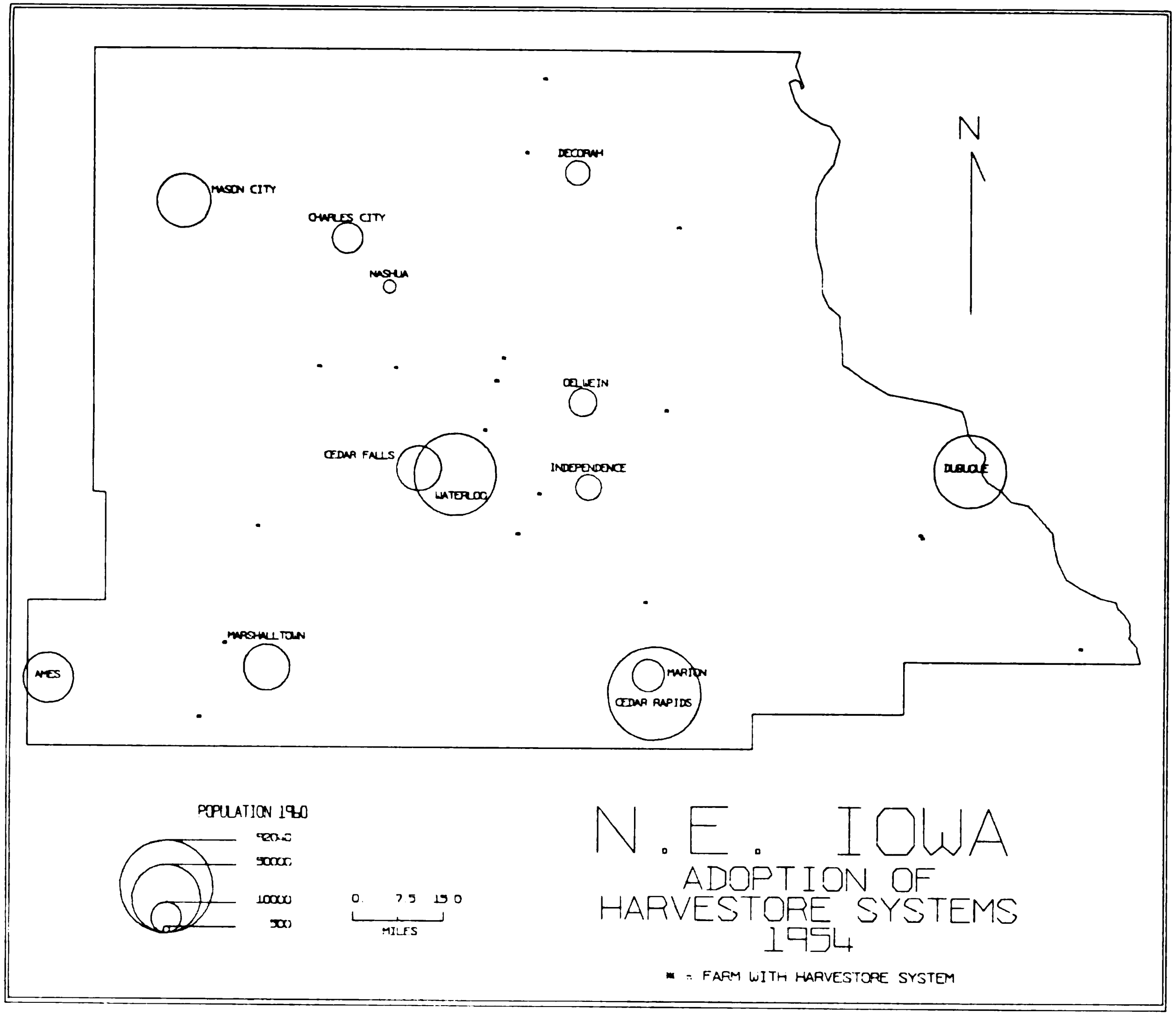
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
1953
= FARM WITH HARVESTORE SYSTEM

Map 11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CEDAR RAPIDS
POPULATION 1960
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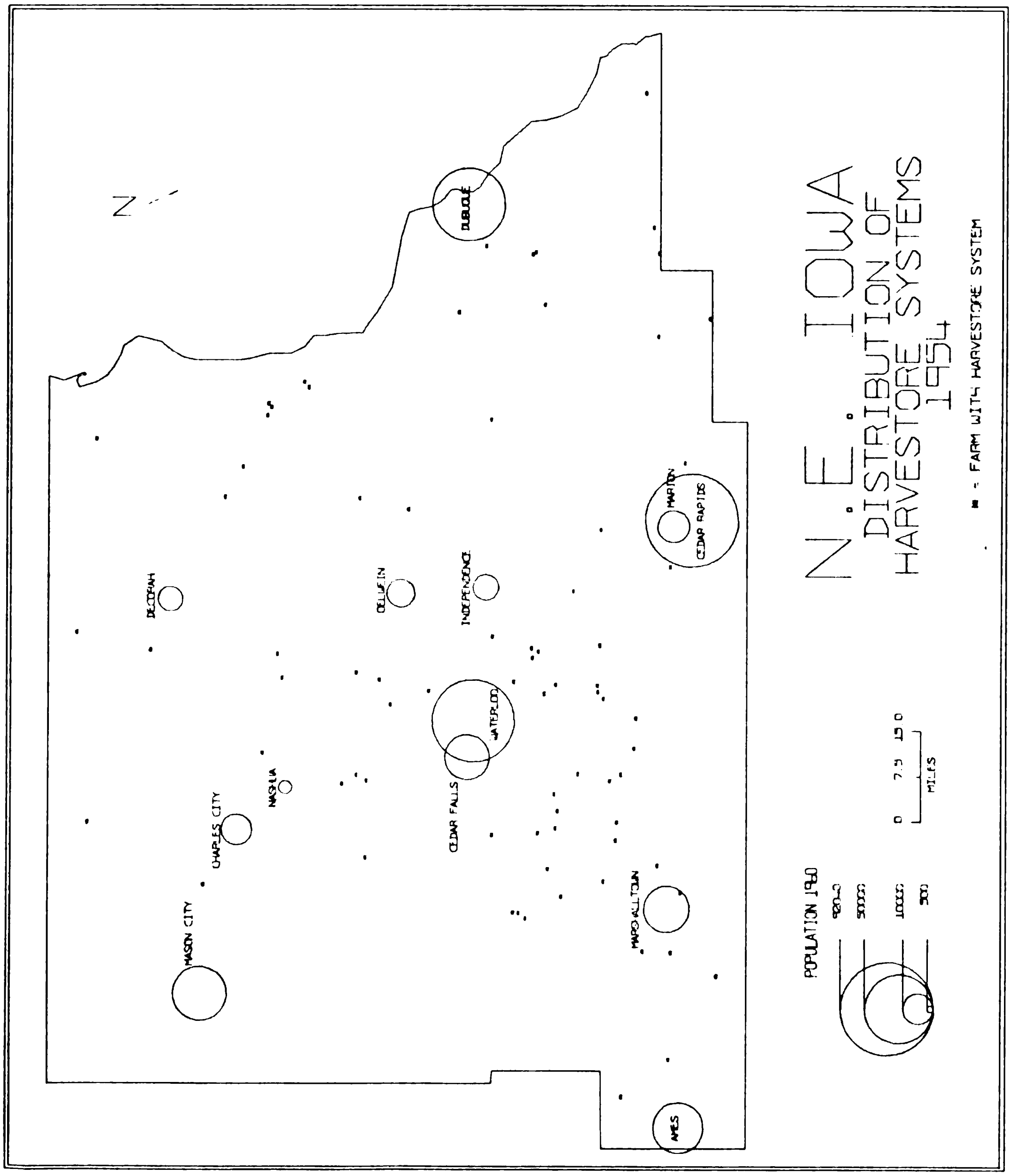
MILES
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1954
= FARM WITH HARVESTORE SYSTEM

Map 12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DISTRIBUTION OF
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1954
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MARSHALLTOWN
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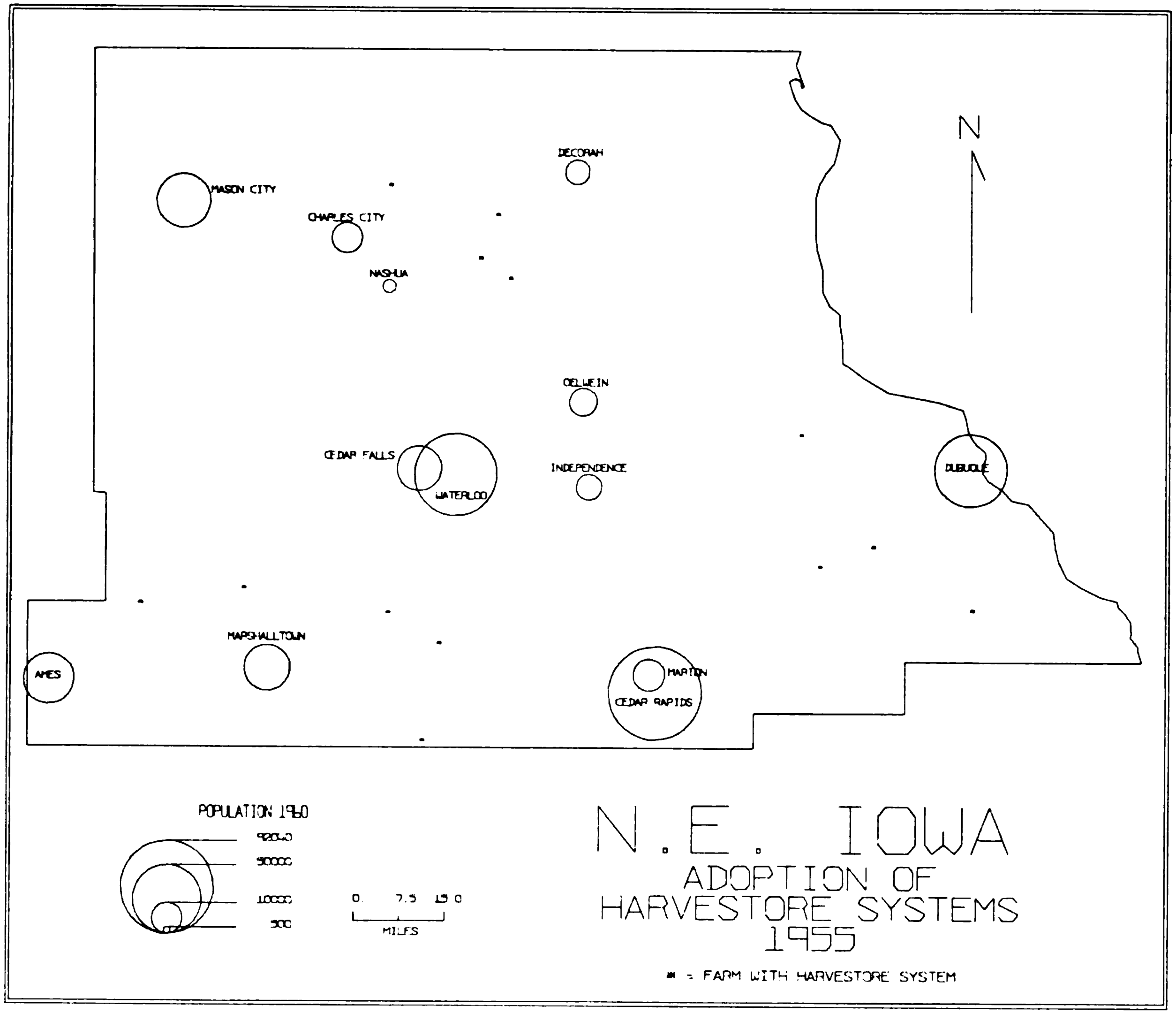
MARION
CEDAR RAPIDS
DUBUQUE

Map 13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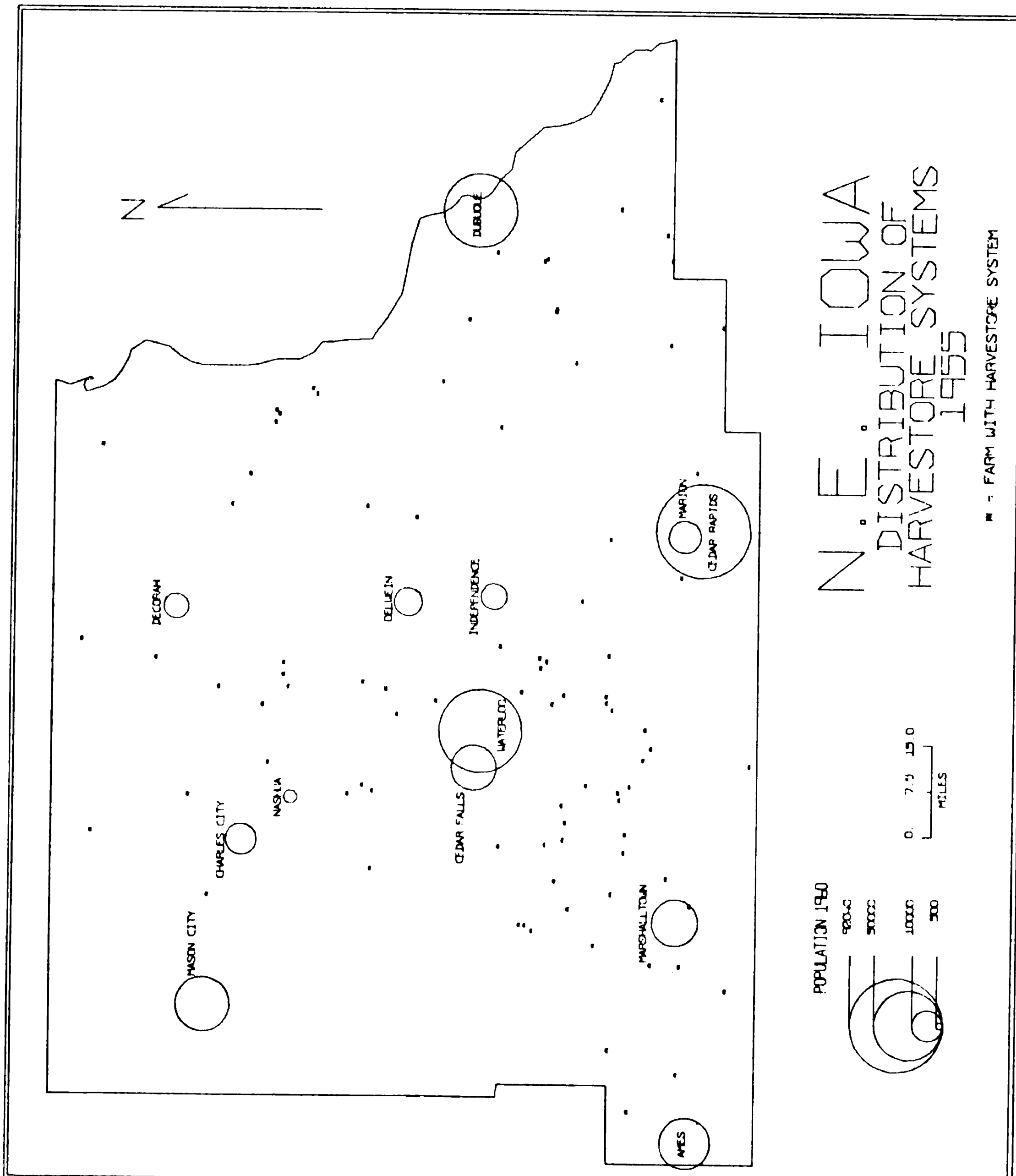
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1955
= FARM WITH HARVESTORE SYSTEM

Map 14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1955
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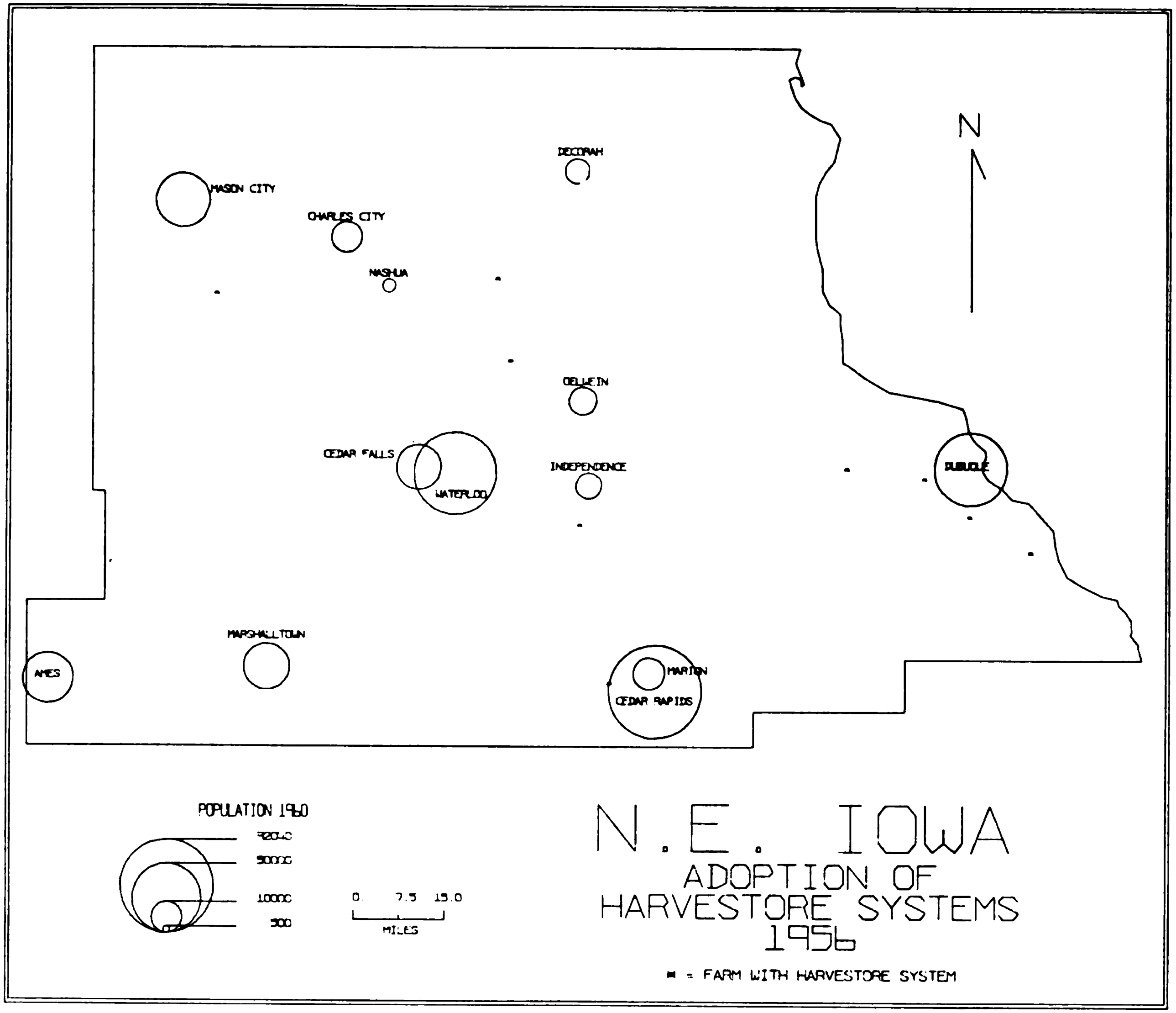
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POPULATION 1960
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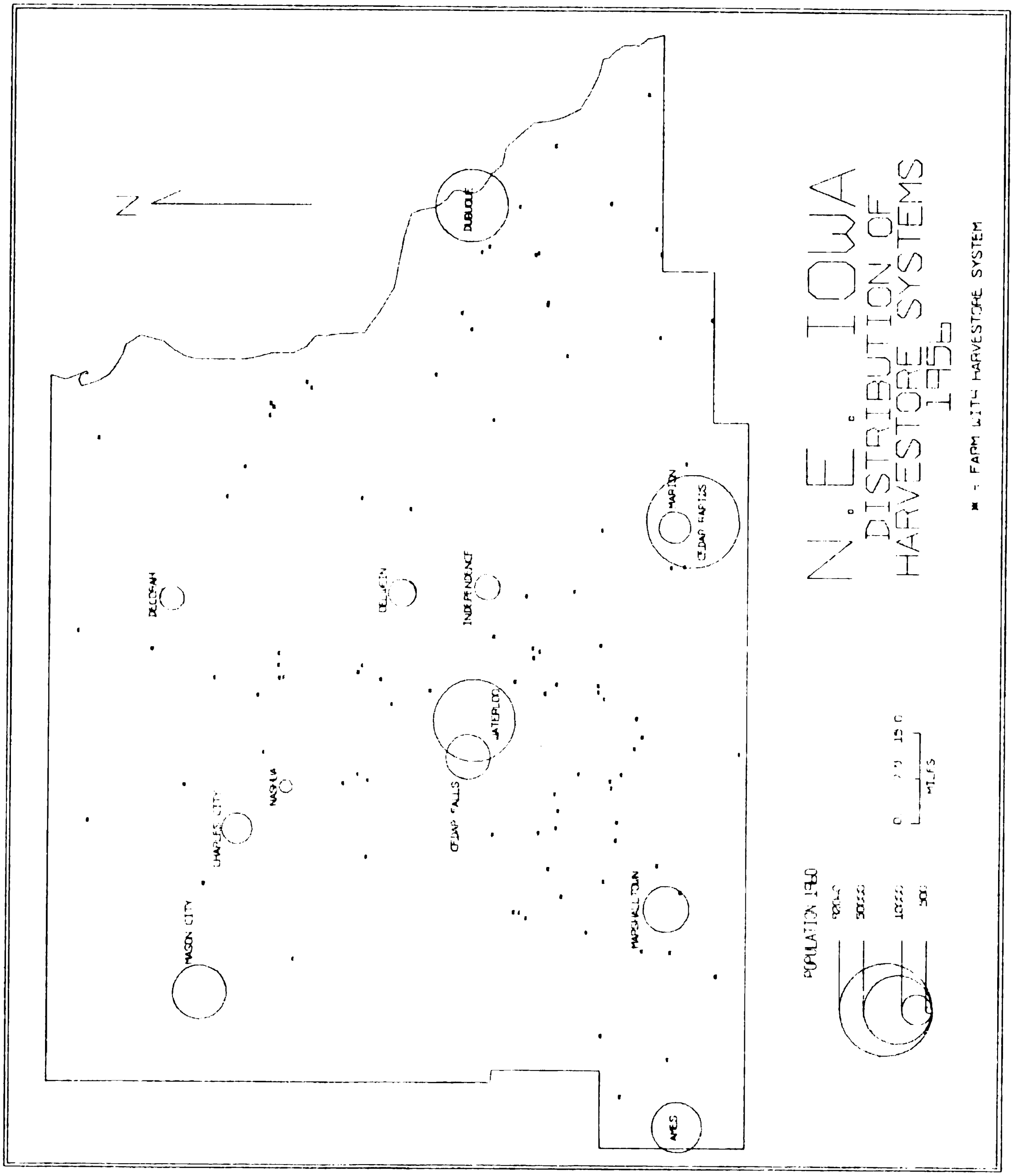
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1956
■ = FARM WITH HARVESTORE SYSTEM

Map 16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DISTRIBUTION OF
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POPULATION 1960
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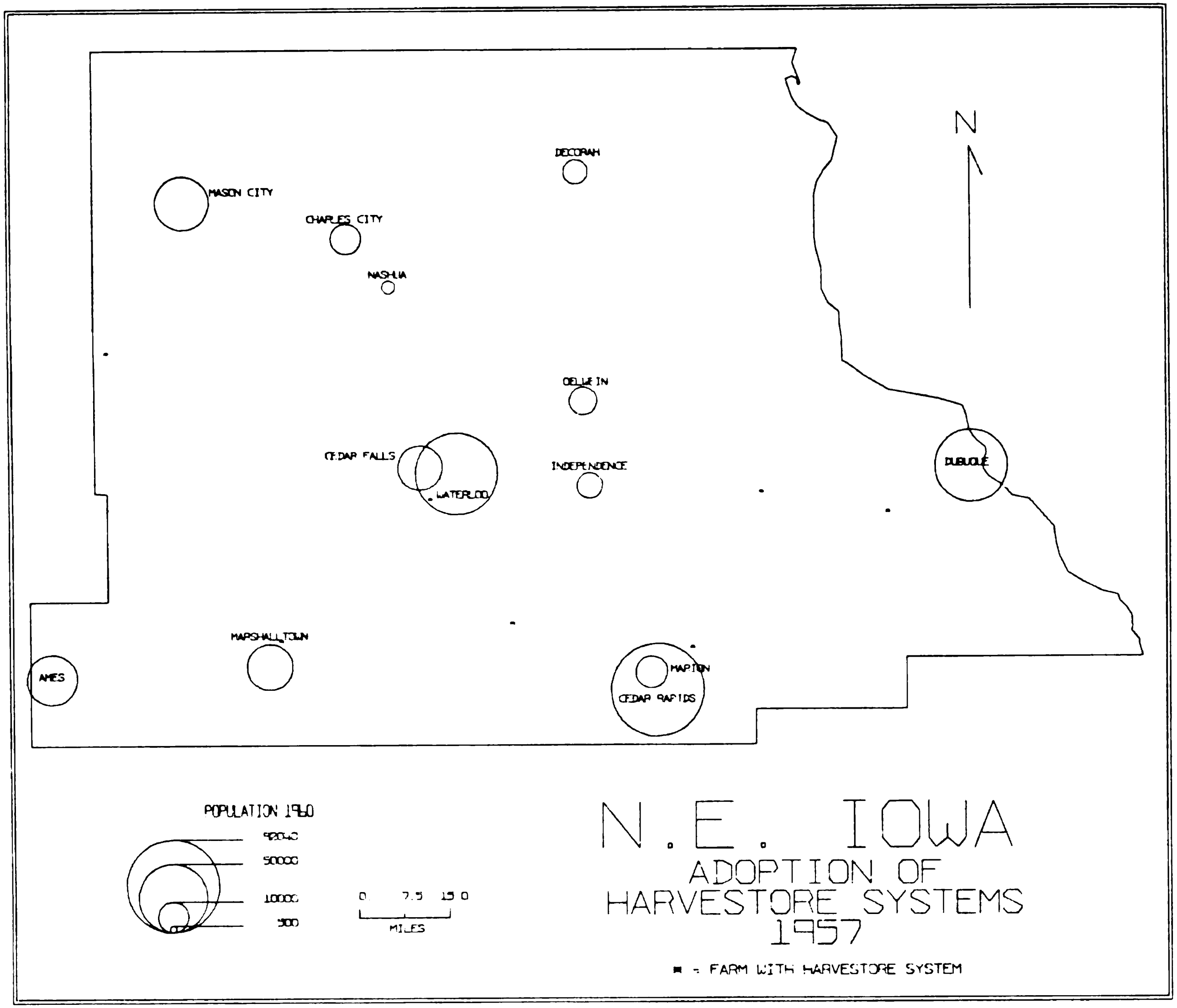
Map 17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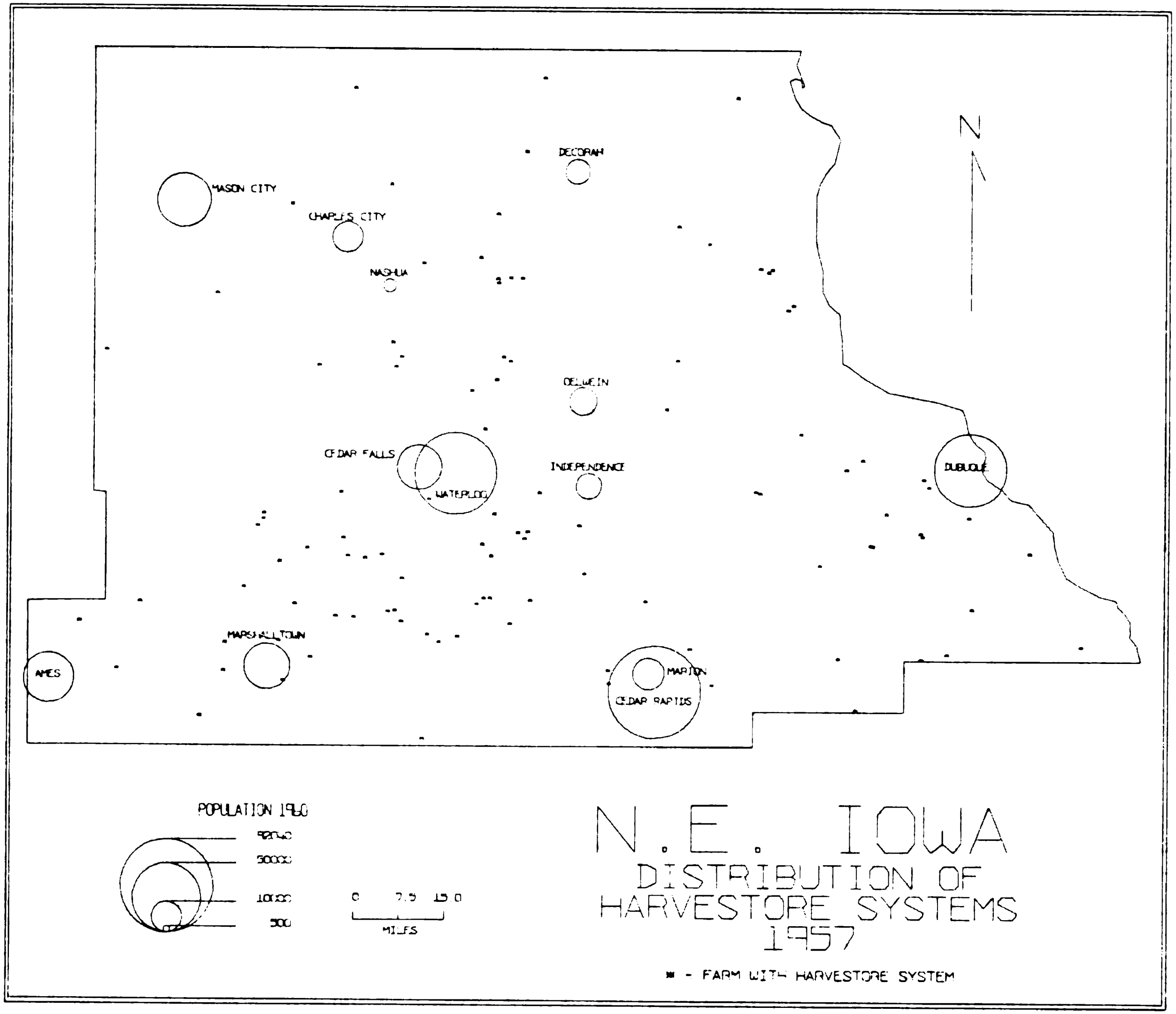
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1957
■ = FARM WITH HARVESTORE SYSTEM

Map 18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POPULATION 1960
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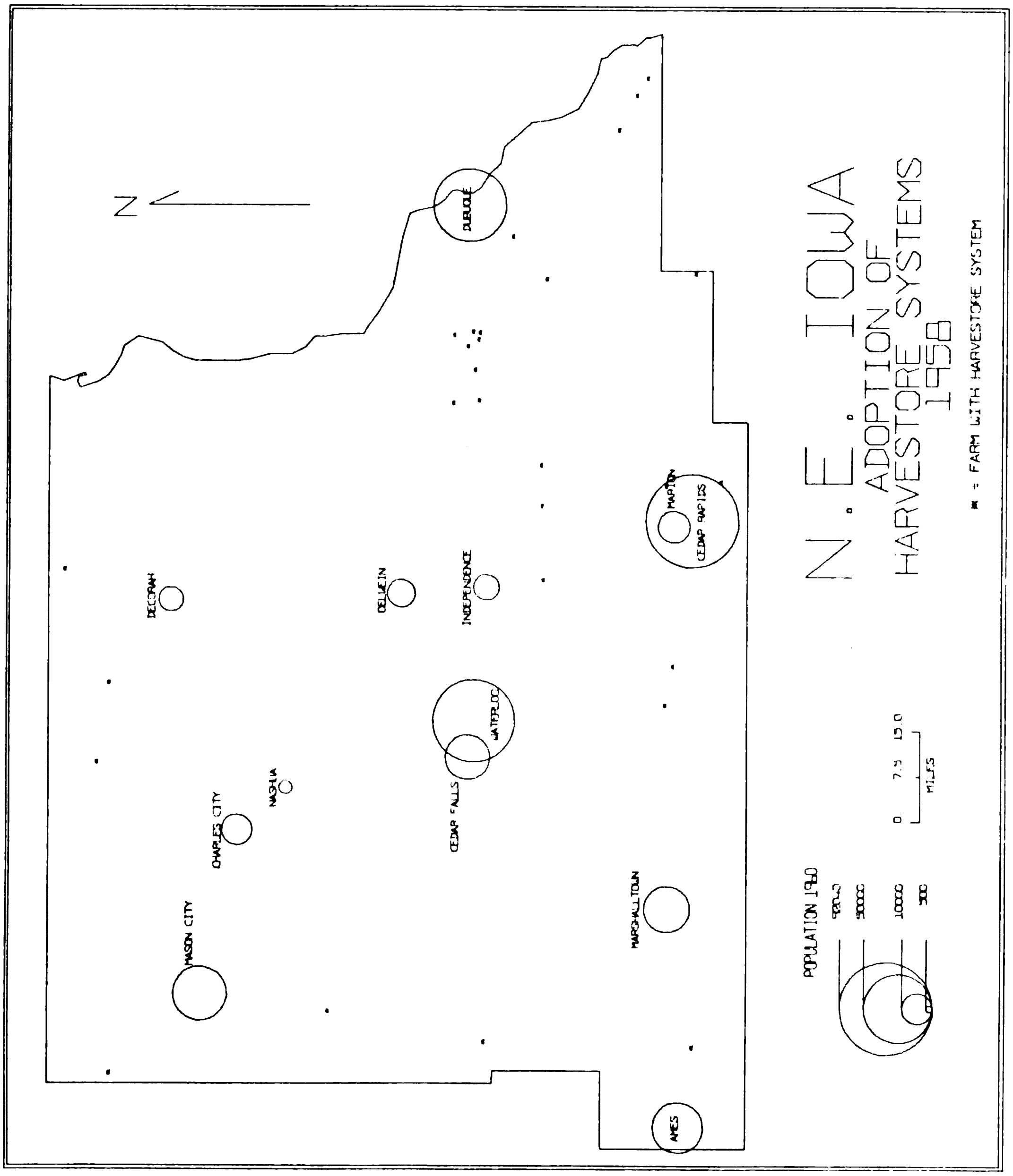
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
1957
* - FARM WITH HARVESTORE SYSTEM

Map 19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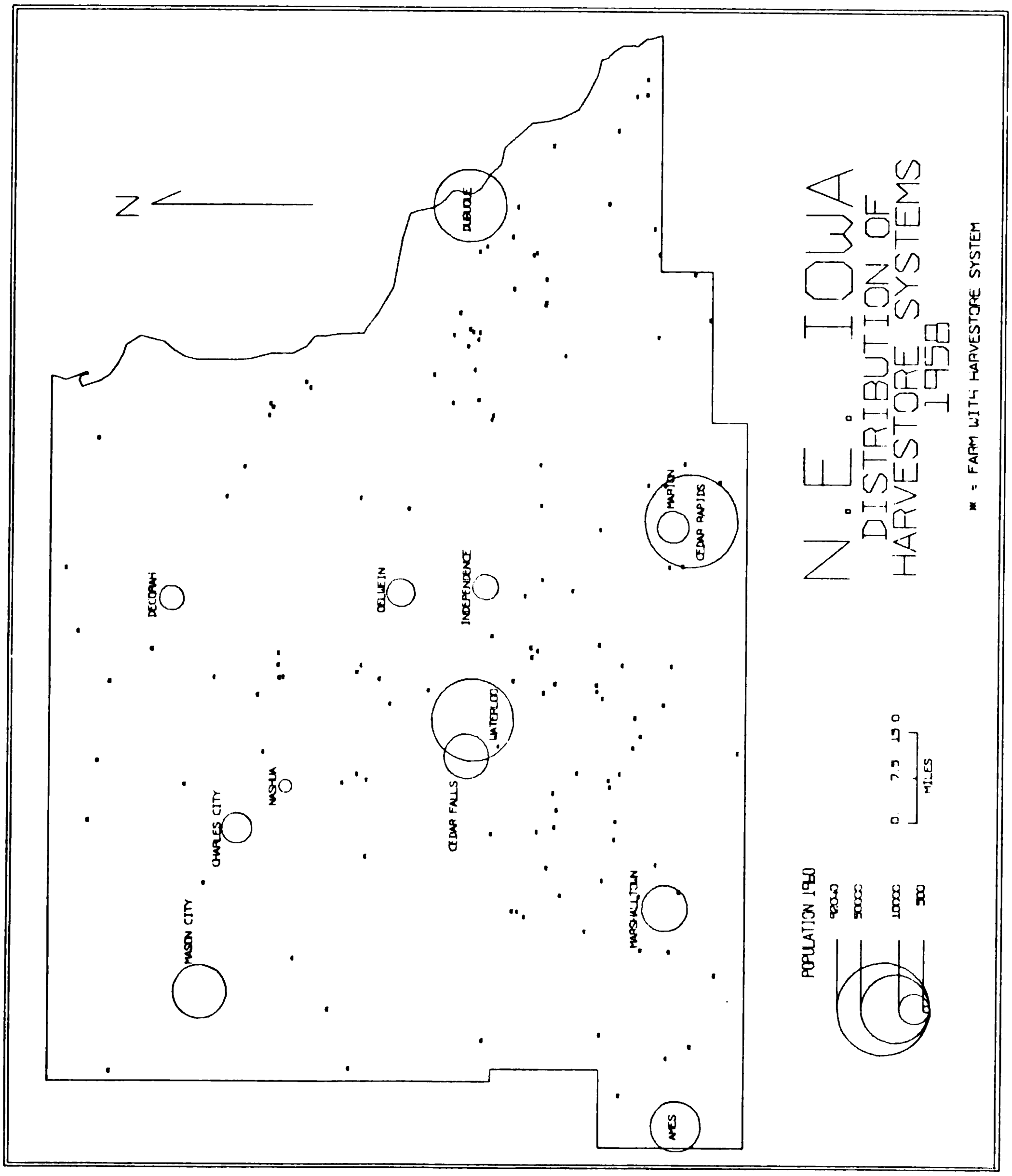
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1958
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CEDAR FALLS
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MARSHALLTOWN
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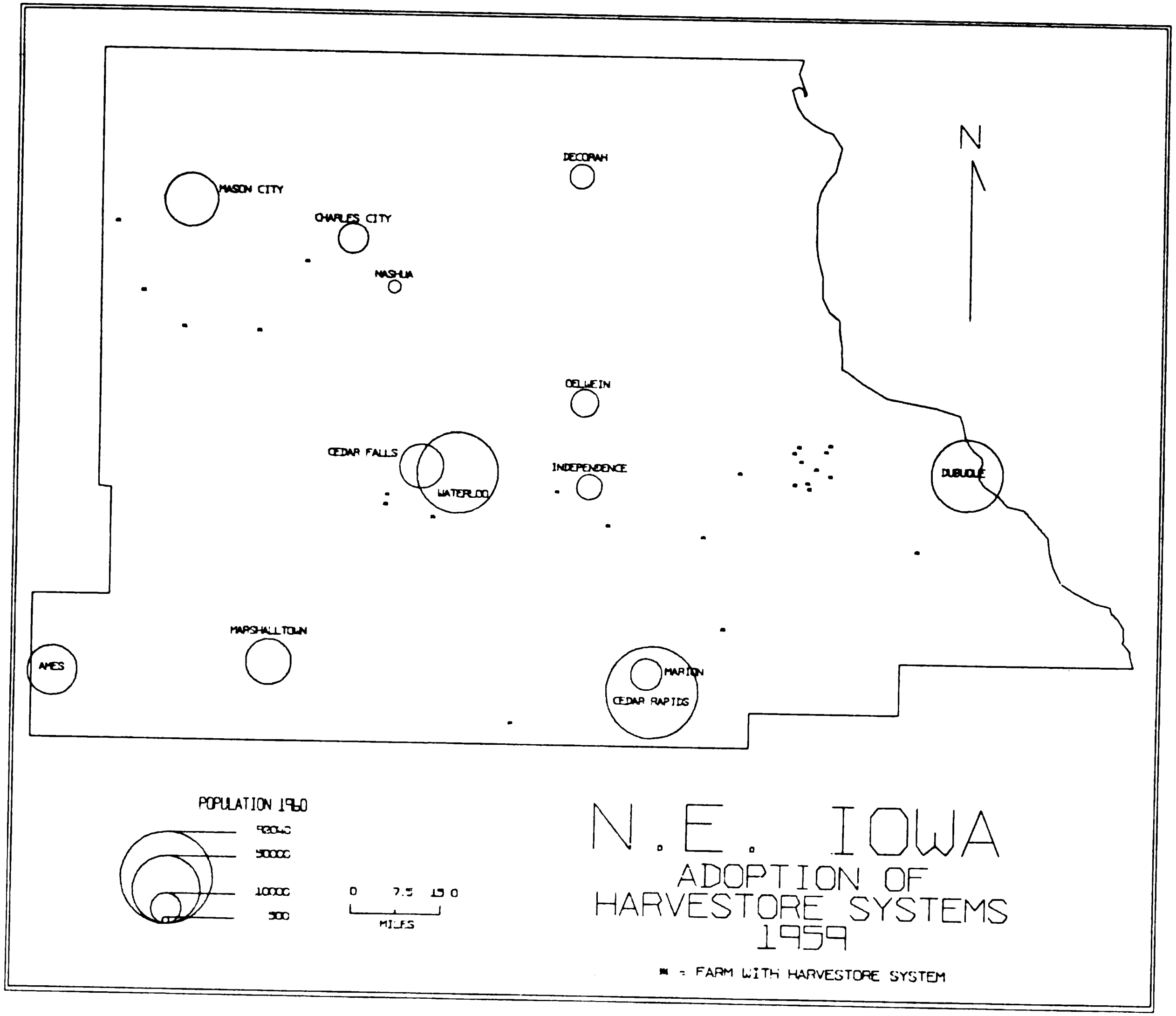
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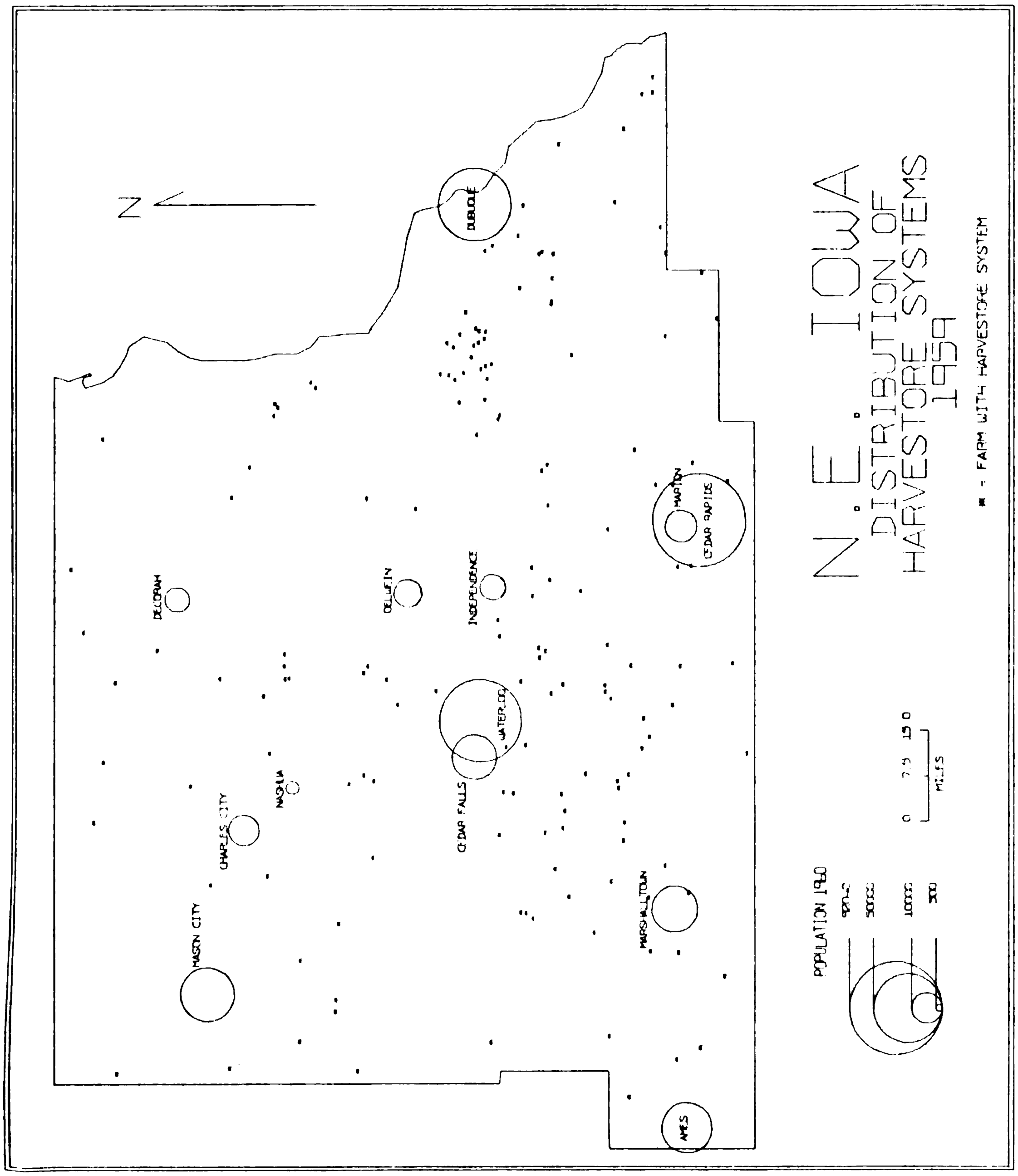
ADOPTION OF
HARVESTORE SYSTEMS
1959
▪ = FARM WITH HARVESTORE SYSTEM

Map 22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1959
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CEDAR FALLS
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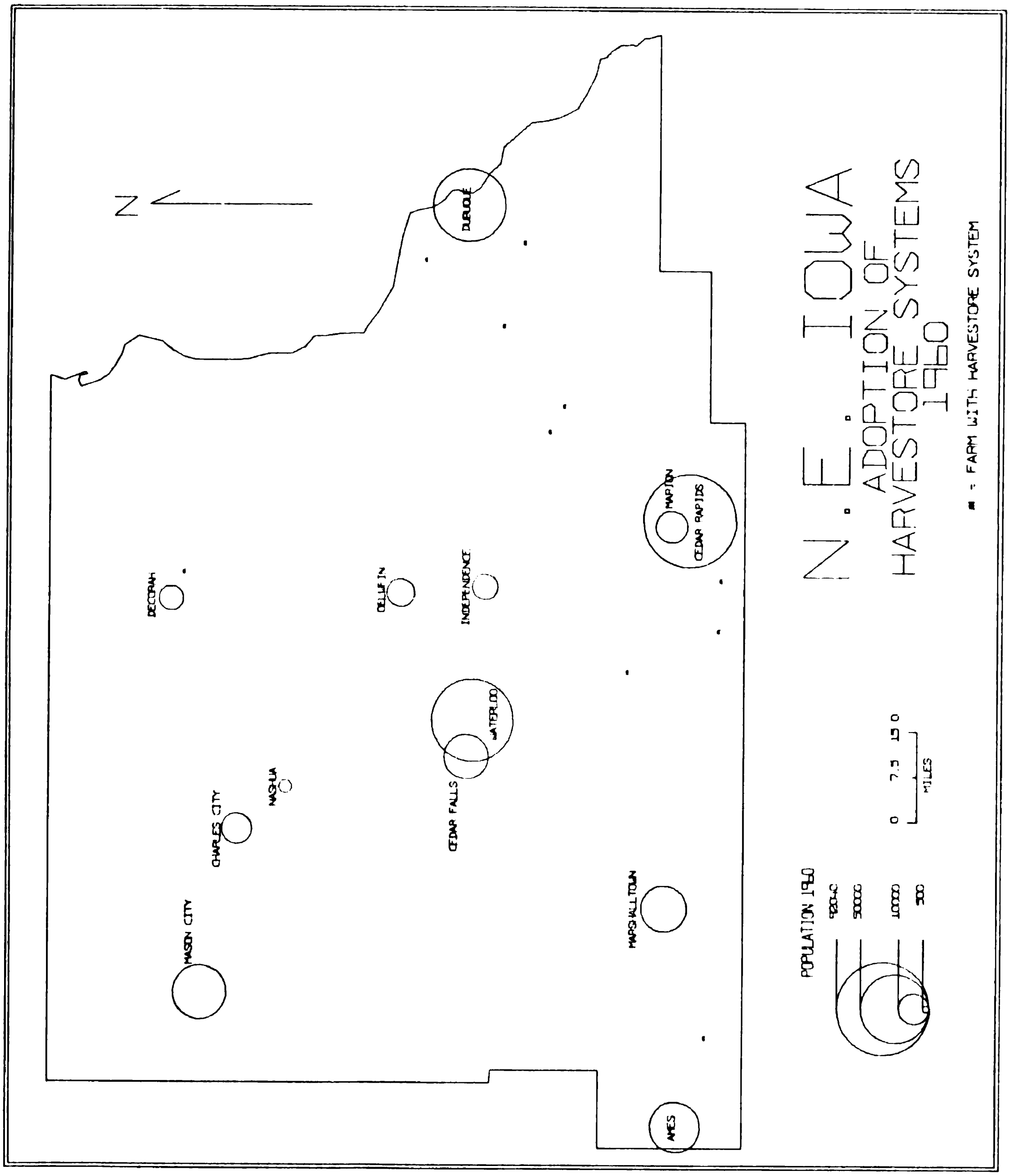
Map 23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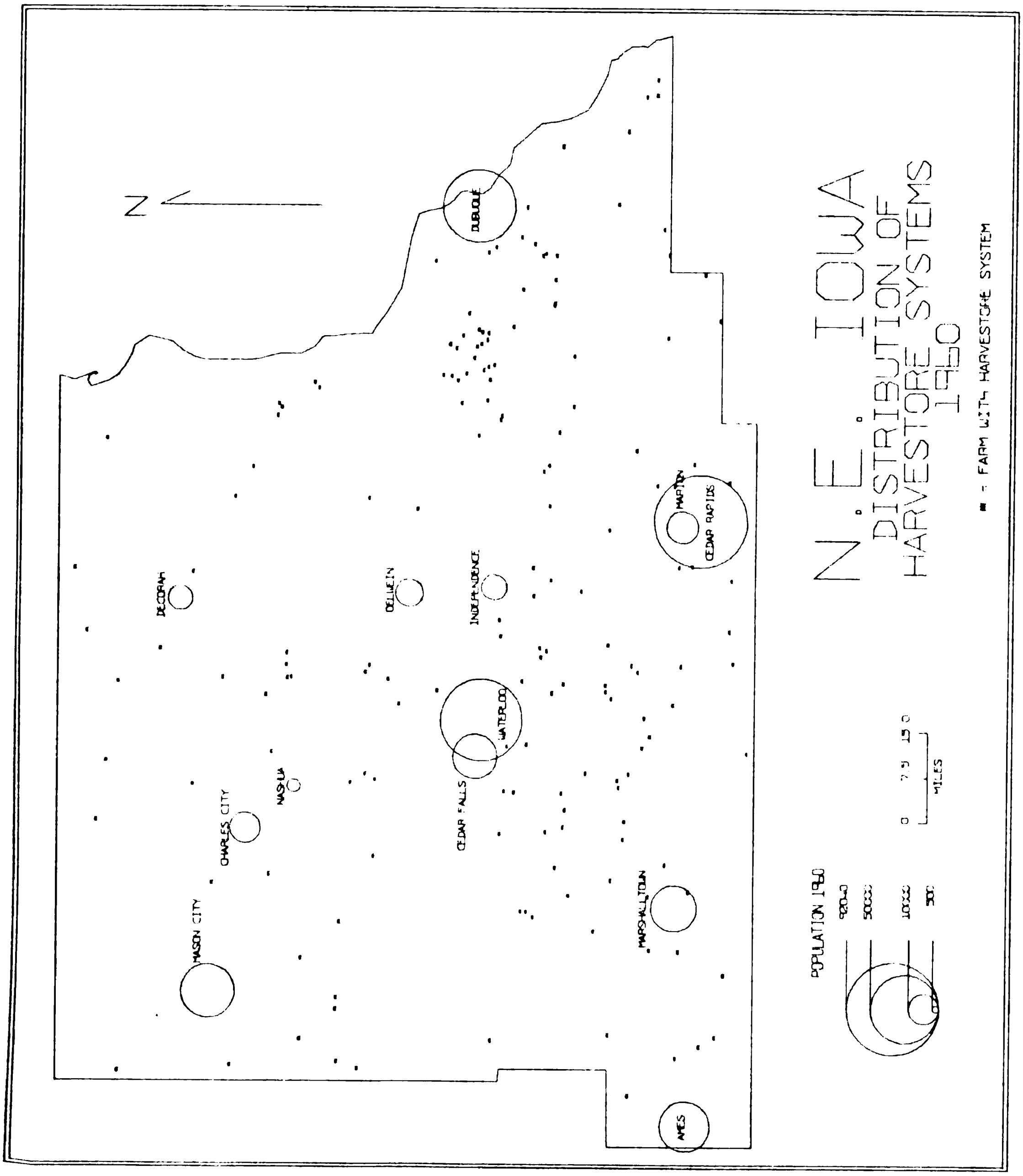
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
POPULATION 1960
0 7.5 15.0
MILES

Map 24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1960
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CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES

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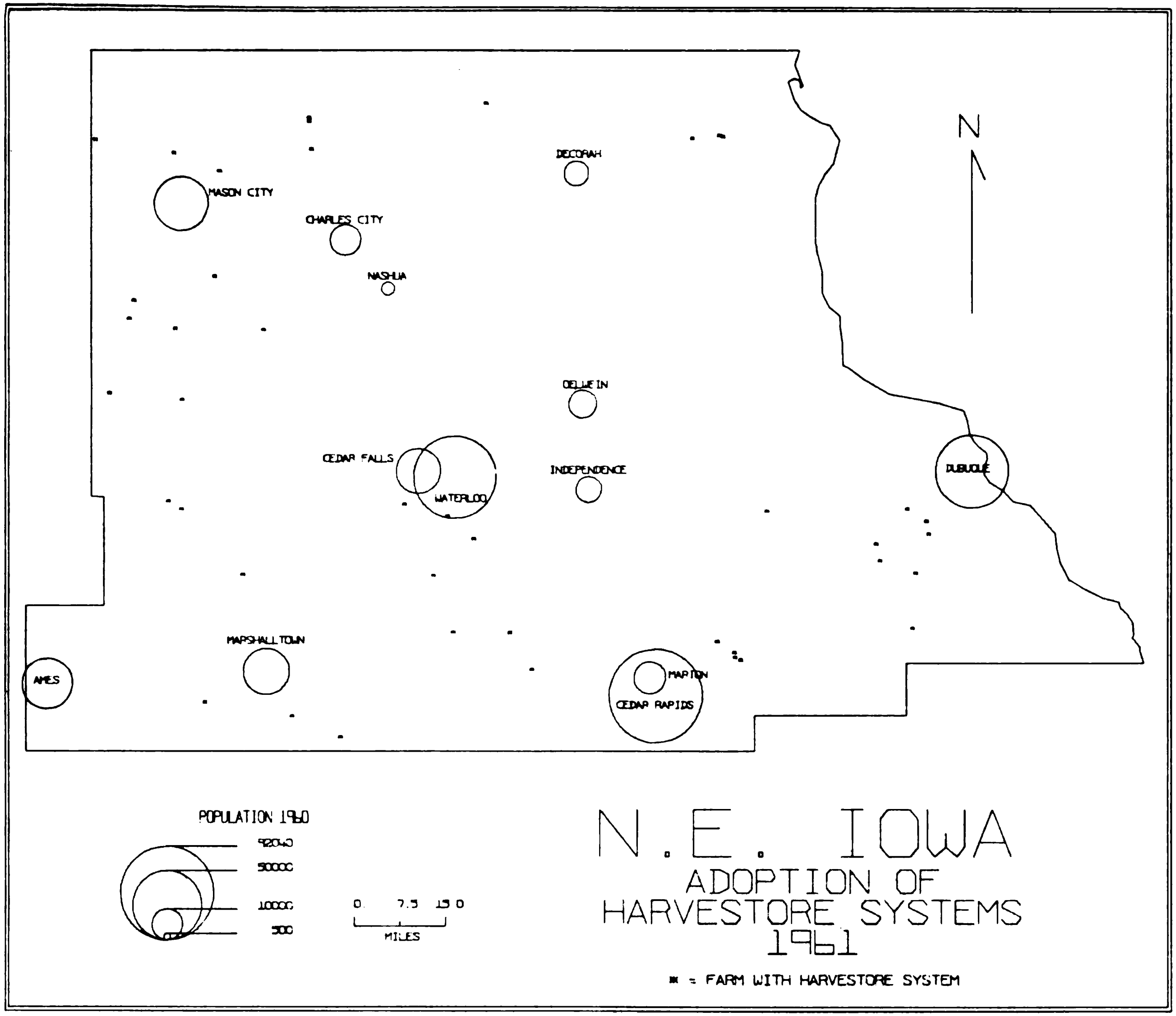
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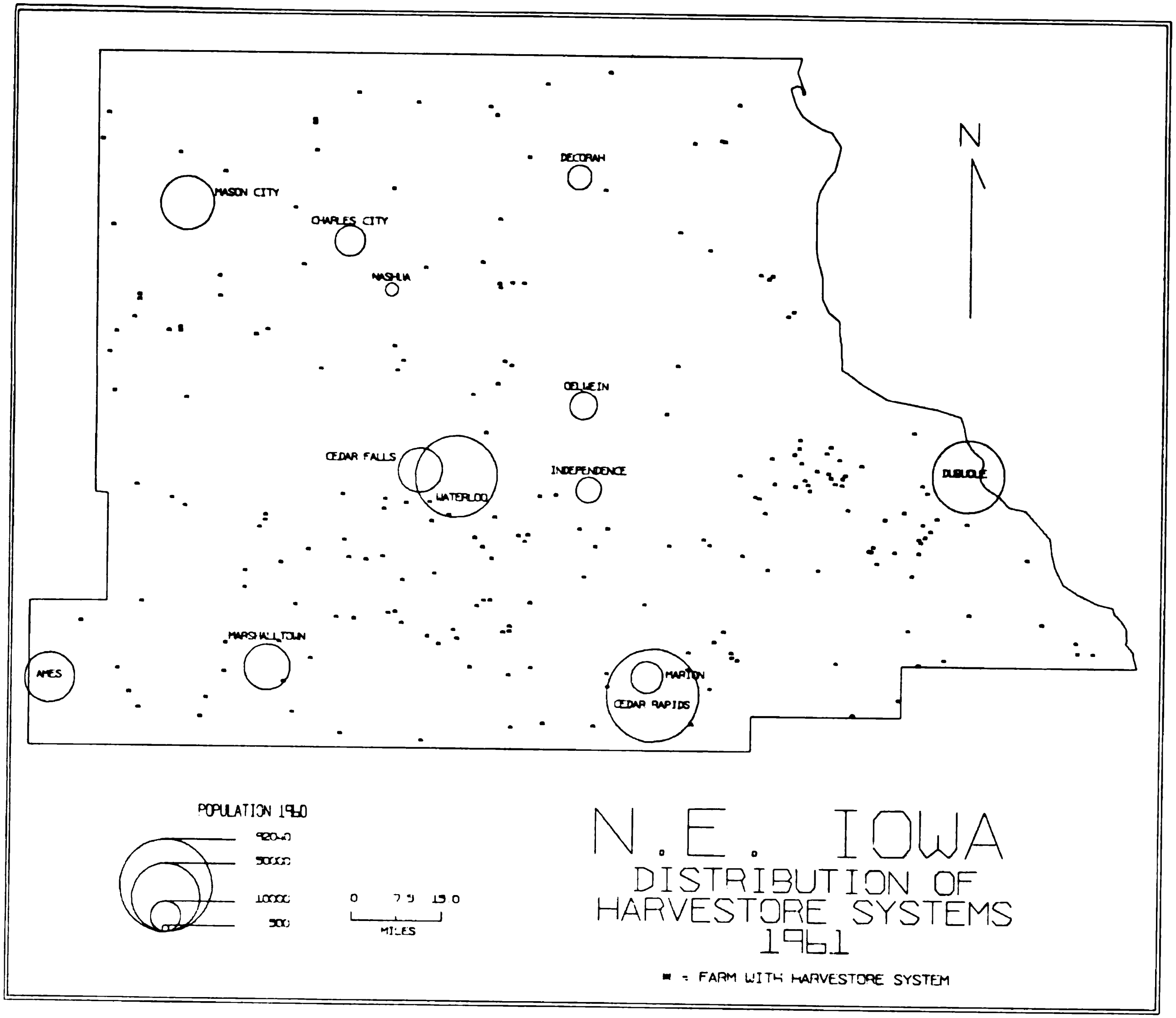
MILES
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1961
■ = FARM WITH HARVESTORE SYSTEM

Map 26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POPULATION 1960
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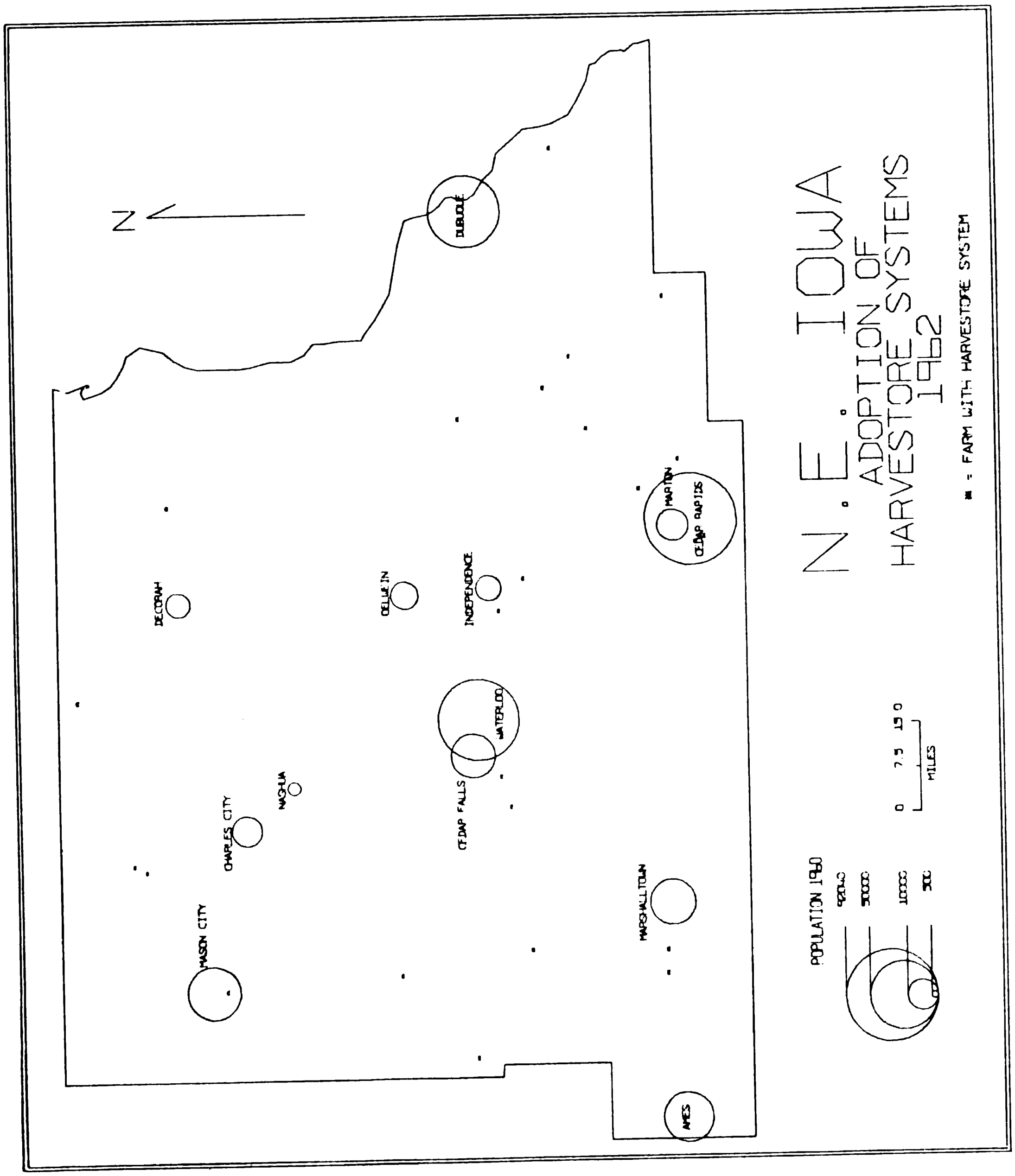
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
1961
■ = FARM WITH HARVESTORE SYSTEM

Map 27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MARION
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OELWEIN
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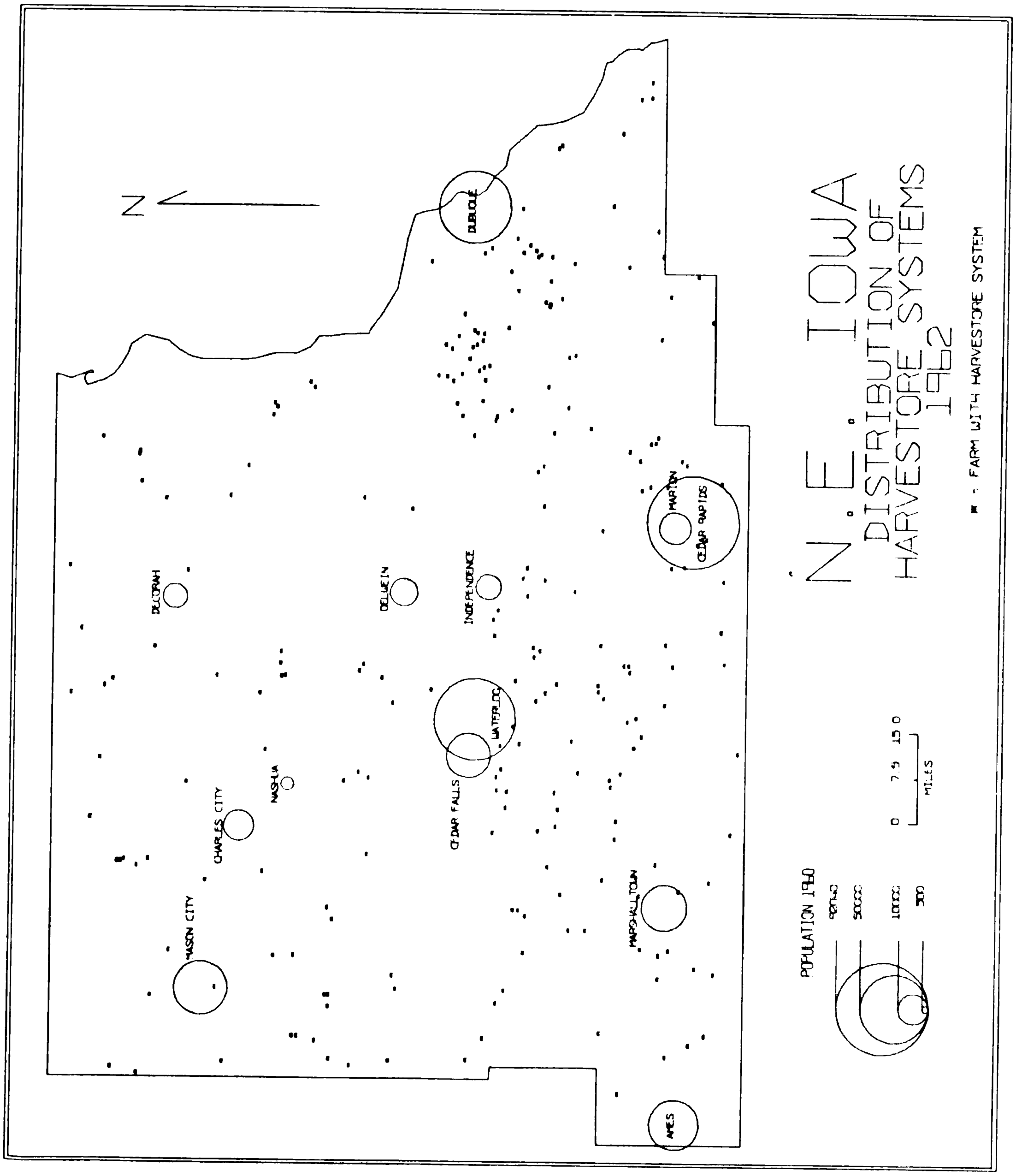
MARSHALLTOWN
AMES
POPULATION 1960
MILES

Map 28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1962
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CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES

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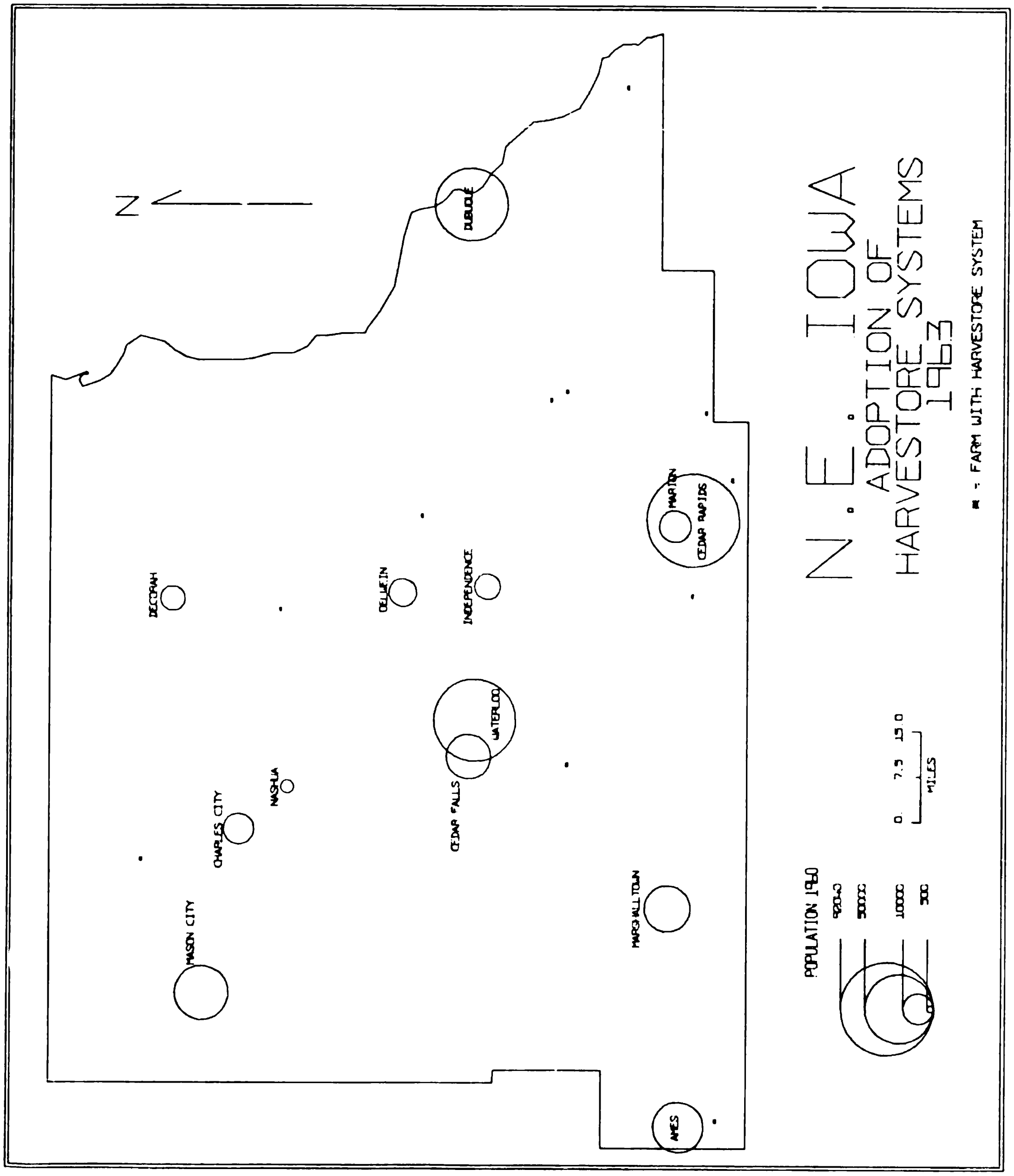
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1963
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CEDAR FALLS
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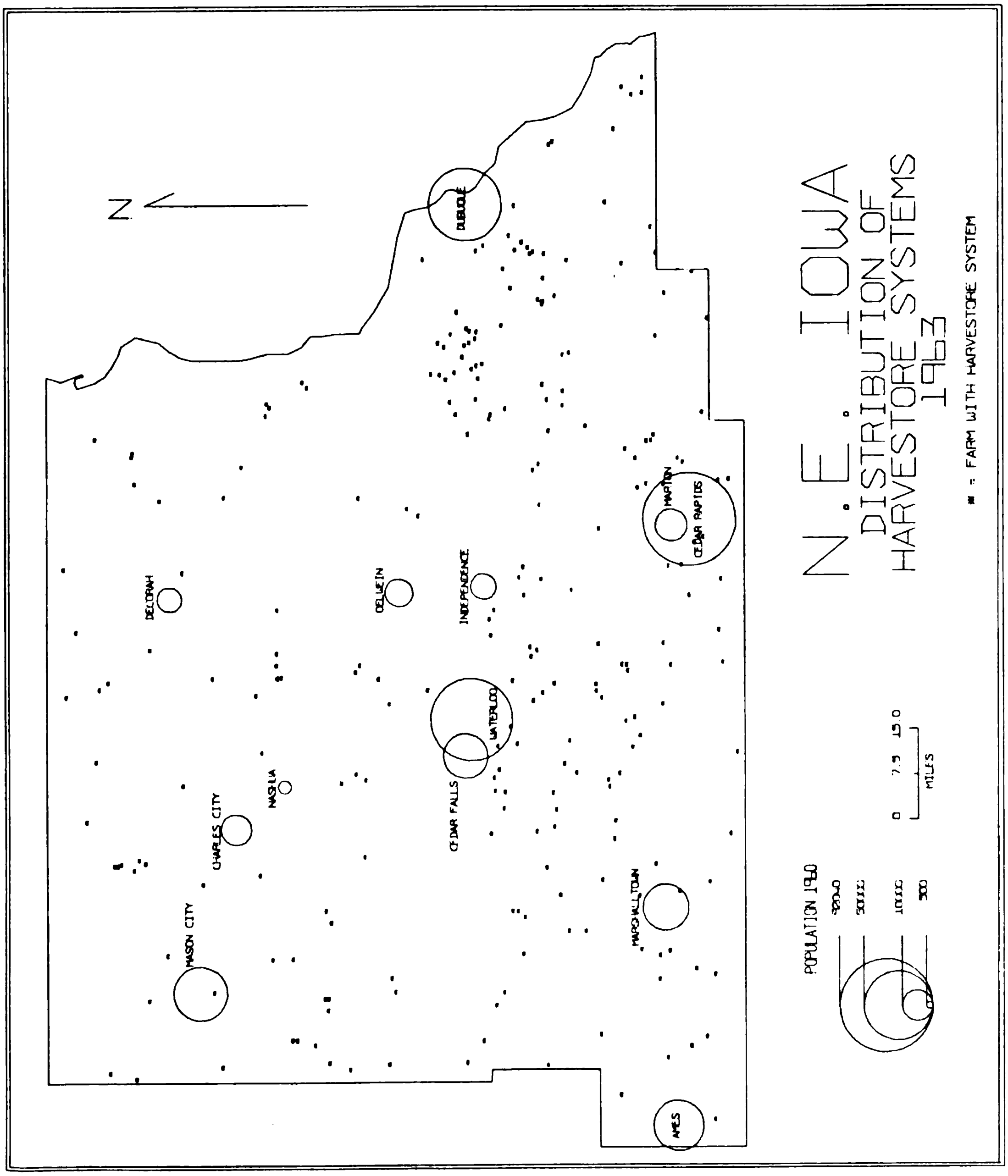
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES

Map 30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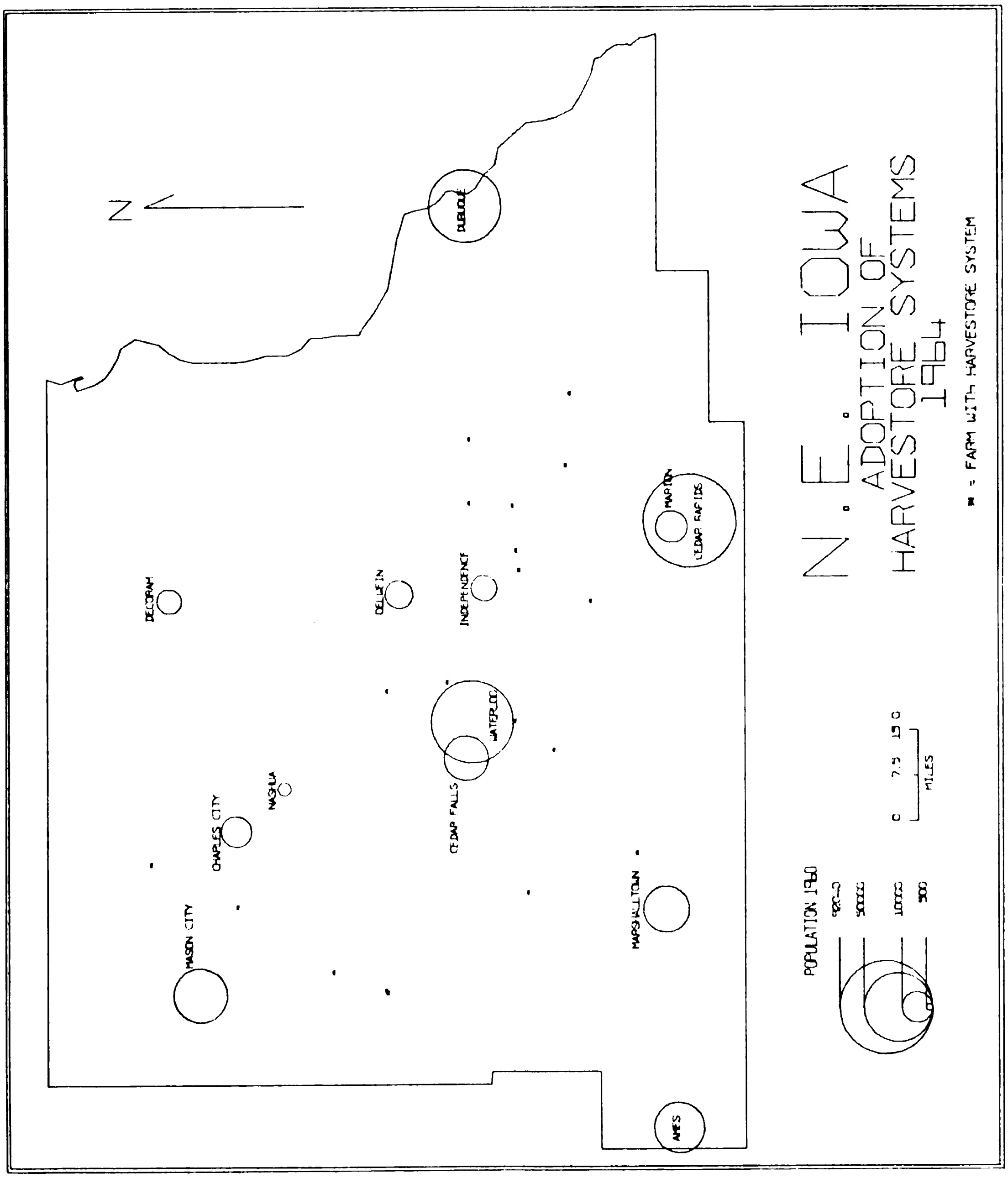
N
POPULATION 1960
MILES
DECORAH
OELWEIN
INDEPENDENCE
DUBUQUE
MARION
CEDAR RAPIDS
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES

Map 31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ADOPTION OF
HARVESTORE SYSTEMS
1964
■ - FARM WITH HARVESTORE SYSTEM
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MARION
CEDAR RAPIDS
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
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MARSHALLTOWN
AMES
0 7.5 15.0
MILES
POPULATION 1960
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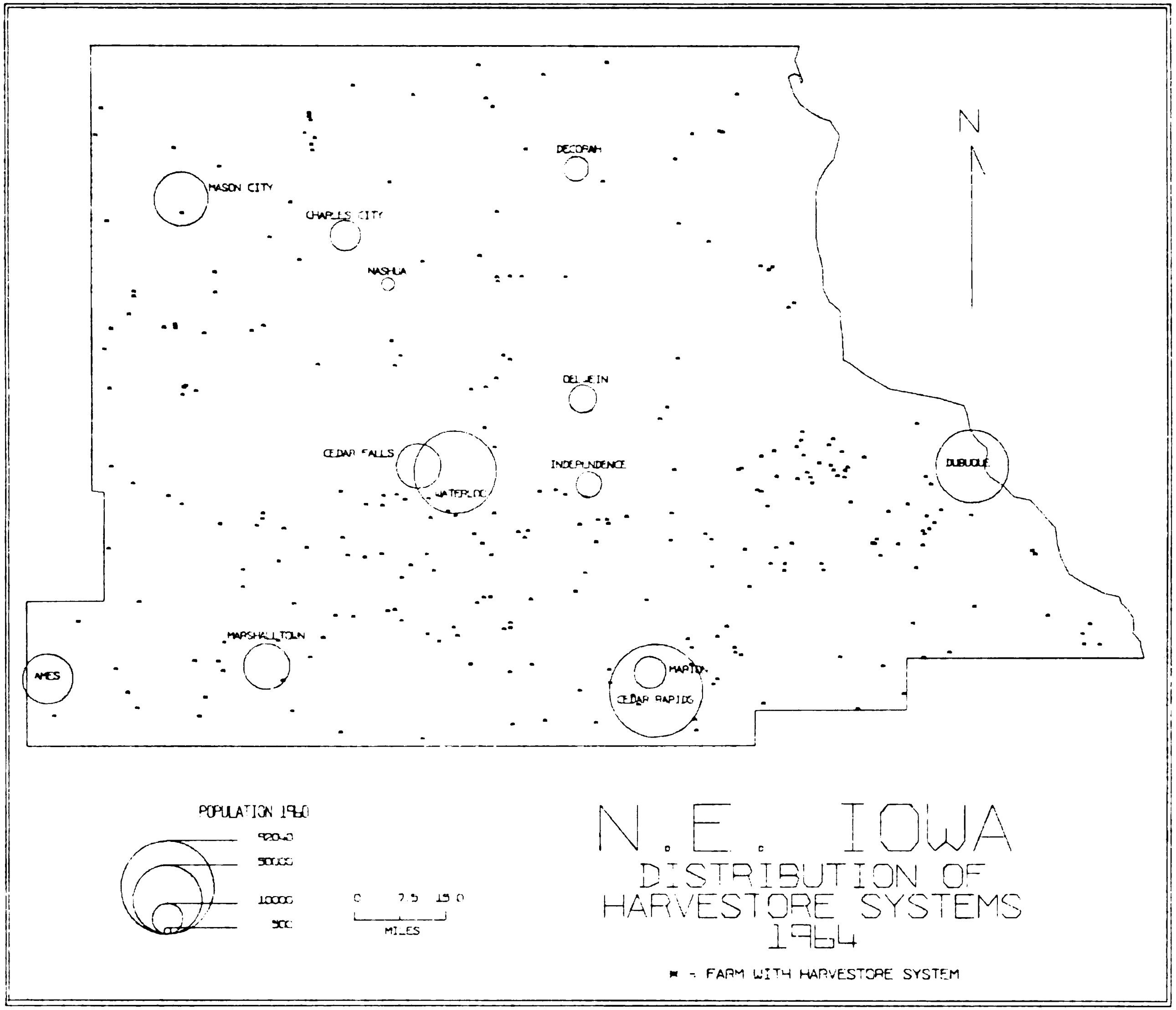
10000
500

Map 32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INDEPENDENCE
DUBUQUE
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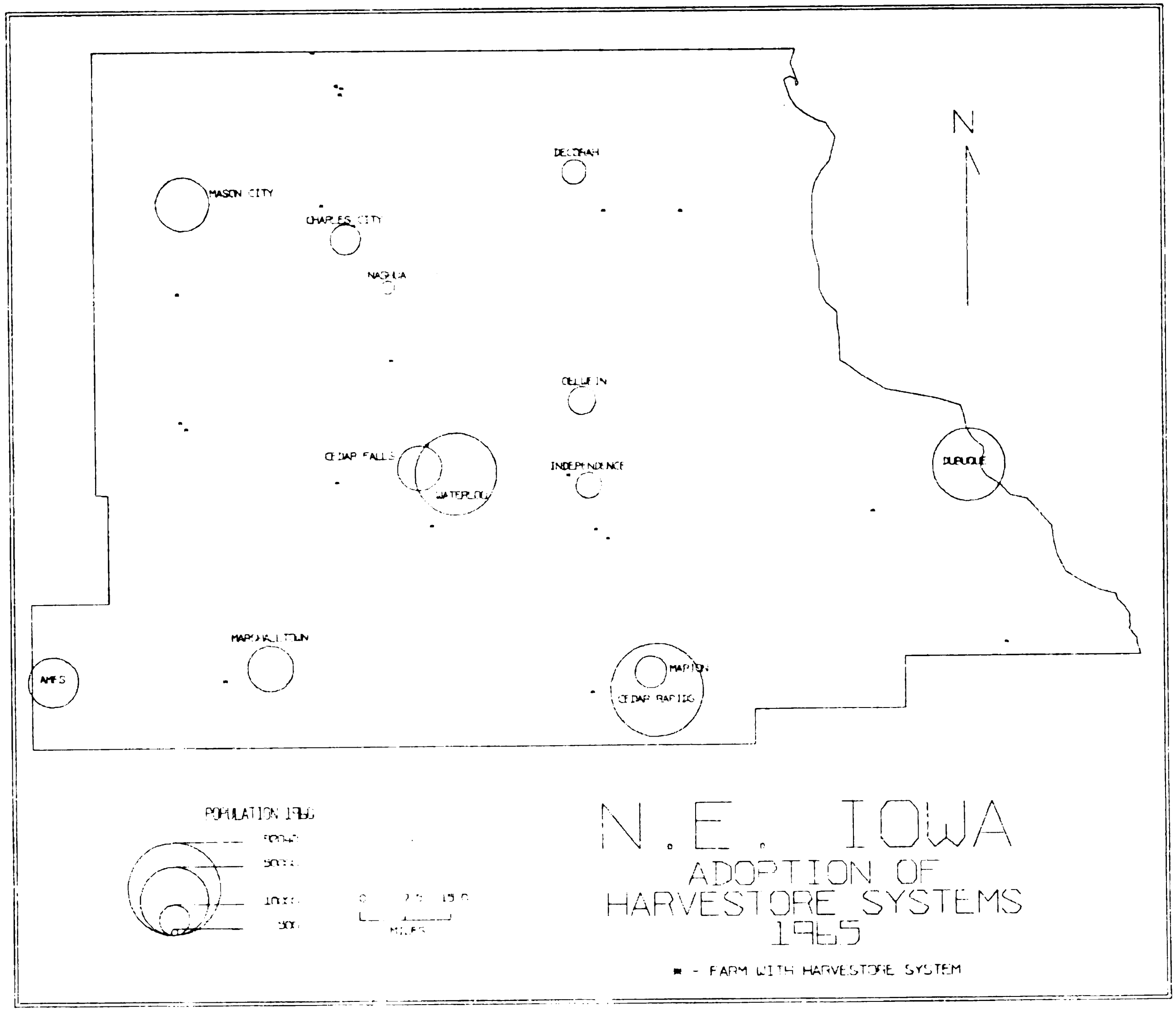
AMES
CEDAR RAPIDS
POPULATION 1960
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
1964
= FARM WITH HARVESTORE SYSTEM

Map 33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DECORAH
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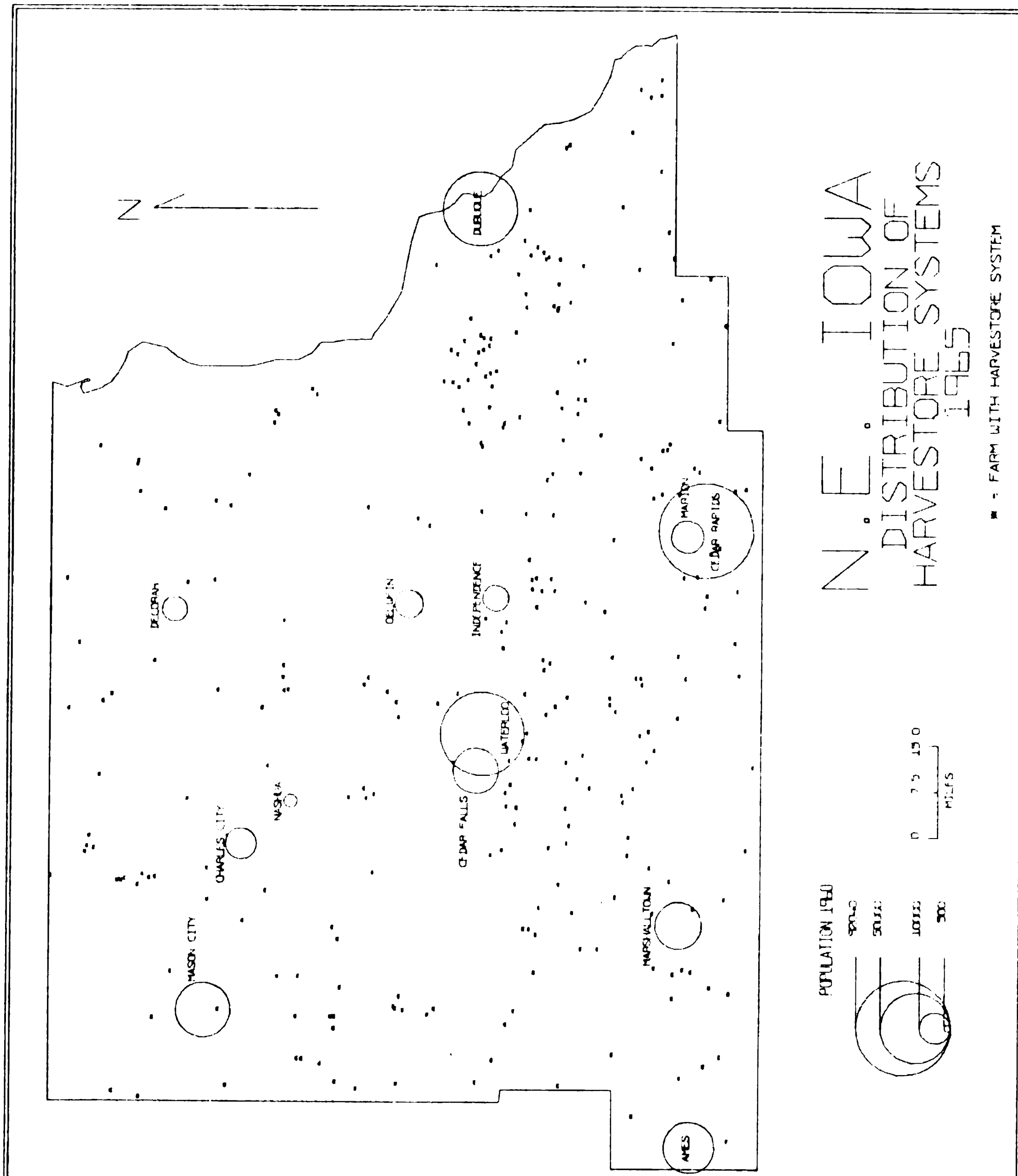
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
MILES
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1965
▪ - FARM WITH HARVESTORE SYSTEM

Map 34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1965
■ = FARM WITH HARVESTORE SYSTEM
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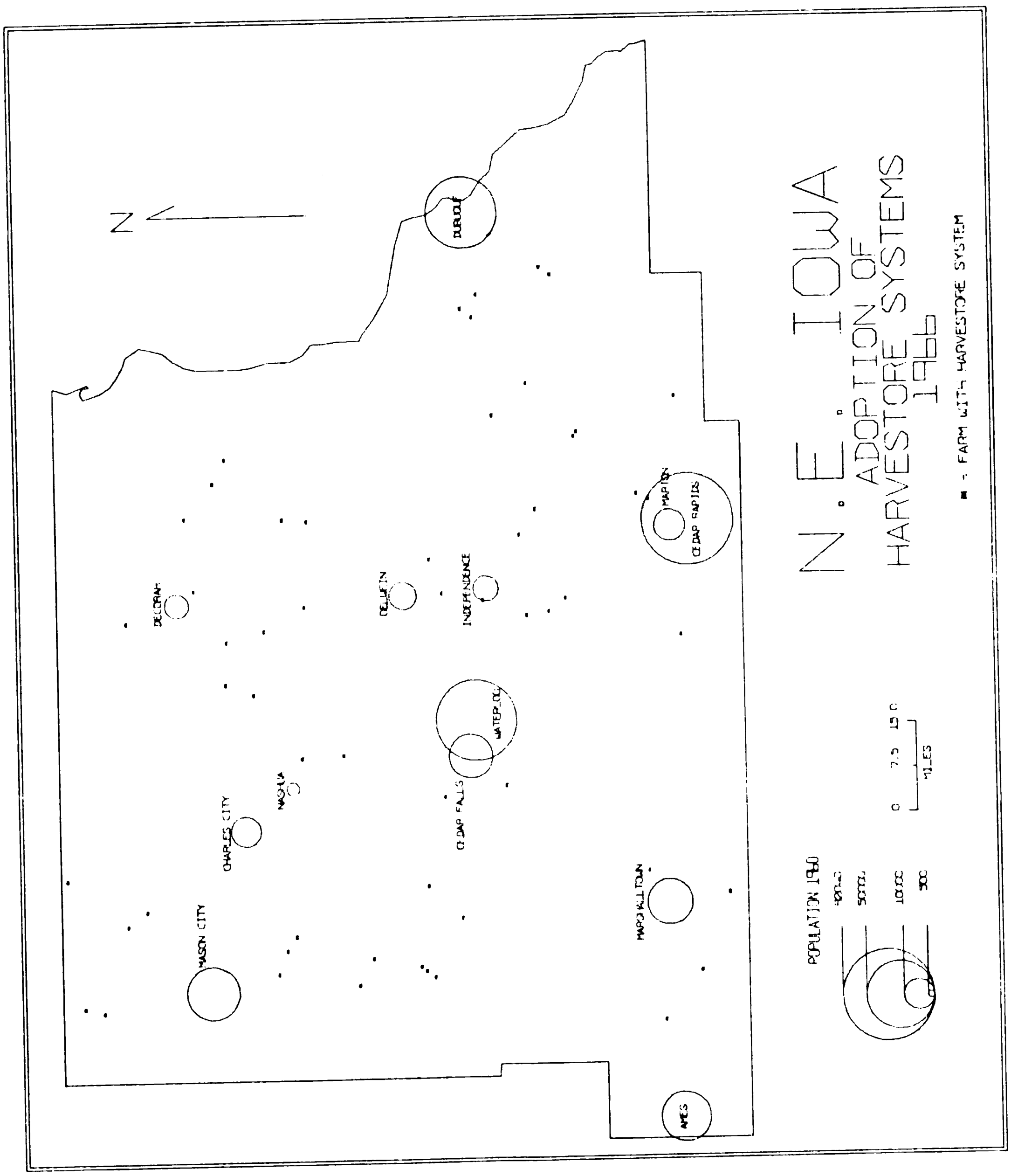
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
MARSHALLTOWN
MARION
CEDAR RAPIDS
DUBUQUE
AMES

Map 35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HARVESTORE SYSTEMS
1966
■ - FARM WITH HARVESTORE SYSTEM
POPULATION 1960
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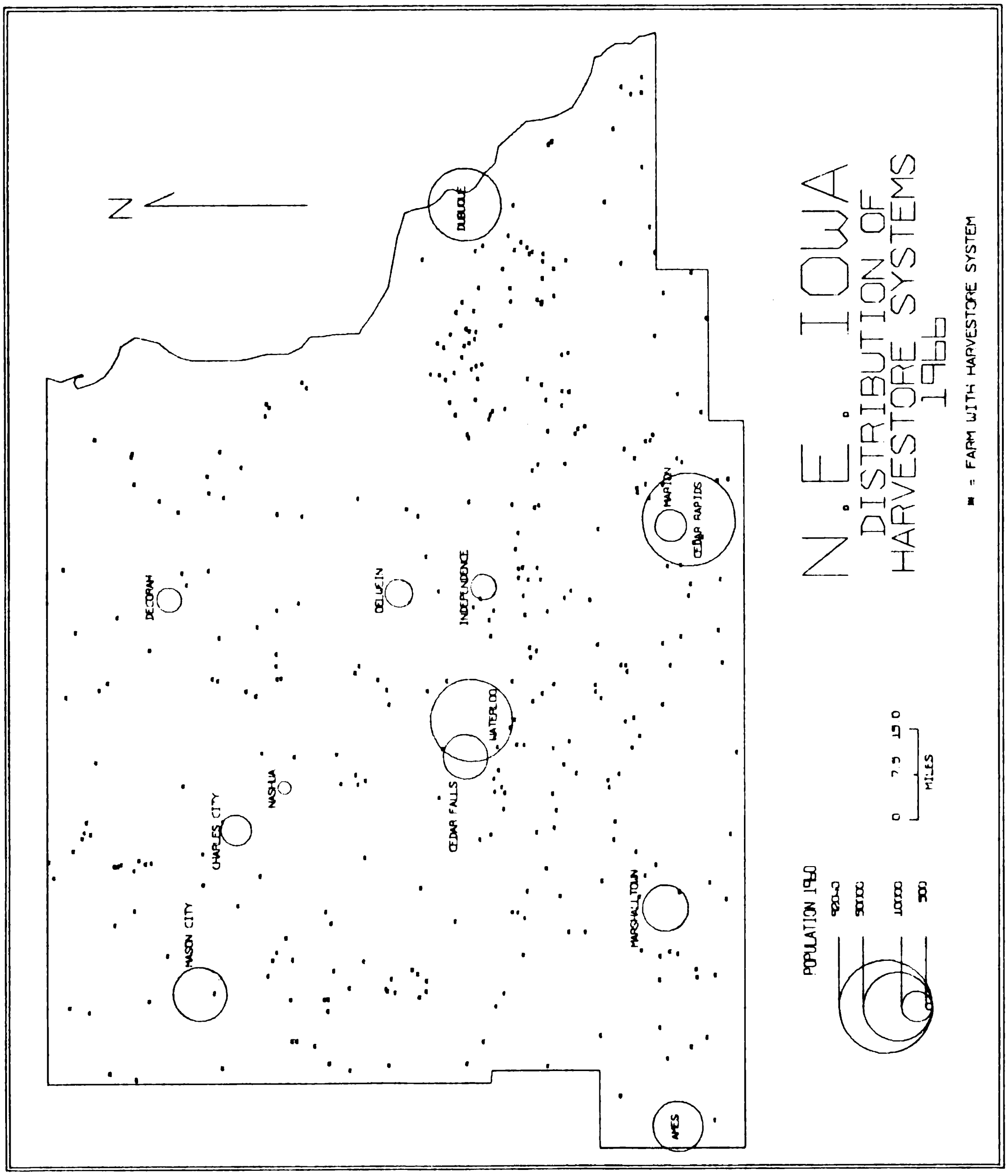
MILES
N
DUBUQUE
MARION
CEDAR RAPIDS
INDEPENDENCE
OELWEIN
DECORAH
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES

Map 36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DISTRIBUTION OF
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1966
= FARM WITH HARVESTORE SYSTEM
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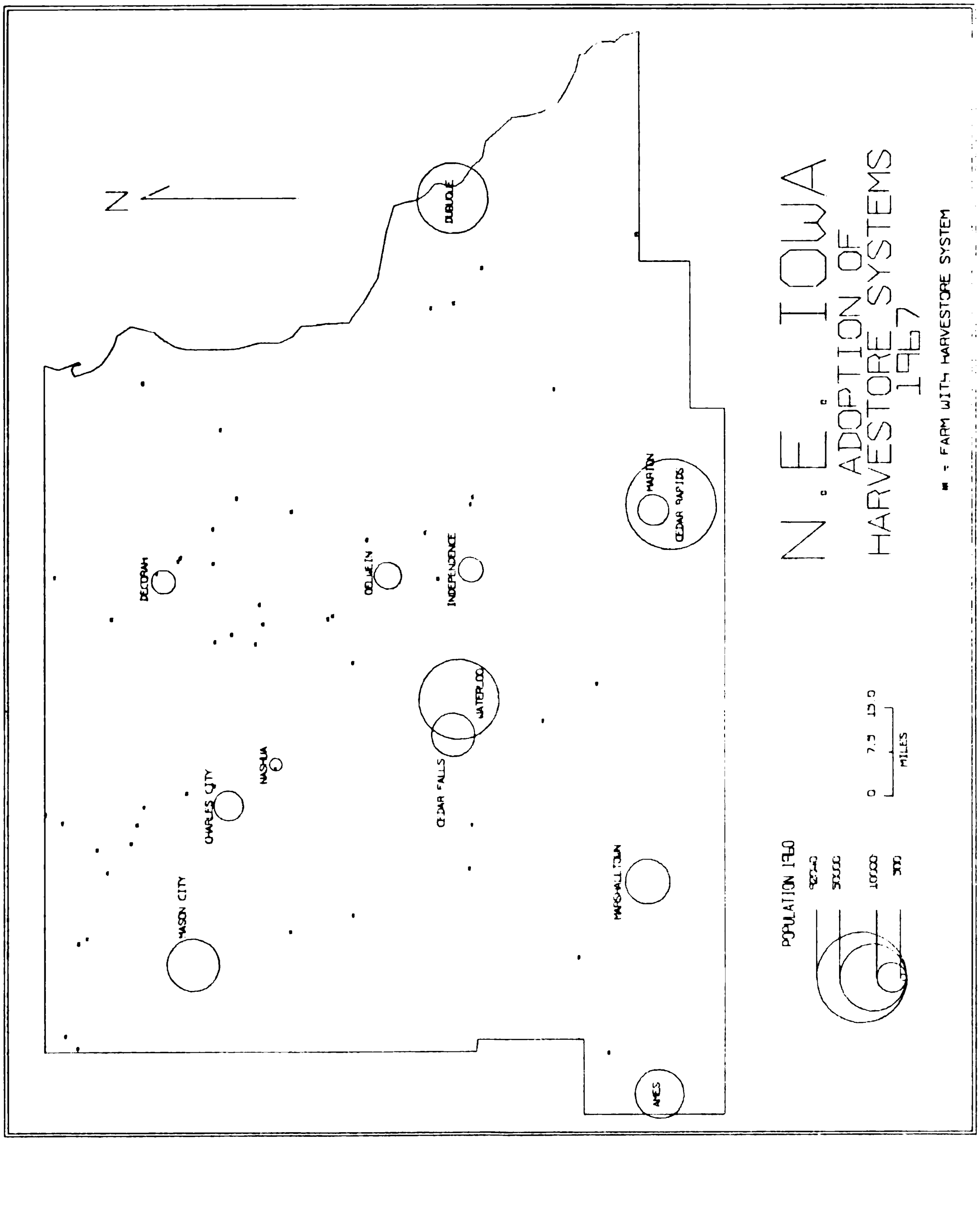
MARION
CEDAR RAPIDS
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
POPULATION 1960
0 7.5 15.0
MILES

Map 37


N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
1967
■ - FARM WITH HARVESTORE SYSTEM
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DECORAH
OELWEIN
INDEPENDENCE
MARION
CEDAR RAPIDS
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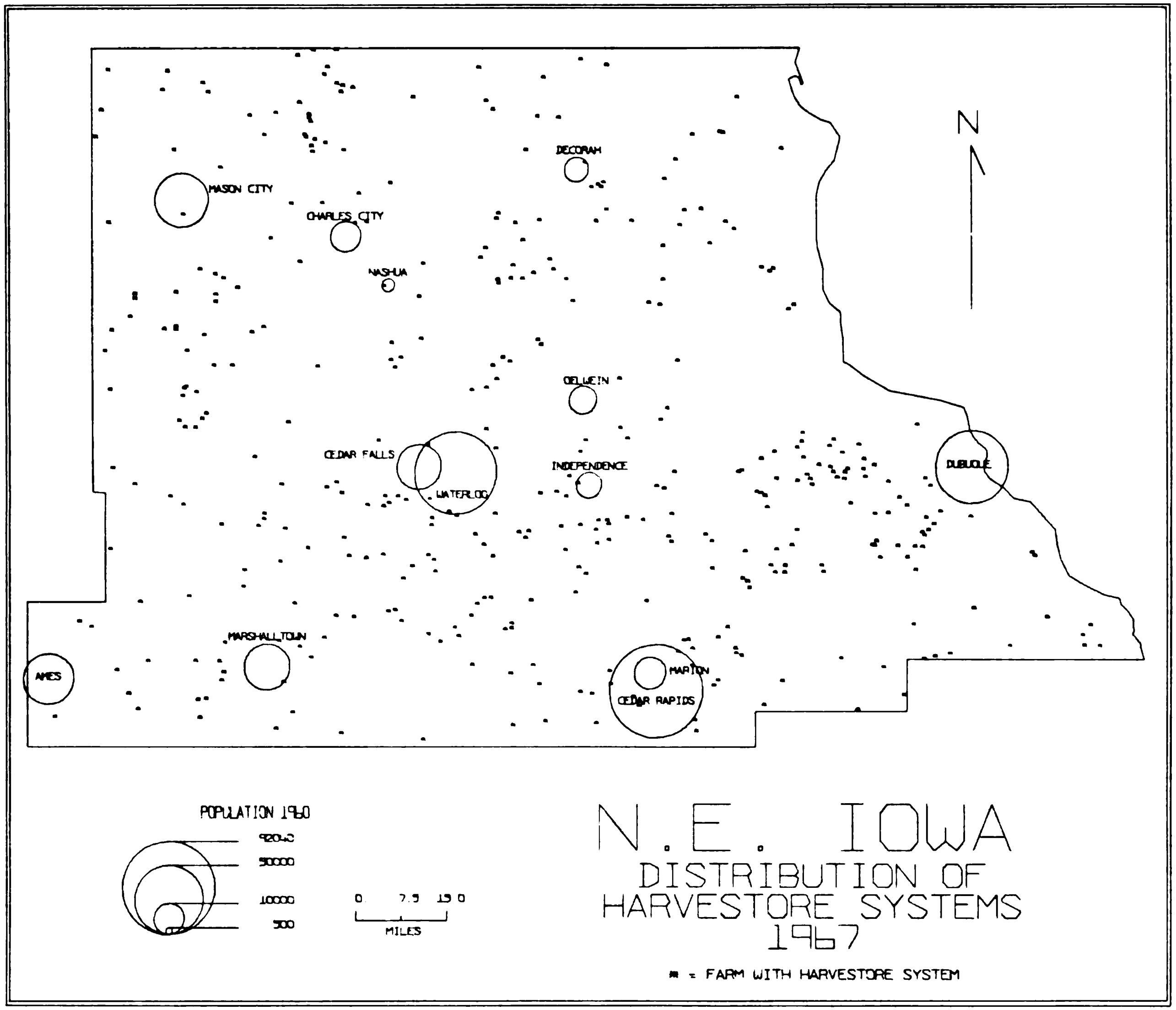
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
POPULATION 1960
MILES

Map 38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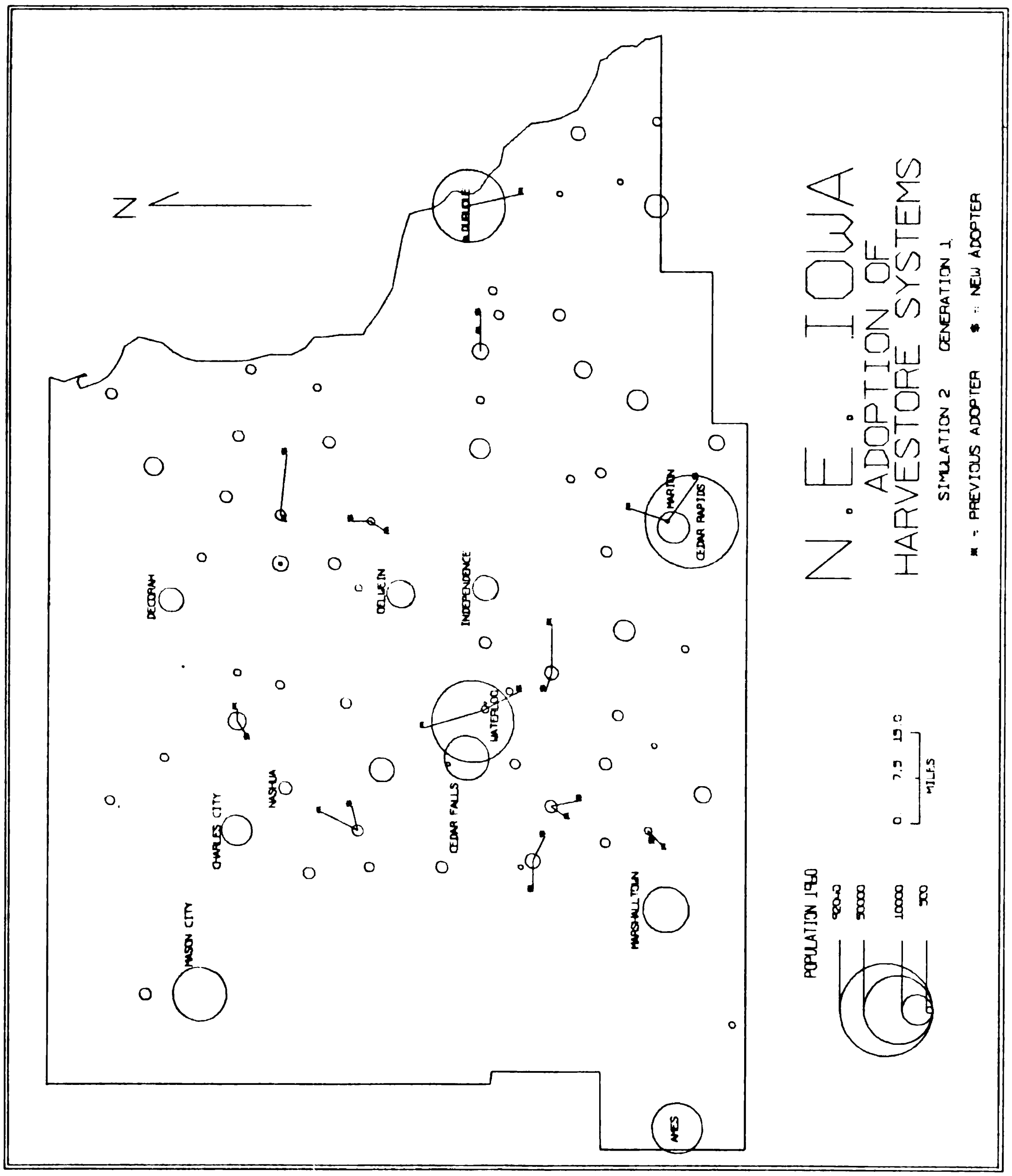
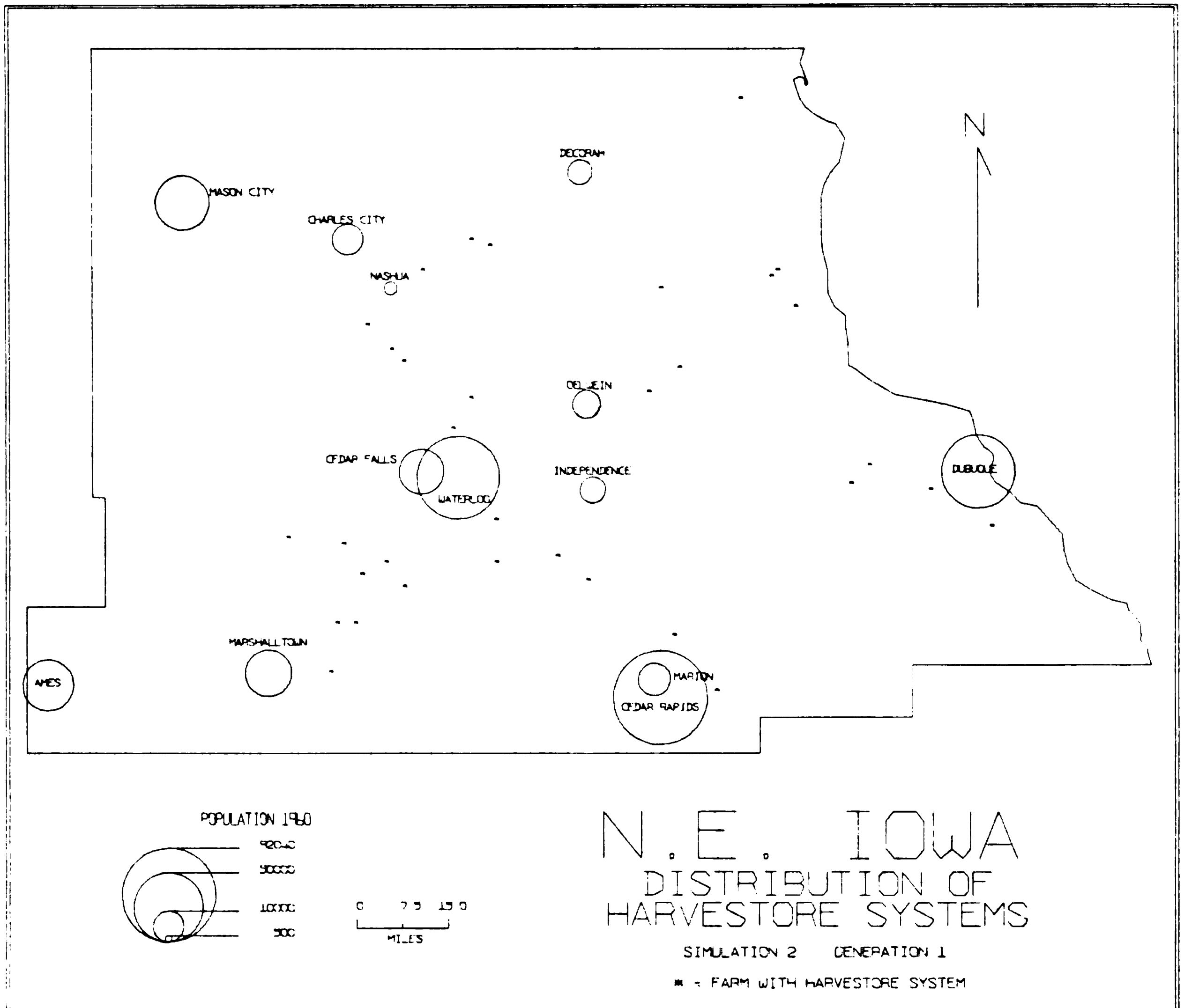
CHARLES CITY
NASHUA
OELWEIN
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
92040
50000
10000
500
0 7.5 15.0
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
1967
■ = FARM WITH HARVESTORE SYSTEM

Map 39


N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2
GENERATION 1
■ = PREVIOUS ADOPTER
✱ = NEW ADOPTER
N
POPULATION 1960
MILES
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
MARSHALLTOWN
MARION
CEDAR RAPIDS
DUBUQUE
AMES

Map 40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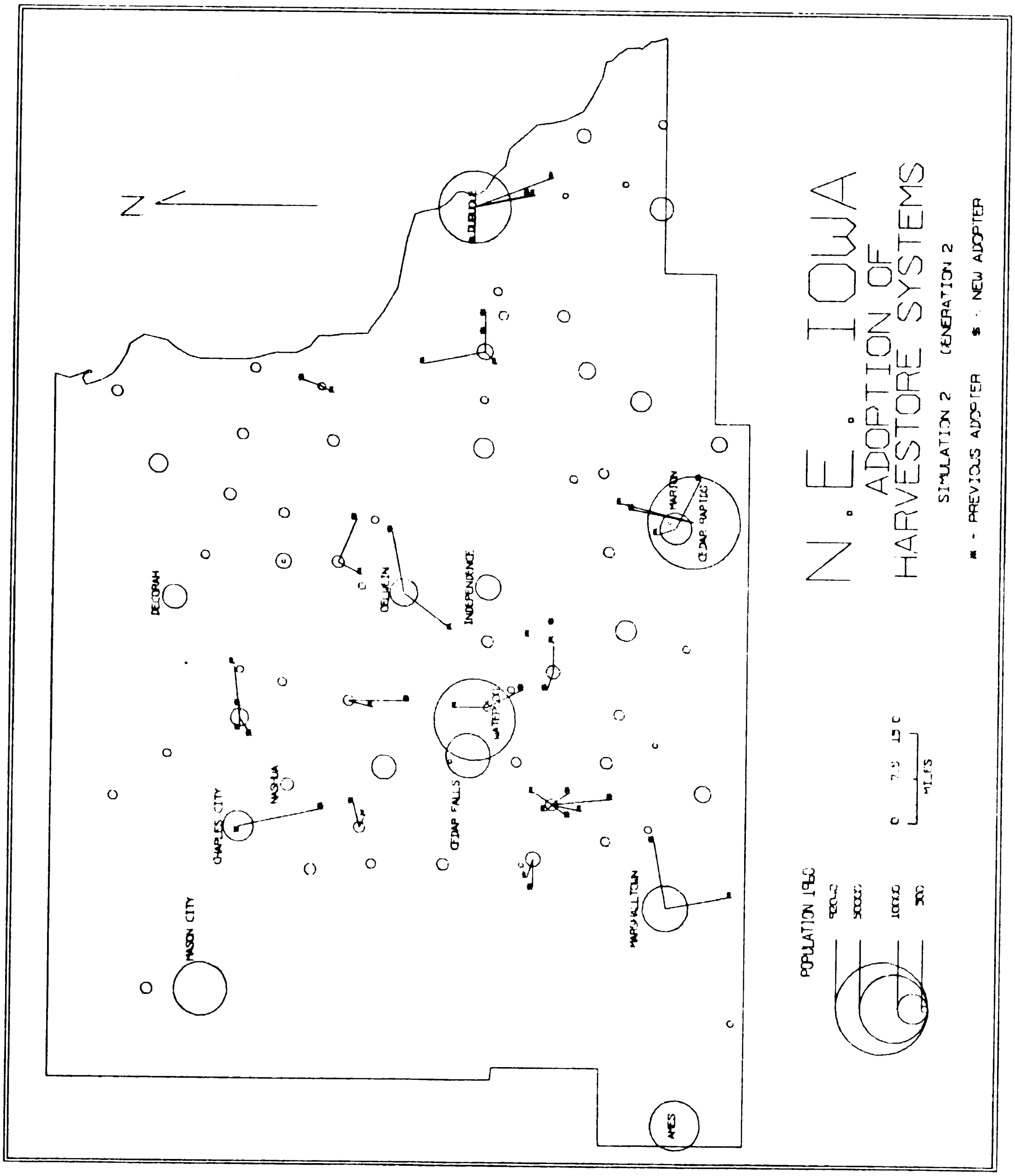
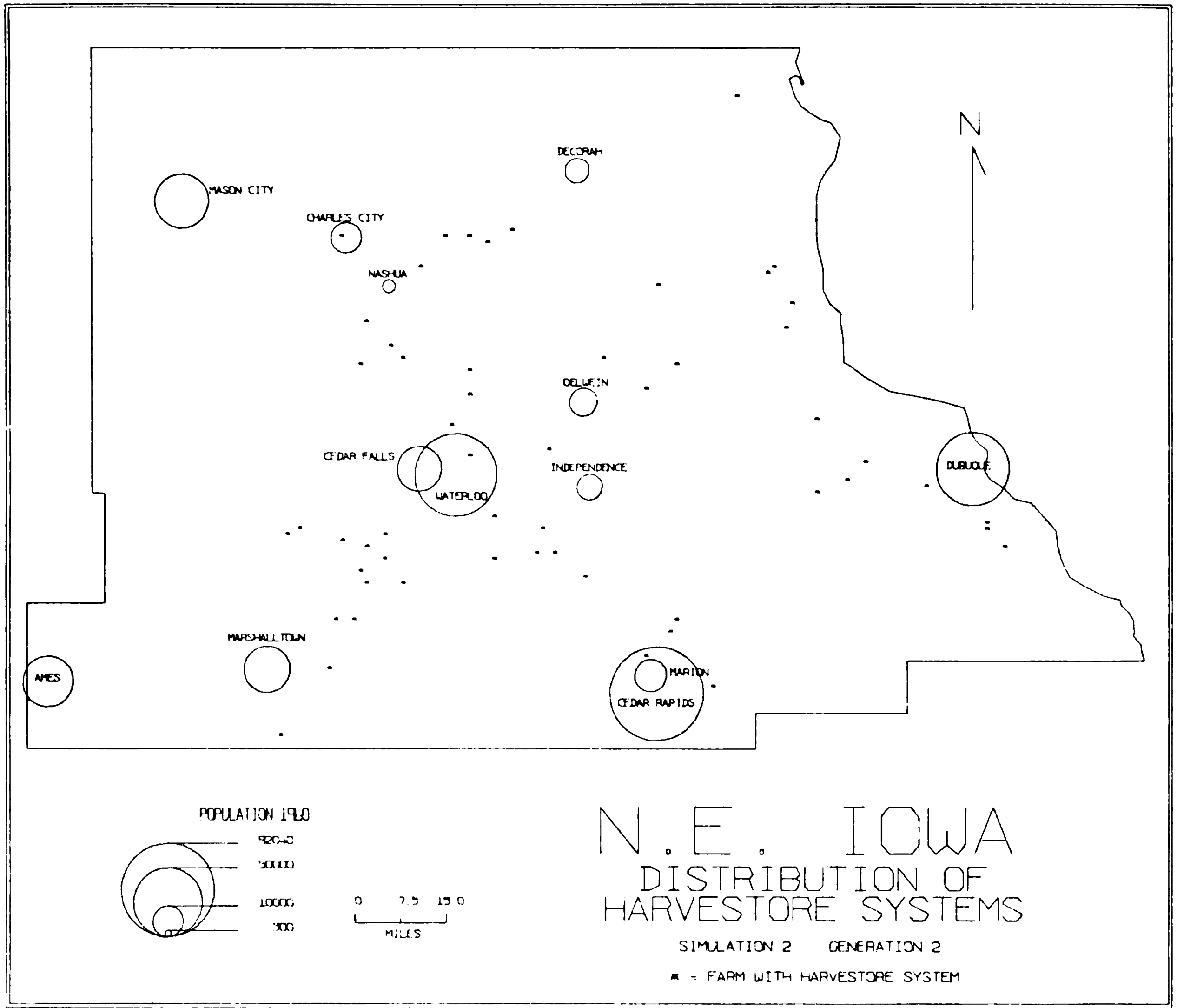
CHARLES CITY
NASHUA
DECORAH
OELWEIN
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 1
* = FARM WITH HARVESTORE SYSTEM

Map 41


N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2
GENERATION 2
PREVIOUS ADOPTER
NEW ADOPTER
POPULATION 1960
MILES
N
DUBUQUE
MARION
CEDAR RAPIDS
INDEPENDENCE
OELWEIN
DECORAH
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES

Map 42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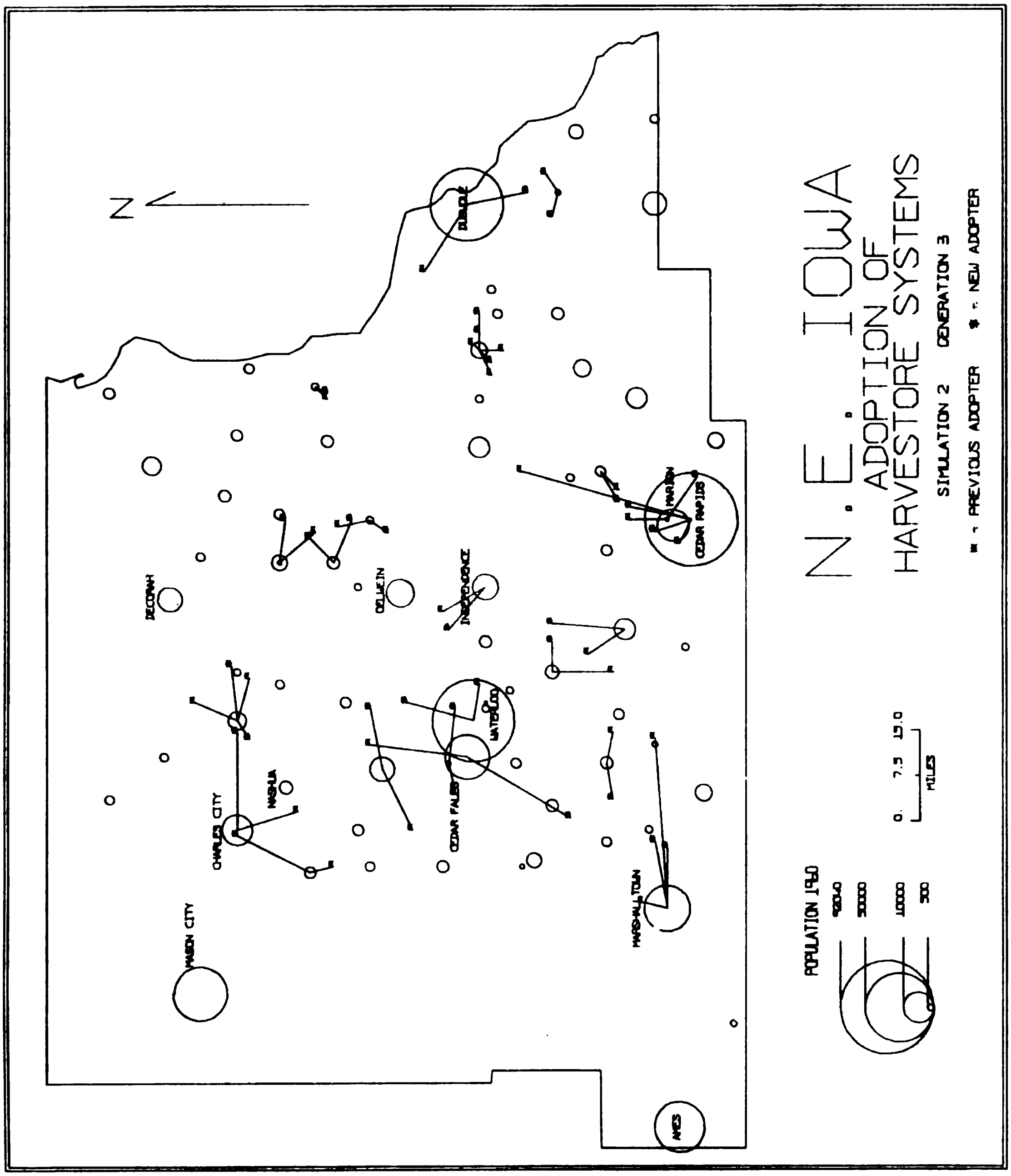
CHARLES CITY
NASHUA
DECORAH
OELWEIN
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION
50000
10000
0 7.5 15.0
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 2
■ - FARM WITH HARVESTORE SYSTEM

Map 43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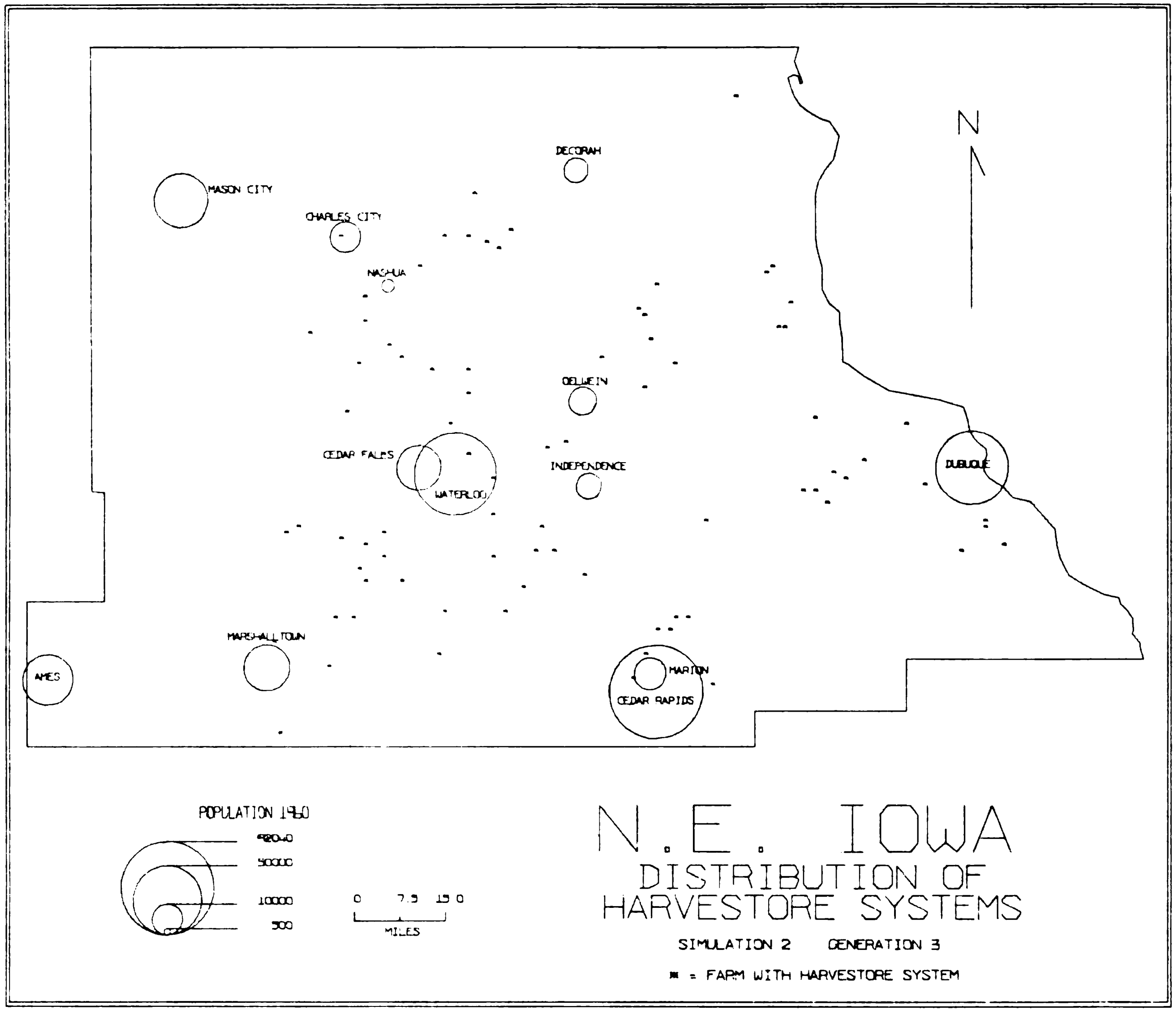
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 3
PREVIOUS ADOPTER
NEW ADOPTER
POPULATION 1960
50000
10000
500
0. 7.5 15.0
MILES
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
MARSHALLTOWN
MARION
CEDAR RAPIDS
DUBUQUE
AMES

Map 44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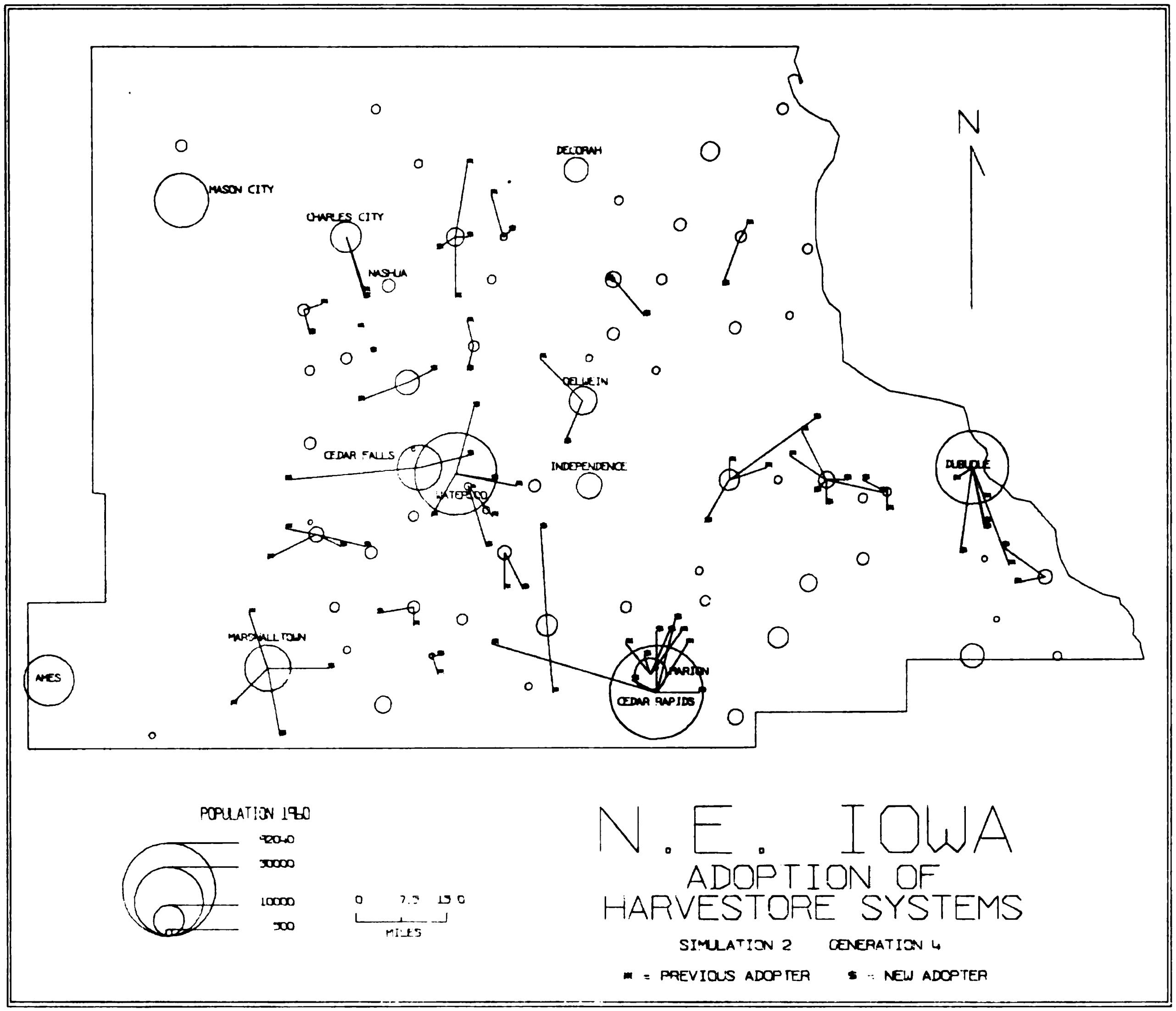
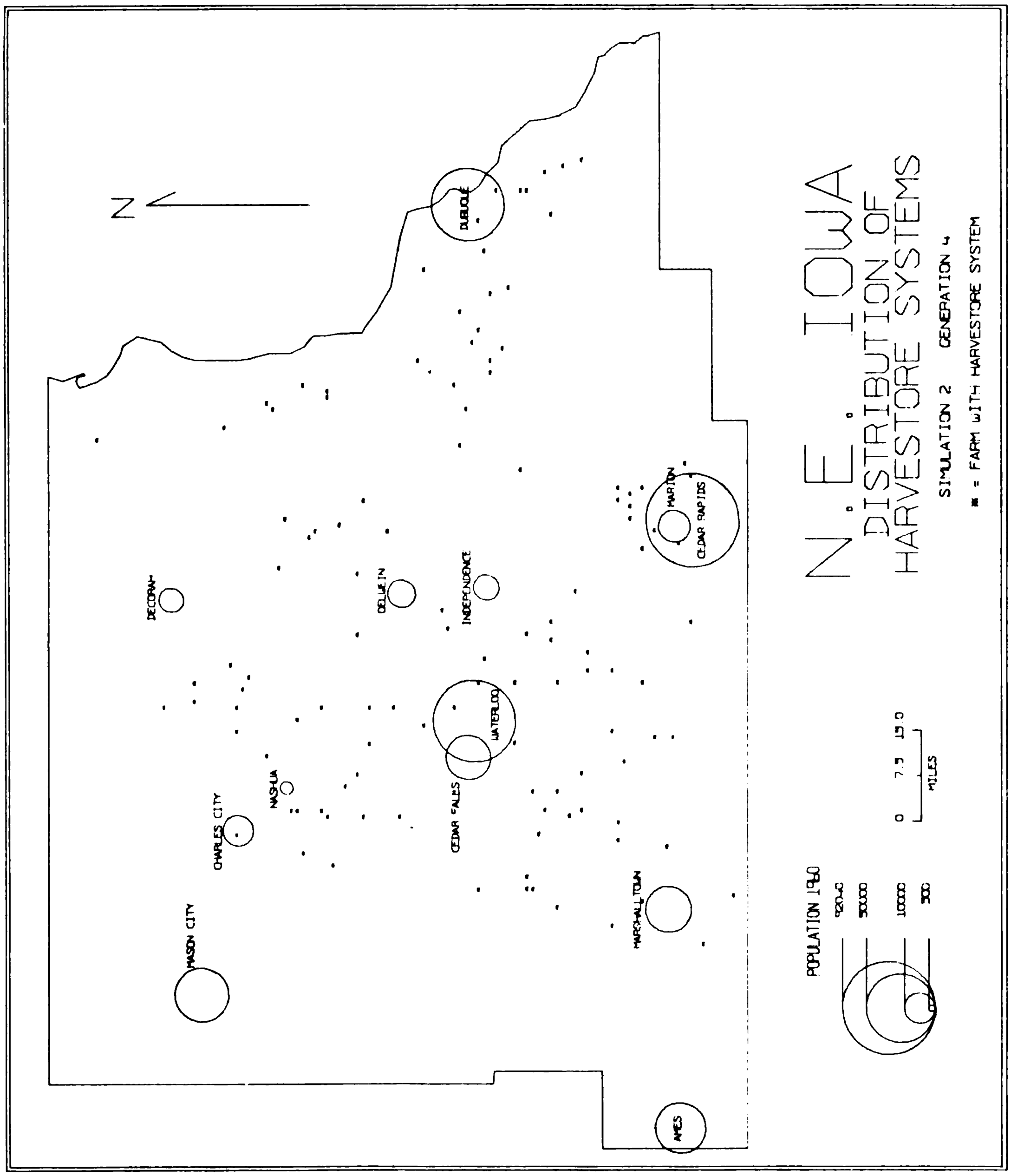
MASON CITY
CHARLES CITY
NASHUA
OELWEIN
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
92040
50000
10000
500
0 7.5 15.0
MILES
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 3
■ = FARM WITH HARVESTORE SYSTEM

Map 45


N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 4
= PREVIOUS ADOPTER $ = NEW ADOPTER
POPULATION 1960
92040
30000
10000
500
0 7.5 15.0
MILES
N
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
CEDAR FALLS
WATERLOO
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS

Map 46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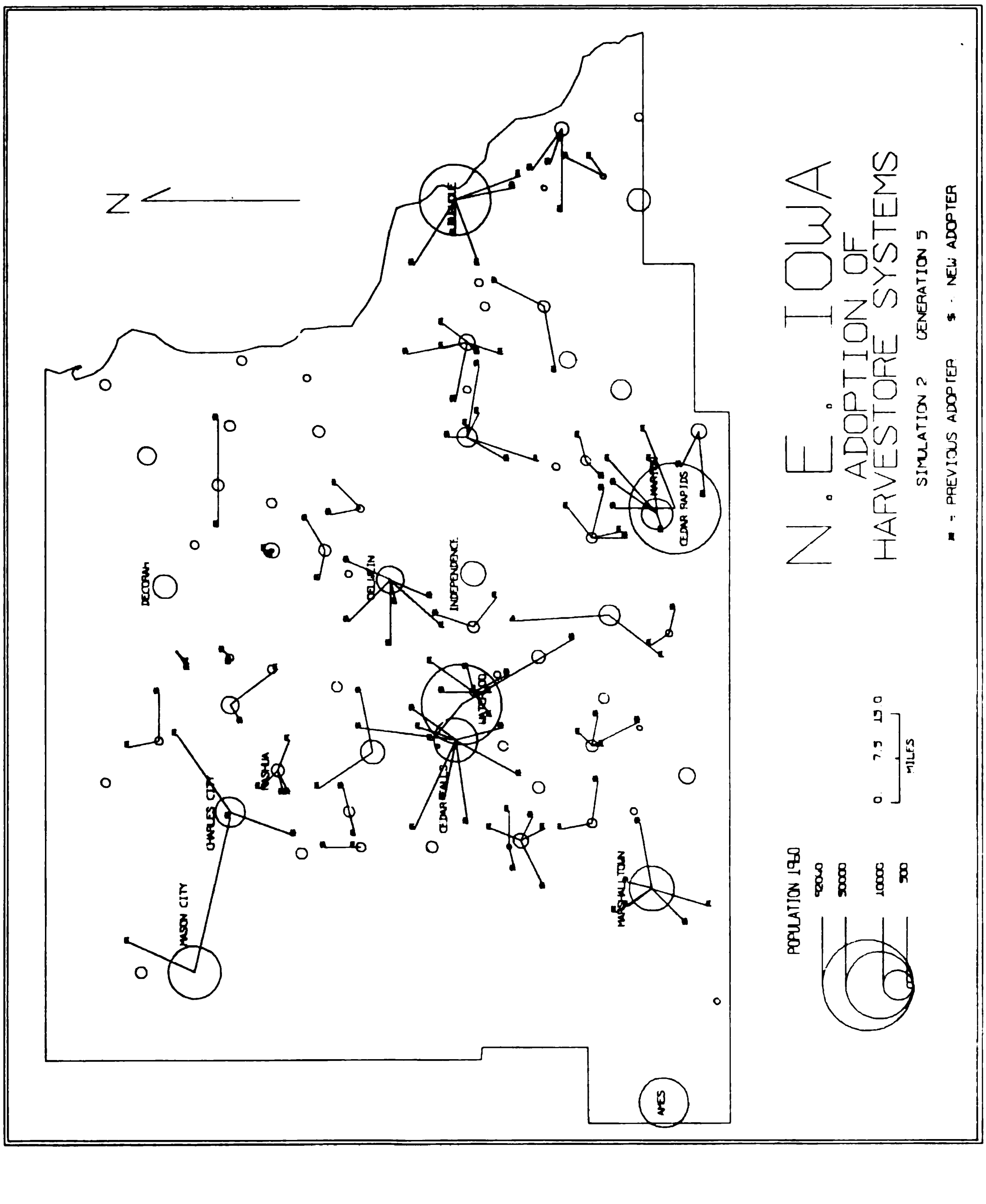
N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 4
= FARM WITH HARVESTORE SYSTEM
DUBUQUE
MARION
CEDAR RAPIDS
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
0 7.5 15.0
MILES
POPULATION 1960
50000
10000
500

Map 47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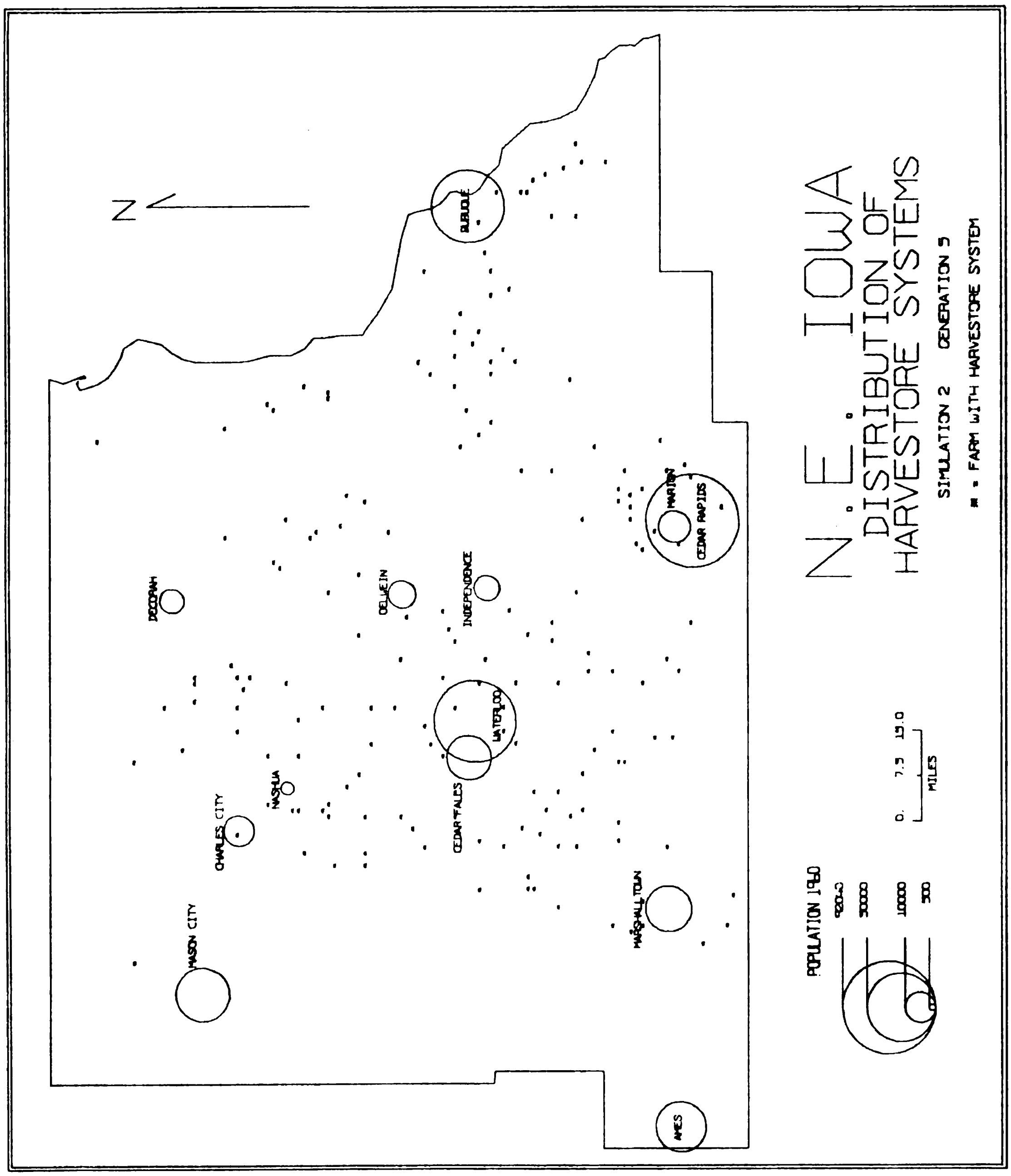
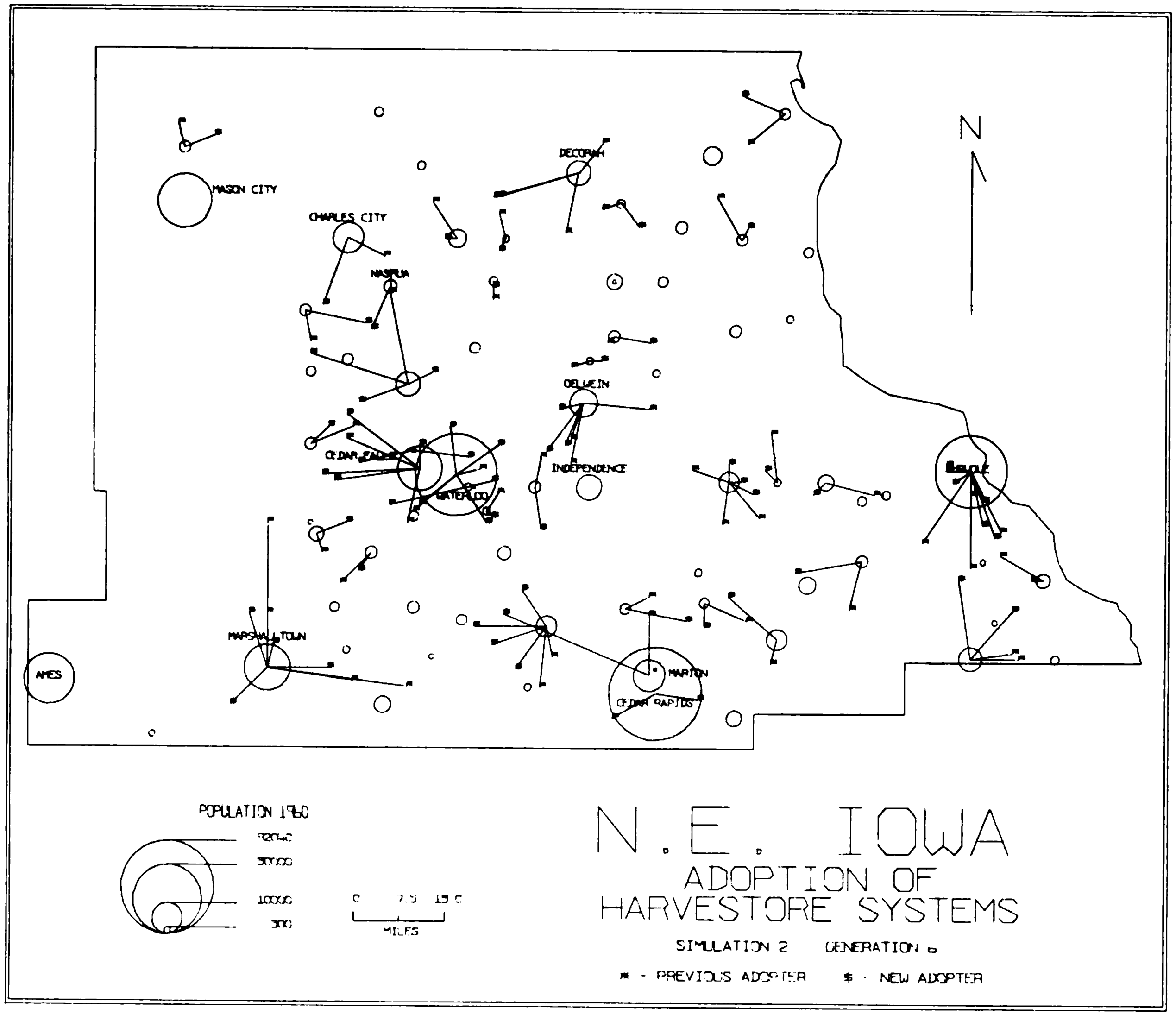
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 5
PREVIOUS ADOPTER
NEW ADOPTER
POPULATION 1960
92040
50000
10000
500
0 7.5 15.0
MILES
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
CEDAR RAPIDS
MARSHALLTOWN
AMES
DUBUQUE

Map 48


N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 5
■ = FARM WITH HARVESTORE SYSTEM
N
DUBUQUE
MARION
CEDAR RAPIDS
INDEPENDENCE
OELWEIN
DECORAH
WATERLOO
CEDAR FALLS
NASHUA
CHARLES CITY
MASON CITY
MARSHALLTOWN
AMES
0. 7.5 15.0
MILES
POPULATION 1960
50000
10000
500

Map 49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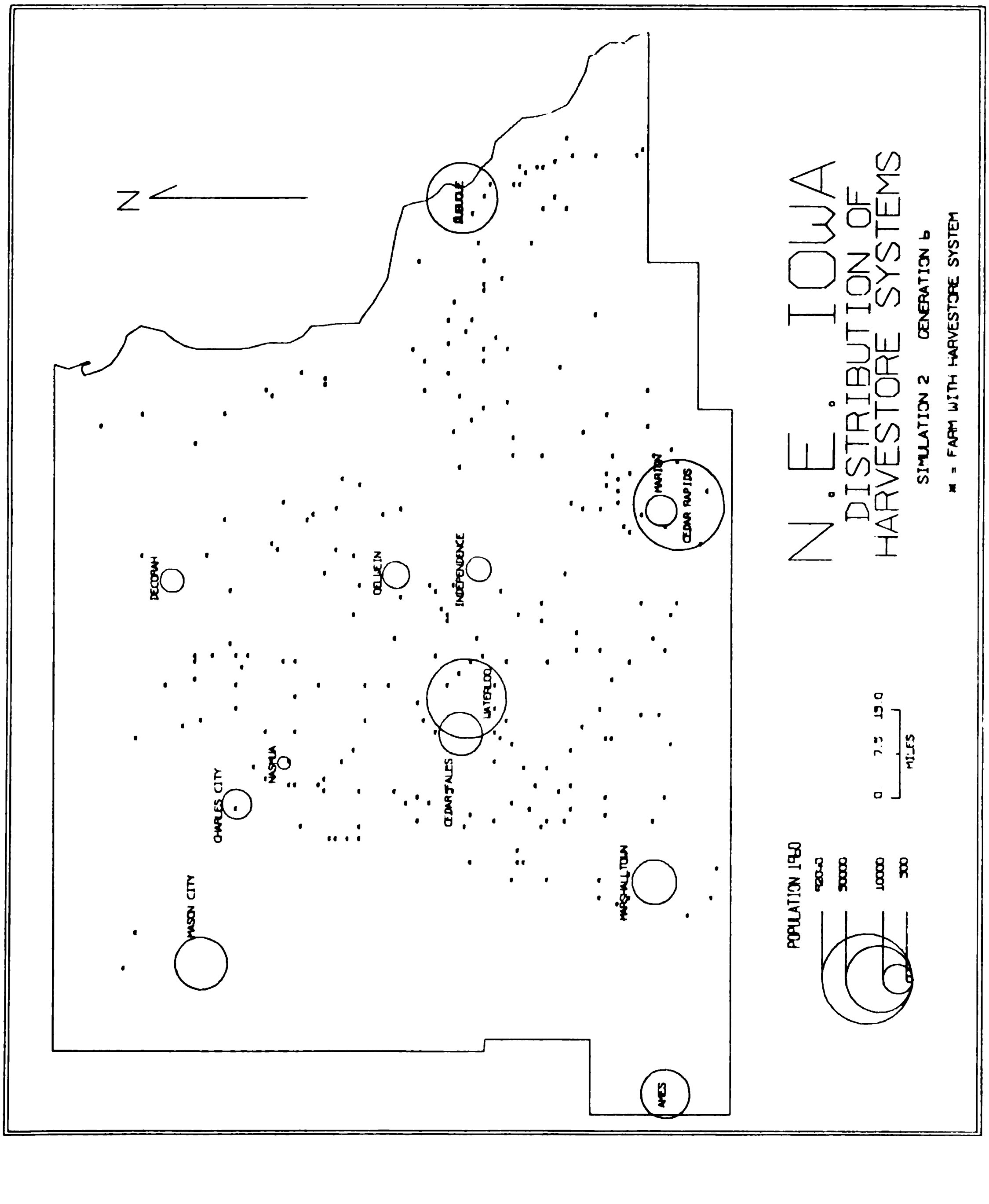
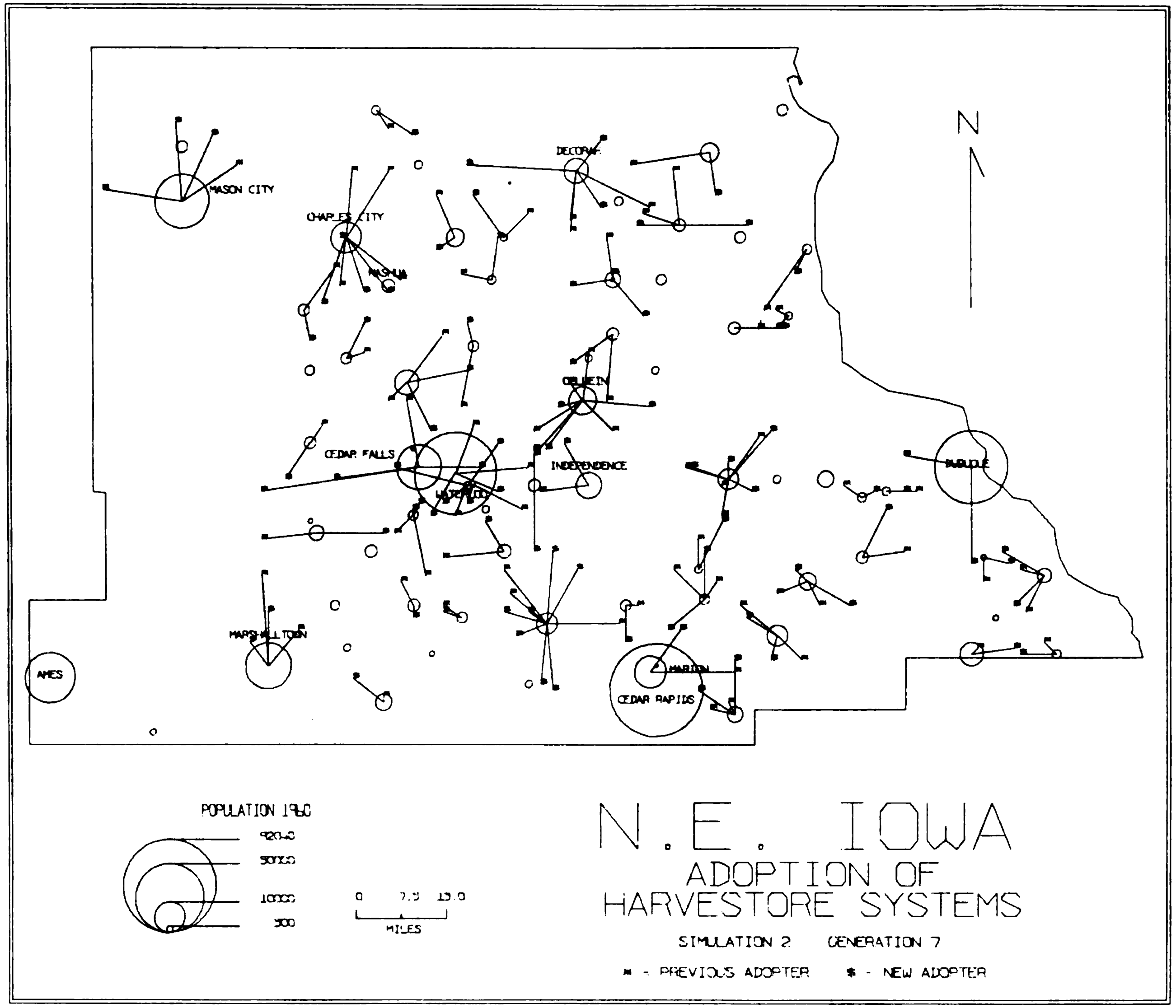
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
CEDAR FALLS
WATERLOO
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
10000
0 7.5 15.0
MILES
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 6
* - PREVIOUS ADOPTER $ - NEW ADOPTER

Map 50


N. E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2
* = FARM WITH HARVESTORE SYSTEM
POPULATION 1960
50000
10000
300
MILES
N
MASON CITY
CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
MARSHALLTOWN
MARION
CEDAR RAPIDS
DUBUQUE
AMES

Map 51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NASHUA
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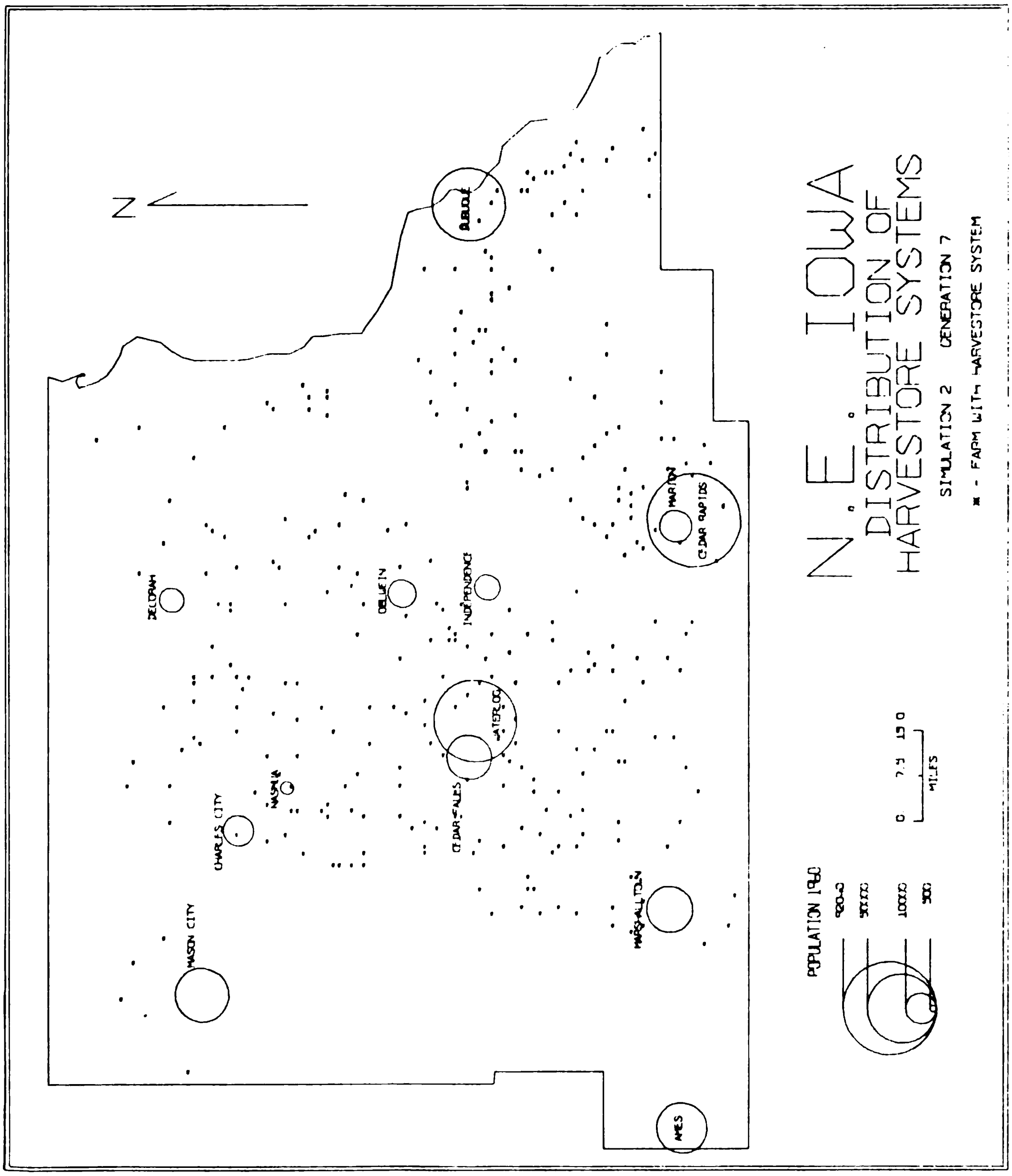
OELWEIN
CEDAR FALLS
WATERLOO
INDEPENDENCE
DUBUQUE
MARSHALLTOWN
AMES
MARION
CEDAR RAPIDS
POPULATION 1960
500
MILES
N.E. IOWA
ADOPTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 7
\# - PREVIOUS ADOPTER $ - NEW ADOPTER

Map 52


N.E. IOWA
DISTRIBUTION OF
HARVESTORE SYSTEMS
SIMULATION 2 GENERATION 7
* - FARM WITH HARVESTORE SYSTEM
POPULATION 1960
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CHARLES CITY
NASHUA
DECORAH
OELWEIN
INDEPENDENCE
WATERLOO
CEDAR FALLS
MARSHALLTOWN
AMES
DUBUQUE
MARION
CEDAR RAPIDS

Map 53

APPENDIX B

A CENTRAL PLACE HIERARCHY OF GOODS AND SERVICES

The similarity between any two locational types is the degree to which one locational type is chosen by individuals who can choose either one. Rather than measure an individual's choice as either accepting or rejecting an alternative central place, the proportion of the individual's household dollar expenditures is assumed to be a reliable measure of his preferences. Therefore, the degree of similarity between locational types can be computed from the sample of household expenditures.

The variety of goods and services offered at a central place varies and tends to be positively correlated with the population size of the central place. Low-order goods, such as grocery items, tend to be offered at all central places, while higher-order goods, such as musical instruments, tend to be offered only at larger central places. It is possible to identify a hierarchy of central places based on the number and variety of goods and services offered. If items being diffused through a central place landscape are influenced by the central place system, then it is reasonable to assume that information pertaining to an innovation circulates through certain levels of the hierarchy.

Certain types of consumer goods and services can be associated with each level of the central place hierarchy.

A low-order good can be found at all levels of the hierarchy, but higher order goods can be offered at only the relatively larger central places. For single purpose shopping trips, one would expect a consumer to patronize a slightly different set of central places when purchasing grocery items than when purchasing musical instruments. Musical instruments are not likely to be found in relatively small central places which offer only a few goods and services. However, a consumer may reside near enough a higher-order central place so that there are no intervening lower-order central places. Thus he will probably make both low-order and high-order purchases at the same central place.

The central place hierarchy is the result of common behavior of consumers with respect to goods and services. It is possible to identify levels of the central place hierarchy by clustering goods and services according to consumer expenditure behavior. To identify levels in Iowa it is first necessary to find an index value measuring similarity between commodities. This is done by considering that for each household in the Iowa sample, two commodities are similar if maximum commodity purchases are in the same central place. A symetrical matrix is constructed with a value of 1 entered if two commodities are similar, 0 is not similar, and left blank if one or both of the commodities were not purchased. By summing the values for all individuals in the sample and dividing by the total number of times the two commodities were declared similar or not similar, an index value can be obtained. By repeating the procedure for all possible pairs of commodities a 70 x 70 similarity matrix can be constructed. The similarity index varies from 0 to 1 for all possible pairs of commodities.[1] The commodities are clustered by levels corresponding to the central place hierarchy by factor analyzing the similarity matrix (see Table B-2).

The factors identify levels of the central place hierarchy, and the commodities can be interpreted as being offered at the level of the hierarchy associated with all higher levels. The group of commodities having their highest loadings on the same factor can be considered as having similar spatial attractiveness for consumers. Factor II represents the lowest level of the central place hierarchy. The goods and services which load highest on this factor are convenience items that are found at all levels of the hierarchy.

Factor I represents the third level of the hierarchy. The goods and services associated with this factor will also be offered at higher-order central places. Factor I and II are the most consistent factors with very few commodities tending to switch factors with different rotated solutions. These factors explain 41.94% of the variance in the similarity matrix.

---

[1]See Table B-1 for a list of the 70 household commodities.

TABLE B-1

70 HOUSEHOLD COMMODITIES

No.	Commodity	No.	Commodity
1	Food Store	36	Toys
2	Deliveries, bulk purchases, baked goods milk	37	Pets, pet care, licenses
3	Food, given as gift	38	Social organization dues
4	Food and beverages away from home	39	Gifts
5	Tobacco, non-food store	40	Running costs of car
6	Beer, non-food store	41	Public transport, school, work
7	Personal care items, non-food store	42	Newspaper
8	Clothing, male adults	43	Books, school supplies
9	Clothing, female adults	44	School expenses, tuition, board and room
10	Clothing, boys	45	Church
11	Clothing, girls	46	Other organizational gifts
12	Gifts and sewing needs	47	Other personal gifts
13	Major appliances	48	Household insurance
14	Minor appliances	49	House insurance
15	Furniture	50	Liability house insurance
16	Household textiles	51	Car insurance
17	Glassware, silver	52	Health and accident insurance
18	Combination other gifts	53	Payment of interest
19	Combination furniture and equipment	54	Payment of principal
20	Electricity	55	Banking costs
21	Telephone	56	Combination payment of interest and principal
22	Fuel	57	Personal property tax
23	Physician	58	Real estate tax
24	Dental	59	Car license
25	Eye care	60	Beauty and barber shop
26	Combination 23,24,25	61	Dry cleaning
27	Prescribed medicines	62	Shoe repair
28	Other medical supplies	63	Watch and jewelery
29	Medical supplies, e.g., wheel chair, crutches	64	Food locker
30	Combination 28 & 29	65	Water softener
31	Motives	66	Laundry and laundromat
32	Other paid admissions	67	TV and appliance repair
33	Musical instruments	68	Household tools
34	Sporting goods	69	Attorney fees
35	Hobby equipment	70	Dues connected with occupation

TABLE B-2

FACTOR ANALYSIS OF COMMODITY SIMILARITY MATRIX

VARIMAX ROTATION-FIVE FACTOR SOLUTION

Factor I	Factor II	Factor III	Factor IV	Factor V
8 +	1 +	20 +	6 +	42 +
9 +	4 +	(30)+	28 +	52 +
10 +	5 +		48 +	
11 +	7 +	41 -	49 +	3 -
12 +	21 +	44 -	50 +	13 -
15 +	22 +	53 -	51 +	14 -
16 +	26 +	54 -	56 +	27 -
17 +	32 +	55 -	69 +	29 -
18 +	38 +	70 -		33 -
23 +	40 +		2 -	
24 +	43 +			
25 +	45 +			
31 +	46 +			
34 +	60 +			
35 +	61 +			
36 +	64 +			
37 +	65 +			
39 +	66 +			
47 +	67 +			
57 +	68 +			
58 +				
59 +				
62 +				
63 +				
(19)-				
Proportion of Variance:				
.2233	.1961	.0824	.0848	.0783
Cumulative Proportion of Variance:				
.2233	.4194	.5018	.5865	.6648
Central Place Rank of Factors:				
3	1	5	2	4

Source: Calculated by the author.

It is now possible to select a set of commodities to use to construct a paired-comparison matrix of preferences between locational types. Unfortunately, since no empirical research has dealt with the problem of associating levels of the central place hierarchy with the type of innovation diffused, a rather arbitrary decision to select the 20 commodities associated with Factor II is made. Factor II commodities represent the lowest level in the central place hierarchy. Thus interaction can take place with all higher levels. Since this is a rural innovation, interaction with this level of the hierarchy can be expected.

APPENDIX C

COMPUTER PROGRAMS WITH NOTES ON PROGRAMS

Program TWOBY

Program ALTERN

Program SPACDIF

COMPUTER PROGRAMS WITH NOTES ON PROGRAMS

Program: TWOBY

Purpose: Computes 2 x 2 comparative time trial statistic for 148 potential adopters. Neighbor at time "t" is defined as first nearest neighbor for first iteration, to the first four nearest neighbors for the fourth iteration. Calculates statistic for years 1946 through 1956.

Restrictions: Program is not generalized, but applies to the Collins, Iowa, 2,4D diffusion data specifically. With minor changes the program can be generalized to analyze other data sets.

Data: Diffusion data with coordinate location of adopter and time of initial adoption. For Collins, Iowa, 2,4D diffusion data see Appendix D.

Program: ALTERN

Purpose: Computes probability of individuals interacting with five ranking locational type towns defined by space preferences.

Restrictions: Maximum number of towns = 750, locational types - 48, central place size categories - 15.

Data: Central place data deck (See Appendix E), size and number of distance categories, size and maximum of population categories, space preference ranking of locational types, space preference probability matrix (See Appendix F), location corrdinates of each individual.

Program: SPACDIF

Purpose: Simulation of the spatial diffusion of an innovation through a central place system, where the probability of individual contact is determined by the location of the individual, characteristics of alternative central place to interact, and revealed space preferences.

Restrictions: Maximum number of towns = 632, adopters = 1030. The number of alternative central places to interact is five for each individual. This program consumes a great deal of computer time and core memory. Therefore, it has not been generalized to analyze different data sets. It is best to make adjustments in the program to correspond to the problem being simulated and the computing facilities available.

Data: Central place data deck, Individual data deck (Computed results of Program Altern).

```
      PROGRAM TWORY(INPUT,OUTPUT)
C      PROGRAM TWORY- TWO BY TWO COMPARATIVE TIME TRIAL FOR
C      148 POTENTIAL ADOPTERS OF 2,4D WEED SPRAY IN THE
C      COLLINS, IOWA MARKET AREA.
      DIMENSION DATA(148,15), DIST(148)
      TYPE REAL N
      N=148.
      A=0.$B=0.$C=0.$D=0.
      DO 3 I=1,148
      DO 1 K=5,14,3
      KK=K+1
      DATA(I,K )=10.
1     DATA(I,KK)=0.
      READ 2, (DATA(I,J),J=1,3)
2     FORMAT (20X,F5.0,2F15.5)
      IF(DATA(I,1).LE.1944) DATA(I,1)=1956
3     CONTINUE
      DO 7 I=1,148
      DO 4 J=1,148
      DIST(J)=SQRT(ABS(DATA(I,2)-DATA(J,2))+ABS(DATA(I,3)-DATA(J,3)))
      IF(I.EQ.J) DIST(J)=10.
4     CONTINUE
      DO 7 M=5,14,3
      MM=M-1
      DO 6 J=1,148
      IF(DIST(J).LT.DATA(I,M)) 5,6
5     DATA(I,M)=DIST(J)
      DATA(I,MM)=J
6     CONTINUE
      DIST(DATA(I,MM))=10.
7     CONTINUE
      DO 16 I=1946,1955
      DO 26 K=1,148
      DO 27 KK=4,13,3
      KKK=KK+2
      IF(I.GT.DATA(DATA(K,KK),1)) DATA(K,KKK)=1.
27    CONTINUE
      PRINT 25, K, (DATA(K,J),J=1,15)
25    FORMAT (I5,X,15F8.3)
26    CONTINUE
      DO 16 JJ=6,15,3
      DO 14 J=1,148
      IF(DATA(J,1)-I) 14,8,11
8     DO 9 M=6,JJ,3
      IF(DATA(J,M).EQ.1) 10,9
9     CONTINUE
      D=D+1
      GO TO 14
```

```
10      C=C+1
        GO TO 14
11      DO 12 M=6,JJ,3
        IF(DATA(J,M).EQ.1) 13,12
12      CONTINUE
        B=B+1
        GO TO 14
3       A=A+1
14      CONTINUE
        T=C+A
        V=D+B
        S=C+D
        R=A+B
        N=S+R
        U=((C*B-D*A)/N)/(SQRT((T*V*S*R)/((N**2)*(N-1))))
         JK=(JJ/3)-1
        PRINT 15,I,JK,C,A,T,D,B,V,S,R,N,U
15      FORMAT(///20X,2I5//3(10X,3F8.0/),10X,F15.5)
        A=0.$B=0.$C=0.$D=0.
16      CONTINUE
        END
```

```
      PROGRAM ALTERN (INPUT=300,OUTPUT=300,TAPE60=INPUT,TAPE16=300,
     X TAPE17=300,TAPE18=300)
          PROGRAM ALTERN - GIVEN DISTANCE CATEGORIES AND POPULATION
          CATEGORIES LOCATIONAL TYPES ARE DEFINED, ALSO GIVEN THE RANK
          OF LOCATIONAL TYPES AND THE PROBABILITY OF ONE TYPE BEING CHOSEN
          OVER ANOTHER, THEN FROM THE LOCATION OF INDIVIDUALS AND NEARBY
          TOWNS THE PROBABILITY OF THAT INDIVIDUAL INTERACTING WITH THE
          FIVE RANKING LOCATIONAL TYPE TOWNS IS CALCULATED USING LUCE≠S
          CHOICE AXIOM.
      DIMENSION  ITOWN(750,4),ILIMITS(15),FMT(7)
      COMMON ISTORE(750,2), IRANK(48), XIND(2), AM(48,48)
      REWIND 16
      REWIND 17
     READ TOWN DECK
      READ 1,K,FMT
1     FORMAT (I5,7A10)
      NTOWN=1
2     READ(K,FMT) (ITOWN(NTOWN,J),J=1,4)
      IF(EOF(K)) 4,3
3     NTOWN=NTOWN+1
      GO TO 2
4     NTOWN=NTOWN-1
     READ DISTANCE DATA
      READ 5, ISIZE,LIMIT
5     FORMAT (2I5)
     READ POPULATION LIMITS
      READ 6, NISIZE,(ILIMITS(J),J=1,NISIZE)
6     FORMAT (10I8)
     READ LOCATIONAL TYPE RANKINGS
      READ 7,K,L,FMT
7     FORMAT (2I5,7A10)
      READ(K,FMT) (IRANK(J),J=1,L)
      PRINT FMT, (IRANK(J),J=1,L)
     READ PROBABILITY MATRIX
      READ 1,K,FMT
      DO 8 I=1,L
9     READ(K,FMT) (AM(J,I),J=1,L)
      PRINT FMT, (AM(J,L),J=1,L)

     MAIN LOOP

     READ INDIVIDUAL DECK
      ID=0
      READ 1,K,FMT
9     READ(16,FMT) KZ, (XIND(I),I=1,2)
      IF(EOF(16)) 17,10
     CALCULATES DISTANCES
10    LO=0
      DO 16 I=1,NTOWN
      DIST=ABS(XIND(1)-ITOWN(I,2))+ABS(XIND(2)-ITOWN(I,3))
      IF(DIST-LIMIT) 11,11,16
     CALCULATES DISTANCE GROUP
11    DO 12 M=ISIZE,LIMIT,ISIZE
      IF(DIST-M) 13,13,12
```

```
12     CONTINUE
13     IDISG=M/ISIZE
     CALCULATE POPULATION GROUP
       DO 14 M=1,NISIZE
       IF(ITOWN(1,4)-ILIMITS(M)) 15,15,14
14     CONTINUE
15     ITOWNG=M
     CALCULATE LOCATIONAL TYPE
       LOCTYPE=IDISG+((ITOWNG-1)*8)
       LO=LO+1
     STORE LOCATIONAL TYPES WITH TOWN ID.
       ISTORE(LO,1)=ITOWN(1,1)
       ISTORE(LO,2)=LOCTYPE
16     CONTINUE
       IF(LO.EQ.0) GO TO 9
       ID=ID+1
     CALL SUBROUTINE WHICH CALCULATES PROBABILITY OF INDIVIDUALS
     INTERACTION WITH RANKING TOWN ALTERNATIVES
       CALL PROB (L,LO,ID)
       GO TO 9
17     CONTINUE
       REWIND 18
       REWIND 17
       END
```

```
       SUBROUTINE PROB(L,LO,ID)
       DIMENSION JR(10),JT(10),A(10),B(10),C(10)
       COMMON ISTORE(750,2), IRANK(48), XIND(2), AM(48,48)
       DO 1 K=1,7
1      C(K)=0.
     DETERMINE NUMBER OF TIMES SAME RANKING ALTERNATIVE AVAILABLE AND
     5 HIGH RANKING ALTERNATIVE LOCATIONAL TYPES
       N=0
       DO 3 K=1,L
       DO 3 J=1,LO
       IF(ISTORE(J,2).EQ.IRANK(K)) 2,3
2      N=N+1
       JR(N)=ISTORE(J,2)
       JT(N)=ISTORE(J,1)
       IF(N.EQ.5) GO TO 4
3      CONTINUE
4      CONTINUE
     DETERMINE PROBABILITIES AND PUNCH
       NN=0
       DO 9 I=1,N
       A(I)=1
       A(6)=1
       DO 6 K=1,N
       IF(I.EQ.K) GO TO 5
```

```
      A(K)=AM(JR(1),JR(K))
5     CONTINUE
      IF(A(K).EQ. 0 .OR. A(K).EQ.1) GO TO 6
      A(K)=(1-A(K))/A(K)
      A(6)=A(6)+A(K)
6     CONTINUE
      DO 7 K=1,N
      B(K)=A(K)/A(6)
7     C(K)=C(K)+B(K)
8     FORMAT (I5,2F5.0,(5(I5,F6.3)))
      NN=NN+1
9     CONTINUE
      DO 10 K=1,N
      C(K)=C(K)/NN
10    C(7)=C(7)+C(K)
      DO 11 K=1,N
11    C(K)=C(K)/C(7)
      WRITE(17,8) I0,XIND(1),XIND(2),(JT(K),C(K),K=1,N)
      END
```

```
      PROGRAM SPACDIF(INPUT=130,OUTPUT=130,TAPE18=130,TAPE19=130,
     X TAPE20=513,TAPE21=130)
      COMMON ITOWN(632,35),IA(1030),IX(1030),IADOPT(1030),IDT(5),PER(5)
         PROGRAM SPACDIF - SPATIAL DIFFUSION OF AN INNOVATION THROUGH A
         CENTRAL PLACE SYSTEM.  GIVEN ID#S FOR ALL CENTRAL PLACES IN THE
         STUDY AREA, INDIVIDUAL DATA ON PROBABILITY OF AN INDIVIDUAL
         INTERACTING WITH EACH OF FIVE CENTRAL PLACES, THE PROGRAM
         SIMULATES THE DIFFUSION PATTERN.
                ITOWN(KT,1)=TOWN ID
                ITOWN(KT,3)=NUMBER OF INDIVIDUALS THAT INTERACT WITH THAT
                 DURING SPECIFIC GENERATION OF SIMULATION
                REMAINDER OF ITOWN ARRAY=ID#S OF INDIVIDUALS WHO INTERACT
                 WITH THAT TOWN DURING SPECIFIC GENERATION OF SIMULATION
      REWIND 18
      REWIND 19
      REWIND 21
      DO 1 I=18,21
    1 REWIND I
         READ TOWN DATA DECK, KT=NUMBER OF TOWNS IN SIMULATION
      KT=1
    2 READ(18,3) ITOWN(KT,1)
    3 FORMAT (4I5)
      IF(EOF(18)) 5,4
    4 KT=KT+1
      GO TO 2
    5 KT=KT-1
      PRINT 3, KT
      REWIND 18
         READ INDIVIDUAL DATA DECK, IOBS=NUMBER OF INDIVIDUALS
         TOWN ID NUMBERS ARE RENUMBERED DURING ANALYSIS
      IOBS=1
      READ(19,7) ID,IA(IOBS),IX(IOBS),IZ,(IDT(J),PER(J),J=1,5)
    7 FORMAT (2I4,I4,X,I4,X,(5(I5,F6.3)))
      IF(EOF(19)) 12,8
    8 IX(IOBS)=(1000*IX(IOBS))+IZ
      DO 10 J=1,5
      DO 9 I=1,KT
      IF(IDT(J).EQ.ITOWN(I,1)) 10,9
    9 CONTINUE
      PRINT 3,IDT(J),IOBS
      STOP
   10 IDT(J)=I
         WRITE ADOPTERS AND INDIVIDUAL DATA ON DISC
      IF(IA(IOBS).EQ.1) WRITE(21,11) ID, IX(IOBS)
   11 FORMAT (I5,I9)
      WRITE (20) ID,(IDT(J),PER(J),J=1,5)
      IOBS=IOBS+1
      GO TO 6
   12 IOBS=IOBS-1
      IOBS=500
      PRINT 3, IOBS
      REWIND 19
      REWIND 20
        INITIATE RANDOM NUMBER GENERATOR
```

```
      START=TIME(STT)
      CALL RANSET(START)
          READ CONTROL CARD FOR PROGRAM
                ISIM=NUMBER OF SIMULATIONS IN RUN
                IGEN=NUMBER OF GENERATIONS PER SIMULATION
      READ 11, ISIM, IGEN
          MAIN LOOP - NUMBER OF SIMULATIONS IN RUN
      DO 27 JSIM=1,ISIM
      WRITE (21,13) JSIM
13    FORMAT (* BEGINING OF SIMULATION NUMBER*,I3)
          SET INITIAL SET OF ADOPTERS FOR EACH SIMULATION
      IOBS=500
      DO 14 K=1,IOBS
14    IADOPT(K)=IA(K)
          LOOP - NUMBER OF GENERATIONS PER SIMULATION
      DO 26 JGEN=1,IGEN
      WRITE(21,15) JGEN,JSIM
15    FORMAT (* ADOPTERS DURING GENERATION NUMBER*,I3,* OF SIMULATION*,
     X I3)
          SET NUMBER OF INDIVIDUALS ASSIGNED TO INTERACT WITH EACH TOWN
          TO ZERO
      DO 16 I=1,NT
16    ITOWN(I,3)=0
          ASSIGN INDIVIDUALS TO TOWNS AND STORE INFORMATION AS TO WHETHER
          THE INDIVIDUAL IS AN ADOPTER OR NON-ADOPTER
      DO 19 K=1,IOBS
      READ (20) ID,(IDT(J),PER(J),J=1,5)
      RAN=RANF(-1)*(-1)
      FPER=0.
      DO 17 J=1,5
      FPER=FPER+PER(J)
      IF(RAN.LT.FPER) GO TO 18
17    CONTINUE
18    MX=IDT(J)
      IF(MX.GT.750) PRINT 3,MX,IDT(J)
      IF(MX.GT.750) GO TO 19
      ITOWN(MX,3)=ITOWN(MX,3)+1
      M=ITOWN(MX,3)+3
      ITOWN(MX,M)=ID
      IF(IADOPT(K).EQ.1) ITOWN(IDT(J),M)=ITOWN(MX     ,M)+10000
19    CONTINUE
      REWIND 20
          DETERMINE PAIRWISE TELLINGS AMONG INDIVIDUALS ASSIGNED TO
          EACH TOWN
      DO 25 I=1,NT
      IF(ITOWN(I,3).LE.1) GO TO 25
      MAX=ITOWN(I,3)
      DO 24 M=1,MAX
      MM=M+3
      IF(ITOWN(I,MM).GT.10000) 20,24
          MM IS TELLER AT TOWN=ITOWN(I,1)
20    IRAN=(RANF(-1)*(1-MAX))+1.5
      IF(IRAN.EQ. M) GO TO 20
      DO 21 N=1,MAX
```

```
      IF(IRAN.EQ.N) GO TO 22
21    CONTINUE
      PRINT 3, IRAN, MAX
      STOP
22    NN=N+3
         NN IS RECEIVER AT TOWN=ITOWN(1,1)
      IF(ITOWN(1,NN).GT.10000) GO TO 24
      IF(IADOPT(ITOWN(1,NN)).EQ.1) GO TO 24
         NN IS ADOPTER DURING THIS GENERATION
      IADOPT(ITOWN(1,NN))=1
      IS=ITOWN(1,NN)
      IF(IS.GT.10000) IS=IS-10000
      IT=ITOWN(1,MM)
      IF(IT.GT.10000) IT=IT-10000
      WRITE(21,23) ITOWN(1,NN),IX(IS),ITOWN(1,1),ITOWN(1,MM),IX(IT),
     X ITOWN(1,1),JSIM,JGEN
23    FORMAT (I5,I9,X,1H1,2I5,I9,X,1H1,3I5)
      IOSS=IOSS+1
24    CONTINUE
25    CONTINUE
      PRINT 3, IOSS
      PRINT 500, (ITOWN(JKT,3),JKT=1,KT)
500   FORMAT (40I3)
26    CONTINUE
27    CONTINUE
      REWIND 21
      END
```

APPENDIX D

DIFFUSION DATA

2,4D Weed Spray in Collins, Iowa

Harvestore Systems in Northeast Iowa

[illegible]. IOWA 2,4D WEED-SPRAY DIFFUSION DATA

SEE GEORGE M. BEAL AND EVERETT M. ROGERS.
*THE ADOPTION OF TWO FARM PRACTICES
IN A CENTRAL IOWA COMMUNITY*

VARIABLE
1. IDENTIFICATION NUMBER OF INDIVIDUAL
2. YEAR USE OF 2,4D WEED SPRAY WAS
2 ADOPTED. IF YEAR EQUALS -0 ADOPTION
HAS NOT YET TAKEN PLACE.
3. EAST-WEST COORDINATE LOCATION FROM
BASE POINT LOCATED OUTSIDE THE STATE
OF IOWA.
4. NORTH-SOUTH COORDINATE LOCATION.

16	1945	183.30401	132.42326
25	1945	181.79961	133.03715
26	1945	181.42131	132.41153
71	1945	183.92473	130.90029
145	1945	180.76735	128.54350
15	1946	183.74939	132.81650
24	1946	181.42522	133.24438
41	1946	181.77126	131.76833
45	1946	181.54545	131.65885
52	1946	182.13195	130.40371
59	1946	181.59433	130.27859
115	1946	185.50831	129.98631
2	1947	183.60704	133.40762
29	1947	180.82405	133.24438
40	1947	181.80352	132.08211
44	1947	181.54448	131.91300
78	1947	183.12512	130.90225
85	1947	181.77517	131.16227
94	1947	180.49169	130.28348
105	1947	182.92962	129.75367
146	1947	179.93255	128.88074
147	1947	179.77615	128.48485
152	1947	180.33822	127.51320
154	1947	181.34018	128.31085
3	1948	181.79179	133.57967
12	1948	183.93939	132.89150
13	1948	183.10459	133.25709
23	1948	180.97361	133.23656
32	1948	179.97556	132.82014
35	1948	180.42522	132.26979
37	1948	180.32063	131.91105
38	1948	180.33040	131.77419
39	1948	180.95699	132.20821
52	1948	183.78738	132.04497

53	1948	185.79863	131.49462
72	1948	184.52884	130.90420
142	1948	180.09873	129.32942
143	1948	180.76735	128.87879
165	1948	182.62463	128.02248
167	1948	183.78016	128.09775
171	1948	183.92473	128.35484
575	1948	185.32454	127.46530
8	1949	183.06138	133.39980
89	1949	179.95691	131.21114
615	1949	185.59581	129.77028
128	1949	183.76833	129.32258
131	1949	183.16716	128.45357
140	1949	180.92130	128.63343
150	1949	180.77517	128.11144
177	1949	185.18866	128.38905
179	1949	183.02542	127.32649
28	1950	180.27957	133.24731
34	1950	179.81818	131.77224
36	1950	180.81427	131.76344
42	1950	180.44503	131.77126
65	1950	185.96481	130.75269
88	1950	181.23167	130.91007
90	1950	180.79668	130.86804
597	1950	179.95405	129.81036
99	1950	181.28641	130.28055
101	1950	180.95992	129.86217
108	1950	184.77126	129.75269
114	1950	185.40274	130.09286
123	1950	184.58651	129.23949
124	1950	184.77610	128.76637
132	1950	182.93548	128.94428
134	1950	182.78104	128.54057
634	1950	181.92180	129.30303
137	1950	181.33236	129.31574
153	1950	179.03255	127.49756
164	1950	181.91496	128.05670
175	1950	185.81036	127.82209
180	1950	182.77517	127.31574
181	1950	181.43205	127.32160
182	1950	180.57253	127.31769
18	1951	182.21017	133.23754
20	1951	182.78104	132.61681
33	1951	179.81916	131.92669
35	1951	180.55034	132.26588
51	1951	183.01760	132.27077
54	1951	184.78495	132.27664
58	1951	183.93548	131.89638
76	1951	183.31085	130.39883
95	1951	180.79668	130.12219

98	1951	181.01173	130.29717
104	1951	183.77322	129.92766
120	1951	185.48680	129.08504
127	1951	184.26100	129.05279
156	1951	181.75269	128.04888
162	1951	182.64027	127.47996
10	1952	184.55034	132.39394
17	1952	182.94423	132.92473
30	1952	180.81134	132.41838
48	1952	182.78096	131.50831
57	1952	183.92766	131.41642
75	1952	183.78066	130.53079
85	1952	180.94819	131.24340
92	1952	179.94819	130.50733
111	1952	183.93255	129.85533
116	1952	185.94135	129.56989
117	1952	185.91691	129.09775
133	1952	182.76637	129.15934
157	1952	181.73998	127.50244
161	1952	182.79668	127.88368
173	1952	184.53959	127.47214
53	1953	183.77224	131.55034
60	1953	184.99925	132.27761
83	1953	182.12708	130.89932
96	1953	180.41447	129.47801
97	1953	180.14370	129.53177
603	1953	182.32845	130.12805
673	1953	183.93548	127.60215
4	1954	182.22092	133.41740
9	1954	184.43891	133.25024
50	1954	181.94917	131.92962
31	1954	180.32160	132.41447
129	1954	183.76637	128.46237
138	1954	181.75171	129.02542
178	1954	185.94819	127.77615
14	1955	183.68524	133.25806
59	1955	185.04838	132.38710
70	1955	184.14370	130.40274
112	1955	183.92375	130.06647
122	1955	184.97752	129.23949
159	1955	180.90323	127.47801
169	1955	183.52688	127.49853
669	1955	183.79081	126.96188
1	-0	180.45650	133.41056
7	-0	183.78690	133.68719
518	-0	181.96481	133.25318
524	-0	181.60117	133.26686
47	-0	182.73216	131.88270
49	-0	181.99218	131.72923
61	-0	185.80645	131.95503
62	-0	185.79081	131.68524
77	-0	182.92473	130.52395

616	-0	185.77419	129.56598
126	-0	184.00293	128.47898
136	-0	181.96188	128.47801
148	-0	179.49550	128.49560
151	-0	180.76246	127.61681
155	-0	181.76442	128.26100
153	-0	181.36364	127.47605
163	-0	181.89345	127.89736
663	-0	183.78201	127.76442
170	-0	182.42571	127.90811
675	-0	185.79081	127.47996
679	-0	182.92962	127.46530

HARVESTORE DIFFUSION DATA-

COORDINATE LOCATION OF ADOPTERS OF HARVESTORE SYSTEMS IN N.E. IOWA FROM 1949 THROUGH 1967.

VARIABLES

1. INDIVIDUAL IDENTIFICATION NUMBER
2. COUNTY CODE
3. EAST-WEST COORDINATE OF INDIVIDUAL ADOPTING HARVESTORE SYSTEM IN MILES FROM A ZERO BASE POINT LOCATED OUTSIDE THE STATE OF IOWA.
4. NORTH-SOUTH COORDINATE LOCATION OF ADOPTER.
5. NUMBER OF HARVESTORE SYSTEMS ADOPTED BY THE INDIVIDUAL.
6. YEAR EACH HARVESTORE SYSTEM WAS ADOPTED.

174	BLAC	238.181	166.055	1	49		
57	CLAY	287.433	200.677	2	50	50	
169	BENT	253.871	156.260	1	50		
278	DUBU	298.929	175.197	1	50		
387	TAMA	214.975	148.984	1	50		
388	TAMA	212.031	149.173	2	50	53	
389	TAMA	222.937	155.402	2	50	51	
2	ALLA	273.134	234.976	1	51		
14	BREM	234.362	186.417	1	51		
17	BREM	222.787	141.929	2	51	51	
20	BREM	221.293	194.362	1	51		
54	CLAY	283.890	206.606	1	51		
55	CLAY	283.283	206.126	1	51		
56	CLAY	268.331	191.496	1	51		
59	CLAY	273.449	210.780	1	51		
177	BLAC	237.654	159.134	2	51	52	
257	DUBU	309.890	170.787	2	51	51	
291	GRUN	213.236	162.008	2	51	52	
299	GRUN	219.630	159.331	2	51	51	
344	LINN	274.134	137.874	1	51		
392	TAMA	226.362	207.472	1	51		
58	CLAY	281.961	206.795	1	52		
121	MITC	215.024	235.433	1	52		
152	BENT	244.181	151.819	2	52	54	
163	BENT	237.523	152.205	1	52		
164	BENT	257.047	140.236	2	52	53	
167	BENT	236.441	152.181	1	52		
172	BENT	235.299	151.235	1	52		
175	BLAC	236.173	151.047	1	52		
176	BLAC	243.693	153.142	2	52	65	
182	BLAC	243.157	162.031	1	52		
242	DELA	281.299	169.858	3	52	60	62
261	DUBU	300.283	161.055	1	52		
283	GRUN	215.874	158.740	1	52		
293	GRUN	214.000	159.087	2	52	52	
294	GRUN	207.299	150.362	2	52	52	
323	JACK	318.717	142.228	1	52		

329	JOHE	217.890	133.882	1	52				
361	MARS	193.543	140.063	2	52	62			
369	MARS	205.254	151.151	1	52				
378	STOR	175.921	140.417	1	52				
390	TAMA	221.767	150.150	3	52	52	66		
33	CHIC	242.593	205.024	1	53				
48	CHIC	233.755	204.260	1	53				
51	CLAY	236.567	199.953	1	53				
76	FLOY	294.685	217.228	2	53	63			
282	GRUD	212.293	169.614	1	53				
285	GRUD	201.142	166.055	1	53				
286	GRUD	202.732	158.118	1	53				
287	GRUD	200.055	155.165	1	53				
321	JACK	312.929	143.087	2	53	61			
331	JOHE	294.969	142.339	1	53				
366	MARS	203.386	138.449	2	53	53			
370	MARS	207.858	142.346	1	53				
373	STOR	159.772	148.228	1	53				
385	TAMA	232.102	145.827	1	53				
386	TAMA	227.150	146.150	5	53	56	61	61	63
391	TAMA	222.858	148.346	1	53				
12	BREM	234.591	191.992	1	54				
13	BREM	238.465	138.205	1	54				
15	BREM	221.843	190.323	1	54				
23	RUTL	209.173	190.465	1	54				
52	CLAY	258.465	213.717	2	54	62			
62	FAYE	266.535	183.433	1	54				
102	HOMA	243.354	225.992	1	54				
135	WILW	246.339	238.165	2	54	56			
186	BLAC	236.583	180.039	1	54				
191	BLAC	242.102	162.969	1	54				
211	RUCH	245.583	169.614	1	54				
270	DURU	308.898	162.551	2	54	56			
271	DURU	303.567	163.047	3	54	54	58		
288	GRUD	199.126	154.024	1	54				
309	JACK	335.134	144.457	4	54	56	58	62	
341	LIMB	263.220	151.701	1	54				
358	MARS	193.764	144.740	1	54				
368	MARS	189.646	132.520	2	54	58			
39	CHIC	238.622	215.646	1	55				
45	CHIC	220.969	220.504	1	55				
46	CHIC	241.764	205.063	1	55				
49	CHIC	235.795	208.441	1	55				
230	DELA	288.764	179.409	1	55				
264	DURU	301.654	160.976	1	55				
306	HARD	195.827	153.937	1	55				
311	JACK	317.087	150.583	2	55	59			
335	JOHE	291.898	157.717	1	55				
372	STOR	179.772	151.496	1	55				
389	TAMA	226.339	128.866	1	55				
383	TAMA	229.055	144.913	4	55	64	64	67	
384	TAMA	220.645	149.953	1	55				
17	BREM	240.740	191.323	1	56				
27	CERR	192.331	202.394	5	56	58	62	63	67

47	CHIC	233.633	204.898	2 56 57
154	KENT	257.223	138.094	1 56
207	BUCH	252.244	164.189	4 56 58 61 64
273	DURH	304.039	172.008	4 56 55 58 65
275	DURH	316.575	155.709	1 56
279	DURH	246.235	173.583	2 56 64
320	JACK	320.630	159.843	1 56
88	FRAN	174.063	102.937	2 57 61
156	KENT	241.313	147.953	1 57
185	BLAC	227.354	158.465	1 57
239	DELA	282.003	159.630	6 57 60 60 62 63 65
247	DURH	302.913	156.283	1 57
349	LTIN	270.559	143.858	1 57
363	ZAVA	292.646	145.031	2 57 59
98	FRAN	183.851	196.583	3 58 58 67
101	HORA	237.959	232.890	1 58
103	HORA	224.801	234.998	2 58 58
133	ETIO	255.717	240.220	3 58 61 67
147	GOAI	173.630	232.677	5 58 58 61 62 63
153	KENT	234.283	141.150	1 58
170	KENT	240.717	139.882	2 58 58
195	BUCH	267.113	161.559	1 58
213	BUCH	254.913	161.299	3 58 61 63
223	DELA	231.575	172.794	1 58
227	DELA	244.528	172.055	2 58 62
238	DELA	244.094	176.276	1 58
240	DELA	273.843	151.717	2 58 58
245	DURH	244.543	172.165	3 58 58 58
246	DURH	245.693	171.361	3 58 58 65
256	DURH	243.425	173.906	2 58 58
258	DURH	311.575	166.543	1 58
263	DURH	304.520	160.906	1 58
267	DURH	295.291	176.181	1 58
274	DURH	295.843	173.063	1 58
304	HAWO	174.772	170.953	2 58 61
312	JACK	337.685	144.417	1 58
315	JACK	329.165	149.142	3 58 61 61
317	JACK	334.843	146.189	1 58
325	JOHN	305.433	136.291	2 58 63
339	LTIN	270.457	141.102	1 58
345	LTIN	271.102	132.071	1 58
377	STOR	177.882	136.528	2 58 64
21	BUTL	198.315	136.063	1 59
26	CERR	174.551	214.071	1 59
29	CERR	173.929	212.504	1 59
75	FLOY	206.181	207.795	3 59 59 61
89	FRAN	185.803	196.504	3 59 59 66
166	KENT	241.126	131.260	2 59 59
190	BLAC	227.701	155.307	2 59 62
201	BUCH	255.929	164.291	1 59
204	BUCH	248.276	169.858	1 59
221	DELA	237.976	171.661	1 59
222	DELA	272.453	162.630	1 59
225	DELA	238.591	177.969	3 59 59 67

231	[illegible]	[illegible]	171.537	2	59	59			
233	DELA	[illegible]	175.543	1	59				
234	DELA	231.551	174.243	1	59				
235	DELA	257.035	176.976	1	59				
236	DELA	240.373	170.084	1	59				
237	DELA	274.755	173.402	2	59	59			
251	DUBR	293.053	173.134	1	59				
254	DUBR	243.042	178.283	1	59				
260	DUBR	293.165	177.268	1	59				
281	DUBR	318.575	155.764	2	59	59			
297	GORD	213.503	167.276	3	59	60	61		
298	GORD	211.992	168.937	1	59				
338	LTHL	276.323	147.362	1	59				
97	FRAN	175.205	196.370	2	60	60			
142	MTNP	255.067	220.630	1	60				
155	REST	254.866	131.575	1	60				
158	REST	233.643	146.961	1	60				
162	REST	245.446	131.830	1	60				
243	DELA	274.515	160.055	2	60	60			
265	DUBR	245.732	157.843	1	60				
267	DUBR	311.472	164.433	1	60				
286	DUBR	307.638	180.772	1	60				
330	[illegible]	283.567	157.717	5	60	61	61	62	66
375	STON	174.409	133.951	2	60	64			
1	ALLA	275.147	228.476	2	61	61			
5	ALLA	270.732	228.504	5	61	61	62	62	66
9	ALLA	275.893	228.819	3	61	62	62		
22	BUTL	200.244	196.937	2	61	62			
24	CFRW	192.228	205.740	1	61				
34	CFRW	178.961	201.748	3	61	61	62		
37	CFRW	143.008	223.094	4	61	61	61	63	
84	FRAN	185.827	135.417	1	61				
85	FRAN	185.756	147.150	1	61				
90	FRAN	178.142	198.772	1	61				
94	FRAN	174.013	186.449	2	61	63			
105	HOGG	236.558	234.315	1	61				
108	MTTC	207.787	231.276	1	61				
125	MTTC	207.750	231.913	3	61	62	62		
127	MTTC	208.173	226.732	2	61	63			
145	PORT	155.512	226.142	1	61				
146	PORT	172.651	228.291	2	61	61			
157	REST	244.323	141.110	2	61	61			
163	REST	240.761	147.142	1	61				
183	BLAC	234.865	152.606	1	61				
188	BLAC	230.567	156.370	1	61				
189	BLAC	223.472	158.283	4	61	62	62	62	
244	CELA	253.024	167.189	1	61				
248	DUBR	304.147	165.520	3	61	61	61		
259	DUBR	306.063	157.520	1	61				
262	DUBR	300.169	161.740	1	61				
268	DUBR	301.583	159.008	2	61	66			
272	DUBR	304.505	153.441	2	61	61			
300	HARD	146.852	156.643	1	61				
302	HARD	184.593	164.787	1	61				

305	HARD	155.764	157.496	1	61		
319	JACK	305.913	147.865	1	61		
319	JACK	317.457	156.959	1	61		
336	LIND	274.730	145.659	1	61		
342	LIN	277.741	143.087	1	61		
352	LIN	273.577	142.685	1	61		
353	LIN	277.622	133.890	1	61		
362	MARS	204.844	133.417	1	61		
371	MARS	140.591	135.685	1	61		
393	TAMA	212.855	129.461	1	61		
394	TAMA	231.449	147.252	1	61		
395	TAMA	228.205	156.559	1	61		
7	ALLA	267.969	224.378	1	62		
35	CERR	185.882	215.386	1	52		
83	FRAN	184.119	186.008	2	62	62	
104	HOWA	235.838	239.772	1	62		
123	MITC	203.047	230.717	3	62	62	67
124	MITC	207.839	228.638	2	62	65	
181	BLAC	222.125	169.110	2	62	62	
209	BUCH	255.228	164.953	2	62	62	
210	BUCH	249.427	169.087	3	62	62	67
228	DELA	282.000	175.362	1	62		
229	DELA	247.003	151.047	1	62		
296	GRUN	217.094	167.496	3	62	65	65
303	HARD	193.947	164.291	2	62	65	
307	HARD	175.189	173.646	1	62		
314	JACK	327.110	159.276	2	62	62	
324	JOHN	302.047	140.882	1	62		
334	JOSE	242.205	156.646	1	62		
337	LIN	274.795	138.709	1	62		
343	LIN	231.113	153.898	1	62		
347	LIN	261.850	134.472	3	62	62	63
348	LIN	259.913	145.317	1	62		
354	LIN	250.945	136.031	1	62		
360	MARS	142.803	141.661	1	62		
365	MARS	138.874	141.748	2	62	63	
61	FAYE	249.913	214.953	1	63		
126	MITC	208.732	227.914	2	63	65	
161	BENT	252.181	136.772	1	63		
212	BUCH	255.366	131.551	2	63	63	
241	DELA	234.480	150.339	3	63	64	64
301	HARD	174.748	160.258	2	63	63	
316	JACK	336.110	147.772	2	63	63	
327	JOSE	285.898	157.685	1	63		
332	JOSE	282.386	134.661	1	63		
346	LIN	271.345	130.283	2	63	63	
376	STON	165.764	132.630	1	63		
381	TAMA	224.386	157.457	3	63	63	64
18	BREA	235.772	186.803	1	64		
73	FLOY	201.283	211.480	1	64		
82	FRAN	187.102	186.635	1	64		
99	FRAN	190.465	195.638	1	64		
100	FRAN	187.433	186.953	1	64		
116	MITC	203.331	225.795	1	64		

165	HFAH	251.520	153.102	1	64			
174	BLAC	231.827	155.661	2	64	64		
180	BLAC	227.047	159.236	1	64			
184	BLAC	236.236	176.860	2	64	64		
212	RICH	267.700	173.157	1	64			
205	RICH	259.937	165.457	2	64	64		
208	RICH	255.664	164.975	2	64	65		
214	RICH	267.331	166.016	1	64			
224	DELA	278.235	173.191	2	64	64		
234	GOOD	213.557	163.575	1	64			
326	JONE	285.772	156.512	2	64	64		
355	LINC	273.913	157.213	1	64			
382	TAMA	210.910	145.551	1	64			
6	ALLA	261.235	216.126	1	65			
10	BREA	221.189	191.551	1	65			
31	CERR	145.764	232.732	4	65	65	67	67
78	FLOY	215.071	214.016	2	65	66		
79	FLOY	209.756	217.276	1	65			
92	FRAN	185.126	181.457	2	65	65		
93	FRAN	187.102	189.354	1	65			
107	MITC	212.370	237.126	1	65			
113	MITC	203.528	242.638	1	65			
118	MITC	213.915	235.764	1	65			
120	MITC	213.345	236.787	2	65	65		
129	STAN	256.465	216.268	2	65	66		
160	PENT	254.087	136.472	1	65			
178	BLAC	227.000	177.528	1	65			
193	BLAC	227.661	164.110	1	65			
195	RICH	254.882	153.354	1	65			
217	RICH	250.370	172.425	1	65			
220	RICH	255.827	151.865	2	65	65		
252	DURH	309.740	166.157	2	65	66		
289	GRUB	212.055	171.394	1	65			
322	JACK	322.835	144.402	1	65			
357	MARS	193.165	138.693	1	65			
4	ALLA	276.000	214.315	1	66			
8	ALLA	271.342	216.370	1	66			
16	BREA	220.142	195.047	1	66			
24	BUTL	213.969	178.118	1	66			
25	BUTL	204.087	181.220	1	66			
30	CERR	195.929	203.528	1	66			
32	CERR	193.583	205.079	1	66			
33	CERR	189.661	206.575	2	66	67		
40	CHIC	238.345	21[illegible]	1	66			
44	CHIC	225.740	20[illegible]	1	66			
50	CHIC	235.559	21[illegible]	1	66			
66	FAYE	251.055	[illegible]	1	66			
67	FAYE	255.772	204.835	1	66			
68	FAYE	265.394	200.701	1	66			
72	FAYE	247.165	208.189	2	66	66		
81	FRAN	188.780	180.276	1	66			
86	FRAN	184.890	181.756	1	66			
87	FRAN	187.645	193.000	3	66	67	67	
91	FRAN	190.598	182.598	1	66			

96	FRE?	192.047	190.638	3	66	66	67	
106	ITC	200.425	228.575	1	66			
111	MITC	205.891	241.819	1	66			
114	MITC	210.299	238.548	1	66			
115	MITC	193.068	231.803	1	66			
132	MTHO	245.386	214.465	1	66			
134	MTHO	266.150	221.268	1	66			
137	MTH	248.203	231.346	1	--			
143	MTHO	254.102	219.374	2	66	67		
144	NORT	184.449	239.229	3	66	66	67	
149	NORT	183.655	236.016	3	66	66	67	
159	RENT	245.441	133.110	1	66			
171	RENT	251.874	157.346	1	66			
187	RLAC	223.701	167.803	1	66			
194	RUCH	253.099	178.165	1	66			
198	RUCH	249.087	163.995	1	66			
203	RUCH	251.795	171.299	1	66			
206	RUCH	262.593	155.008	1	66			
209	RUCH	240.669	160.157	1	66			
213	RUCH	253.764	180.236	1	66			
215	RUCH	266.803	162.293	1	66			
226	DELA	237.937	163.417	1	66			
232	DELA	232.622	169.228	1	66			
249	DURU	309.630	174.228	1	66			
253	DURU	317.367	160.819	2	66	67		
255	DURU	299.126	172.315	1	66			
277	DURU	302.969	171.496	1	66			
292	GRUN	198.614	175.551	1	66			
313	JACK	306.947	159.971	1	66			
333	JOHE	285.378	138.583	1	66			
340	LING	269.134	145.165	1	66			
350	LING	258.147	143.268	1	66			
351	LING	278.890	155.528	1	66			
356	LING	279.683	155.071	1	66			
359	MARS	189.283	135.535	1	66			
364	MARS	202.173	130.677	1	66			
367	MARS	205.033	134.110	2	66	67		
374	STOR	181.055	141.724	1	66			
3	ALLA	245.331	226.228	1	67			
11	BREW	237.890	190.685	1	67			
36	CEDR	192.367	201.228	1	67			
41	CHIC	241.441	214.047	1	67			
42	CHIC	241.994	207.189	1	67			
43	CHIC	242.701	211.220	1	67			
53	CLAY	277.394	213.110	1	67			
60	FAYE	245.882	194.039	1	67			
63	FAYE	247.772	216.438	1	67			
64	FAYE	245.333	194.898	1	67			
65	FAYE	263.567	201.047	1	67			
69	FAYE	244.488	205.898	1	67			
70	FAYE	258.717	188.307	1	67			
71	FAYE	265.780	210.354	1	67			
74	FLOY	215.748	218.819	1	67			
77	FLOY	219.969	203.835	1	67			

80	FLOY	[illegible]	[illegible]	1	67
95	FRAN	[illegible]	[illegible]	1	67
109	MITC	[illegible]	[illegible]	1	67
110	MITC	[illegible]	[illegible]	1	67
112	MITC	[illegible]	[illegible]	1	67
117	MITC	[illegible]	[illegible]	1	67
119	MITC	[illegible]	[illegible]	1	67
122	MITC	207.283	[illegible]	1	67
128	MITC	213.449	[illegible]	1	67
130	WINN	252.984	[illegible]	1	67
131	WINN	245.299	[illegible]	1	67
136	WINN	254.743	[illegible]	1	67
138	WINN	260.559	214.617	1	67
139	WINN	252.449	231.165	1	67
140	WINN	255.173	[illegible]	1	67
141	WINN	255.701	[illegible]	1	67
148	WORT	190.339	247.155	1	67
150	WORT	191.220	[illegible]	1	67
151	WORT	174.654	[illegible]	1	67
173	BENT	234.291	[illegible]	2	67 67
192	BLAC	227.992	159.472	1	67
197	BUCH	266.000	170.344	1	67
199	BUCH	252.150	176.276	1	67
216	BUCH	264.772	170.772	1	67
218	BUCH	259.929	179.465	1	67
[illegible]	[illegible]	293.843	173.598	1	67
[illegible]	[illegible]	298.031	177.465	1	67
[illegible]	[illegible]	304.811	[illegible]	1	67
[illegible]	GRUD	210.457	170.559	1	67
295	[illegible]	203.016	[illegible]	1	67
308	[illegible]	197.882	[illegible]	1	67
[illegible]	[illegible]	311.495	[illegible]	1	67
[illegible]	JONE	294.213	[illegible]	1	67
[illegible]	[illegible]	171.764	167.315	1	67

APPENDIX E

CENTRAL PLACES IN N.E. IOWA

CENTRAL PLACES IN N.E. IOWA STUDY AREA

VARIABLE

1. NAME OF CENTRAL PLACE
2. CENTRAL PLACE IDENTIFICATION NUMBER
3. EAST-WEST COORDINATE LOCATION OF CENTRAL PLACE IN MILES FROM A ZERO BASE POINT LOCATED OUTSIDE THE STATE OF IOWA.
4. NORTH-SOUTH COORDINATE LOCATION OF CENTRAL PLACE
5. 1960 POPULATION OF CENTRAL PLACE

ACKLEY	2	196	176	1730
ALBION	16	198	145	590
ALDEN	18	178	174	840
ALEXANDER	19	177	194	290
ALLISON	25	208	190	950
ALPHA	26	245	208	110
ALTA VISTA	28	226	221	280
AMBER	33	291	148	120
AMES	35	165	139	27000
ANAMOSA	36	285	146	4620
ANDREW	39	321	149	350
APLINGTON	44	203	178	810
AREDALE	49	196	195	150
ARLINGTON	54	265	190	610
ASBURY	58	312	175	70
ATKINS	64	255	138	530
AURORA	72	262	181	220
AUSTINVILLE	73	199	178	130
BALDWIN	83	308	144	230
BALLTOWN	85	307	183	40
BANGOR	87	193	149	90
BANKSTOWN	88	302	174	40
BASSETT	93	222	212	130
BEAMAN	102	206	153	250
BELLE PLAINE	108	234	130	2920
BELLEVUE	109	329	156	2180
BERNARD	118	308	161	140
BERTRAM	119	273	134	170
BEVERLY	124	212	132	30
BLAIRSTOWN	131	245	131	580
BOLAN	142	191	233	30
BOYD	150	234	209	50
BRADFORD	154	185	162	200
BRANDON	156	248	160	320
BREMER	160	226	192	80
BRISTOW	164	202	191	220
BUCKEYE	175	178	168	190
BUCKINGHAM	177	220	156	90
BURCHINAL	180	185	214	80
BURDETTE	181	180	177	10
BURR OAK	184	254	239	200
CALMAR	194	256	227	950

CAMBRIDGE	198	170	130	590
CARPENTER	207	196	236	180
CARTERSVILLE	212	191	206	40
CASCADE	213	299	159	1600
CASTALIA	216	264	215	220
CASTLE HILL	220	228	173	930
CEDAR FALLS	223	226	174	21200
CEDAR RAPIDS	224	265	137	92040
CENTER GROVE	227	314	174	30
CENTER JCT	228	294	146	200
CENTER POINT	229	260	151	1240
CENTRAL CITY	231	273	152	1090
CENTRAL HEIG	232	185	216	90
CENTRALIA	233	308	172	80
CHAPIN	234	186	197	200
CHARLES CITY	236	214	212	9960
CHELSEA	241	228	132	450
CHESTER	243	229	241	210
CHICKASAW	245	220	209	50
CHURCH	247	281	232	30
CLARKSVILLE	257	214	192	1330
CLAYTON	258	292	202	130
CLAYTON CENT	259	293	202	50
CLEAR LAKE	262	178	216	6160
CLEMONS	264	189	145	200
CLERMONT	265	265	208	570
CLUTIER	273	228	143	290
COGGON	278	272	157	670
COLESBURG	280	289	183	350
COLLINS	283	182	130	440
COLO	284	182	138	570
COWELL	288	217	218	120
COMMUNIA	290	282	195	30
CONOVER	294	253	222	40
CONRAD	295	204	153	800
COULTER	315	178	188	320
COVINGTON	318	262	138	70
CRESCO	324	241	233	3810
DECORAH	353	252	223	6440
DEERCREEK	356	191	241	10
DELAWARE	358	282	172	170
DELHI	359	282	168	460
DENVER	367	231	185	830
DEVON	372	229	216	10
DE WAR	373	236	174	70
DIKE	379	216	170	630
DINSDALE	380	220	156	80
DONNAN	385	254	201	30
DORCHESTER	388	272	240	100
DOUGHERTY	390	196	202	400
DUBUQUE	396	317	174	56610
DUMONT	399	198	190	720
DUNBAR	400	209	134	80
DUNDEE	403	272	178	180

DUNKERTON	404	240	177	510
DURANGO	407	312	172	40
DYERSVILLE	410	293	172	2820
DYSART	411	233	149	1200
EAGLE CENTER	414	230	160	40
EARLVILLE	418	285	172	670
EDGEWOOD	424	279	183	770
ELBERON	427	233	138	210
ELDORA	429	192	163	3220
ELDORADO	430	257	211	100
ELGIN	433	266	205	1120
ELKADER	434	278	197	1530
ELKPORT	437	285	190	100
ELMA	442	226	224	710
ELON	443	278	227	230
EMELINE	447	307	151	20
EPWORTH	452	303	170	700
ELY	463	270	129	230
FAIRBANKS	465	245	182	650
FAIRFAX	466	259	132	530
FAIRVIEW	469	284	143	50
FARLEY	471	299	169	920
FARMERSBURG	473	280	205	250
FAULKNER	479	193	179	50
FAYETTE	480	258	196	1600
FERGUSON	482	204	133	190
FERN	483	208	171	40
FERNALD	484	177	144	100
FERTILE	485	176	225	390
FESTINA	486	255	216	150
FILLMORE	488	304	161	20
FLOYD	495	210	216	400
FORT ATKINSO	500	251	217	350
FRANKVILLE	507	267	221	100
FREDERICKSBU	509	236	205	800
FREDERICKA	510	233	199	250
FREEPORT	513	261	226	100
FROELICH	515	283	209	50
FULTON	518	317	150	100
GARBER	527	286	190	150
GARDEN CITY	528	177	155	100
GARNAVILLO	532	287	199	600
GARRISON	534	241	147	420
GARWIN	535	214	144	550
GENEVA	538	191	185	220
GILBERT	550	164	145	320
GILBERTVILLE	551	237	167	530
GILMAN	553	208	129	490
GLADBROOK	556	212	151	950
GORDONS FERR	567	327	166	40
GRAF	571	306	173	50
GRAFTON	572	194	230	270
GREELEY	584	282	179	370
GREENE	587	207	200	1430

GREEN ISLAND	589	335	150	100
GREEN MOUNTA	590	207	145	200
GRUNDY CENTE	596	209	163	2400
GUNDER	599	273	207	50
GUTTENBERG	602	295	192	2090
HALE	607	296	139	70
HAMPTON	612	182	189	4500
HANLONTOWN	616	178	227	190
HANSELL	618	192	190	170
HARPERS FERR	623	291	221	210
HAVERHILL	636	200	133	150
HAWKEYE	638	251	203	520
HAZLETON	644	253	183	660
HESPER	651	259	241	140
HIGHLANDVILLE	655	264	238	60
HOLLAND	665	208	165	260
HOLY CROSS	669	299	180	160
HOPKINTON	675	287	162	770
HORTON	677	224	196	80
HUBBARD	681	183	159	810
HUDSON	682	225	166	1080
HURSTVILLE	689	316	146	100
HUXLEY	691	165	130	490
INDEPENDENCE	697	254	171	7070
IONIA	701	225	210	260
IOWA CENTER	702	175	131	30
IOWA FALLS	704	184	174	5560
IRONHILLS	707	307	151	40
IRVING	708	233	133	80
JACKSON JCT	714	245	213	90
JANESVILLE	718	225	183	650
JESUP	723	245	171	1490
JOICE	727	175	232	230
JULIEN	730	312	174	40
KENDALLVILLE	735	264	102	1240
KELLERTON	740	163	134	240
KENSETT	744	186	232	410
KESLEY	749	202	185	120
KEYSTONE	751	238	137	520
KEY WEST	752	315	170	80
KLINGER	764	237	163	500
LA MOILLE	787	195	139	100
LAMONT	789	266	179	550
LA MOTTE	790	319	159	320
LANGWORTHY	795	288	152	70
LANSING	796	286	233	1320
LA PORTE CITY	798	240	160	1950
LATIMER	801	178	191	440
LAUREL	802	201	129	220
LAWLER	805	240	212	530
LAWN HILL	806	190	156	40
LE GRAND	812	209	138	460
LIME SPRINGS	829	234	239	580
LINCOLN	831	213	156	180

LISBON	830	280	133	1230
LISCOMB	837	197	150	300
LITTLE CEDAR	838	212	235	80
LITTLE PORT	839	260	191	120
LITTLETON	842	247	175	250
LITTLE TURKE	843	243	216	40
LOURDES	858	233	224	40
LUANA	864	276	212	280
LUXEMBURG	869	296	181	160
LUZERNE	870	239	131	140
MC CALLSBURG	876	177	149	270
MC GREGOR	879	290	210	1040
MC INTIRE	880	217	237	270
MANCHESTER	893	277	172	4400
MANLY	895	187	227	1420
MAQUOKETA	902	317	143	5910
MARBLE ROCK	904	205	205	440
MARIETTA	907	197	144	80
MARION	908	204	140	10880
MARQUETTE	911	290	211	570
MARSHALLTOWN	913	201	141	22520
MARTELLE	914	282	139	250
MASON CITY	920	187	218	30640
MASONVILLE	921	269	172	170
MASSY	923	322	169	30
MAXWELL	927	176	129	770
MAYNARD	929	254	192	520
MEDERVILLE	932	279	191	60
MELBOURNE	935	192	133	520
MELTONVILLE	936	196	239	50
MESERVEY	945	173	201	330
MEYER	946	210	239	40
MILES	951	335	143	380
MITCHELL	960	204	230	240
MONA	970	200	241	60
MONMOUTH	973	306	144	290
MONONA	974	279	212	1350
MONTICELLO	981	290	155	3190
MONTOUR	982	212	136	450
MORLEY	990	288	138	120
MORRISON	992	213	161	140
MOUNT AUBURN	997	243	155	190
MOUNT VERNON	1006	278	133	2590
NASHUA	1017	221	204	1740
NEVADA	1022	174	139	4230
NEW ALBIN	1024	283	242	640
NEWHALL	1031	250	137	500
NEW HAMPTON	1032	232	212	3460
NEW HARTFORD	1033	217	177	650
NEW HAVEN	1034	215	228	120
NEW PROVIDEN	1039	189	157	210
NEW VIENNA	1043	293	177	260
NORA SPRINGS	1046	197	217	1280
NORTH BUENA	1052	302	186	150

NORTH WASHIN	1056	227	215	160
NORTHWOOD	1058	187	238	1770
NORWAY	1050	252	131	520
OELWEIN	1077	253	165	8280
OLIN	1083	293	138	700
ONEIDA	1086	281	176	80
ONSLOW	1087	299	146	270
ONTARIO	1088	162	141	100
ORAN	1090	245	187	120
ORCHARD	1092	209	223	120
OSAGE	1097	207	227	3750
OSSIAN	1102	259	218	830
OSTERDOCK	1103	299	190	50
OTTER CREEK	1108	317	155	40
OWASA	1112	187	168	100
OXFORD JCT	1114	302	137	720
OXFORD MILLS	1115	301	136	110
PALO	1125	259	142	390
PARKERSBURG	1132	208	178	1470
PEOSTA	1141	308	170	50
PETERSBURG	1149	289	177	120
PLAINFIELD	1159	221	196	440
PLYMOUTH	1173	191	224	420
POPEJOY	1178	175	179	190
PORTLAND	1179	192	217	70
POSTVILLE	1181	269	214	1550
PRAIRIEBURG	1183	277	155	230
PRESTON	1187	331	143	820
PROTIVIN	1193	243	222	300
QUARRY	1198	208	139	120
QUASQUETON	1199	260	165	370
RADCLIFFE	1204	175	159	620
RANDALIA	1208	254	198	110
RAYMOND	1213	237	171	380
READLYN	1215	236	186	550
REINBECK	1222	218	160	1620
RICEVILLE	1227	219	233	900
RICKARDSVILL	1231	305	178	80
RIDGEWAY	1234	248	228	270
ROBINS	1245	266	143	430
ROBINSON	1246	270	162	60
ROCK FALLS	1249	193	222	160
ROCKFORD	1250	200	211	940
ROCKWELL	1253	188	206	770
ROLAND	1257	171	149	750
ROSSVILLE	1268	279	221	100
ROWLEY	1270	256	164	230
RUDD	1273	203	216	440
RYAN	1279	275	163	350
RICHFIELD	1281	245	204	60
SABULA	1282	342	144	890
SAGEVILLE	1284	315	178	110
SAINT ANSGAR	1285	202	234	1010
SAINT ANTHON	1286	187	146	130

SAINT DONATUS	1289	325	168	100
SAINT LUCAS	1291	251	212	210
SAINT OLAF	1293	279	203	170
SARATOGA	1304	228	233	90
SAUDE	1306	241	221	40
SCOTCH GROVE	1312	296	151	60
SHEFFIELD	1331	187	200	1160
SHELL ROCK	1335	218	187	1110
SHELLSBURG	1336	255	144	620
SHERRILL	1339	310	181	140
SLATER	1354	162	129	720
SPILLVILLE	1368	250	222	390
SPRAGUEVILLE	1370	329	144	100
SPRINGBROOK	1371	327	151	140
SPRINGVILLE	1376	277	142	780
STACYVILLE	1377	209	238	590
STANLEY	1379	258	182	160
STATE CENTER	1383	189	138	1140
STEAMBOAT RO	1384	194	166	430
STONE CITY	1391	283	146	200
STORY CITY	1393	162	150	1770
STOUT	1394	212	174	140
STRAWBERRY P	1397	272	186	1300
SUMNER	1405	243	196	2170
SWALEDALE	1411	182	206	220
TAMA	1422	220	135	2920
THORNTON	1434	178	203	450
TODDVILLE	1443	263	144	100
TOETERVILLE	1444	201	239	50
TOLEDO	1445	219	136	2850
TRAER	1449	225	151	1620
TRIPOLI	1454	235	194	1180
TROY MILLS	1456	266	158	150
UNION	1468	195	155	530
URBANA	1472	255	154	540
VAN CLEVE	1481	194	132	40
VAN HORNE	1483	244	138	550
VENTURA	1487	173	216	280
VINING	1492	229	137	120
VINTON	1494	247	148	4780
VIOLA	1495	280	145	150
VOLGA CITY	1497	272	194	360
VOLNEY	1498	280	215	30
VOORHIES	1499	224	160	80
WADENA	1502	265	196	280
WALFORD	1506	257	129	260
WALKER	1507	259	159	580
WASHBURN	1514	235	167	180
WATERLOO	1517	232	173	71760
WATERVILLE	1518	283	222	180
WATKINS	1519	249	130	120
WAUBEEK	1521	276	150	120
WAUCOMA	1522	246	212	360
WAUKON	1524	274	226	3640

WAUKON JUNCT	1525	291	217	30
WAVERLY	1526	224	188	6360
WELLSBURG	1534	201	168	830
WESTERN COLL	1544	267	128	100
WESTGATE	1546	248	192	210
WEST MITCHELL	1549	203	229	110
WEST UNION	1555	258	205	2550
WHITTEN	1565	197	156	180
WHITTIER	1566	276	144	170
WILKE	1570	174	172	100
WINTHROP	1583	262	171	650
WORTHINGTON	1595	293	166	360
WYOMING	1596	300	143	800
ZEARING	1606	182	148	530
ZWINGLE	1609	315	160	110

APPENDIX F

SPACE PREFERENCE MATRIX

SPACE PREFERENCE MATRIX- PROBABILITY THAT COLUMN LOCATIONAL TYPE IS PREFFFERED TO ROW LOCATIONAL TYPE

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	.07	.01	.00	.00	0.00	0.00	0.00	.78	.32	.05	.00
2	.93	0.00	.09	.01	.01	.00	0.00	0.00	.98	.90	.35	.04
3	.99	.91	0.00	.09	.05	.01	.01	0.00	1.00	.99	.84	.27
4	1.00	.99	.91	0.00	.43	.10	.05	0.00	1.00	1.00	.97	.84
5	1.00	.99	.95	.57	0.00	.18	.03	0.00	1.00	1.00	.99	.87
6	1.00	1.00	.99	.90	.82	0.00	.34	0.00	1.00	1.00	1.00	.97
7	1.00	1.00	.99	.95	.96	.66	0.00	0.00	1.00	1.00	1.00	.98
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
9	.22	.02	.00	0.00	0.00	0.00	0.00	0.00	0.00	.08	.01	.00
10	.68	.10	.01	.00	.00	0.00	0.00	0.00	.92	0.00	.09	.01
11	.95	.65	.16	.03	.01	0.00	.00	0.00	1.00	.91	0.00	.20
12	1.00	.96	.73	.16	.13	.03	.02	0.00	1.00	.99	.80	0.00
13	1.00	1.00	.86	.47	.49	.12	.10	0.00	1.00	1.00	1.00	.93
14	1.00	.97	.89	.56	.28	.11	0.00	0.00	1.00	1.00	.97	.82
15	1.00	1.00	.99	.91	.84	.65	.31	0.00	1.00	1.00	1.00	.99
16	1.00	1.00	.98	.69	.51	.28	.14	0.00	1.00	1.00	.99	.86
17	.09	.01	0.00	0.00	0.00	0.00	0.00	0.00	.28	.01	0.00	0.00
18	.40	.06	.00	0.00	0.00	0.00	0.00	0.00	.78	.24	.01	.00
19	.93	.39	.13	.01	.01	.01	0.00	0.00	.99	.85	.39	.03
20	.98	.59	.35	.04	.02	.00	.01	0.00	1.00	.96	.58	.04
21	.99	.91	.60	.07	.10	0.00	0.00	0.00	1.00	.98	.93	.53
22	1.00	1.00	1.00	.97	1.00	.97	.86	0.00	1.00	1.00	1.00	1.00
23	1.00	1.00	.97	.73	.61	.34	.24	0.00	1.00	1.00	1.00	.97
24	1.00	.98	.91	.30	.25	.07	.08	0.00	1.00	1.00	.93	.99
25	.02	.00	.00	0.00	0.00	0.00	0.00	0.00	.13	.00	0.00	0.00
26	.24	.03	.00	0.00	0.00	0.00	0.00	0.00	.58	.17	.03	.00
27	.72	.18	.04	.00	0.00	.00	0.00	0.00	.88	.61	.03	.00
28	.94	.60	.09	.03	.01	.00	0.00	0.00	.97	.84	.29	.15
29	1.00	.95	.79	.24	.14	.05	0.00	0.00	1.00	.99	.98	.67
30	1.00	.99	.79	.10	.48	.26	0.00	0.00	1.00	1.00	.98	.19
31	1.00	1.00	.98	.70	.60	.45	.38	0.00	1.00	1.00	1.00	.98
32	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
33	.05	.00	0.00	0.00	0.00	0.00	0.00	0.00	.08	.00	.00	0.00
34	.17	.01	.00	0.00	0.00	0.00	0.00	0.00	.39	.11	.00	.00
35	.38	.05	.00	0.00	0.00	0.00	0.00	0.00	.64	.25	.00	0.00
36	.77	.32	.03	.03	0.00	0.00	.00	0.00	.90	.70	.29	.03
37	.94	.72	.09	.03	.01	.00	0.00	0.00	.99	.93	.48	.28
38	.99	.91	.57	.04	.03	0.00	0.00	0.00	1.00	.98	.79	.03
39	.99	.87	.70	.21	.08	0.00	0.00	0.00	1.00	.98	.89	.86
40	1.00	.99	.80	.73	.68	.30	0.00	0.00	1.00	1.00	.99	.96
41	.01	.00	0.00	0.00	0.00	0.00	0.00	0.00	.06	.01	.00	0.00
42	.08	.01	.01	0.00	0.00	0.00	0.00	0.00	.37	.02	.01	0.00
43	.25	.03	0.00	0.00	0.00	0.00	0.00	0.00	.67	.15	.02	0.00
44	.70	.10	.02	.00	.00	0.00	0.00	0.00	.92	.49	.06	.00
45	.79	.22	.11	.01	.00	0.00	0.00	0.00	.95	.64	.08	.03
46	.89	.45	.02	.01	.00	0.00	0.00	0.00	.98	.89	.22	.00
47	.99	.47	.06	.00	.01	.01	0.00	0.00	1.00	.82	.36	.11
48	.96	.56	.08	.00	.04	0.00	0.00	0.00	1.00	.95	.67	.45

SPACE PREFERENCE MATRIX- (CONTINUED)

	13	14	15	16	17	18	19	20	21	22	23	24
1	.00	.00	0.00	.00	.91	.60	.07	.02	.01	0.00	0.00	.00
2	.00	.03	.00	.01	1.00	.94	.61	.31	.08	0.00	.00	.02
3	.14	.11	.01	.03	1.00	1.00	.87	.65	.40	.00	.03	.09
4	.53	.44	.09	.31	1.00	1.00	.99	.96	.93	.03	.27	.70
5	.51	.72	.16	.49	1.00	1.00	.99	.98	.90	0.00	.39	.75
6	.88	.89	.35	.72	1.00	1.00	1.00	1.00	1.00	.03	.66	.93
7	.90	1.00	.69	.86	1.00	1.00	1.00	1.00	1.00	.14	.76	.92
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	0.00	0.00	0.00	0.00	.72	.22	.01	.00	0.00	0.00	0.00	0.00
10	0.00	.00	0.00	0.00	.99	.76	.15	.04	.02	0.00	0.00	.00
11	.00	.03	.00	.01	1.00	.99	.61	.42	.07	.00	.01	.07
12	.07	.18	.01	.14	1.00	1.00	.97	.96	.47	0.00	.03	.01
13	0.00	.49	.08	.56	1.00	1.00	1.00	1.00	.89	.02	.26	.83
14	.51	0.00	.07	.31	1.00	1.00	.94	.87	.87	0.00	.10	.41
15	.92	.93	0.00	.94	1.00	1.00	1.00	.99	.99	.51	.85	.89
16	.44	.69	.06	0.00	1.00	1.00	.97	.96	.87	.01	.28	.79
17	.00	.00	0.00	0.00	0.00	.05	.02	0.00	.00	0.00	0.00	0.00
18	0.00	.00	0.00	.00	.95	0.00	.04	.02	.01	0.00	0.00	0.00
19	.00	.06	.00	.03	.98	.96	0.00	.08	.06	0.00	.00	0.00
20	.00	.13	.01	.04	1.00	.98	.92	0.00	.46	.00	0.00	0.00
21	.10	.13	.01	.13	1.00	.99	.94	.54	0.00	.01	.03	0.00
22	.98	1.00	.49	.99	1.00	1.00	1.00	1.00	.99	0.00	1.00	1.00
23	.74	.93	.15	.72	1.00	1.00	1.00	1.00	.97	0.00	0.00	.87
24	.17	.59	.11	.21	1.00	1.00	1.00	1.00	1.00	0.00	.13	0.00
25	0.00	0.00	0.00	0.00	.56	.03	0.00	0.00	.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	.84	.26	.02	.02	.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	.93	.81	.21	.07	.01	0.00	0.00	.01
28	.02	.04	.00	0.00	1.00	.99	.68	.52	.13	0.00	.00	.07
29	.05	0.00	.00	0.00	1.00	1.00	.97	.82	.74	0.00	.14	.06
30	.17	.89	.07	.39	1.00	1.00	.99	.82	.83	0.00	0.00	0.00
31	.16	.19	.11	.77	1.00	1.00	1.00	1.00	.86	.39	.78	.27
32	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
33	0.00	0.00	0.00	0.00	0.00	.02	0.00	.01	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	.00	.70	.14	.05	.00	.00	0.00	0.00	0.00
35	.00	0.00	0.00	0.00	.96	.52	.01	.01	.01	0.00	0.00	0.00
36	0.00	.02	0.00	0.00	.96	.88	.25	.13	.06	0.00	0.00	0.00
37	.07	.07	0.00	.02	.99	.96	.45	.15	.03	0.00	.01	.08
38	.01	0.00	.01	.30	1.00	.99	.94	.58	.79	0.00	.03	0.00
39	.45	.50	.05	0.00	1.00	1.00	.99	.96	.49	0.00	.11	0.00
40	.56	.76	.23	0.00	1.00	1.00	1.00	.94	1.00	.14	.15	.67
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	.38	.22	0.00	.01	.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	.63	.36	.01	.00	.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	.92	.73	.02	.02	.03	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	.94	.91	.31	.03	.00	0.00	0.00	0.00
46	0.00	0.00	.00	0.00	.99	.86	.30	.45	.02	0.00	0.00	.05
47	0.00	.04	.00	0.00	.98	.95	.57	.14	.17	0.00	0.00	0.00
48	.00	0.00	.01	0.00	1.00	.99	.54	.65	.11	0.00	.02	.01

SPACE PREFERENCE MATRIX- (CONTINUED)

	25	26	27	28	29	30	31	32	33	34	35	36
1	.98	.77	.28	.06	.00	.00	0.00	0.00	.95	.83	.62	.23
2	1.00	.97	.82	.40	.04	.01	.00	0.00	1.00	.99	.95	.68
3	1.00	1.00	.96	.91	.21	.21	.02	0.00	1.00	1.00	1.00	.97
4	1.00	1.00	1.00	1.00	.76	.90	.30	0.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	.99	.86	.52	.40	0.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	.95	.74	.55	0.00	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	.62	0.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
9	.87	.42	.12	.03	.00	0.00	0.00	0.00	.91	.61	.36	.10
10	1.00	.83	.39	.16	.01	.00	0.00	0.00	1.00	.89	.75	.30
11	1.00	.97	.97	.71	.02	.02	.01	0.00	1.00	1.00	1.00	.71
12	1.00	1.00	1.00	.85	.33	.81	.02	0.00	1.00	1.00	1.00	.97
13	1.00	1.00	1.00	.98	.95	.83	.84	0.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	.96	1.00	.11	.81	0.00	1.00	1.00	1.00	.98
15	1.00	1.00	1.00	1.00	1.00	.93	.89	0.00	1.00	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00	1.00	.61	.23	0.00	1.00	1.00	1.00	1.00
17	.44	.16	.08	.00	0.00	0.00	0.00	0.00	0.00	.29	.03	.03
18	.97	.74	.19	.01	.01	0.00	0.00	0.00	.98	.86	.48	.12
19	1.00	.98	.79	.31	.03	.01	0.00	0.00	1.00	.95	.99	.75
20	1.00	.98	.93	.48	.18	.18	0.00	0.00	.99	1.00	.99	.87
21	1.00	1.00	.99	.87	.26	.17	.14	0.00	1.00	1.00	.99	.94
22	1.00	1.00	1.00	1.00	1.00	1.00	.61	0.00	1.00	1.00	1.00	1.00
23	1.00	1.00	1.00	1.00	.86	1.00	.22	0.00	1.00	1.00	1.00	1.00
24	1.00	1.00	.99	.93	.94	1.00	.73	0.00	1.00	1.00	1.00	1.00
25	0.00	.34	0.00	0.00	0.00	.00	0.00	0.00	0.00	.03	.02	.01
26	.66	0.00	.08	.00	0.00	0.00	0.00	0.00	1.00	.98	.47	.01
27	1.00	.92	0.00	.21	.00	.00	0.00	0.00	1.00	.92	.89	.38
28	1.00	1.00	.79	0.00	.02	.02	0.00	0.00	1.00	1.00	.97	.86
29	1.00	1.00	1.00	.98	0.00	.45	.05	0.00	1.00	1.00	1.00	.98
30	1.00	1.00	1.00	.98	.55	0.00	.36	0.00	1.00	1.00	1.00	.99
31	1.00	1.00	1.00	1.00	.95	.64	0.00	0.00	1.00	1.00	1.00	1.00
32	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00
33	0.00	0.00	.00	.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	.01
34	.97	.02	.08	.00	.00	0.00	0.00	0.00	0.00	0.00	.08	0.00
35	.98	.53	.11	.03	.00	.00	0.00	0.00	1.00	.92	0.00	.12
36	.99	.99	.62	.14	.02	.01	.00	0.00	.99	1.00	.89	0.00
37	1.00	.99	.93	.81	.02	0.00	0.00	0.00	.99	1.00	1.00	.78
38	1.00	1.00	.92	.94	.37	.06	0.00	0.00	1.00	1.00	1.00	.93
39	1.00	1.00	.99	.78	.24	.21	.03	0.00	1.00	1.00	1.00	.90
40	1.00	1.00	1.00	1.00	.89	1.00	.42	0.00	1.00	1.00	1.00	1.00
41	.51	.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.13	0.00	0.00
42	0.00	0.00	.00	.00	0.00	0.00	0.00	0.00	0.00	.13	0.00	.01
43	.91	.36	.05	.00	.00	0.00	0.00	0.00	1.00	.87	.21	.09
44	.99	.79	.11	.02	.00	0.00	0.00	0.00	.99	.84	.83	.23
45	.92	.88	.34	.43	.01	0.00	.00	0.00	1.00	.98	.77	.42
46	1.00	.98	.79	.43	0.00	.01	0.00	0.00	1.00	1.00	.98	.85
47	1.00	.94	.67	.55	.02	0.00	.00	0.00	1.00	1.00	.97	.61
48	.99	.98	.98	.83	.10	.16	.01	0.00	1.00	1.00	1.00	.97

SPACE PREFERENCE MATRIX- (CONTINUED)

	37	38	39	40	41	42	43	44	45	46	47	48
1	.06	.01	.01	.00	.99	.92	.75	.30	.21	.11	.10	.04
2	.28	.10	.13	.01	1.00	1.00	.97	.90	.78	.55	.53	.34
3	.91	.43	.30	.20	1.00	.99	1.00	.98	.89	.98	.93	.92
4	.97	.96	.79	.27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	.99	.97	.92	.32	1.00	1.00	1.00	1.00	1.00	1.00	.99	.96
6	1.00	1.00	1.00	.70	1.00	1.00	1.00	1.00	1.00	1.00	.99	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	.01	.01	0.00	0.00	.94	.64	.33	.08	.05	.02	.00	.00
10	.07	.02	.02	.00	.99	.98	.85	.51	.36	.11	.18	.05
11	.52	.21	.11	.01	1.00	.99	.98	.94	.92	.78	.64	.33
12	.72	.98	.14	.04	1.00	1.00	1.00	1.00	.97	1.00	.89	.55
13	.93	.99	.55	.44	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	.93	1.00	.50	.24	1.00	1.00	1.00	1.00	1.00	1.00	.96	1.00
15	1.00	.99	.95	.77	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.99
16	.98	.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	.01	0.00	.00	0.00	0.00	.62	.37	.08	.06	.01	.02	.00
18	.04	.01	.00	0.00	1.00	.78	.64	.27	.09	.14	.05	.01
19	.55	.06	.01	0.00	1.00	1.00	.99	.98	.68	.70	.43	.46
20	.85	.42	.04	.06	1.00	.99	1.00	.98	.97	.55	.86	.35
21	.97	.21	.51	0.00	1.00	1.00	1.00	.97	1.00	.98	.83	.89
22	1.00	1.00	1.00	.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23	.99	.96	.89	.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.98
24	.92	1.00	1.00	.33	1.00	1.00	1.00	1.00	1.00	.95	1.00	1.00
25	.00	0.00	0.00	0.00	.49	0.00	.09	.01	.08	.00	.00	.01
26	.01	.00	.00	.00	.22	1.00	.64	.21	.12	.02	.06	.02
27	.07	.08	.01	.01	1.00	1.00	.95	.89	.66	.21	.33	.02
28	.19	.06	.22	0.00	1.00	1.00	1.00	.98	.57	.57	.45	.17
29	.98	.63	.76	.11	1.00	1.00	1.00	1.00	.99	1.00	.98	.90
30	1.00	.94	.79	0.00	1.00	1.00	1.00	1.00	1.00	.99	1.00	.84
31	1.00	1.00	.97	.58	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.99
32	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
33	.01	0.00	0.00	0.00	0.00	0.00	0.00	.01	.00	0.00	.00	.00
34	.01	0.00	0.00	0.00	.87	.86	.13	.16	.02	0.00	.00	0.00
35	0.00	.00	.00	0.00	1.00	1.00	.79	.17	.23	.02	.03	.00
36	.22	.07	.10	0.00	1.00	.99	.91	.77	.58	.15	.38	.03
37	0.00	.05	.01	.01	1.00	1.00	.96	.99	.77	.32	.79	.76
38	.94	0.00	.08	.03	1.00	1.00	1.00	1.00	.96	.88	.98	.21
39	.99	.91	0.00	.57	1.00	1.00	1.00	1.00	1.00	.98	.98	.90
40	.99	.97	.43	0.00	1.00	1.00	1.00	1.00	.99	.99	1.00	.96
41	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	.00	0.00
42	.00	0.00	0.00	0.00	1.00	0.00	.05	.03	.00	0.00	.01	0.00
43	.04	0.00	0.00	0.00	.99	.95	0.00	.11	.03	.01	.01	.00
44	.01	.00	0.00	0.00	1.00	.98	.89	0.00	.25	.00	.03	.04
45	.23	.04	0.00	.01	1.00	1.00	.97	.75	0.00	.47	.08	.05
46	.68	.12	.03	.01	1.00	1.00	.99	1.00	.53	0.00	.51	.09
47	.21	.02	.02	0.00	1.00	.99	.99	.97	.92	.49	0.00	.59
48	.24	.79	.10	.03	1.00	1.00	1.00	.96	.95	.91	.41	0.00

APPENDIX G

SIMULATION 2:

SPATIAL DIFFUSION OF HARVESTORE SYSTEMS IN N.E. IOWA

SPACDIF - SPATIAL DIFFUSION OF HARVESTORE
SYSTEMS IN N.E. IOWA.
SIMULATION 2

VARIABLES
1. ADOPTER IDENTIFICATION NUMBER
2. EAST-WEST COORDINATE LOCATION OF ADOPTER.
3. NORTH-SOURTH COORDINATE LOACTION OF ADOPTER.
4. IDENTIFICATION NUMBER OF PREVIOUS ADOPTER WHO TOLD NEW ADOPTER ABOUT THE INNOVATION.
5. CENTRAL PLACE IDENTIFICATION NUMBER WHERE INFORMATION TRANSFER TOOK PLACE.

INITIAL ADOPTERS
GENERATION 0

24	299	172
48	237	165
61	265	193
72	252	157
131	218	193
133	237	161
149	279	236
171	311	174
190	219	150
205	212	143
229	276	204
231	219	155
233	288	202
274	213	161
342	235	184
367	229	210
421	298	206
452	220	157
458	272	136

GENERATION 1

163	263	187	61	54
336	217	198	131	257
460	319	165	171	396
94	296	172	24	410
45	265	204	229	433
101	231	181	48	456
252	211	141	205	535
192	204	163	274	596

GENERATION 2

441	267	147	458	652
415	248	160	133	798
420	234	212	367	1032
32	216	157	231	1222
165	246	164	415	156
97	268	149	441	224
107	213	212	336	236
187	216	191	131	257
158	319	164	171	396
19	322	161	460	396
6	291	170	24	410
378	291	182	94	410
161	234	176	48	456
43	256	192	61	490
380	286	147	233	532
267	206	164	192	596
124	245	160	133	798
484	263	143	458	908
393	203	130	205	913
92	230	212	367	1032
176	241	213	420	1032
292	247	177	163	1077
37	220	153	32	1222
424	217	155	190	1222
221	217	161	452	1222
446	234	190	342	1454
246	264	195	163	54

GENERATION 3

75	228	190	32	223
79	261	139	441	224
273	273	165	484	224
283	270	149	97	231
486	217	202	92	236
408	306	181	158	396
471	289	170	6	410
349	294	173	24	410
100	293	168	94	410
438	262	200	61	480
481	285	197	380	532
254	208	196	107	587
109	265	147	458	652
181	250	178	292	697
84	315	160	19	790
532	240	150	124	798
30	202	145	205	913
245	229	143	252	913
499	235	219	176	1032
401	239	210	367	1032
527	220	176	161	1053
464	263	199	45	1155

166	230	150	190	1449
135	243	154	415	1494
511	238	172	342	1517
83	214	183	446	1526

GENERATION 4

125	324	155	19	109
508	204	172	161	223
544	272	137	79	224
536	238	145	97	224
212	270	145	109	224
55	217	203	486	236
555	229	140	245	273
268	323	158	84	396
487	319	159	158	396
543	314	172	460	396
112	287	176	6	410
506	302	170	94	410
266	289	130	100	410
477	303	167	24	452
542	238	166	133	456
368	210	291	254	587
22	201	159	221	596
385	204	164	274	596
561	240	154	135	798
206	238	219	176	805
347	277	175	273	893
503	293	174	378	893
140	269	147	441	908
33	260	145	484	908
442	193	150	252	913
439	195	135	393	913
128	280	214	229	974
63	234	224	367	1032
244	232	202	420	1032
21	246	192	181	1077
317	257	205	464	1155
533	216	197	131	1335
296	225	148	190	1449
455	234	198	446	1454
184	248	137	165	1494
149	242	171	342	1517
413	228	166	511	1517
204	216	185	75	1526

GENERATION 5

10	208	191	254	25
397	324	151	125	39
517	269	194	246	54
188	315	156	19	109

239	327	156	268	109
375	283	157	477	213
519	223	180	37	223
222	211	131	75	223
73	216	176	101	223
99	212	172	413	223
2	278	142	109	224
531	261	146	33	229
381	265	155	47	229
282	277	153	283	231
265	227	221	369	236
215	219	191	131	257
243	321	163	158	396
137	306	170	171	396
539	313	174	408	396
182	246	176	6	410
220	292	176	378	410
423	291	166	503	410
49	225	229	63	442
377	234	168	48	455
566	230	168	161	456
554	239	178	511	456
53	253	197	464	480
510	211	156	190	556
447	211	159	22	596
150	211	168	274	596
34	214	155	385	665
518	250	167	292	723
492	239	212	176	805
169	273	160	273	893
389	281	170	347	893
213	279	172	471	893
410	273	148	79	908
586	273	141	140	908
255	199	145	30	913
584	198	131	205	913
186	197	147	439	913
284	192	229	107	920
228	267	132	458	1006
316	226	202	55	1017
129	218	207	486	1017
227	238	204	367	1032
474	245	176	21	1077
341	242	185	43	1077
209	249	134	181	1077
172	258	206	317	1155
504	262	214	128	1181
173	239	219	206	1306
299	225	149	166	1449
573	227	153	245	1449
47	242	141	184	1483
191	240	139	165	1494
326	226	178	135	1517
66	218	197	446	1526

GENERATION 6

134	284	142	282	36
403	322	150	239	109
207	247	151	375	213
514	214	179	63	223
294	224	155	99	223
216	219	173	326	223
240	258	133	458	224
396	264	153	283	229
384	280	149	410	231
630	220	209	368	235
185	256	228	173	353
110	250	213	206	353
565	317	170	243	396
416	309	162	460	396
196	322	164	487	396
553	317	158	539	396
175	313	175	543	396
211	301	170	6	410
494	284	180	503	418
76	221	168	511	456
633	257	195	246	430
655	238	202	227	509
120	239	170	542	551
98	208	195	346	587
449	210	160	34	596
78	246	176	165	723
74	280	228	148	796
637	239	216	401	805
520	276	155	213	893
113	271	174	347	893
260	282	166	389	893
636	185	231	284	895
62	325	143	188	902
261	324	144	397	902
605	264	150	532	908
87	201	165	30	913
103	224	138	252	913
153	201	150	439	913
46	215	139	442	913
65	251	191	43	929
411	275	219	128	974
122	221	206	66	1017
568	228	218	92	1032
448	216	175	161	1053
466	251	175	181	1077
168	251	179	209	1077
102	264	184	292	1077
399	256	217	504	1102
311	215	131	222	1132
541	213	155	32	1222
654	248	143	47	1494
515	235	148	135	1494

523	246	138	536	1494
343	226	168	48	1517
51	236	174	101	1517
625	225	167	554	1517
402	221	203	75	1526
406	208	193	204	1526

GENERATION 7

180	279	151	134	36
598	289	142	384	36
450	325	157	397	109
315	326	150	403	109
202	257	212	172	1555
139	306	160	477	213
383	200	170	51	223
69	224	185	99	223
664	262	151	33	229
556	268	157	169	231
111	275	155	441	231
346	213	204	55	236
321	223	205	107	236
89	215	223	368	236
591	221	223	402	236
609	217	193	336	257
329	272	162	520	278
546	264	217	63	353
674	251	215	185	353
200	251	213	399	353
29	306	176	553	396
585	230	151	166	411
677	282	197	380	434
516	243	167	377	438
707	308	170	137	452
93	222	174	554	456
638	232	166	566	456
596	295	171	211	471
624	257	185	65	480
669	233	206	492	509
579	285	209	481	532
151	212	207	88	587
59	200	162	37	596
318	227	156	343	682
513	222	163	625	682
177	246	170	181	697
230	245	177	124	723
694	319	155	268	790
263	230	159	43	798
256	244	216	499	805
615	283	200	421	879
96	282	179	113	893
309	276	171	347	893
512	276	156	389	893

104	270	174	494	893
208	313	144	261	902
363	278	140	140	908
459	206	147	153	913
500	200	156	255	913
373	174	220	284	920
635	196	224	636	920
456	292	151	207	981
562	285	153	375	981
712	274	134	2	1036
52	277	135	544	1005
649	229	219	367	1032
71	251	138	102	1077
143	253	180	209	1077
462	245	180	292	1077
617	254	193	474	1077
189	210	131	508	1132
253	251	204	464	1155
271	268	223	128	1181
457	263	216	504	1181
623	329	145	62	1187
86	221	230	49	1227
26	220	136	46	1422
666	223	155	244	1449
334	233	134	455	1454
660	259	148	72	1494
610	240	157	184	1494
608	244	150	415	1494
570	241	153	523	1494
203	242	146	532	1494
354	235	131	120	1517
683	244	174	413	1517
705	261	224	411	1524
70	221	135	446	1526
226	230	136	519	1526

APPENDIX H

A BRIEF DESCRIPTION OF THE NORTHEAST IOWA STUDY AREA

A BRIEF DESCRIPTION OF THE NORTHEAST IOWA STUDY AREA

Northeast Iowa is located in the Corn Belt in the heart of the American Midwest. The study area includes 26 counties in the northeast corner of the State of Iowa and covers an area of 15,236 square miles. The area extends from south of Cedar Rapids 114 miles north to the Minnesota border and from west of Ames 180 miles east to the Mississippi River (see Map 1).

Even though in this study Northeast Iowa is considered to be a homogeneous agricultural region with little variation in either physical character or agricultural land use, diversity does exist. Relative to variations in the physical and agricultural landscape in other regions of the United States, especially in contrast to the differences between arid mountains and irrigated valleys in the West, the differences are more subtle.[1]

Northeast Iowa is an agricultural region with rich soil, good climate, and a favorable topography. The surface of the area is an undulating plain dissected by several tributaries of the Mississippi River that flow in broad parallel valleys

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[1]Neil E. Salisbury, "Agricultural Productivity and the Physical Resource Base of Iowa," Iowa Business Digest, XXXI (1960), p. 27.

bordered by valley bluffs with rock outcrops.[2] The roughest terrain in the area lies along the Mississippi River where glacial deposits are thin or have long been stripped from the hillsides by erosion.[3]

The soils in the area are the product of thick loess deposits which have been leached and are less fertile than the prairie soils, but sufficiently good to produce high yields. The best soils are in the southern portion of the area and as one moves north, especially into the Driftless Area along the Mississippi River, the soils tend to be thinner, lighter, and less fertile.[4]

In an area as small as Northeast Iowa the climate does not vary significantly from one portion to another. The average annual precipitation varies from 30 to 36 inches with most occuring during the growing season. The warmest month, July, has a mean temperature of 74°F in the southern portion of the area and 72°F in the northern portion. From north to south there is less than a five day difference in the length of the growing season.[5] The variations in the heat and moisture resource in Northeast Iowa are such that climatic conditions do not place limits upon midlatitude grain (particularily

[2]John H. Garland (ed.), The North American Midwest (New York: John Wiley, 1955), p. 105.

[3]Salisbury, "Agricultural Productivity," p. 29.

[4]Garland, The North American Midwest, pp. 104-105, 147.

[5]U.S., Department of Agriculture, Yearbook of Agriculture, 1941 (Washington, D.C.: Government Printing Office, 1941). pp. 862-872.

corn) production.[6]

Agricultural productivity varies spatially from north to south in Northeast Iowa. Higher productivity per acre occurs in the southern portion of the region than in either the north or the northeast. Climatic resources of heat and moisture have little influence on the spatial pattern of agricultural productivity. Topography apparently has the greatest influence on agricultural productivity; flat land generally being more conducive to high agricultural productivity than rough, dissected land. When soil characteristics are taken into account with terrain differences, most of the variation in agricultural productivity in Northeast Iowa can be explained.[7]

Northeast Iowa is a dairy region with both hog and beef cattle production being an important part of the rural economy. Most of the crops harvested are feed crops which are largely fed to livestock on the farm. The dominant crops are corn, oats, and hay. Corn is the most important feed crop harvested in the region and is used as a grain to fatten both hogs and beef cattle for meat production and as silage which is a high quality, moist feed for dairy cattle.[8]

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[6] Salisbury, "Agricultural Productivity," p. 28.

[7] Salisbury, "Agricultural Productivity," p. 31.

[8] Garland, The North American Midwest, p. 146.

On most farms in the area livestock production is diversified with varying emphasis on dairy cattle, hogs, and beef cattle. Diversification in livestock production allows a farmer to spread his work load over a period of time and to reduce the risk as far as farm prices are concerned. With agricultural productivity being greater in the southern part of the area, particularly corn production, there is a tendency for hog production to be relatively more important in diversified livestock operations in the south. The difference in emphasis on hog production between the northern and southern portions of the area is a matter of degree rather than a difference in the type of farming.

The distribution of rural settlement, farm ownership, and standard of living tend to correspond with variations in agricultural productivity. Except for variations in rural population density along river valleys, in the Driftless Area along the eastern edge of the study area, and near larger urban centers most of the area has from 25 to 35 persons per square mile. There is a general tendency for rural population density and standard of living to be higher in the south and to decrease towards the north.[9] Farm size varies very little throughout the area but because of the high capital investment required in dairy operations the

[9]U.S. Department of Commerce, Bureau of the Census, <u>County and City Data Book, 1962</u> (Washington, D.C.: Government Printing Office, 1962), pp. 112-131.

proportion of farmers owning their own farm is slightly higher in the northern area.[10]

Even though the variation in agricultural productivity is not very great in Northeast Iowa, it is the key to understanding most of the economic diversity of the region. Relative to variation in physical and agricultural character in other regions in the United States, Northeast Iowa is a fairly homogeneous area.

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[10] County and City Data Book, 1962, pp. 112-131.